Analysis and Adaptation of the Evolutionary Game of Multi-Subject Behavior Decision-Making in the Prevention and Control of the New Crown Epidemic

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Abstract. In order to smooth out the game relationship and strategy selection between multiple participants in the prevention and control of the new crown epidemic, a three-way behavioral decision-making evolution game model of local governments, enterprises and the public was constructed, and the In order to smooth out the game relationship and strategy selection between multiple participants in the prevention and control of the new crown epidemic, a three-way behavioral decision-making evolution game model of local governments, enterprises and the public was constructed, and the impact of major factors such as willingness to participate, incentive degree and production limit on the stability strategy of the evolutionary system was investigated. Impact of major factors such as willingness to participate, incentive degree and production limit on the stability strategy of the evolutionary system The impact of major factors such as willingness to participate, incentive degree and production limit on the stability strategy of the evolutionary system was analyzed, and simulated with the help of MATLAB platform, and corresponding adaptation countermeasures were proposed according to the analysis The results of the analysis were presented in the following sections.

Keywords: Epidemic prevention and control · Multi-subject · Behavioral decision-making · Three-way game

1 Introduction

Since the outbreak of the New Crown epidemic, it has caused great loss of life and property for all mankind, with over 580 million cumulative confirmed cases and over 6.4 million cumulative deaths worldwide as of August 2022 [1]. It also poses a huge challenge to China's emergency management system. At this stage, the prevention and control management of new crown epidemics in China has entered a normalised stage. In order to control epidemics in a more rational way, an epidemic prevention and control model should be built with the participation of multiple subjects, such as local governments, enterprises and the public. However, in the actual prevention and control, the

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different objectives, interests and status of each participating subject may give rise to conflicts between them [2]. And due to the special nature of epidemics and other reasons, the negative mentality of participating subjects may prevail. The problem of the game relationship and strategy selection among multiple actors is being addressed, and countermeasures are being proposed to eliminate the negative impact of the negative psychology of the participating actors on the epidemic prevention and control, and to mobilize their enthusiasm to participate in the epidemic prevention and control, so as to carry out accurate epidemic prevention and control, which has become an urgent problem in the new epidemic emergency management system.

Some scholars have pointed out that the ultimate goal of emergency management cannot be achieved by relying on the government alone, and that NGOs, enterprises, media and the public need to be encouraged and guided to actively participate in emergency management in order to bring into play the strengths and specialties of each entity [3]. Some scholars also emphasise the importance of the participation of actors to the effectiveness of governance, and propose to speed up the construction of a multi-faceted collaborative governance mechanism to realise the transformation from 'unified' government regulation to 'diversified' social governance. For example, based on the theory of collaborative governance in public crises, Ren Huiying has proposed to build a multi-subject—whole process linkage model for emergency volunteer services, creating a government-led multi-subject collaborative pattern and forming a whole process linkage before, during and after major emergencies [4]. Yao Chen et al. analyse the constraints of emergency information coordination from the perspective of inter-governmental, inter-governmental and inter-non-governmental organisation relations and propose strategic options for optimising the coordination mechanism of multiple actors in emergency management [5]. Zhang Chaohan et al. address the New Coronary Pneumonia epidemic with the value of "community of human destiny" as a guide to build a unified global public health governance framework, replenish the "governance deficit" in global health and address the obstacles to the implementation of cooperation mechanisms [6]. Behavioural economist Amos Tversky found that when faced with a public health emergency, individuals choose between positive and negative preventive and control behaviours by assessing potential gains and losses [7]. Huang et al. suggest that the public's willingness to participate depends on the costs and benefits of emergency management, and that when the costs are high, they will choose more negative strategies to respond, and vice versa [8]. Zhu Hongmiao and Lu Xiaolin et al. argue that raising public awareness of prevention and control can help reduce the number of infections and is important for rapid control of the spread of the epidemic [9, 10]. Xu et al. argue that if companies do not strictly enforce regulations during an epidemic, they may gain more revenue at the expense of public health and social safety, which poses a high risk of further spread of the epidemic and endangers public health [11]. Cheng et al. analysed the cooperation process between mask production and quarantine hotel service enterprises and the government during the New Crown epidemic, revealing inter-organisational efforts to first pool resources in response to the epidemic and later enhance the sustainability of cooperation through reciprocity and institutionalisation, as well as the resource motivation in the inter-organisational cooperation process [12]. Yin et al. studied three COVID-19 EP in order to improve the effectiveness of epidemic prevention (EP) in urban sustainability transformation models to reveal intercity multi-actor EP mechanisms [13].

Some scholars have also studied the interactive process of multi-subject participation game in emergency management from the perspective of evolutionary game. For example, Yang et al. included the strength of government regulation into the model to explore the influence of government regulation on public prevention and control strategies, and found that government regulation imposed on the public helps to motivate the public to adopt prevention and control strategies and reduce social losses [14]. Xu Hui studied the behavioural strategy choices of central government, local government, social organisations and residents in public health emergencies, constructed a multi-subject game evolutionary model of emergency governance risk governance, and sought the optimal equilibrium of program governance strategies in the evolutionary game equilibrium process [15]. Jia Fangju et al. constructed a stochastic evolutionary game model for collaborative prevention and control of public health emergencies to analyse the evolutionary stabilisation strategies and evolutionary processes of local governments and the public in the context of epidemic prevention and control for the problem of high uncertainty in the strategic interaction and behavioural evolution of local governments and the public in public health emergencies [16]. The current research on asymmetric cooperation between government organisations with public authority and the public in emergency response to major emergencies conditions is relatively abundant and provides theoretical support for this study. However, under the current normalization of the prevention and control of the new crown epidemic, there are fewer studies or studies focusing on one-way dependency relationships between local governments, enterprises and the public, and the dynamic processes of inter-organizational and inter-subject emergency cooperation need to be further understood.

Therefore, this study introduces the incentive mechanism and constructs a game model for the evolution of the behavioural decisions of the local government, enterprises and the public. The impact of the main factors, such as the willingness to participate, the degree of incentive and the intensity of production restriction, on the stabilisation strategy of the evolving system is analysed and simulated with the help of MATLAB platform, and corresponding adaptive countermeasures are proposed based on the analysis results. The results of the study can be used as a reference for the precise prevention and control of the new crown epidemic.

2 Problem Description and Model Construction

2.1 Problem Description

Local governments, enterprises and the public all make decisions with the objective of maximising their own interests. This paper explores the effects of willingness to participate, degree of incentive, and intensity of production restriction on each subject by constructing an evolutionary game model, as shown in Table 1 of.

Table 1. Model parameter settings

Parameters	Definition
Q_1	Tax revenue generated for local governments from normal production operations
Q_2	Proceeds from normal production and operation of the business
Q_3	Proceeds from normal productive activities of the public
W	Benefits to local authorities with active corporate assistance
U	Local government incentive benefits for enterprises after assistance to local governments
R	Gains from active local government stewardship
P	Local government incentive gains when the public is actively involved
C_1	Loss of public participation in outbreak prevention and control under active governance by local governments
C_2	Costs for companies to respond to local government policy
C_3	Additional costs of active public participation in the fight against the epidemic
E	Losses to the public when companies passively assist local authorities
N	Potential losses from passive corporate assistance when the public is actively involved in outbreak prevention and control
S	Local governments invest in incentive funding
L	Excitation factor ($0 \le L \le 1$)
T	Cost of capital for companies to assist local governments
K	Companies fined by local authorities for breaching local government policies
m	Production limit factor ($0 \le m \le 1$)

2.2 Modeling the Evolution of Behavioural Strategies of Local Governments, Businesses and the Public

In the game model, the participating subjects make their strategic choices according to their own willingness. Assume that the local government's willingness to choose active governance is x and negative governance is 1−x; the enterprises' willingness to choose active assistance is y and negative assistance is 1−y; the public's willingness to choose active participation is z and the willingness to choose non-participation is 1−z, x,y,z ∈[0, 1]. Based on the assumptions, the payoff matrix of the three-party game in Table 2 is derived.

Table 2. Local government-business-public tripartite game payoff matrix

Strategy Selection				Local government	
				Active Governance x	Negative Governance $1\text{-}x$
Enterprise Industry	Active assistance$y$	Public Crowd	Active Participation$z$	Q_1+R-S $(1-m)(1+L)(Q_2+U-C_2-T)$ $(1-m)(1+L)(Q_3+P-C)_3$	Q_1+W Q_2 Q_3-C_3
			Non-participation $1-z$	$Q_1+W+R-S$ $(1-m)(1+L)(Q_2+U-C_2-T)$ $(1-m)(Q_3-C)_1$	Q_1+W Q_2 Q_3
	Negative assistance $1-y$	Public Crowd	Active Participation z	$Q_1+R-S+K$ $(1-m)(Q_2-N-K)$ $(1-m)(1+L)(Q_3+P-C_3-E)$	Q_1+K Q_2-K Q_3-C_3-E
			Non-participation $1-z$	Q_1-S+K $(1-m)(Q_2-K)$ $(1-m)(Q_3-C_1-E)$	Q_1+K Q_2-K Q_3-E

3 Analysis of the Tripartite Evolutionary Model of Local Government, Business and the Public

3.1 Equilibrium Analysis of Local Government Games

According to Table 2, the expected benefits for local governments choosing the "active governance" strategy μ_{x1} and the expected benefits for "negative governance" μ_{x2} and the average benefits are as follows $\overline{\mu_x}$.

$$\mu_{x1} = yz(Q_1 + R - S) + y(1 - z)(Q_1 + W + R - S) + (1 - y)z(Q_1 + R - S + K) \\ +(1 - y)(1 - z)(Q_1 - S + K) \tag{1}$$

$$\mu_{x2} = yz(Q_1 + W) + y(1 - z)(Q_1 + W) + (1 - y)z(Q_1 + K) \\ +(1 - y)(1 - z)(Q_1 + K) \tag{2}$$

$$\overline{\mu_x} = x\mu_{x1} + (1 - x)\mu_{x2} \tag{3}$$

The replication dynamic equation for local governments choosing an active governance strategy is

$$F(x) = \frac{d_x}{d_t} = x(\mu_{x1} - \overline{\mu_x}) \\ =x(1 - x)(Ry + Rz - Ryz - Wyz - S) \tag{4}$$

The first order partial derivatives of F(x) with respect to x and the set $G(z)$ are

$$\frac{dF(x)}{dx} = (1 - 2x)(Ry + Rz - Ryz - Wyz - S) \tag{5}$$

$$G(z) = Ry + Rz - Ryz - Wyz - S \tag{6}$$

Equation (6) gives $z^* = \frac{S-Ry}{R-Ry-Wy}$, and according to the stability theorem for differential equations, the evolutionary steady state is satisfied when $F(x) = 0$ and $\frac{dF(x)}{dx} \prec 0$ such that $F(x) = 0$, and thus $x = 0$,$x = 1$,$z = z^*$, are discussed in three cases as follows:

(1) $z = z^* = \frac{S-Ry}{R-Ry-Wy}$ at $F(x) = 0$, when x taking any value is a stable equilibrium and the local government's strategy choice does not change over time.
(2) At $0 \prec z \prec z^* \prec 1$, substituting $x = 0, x = 1$ into $\frac{dF(x)}{dx}$ respectively, it is found that $\left.\frac{dF(x)}{dx}\right|_{x=0} \prec 0, \left.\frac{dF(x)}{dx}\right|_{x=1} \succ 0$ i.e.$x = 0$ is the evolutionary stabilization strategy of the local government, when the probability of the public choosing active participation is less than z^*, the local government chooses negative governance.
(3) $0 \prec z^* \prec z \prec 1$, found that $\left.\frac{dF(x)}{dx}\right|_{x=0} \succ 0, \left.\frac{dF(x)}{dx}\right|_{x=1} \prec 0$, i.e.$x = 1$ are the evolutionary stabilization strategies of local governments, and local governments choose active governance when the probability of the public choosing active participation is greater than that of z^*, and the public's strategy choice plays an important role in whether local governments are active in governance.

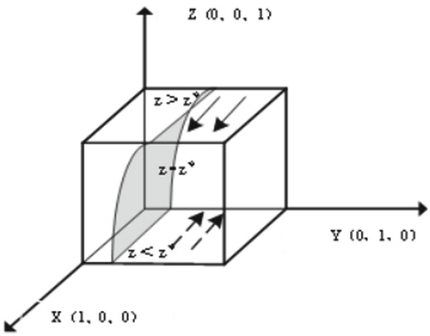

Fig. 1. Schematic diagram of the evolutionary path of local government

Based on the above analysis, the evolutionary phase diagram of local governments can be drawn as shown in Fig. 1. In the diagram, the cross-sectional area x tends to 0, where the local government tends to choose a negative governance strategy, and the cross-sectional area x tends to 1, where the local government chooses a positive governance strategy.

3.2 Equilibrium Analysis of the Enterprise Game

The expected benefits for companies choosing the 'active assistance' strategy μ_{y1} and the expected benefits for companies choosing the 'passive assistance' strategy μ_{y2} and the average benefits $\overline{\mu_y}$ are

$$\begin{aligned}\mu_{y1} &= xz(1-m)(1+L)(Q_2+U-C_2-T)+(1-x)zQ_2+x(1-z)\\&(1-m)(1+L)(Q_2-C_2+U-T)+(1-x)(1-z)Q_2\end{aligned} \tag{7}$$

$$\begin{aligned}\mu_{y2} &= xz(1-m)(Q_2-N-K)+(1-x)z(Q_2-K)+x(1-z)\\&(1-m)(Q_2-K)+(1-x)(1-z)(Q_2-K)\end{aligned} \tag{8}$$

$$\overline{\mu_y} = y\mu_{y1}+(1-y)\mu_{y2} \tag{9}$$

The replication dynamics equation for a firm's active assistance strategy is

$$\begin{aligned}F(y) &= \frac{dy}{dt} = y(\mu_{y1}-\overline{\mu_y})\\&= y(1-y)[K-x(C_2+T-U+C_2L-LQ_2+LT-LU)\\&(1+m)+xm(K+Nz)-Nz]\end{aligned} \tag{10}$$

$F(y)$ The first-order partial derivatives with respect to y and the set $G(x)$ are as follows, respectively

$$\begin{aligned}\frac{dF(y)}{dy} &= (1-2y)[K-x(C_2+T-U+C_2L-LQ_2+LT-LU)\\&(1+m)+xm(K+Nz)-Nz]\end{aligned} \tag{11}$$

$$G(x) = [K - x(C_2 + T - U + C_2L - LQ_2 + LT - LU)\\ (1 + m) + xm(K + Nz) - Nz] \tag{12}$$

From Eq. (12) we have:
$x^* = \frac{k - Nz}{(C_2 + T - U - C_2L - LQ_2 + LT - LU)(1+m) - m(K + Nz)}$, the stable evolutionary state is satisfied when $F(y) = 0$ and $\frac{dF(y)}{dy} \prec 0$ such that $F(y) = 0$, and thus $y = 0$, $y = 1$ and $x = x^*$, are discussed in three cases as follows:

(1) $x = x^* = \frac{k - Nz}{(C_2 + T - U - C_2L - LQ_2 + LT - LU)(1 + m) - m(K + Nz)}$ When $F(y) = 0$, at which point y takes any value is a stable equilibrium and the firm's strategy choice does not change over time.
(2) At $0 \prec x \prec x^* \prec 1$, substituting $y = 0$, $y = 1$ into $\frac{dF(y)}{dy}$ respectively, it is found that $\left.\frac{dF(y)}{dy}\right|_{y=0} \prec 0$, $\left.\frac{dF(y)}{dy}\right|_{y=1} \succ 0$ i.e.$y = 0$ is the evolutionary stabilization strategy of enterprises, and enterprises tend to choose negative assistance when the probability of local government choosing active governance is less than x^*.
(3) At $0 \prec x^* \prec x \prec 1$, it is found that $\left.\frac{dF(y)}{dy}\right|_{y=0} \succ 0$, $\left.\frac{dF(y)}{dy}\right|_{y=1} \prec 0$ i.e.$y = 1$ are the evolutionary stable strategies of enterprises, and when the probability of local government choosing active governance is greater than x^*, enterprises tend to actively assist and their strategy choice is influenced by the strategy choice of local government.

Based on the above analysis, a schematic diagram of the evolutionary path of local government strategies is obtained, as shown in Fig. 2. In the upper half of the cross-section of the diagram area for y tends to 1, enterprises choose the positive assistance strategy; in the lower half of the cross-section area for y tends to 0, enterprises tend to choose the negative assistance strategy.

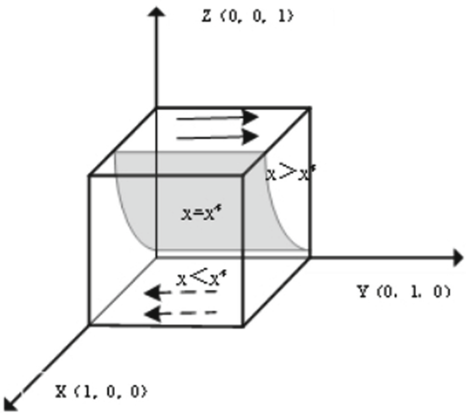

Fig. 2. Schematic diagram of the evolutionary path of a business

3.3 Equilibrium Analysis of the Public Game

The expected returns for the public choosing the 'active' strategy μ_{z1}, the expected returns for those choosing 'not participating' μ_{z2} and the average returns are $\overline{\mu_z}$

$$\begin{aligned}\mu_{z1} &= xy(1-m)(1+L)(Q_3 - C_3 + P) + (1-x)y(Q_3 - C_3) \\ &+x(1-y)(1-m)(1+L)(Q_3 + P - C_3 - E) \\ &+(1-x)(1-y)(Q_3 - C_3 - E)\end{aligned} \tag{13}$$

$$\begin{aligned}\mu_2 &= xy(1-m)(Q_3 - C_1) + (1-x)yQ_3 + x(1-y) \\ &(1-m)(Q_3 - C_1 - E) + (1-x)(1-y)(Q_3 - E)\end{aligned} \tag{14}$$

$$\overline{\mu_z} = z\mu_{z1} + (1-z)\mu_{z2} \tag{15}$$

The replication dynamic equation for active public participation is

$$\begin{aligned}F(z) &= \frac{dz}{dt} = z(\mu_{z1} - \overline{\mu_z}) \\ &= z(1-z)[x(C_1 + P - C_3L - EL \\ &+LP + LQ_3 + ELy)(1-m) + xmC_3 - C_3]\end{aligned} \tag{16}$$

$F(z)$ The first order partial derivatives with respect to z and the set $G(y)$ are:

$$\begin{aligned}\frac{dF(z)}{dz} &= (1-2z)[x(C_1 + P - C_3L - EL + LP + LQ_3 \\ &+ELy)(1-m) + xmC_3 - C_3]\end{aligned} \tag{17}$$

$$\begin{aligned}G(y) &= [x(C_1 + P - C_3L - EL + LP + LQ_3 \\ &+ELy)(1-m) + xmC_3 - C_3]\end{aligned} \tag{18}$$

From Eq. (18) we have:
$y^* = \frac{-x(C_1+P-C_3L-EL+LP+LQ_3)(1-m)-xmC_3+C_3}{ELx(1-m)}$, when $F(z) = 0$ and $\frac{dF(z)}{dz} \prec 0$, satisfying the evolutionary steady state, such that $F(z) = 0$, and thus $z = 0$,$z = 1$ and $y = y^*$, are discussed in the following three cases:

(1) $y = y^* = \frac{-x(C_1+P-C_3L-EL+LP+LQ_3)(1-m)-xmC_3+C_3}{ELx(1-m)}$ When $F(z) = 0$, at which point z takes any value, is a stable equilibrium and the public's strategy choice does not change over time.
(2) At $0 \prec y \prec y^* \prec 1$,$z = 0$,$z = 1$, are substituted into $\frac{dF(z)}{dz}$, and it is found that $\left.\frac{dF(z)}{dz}\right|_{z=1} < 0$, $\left.\frac{dF(z)}{dz}\right|_{z=0} > 0$,$z = 1$ is the public's evolutionary stabilization strategy, and the public chooses the active participation strategy when the probability of the company's active assistance is less than y^*.
(3) At $0 < y^* < y < 1$, it is found that $\left.\frac{dF(z)}{dz}\right|_{z=0} < 0$, $\left.\frac{dF(z)}{dz}\right|_{z=1} > 0$,$z = 0$ is the public's evolutionary stabilization strategy, and the public chooses the non-participation strategy when the probability of active corporate assistance is greater than that of y^*.

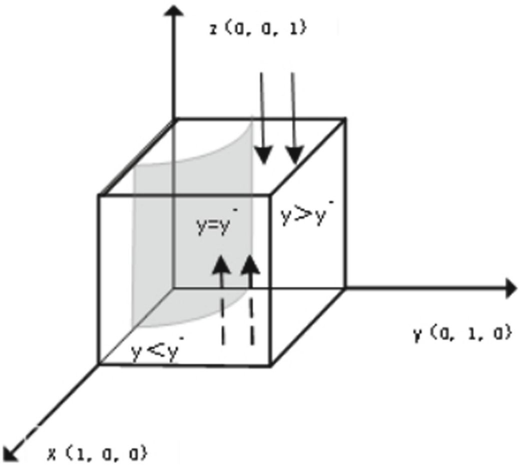

Fig. 3. Schematic diagram of the evolutionary path of the public

Based on the above analysis, a schematic diagram of the evolutionary path of local government strategies is obtained, as shown in Fig. 3, where the public chooses an active participation strategy when the cross-section z tends to 1, and the public tends to choose a non-participation strategy when the cross-section area z tends to 0.

4 Numerical Simulation Analysis

In the evolution process of the three-party game subjects, the different initial values will affect the evolution results of the three-party game subjects. In order to analyse the effect of active governance by local governments on the evolution results of the system, the following numerical simulation is used to discuss the influence of each subject's willingness to participate, the degree of local government incentives and the strength of production restrictions on the evolution results, in order to further explore the influence of active governance by local governments on the subjects' willingness to participate, and the incentive mechanism on the enthusiasm of enterprises and the public to participate. In order to further explore the impact of active governance on the willingness of local governments to participate, and the impact of incentives on the participation of enterprises and the public, the parameters are taken into account on the basis of the equilibrium principle of [17] and the values assigned in the literature [18]. The parameters are standardised in RMB million, as shown in Table 3.

4.1 Influence of Different Subjects' Initial Willingness to Participate on Evolutionary Outcomes

(1) Assuming other parameters remain unchanged, Fig. 4(a) shows the impact on the evolutionary results when the initial willingness to participate of local governments, enterprises and the public is 0.2, 0.5, 0.7 and 0.9 respectively, where x, y and z denote

Table 3. Initial parameter settings

Parameters	Numerical values	Parameters	Numerical values	Parameters	Numerical values
S	100	Q_2	20	C_3	2
R	150	T	10	Q_3	15
W	20	U	15	C_1	5
K	15	N	15	E	1
C_2	10	P	5		

the proportion of active governance by local governments, the proportion of active assistance by enterprises and the proportion of active participation by the public respectively. Figure 4(a) shows that as the initial willingness of the three parties increases, the rate of evolution to the stable point (1, 1, 1) becomes faster. When the initial willingness is 0.2, the epidemic has caused a shortage of human, material and financial resources for the local government, which has put greater pressure on the local government to prevent and control the epidemic. The local government gradually starts to provide incentives to the public and enterprises through active governance, in order to encourage more subjects to cooperate with the local government to prevent and control the epidemic and reduce the cost of prevention and control. As the degree of local government incentive increases, the game is played many times between the subjects, and after many imitative learning and dynamic adjustment, a stable state will eventually form under active prevention and control; when the initial willingness is at 0.5, the initial willingness of all three parties is at a medium level, at this time the local government's behavioural decisions will directly affect the evolutionary results, the local government adopts active governance for incentive, and the subjects of all parties will consider that the expected benefits are greater than the When the initial willingness is 0.7, all three parties are more concerned about the overall health of society and tend to actively participate in the prevention and control of the epidemic, so as to prevent widespread infection and control the spread of the epidemic. Reduce their respective losses during the epidemic and to resume work and production within a short period of time. Therefore, the three parties are more inclined to actively prevent and control the epidemic and to quickly reach a stable state of evolution.

(2) As shown in Fig. 4(b), the impact of changes in the initial willingness of local governments on the evolutionary outcome when enterprises and the public are at a medium willingness of 0.5. When the initial willingness of the local government is 0.2, in the short term, due to the small number of infected people, the local government tends to refrain from active governance, but as the number of infected people increases over time, the cost of prevention and control for the local government increases, and it gradually tends to choose active governance to obtain the power of social organizations for more efficient prevention and control of the epidemic, thus reducing the cost of prevention and control; as the initial willingness As the initial

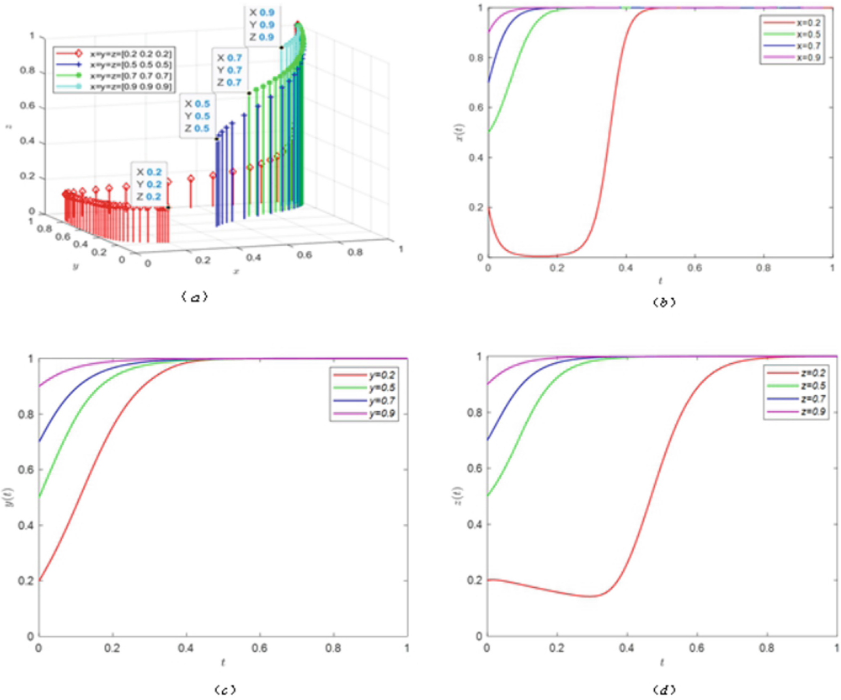

Fig. 4. Impact of changes in willingness to participate on the evolution of the system

willingness increases to 0.9, the rate of evolution of local governments to a stable state increases. Figure 4(c) shows the impact on the evolution of the system as the initial willingness of firms changes when the initial willingness of both the local government and the public is medium willingness 0.5. As firms consider that the benefits of a positive strategy outweigh the costs, the initial willingness increases and the speed of evolution to the steady state increases. Figure 4(d) shows the impact of the change in the public's initial willingness to evolve to a steady state when both the local government and the firm's initial willingness is medium willingness 0.5. When the public's initial willingness is 0.2, the public is more concerned about the harm caused by the virus to itself and has a low willingness to participate, but with the active governance of the local government or the consideration that the epidemic brings greater economic losses to the public, the public gradually tends to actively participate in prevention and control in order to reduce the losses caused by the epidemic. The rate of evolution to a stable equilibrium state increases as the initial willingness increases.

4.2 Impact of the Degree of Local Government Incentives on Evolutionary Outcomes

The evolutionary game trajectory of the participants with different incentive levels is shown in Fig. 5(a), with the incentive level L increasing, the incentive effect becomes

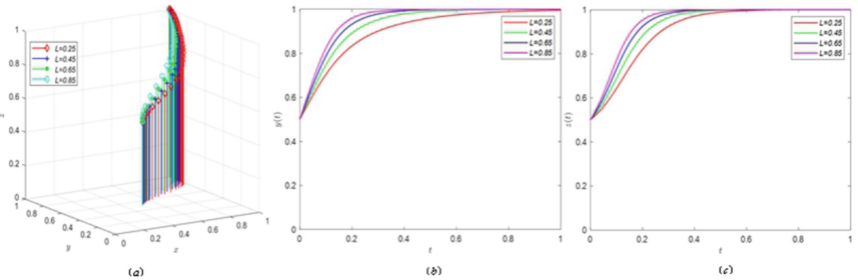

Fig. 5. Effect of changes in the degree of incentive on the evolution of the system

more obvious. As the incentive coefficient increases to 0.85, the faster the system evolves to a steady state i.e. the incentive level affects the strategy choice of both the firm and the public; as shown in Fig. 5(b), the firm evolves to a steady state faster when L is 0.85 than when L is 0.25, and the incentive level has a greater impact on the evolutionary speed of the firm; as shown in Fig. 5(c), over time, when the incentive coefficient L is 0.85 the public chooses to actively participate in the evolution of the strategy faster than the rate at which it reaches a steady state when the incentive coefficient L is 0.25. From the graphs in Fig. 5(b)(c), it can be seen that local government incentives can change the speed of behavioural strategy choice for both firms and the public. At a local government incentive coefficient of 0.25, firms evolve to a steady state more slowly than the public, and firms are more influenced by the degree of incentive than the public. Local government incentives can draw the attention of enterprises and the public to public health emergencies, prompting a change in their behavioural strategy choices and having an incentive effect on their participation behaviour.

4.3 Influence of the Strength of Local Government Production Restrictions on Evolutionary Outcomes

The impact of different production restriction coefficients on the evolutionary outcome is shown in Fig. 6(a). When the probability of strategy selection is all 0.5 for local government, enterprises and the public, the overall willingness of each subject to participate gradually decreases as the intensity of production restriction increases; as shown in Fig. 6(b), the increase in the intensity of production restriction significantly increases the speed at which enterprises reach the evolutionary stable state, as the production of enterprises is restricted during the epidemic prevention and control. As the production of enterprises is restricted during the epidemic prevention and control, their economic returns are hit to a certain extent. If enterprises can actively assist local governments in the prevention and control of the epidemic, they can effectively use their existing resources to their advantage, obtain subsidies from local governments and assist local governments to resume normal production and operation more quickly. Therefore, it is in the interest of the local government to actively assist them in the face of greater production restrictions. Therefore, the stronger the production restriction, the more enterprises tend to actively assist; as shown in Fig. 6(c), under low production restriction, the public is more inclined to choose to actively participate in epidemic prevention and control,

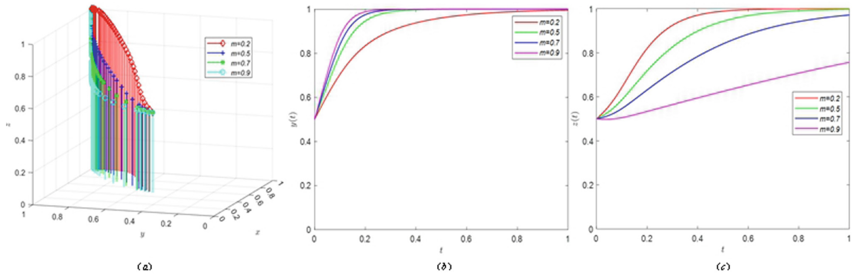

Fig. 6. Impact of changes in the intensity of production restrictions on the evolution of the system

and as the production restriction strength m increases to 0.7 and 0.9, the number of infected people is mostly at this time, and the public is more concerned about their own health and avoid contact with more people, so for the public, the stronger the production restriction, the more the public tends to choose the non-participation strategy Therefore, the stronger the restriction, the more likely the public will choose not to participate in the strategy.

5 Conclusions and Adaptations

5.1 Conclusion

Epidemic prevention and control gradually takes on a long-term character, which makes the participants in epidemic prevention and control make behavioural decisions under limited rationality. Differences in the external environment influence the behavioural strategy choices of participating actors. From a stakeholder perspective, an evolutionary game analysis of the behavioural decision-making process of local governments, enterprises and the public, among other participants in epidemic prevention and control, leads to the following conclusions:

(1) The different willingness to participate of local governments, enterprises and the public have different effects on the evolution of the system to a steady state. The rate of evolution to a steady state varies with the initial willingness of local governments and the public, and the rate of evolution to a steady state is more influenced by the initial willingness of local governments and the public. Different initial willingness of enterprises has a smaller impact on the rate of evolution to a steady state.

(2) Incentives influence the choice of positive or negative prevention and control strategies of enterprises and the public. Under the influence of incentive factors, the choice of positive or negative attitudes by enterprises and the public is directly related to the cost-benefit. The evolutionary process shows that firms and the public evolve to stable strategies faster under high levels of local government incentives than under low levels of incentives, i.e. firms and the public make their strategic choices more resolutely when they are rational. In addition, firms are more sensitive to the level of incentive, with a greater difference in the speed of evolution to a stable state at low levels of incentive compared to high levels of incentive.

(3) When local government production restrictions increase, firms evolve to a steady state faster, when the public is more inclined to choose a non-participation strategy and the public is more sensitive to the intensity of production restrictions.

5.2 Adaptation Responses

Based on the above findings, the following adaptive responses are proposed:

(1) Incentive mechanisms should be improved to maximize their effectiveness in epidemic prevention and control

Local governments should fully mobilise social resources through the implementation of incentive mechanisms, make full use of internal resources and information of enterprises, mobilise experts and scholars and unite the public to formulate scientific and effective prevention and control plans for the emergency prevention and control of major public health emergencies. This will enable each of them to actively cooperate with local governments and departments at all levels, which can effectively control the costs of epidemic prevention and control and bring the maximum effectiveness of social organisations. However, while implementing the incentive mechanism, the irregularities and free-riding behaviour of each participating body should be restrained, especially for enterprises whose incentive level is more sensitive.

(2) Local governments should formulate reasonable policies to limit production

The public is sensitive to the intensity of production restrictions and tends to choose a non-participation strategy when production restrictions reach a certain level, so a high level of production restrictions is not conducive to the public's ability to work with local governments to prevent and control the epidemic. When production restrictions are at a moderate level, the public tends to choose the strategy of active participation, and this will lead to the joint prevention and control of the epidemic by multiple actors.

The next step will be to expand and deepen the analysis of the game between the state and the country, in addition to the analysis of the game between more diverse subjects.

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