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Research Article

Research on Social Governance of Network Public Opinion: An Evolutionary Game Model

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Compared with the past, public opinion in the we-media era has become more difficult. How to incentivize social networking providers (SNPs) to participate in network public opinion governance and guide we-media practitioners (WPs) to standardize their dissemination are prominent problems that urgently need to be solved in response to network public opinion. This article supplements the perspective of network public opinion governance research and constructs a tripartite evolutionary game model including government, SNPs, and WPs. Then, after analyzing the influencing factors of the evolution of different agents' strategies through model solving and numerical simulation, this article finds that reasonable rewards and punishments can promote SNPs to participate in network public opinion governance. Finally, this article proposes that the government should build a social governance system for network public opinion, which will effectively reduce governance costs and improve governance efficiency.

1. Introduction

With the development of Internet technology, different forms of social networking sites such as instant messaging, online forums, and short videos have sprung up [1]. The real world and the virtual network world are interpenetrating. While enjoying information sharing and expressing opinions more conveniently and quickly, people also suffer from the uncertainty brought by massive amounts of information to their lives. Compared with the traditional media era, the dissemination of rumors and false information in We-media era is more dangerous [2]. If the government handles these disseminations improperly, its own authority will be challenged, and it is more likely to cause panic among the people and endanger social stability. Especially after 2020, COVID-19 pandemic had caused great panic among people, and there had been one after another storm of public opinion in China. With the spread of COVID-19 on a large scale in society, the information related to the epidemic on the Internet had exploded, and rumors had spewed out [3, 4].

Previous researches on network public opinion governance have achieved some results. These studies mainly focused on the application of computer technology in network public opinion governance and the description of the evolution of network public opinion by mathematical models. Using data mining and other technologies to obtain and analyze the trend of public opinion has become an important topic in the field of network public opinion governance [5–7]. Wei-Dong H et al. [10] studied on the evolutionary mechanism of multiagent in opinion dissemination by using social network analysis methods and sentiment mining analysis techniques and also discussed the role of users in social network sentiment dissemination. Chen et al. [9] proposed to use rough set theory to reduce the network public opinion monitoring index system. Then, they constructed a more scientific monitoring index system of network public opinion, and determined the weight of the index using the analytic hierarchy process. Li et al. [10] proposed and implemented an effective time + user dual attention mechanism model to analyze and predict the textual information of public opinion. Processing public opinion texts, images, or videos through computer technology is the most important step in network public opinion analysis and governance [11]. It is beneficial for the network public opinion management department to quickly grasp the development and evolution of public opinion, and take corresponding measures according to different situations.

From the perspective of the evolution of network public opinion, some scholars seek the rules for the development of public opinion and provide help for network public opinion governance. Yao [12] discussed for the application of cellular automata simulation model of internet evolution of public opinion. Lian et al. [13] pointed out that the network public opinion topology structure based on the classic BA model has the defects of simple scope and not rigorous deduction, and overcame these defects to deduce a model based on complex network theory. Gao et al. [14] introduced eight mechanisms working on formation and dissemination of public opinion on network, and further proposed a comprehensive causal relationship model based on system dynamics to explore the factors affecting the consequence of public opinion on network. Qiu et al. [15] built the temporal model based on the time series forecasting model for emergency network public opinion, and analyzed the change of public opinion trend from a quantitative perspective. In addition, it is also popular to study the evolution of online public opinion through game theory. Wei et al. [16] combined game theory with traditional SIRS epidemic model to propose an improved model, and experimentally verified the model through specific events. Wang et al. [17] proposed a tripartite evolutionary game model including netizens, media, and the government, analyzed the possible equilibrium strategies and its' stability conditions. Yin et al. [18] proposed an agent-based online opinion formation model based on attitude change theory, group behavior theory, and evolutionary game theory.

However, based on the spiral of silence and two-stage propagation theory [19–21], we find that the previous research perspective rarely mentioned social networking providers (SNPs) and we-media practitioners (WPs). If WPs is not involved, the research on social governance of network public opinion would lack guidance for practice. SNPs should also shoulder corresponding social responsibilities. Therefore, combined with the characteristics of the we-media era, this article proposes a three-party evolutionary game model including government, SNPs, and WPs. Then, we analyzed the strategic stability and influencing factors of all parties in the process of public opinion evolution and used MATLAB to conduct simulation experiments.

2. Evolutionary Game Model

2.1. Problem Description. At present, the government hopes to weaken the impact of online public opinion on social stability through policies and other means. WPs would like to attract more fans by creating content on social networking sites including text, pictures, and videos, and make money by providing fans with advertisements, paid reading, and e-commerce service [22]. SNPs will cooperate with WPs, provide them with traffic exposure services, and share in the profits of WPs. However, in order to pursue more interests, WPs may distort facts and exaggerate information to gain more attention in the dissemination of online public opinion. To save costs, SNPs may not verify the authenticity of content posted by WPs on their social networking sites. This article holds that the main players in the social governance of network public opinion are the government, SNPs, and WPs.

2.2. Hypothesis of the Evolutionary Game Model. It is assumed that all three parties are bounded rational in the game process.

2.2.1. Gaming Strategy. The government's game strategy is active prevention and passive intervention; the government could choose different strategies for online public opinion caused by emergencies. SNPs' game strategy is supervision and nonsupervision; SNPs could choose whether to supervise the content spread on social networking sites when network public opinion occurs. WPs' strategy is seeking truth from facts and distorting facts; WPs could seriously search for information, publish creations rationally, or gain more traffic by distorting facts.

2.2.2. Cost. The government will not directly interfere with the fact that WPs participate in online public opinion dissemination, but it can formulate relevant regulations and systems for the dissemination of Internet information to actively prevent sudden online public opinion, and the cost incurred is C_g. When online public opinion breaks out, it takes time for WPs to choose the strategy of seeking truth from facts. The time and labor cost is C_l. The cost of personnel, financial, and material resources required for SNPs to choose to supervise online public opinion is C_p.

2.2.3. Gains and Losses. When the government chooses the strategy of active prevention, the social stability benefit obtained at this time is denoted as G_1, and α is the benefit coefficient when the government chooses the passive intervention strategy, that is, the benefit of social stability at this time is αG_1, $\alpha \in (0, 1)$. The initial earnings of SNPs and WPs before the emergency are P_1 and L_1. When SNPs chooses the supervision strategy, these sites get word-of-mouth promotion and more users are recorded as P_2. When WPs choose the strategy of seeking truth from facts, the benefit for social stability is G_2, and this strategy will also enhance their own image and fans so that they can obtain more business cooperation L_2. The sharing coefficient between SNPs and the WPs for the benefit brought by business cooperation is β, the benefit of SNPs due to the image enhancement of self-media practitioners is βL_2, and the personal benefit of WPs is $(1-\beta)L_2$, $\beta \in (0, 1)$. When WPs are tempted by interests L_3, these interests could come from short-term explosions or funding from certain interest groups that affect social stability, and choose the strategy of distorting facts. The loss to social stability is G_3.

2.2.4. Rewards and Penalties. When network public opinion spreads in SNPs and causes great harm to the social stability, the government penalty for SNPs is W. The WPs who choose the strategy of distorting facts in the propagation will be called by the government to boycott and lose the initial income. When the government's strategy is active prevention, SNPs who choose the strategy of supervision will be exempted from partial penalties, and the reduction coefficient is γ. At this time, the government penalty for SNPs is γW, $\gamma \in (0,1)$. For SNPs that do not endanger social stability due to the spread of network public opinion, the government will reduce taxes as H. When SNPs choose the strategy of supervision, WPs choose strategy of seeking truth from facts will be promoted as K by the SNPs, and choose strategy of distorting facts will be punished as U by the SNPs.

2.3. Payoff Matrix. According to the above five assumptions, we have obtained the payoff matrix about government, SNPs, and WPs, as shown in Table 1.

In this evolutionary game model, government, SNPs, and WPs make strategic choices based on their own circumstances. The probability of the government choosing the strategy of active prevention is written as x, then the probability of choosing the strategy of passive intervention is $1-x$; the probability of SNPs choosing the strategy of supervision is defined as y, the probability of choosing the strategy of nonsupervision is $1-y$; the probability of WPs to choose the strategy of seeking truth from facts is represented by z, then the probability of choosing the strategy of distorting facts that distorts the truth is $1-z$, $x, y, z \in (0,1)$.

2.4. Replicator Dynamics Equation. For the government, the expected revenue of choosing the strategy of active prevention is π_{x1}, the expected revenue of choosing the strategy of passive intervention is π_{x2}, and the average expected revenue is $\overline{\pi}_x$.

$$\begin{aligned}
\pi_{x1} &= yz\left(G_1+G_2-C_g-H\right)+y(1-z)\left(G_1+\gamma W-C_g-G_3\right)+(1-y)z\left(G_1+G_2-C_g-H\right)+(1-y)\\
&\quad (1-z)\left(G_1+W-C_g-G_3\right),\\
\pi_{x2} &= yz\left(\alpha G_1+G_2\right)+y(1-z)\left(\alpha G_1+W-G_3\right)+(1-y)z\left(\alpha G_1+G_2\right)+(1-y)(1-z)\left(G_1+W-G_3\right),\\
\overline{\pi}_x &= x\pi_{x1}+(1-x)\pi_{x2}.
\end{aligned} \tag{1}$$

For SNPs, the expected revenue of choosing the strategy of supervision is π_{y1}, the expected revenue of choosing the strategy of nonsupervision is π_{y2}, and the average expected revenue is $\overline{\pi}_y$.

$$\begin{aligned}
\pi_{y1} &= xz\left[P_1+P_2+H+(1-\beta)L_2-C_p-K\right]+x(1-z)\left(P_1+P_2+U-C_p-\gamma W\right)\\
&\quad +(1-x)z\left[P_1+P_2+(1-\beta)L_2-C_p-K\right]+(1-x)(1-z)\left(P_1+P_2+U-C_p-W\right),\\
\pi_{y2} &= xz\left[P_1+H+(1-\beta)L_2\right]+x(1-z)\left(P_1-W\right)+(1-x)z\left[P_1+(1-\beta)L_2\right]+(1-x)(1-z)\left(P_1-W\right),\\
\overline{\pi}_y &= y\pi_{y1}+(1-y)\pi_{y2}.
\end{aligned} \tag{2}$$

For WPs, the expected revenue of choosing the strategy of seeking truth from facts is π_{z1}, the expected revenue of choosing the strategy of distorting facts is π_{z2}, and the average expected revenue is $\overline{\pi}_z$.

$$\begin{aligned}
\pi_{z1} &= xy\left(L_1+\beta L_2+K-C_l\right)+x(1-y)\left(L_1+\beta L_2-C_l\right)+(1-x)y\left(L_1+\beta L_2+K-C_l\right)\\
&\quad +(1-x)(1-y)\left(L_1+\beta L_2-C_l\right),\\
\pi_{z2} &= xy\left(L_3-U\right)+x(1-y)L_3+(1-x)y\left(L_1+L_3-U\right)+(1-x)(1-y)\left(L_1+L_3\right),\\
\overline{\pi}_z &= z\pi_{z1}+(1-z)\pi_{z2}.
\end{aligned} \tag{3}$$

Table 1: The payoff matrix about government, SNPs, and WPs.

		WPs (seeking truth from facts)	WPs (distorting facts)
Government (active prevention)	SNPs (supervision)	$G_1 + G_2 - C_g - H$ $P_1 + P_2 + H + (1-\beta)L_2 - C_p - K$ $L_1 + \beta L_2 + K - C_l$	$G_1 + \gamma W - C_g - G_3$ $P_1 + P_2 + U - C_p - \gamma W$ $L_3 - U$
	SNPs (nonsupervision)	$G_1 + G_2 - C_g - H$ $P_1 + H + (1-\beta)L_2$ $L_1 + \beta L_2 - C_l$	$G_1 + W - C_g - G_3$ $P_1 - W$ L_3
Government (passive intervention)	SNPs (supervision)	$\alpha G_1 + G_2$ $P_1 + P_2 + (1-\beta)L_2 - C_p - K$ $L_1 + \beta L_2 + K - C_l$	$\alpha G_1 + W - G_3$ $P_1 + P_2 + U - C_p - W$ $L_1 + L_3 - U$
	SNPs (nonsupervision)	$\alpha G_1 + G_2$ $P_1 + (1-\beta)L_2$ $L_1 + \beta L_2 - C_l$	$\alpha G_1 + W - G_3$ $P_1 - W$ $L_1 + L_3$

The replicator dynamics equation of the government can be obtained as follows [23–28]:

$$F(x) = \frac{dx}{dt} = x(1-x)\left(\pi_{x1} - \overline{\pi}_x\right) = x(1-x)\left(\pi_{x1} - \pi_{x2}\right) = x(1-x)\left[W - zH - C_g(1-\alpha)G_1 - y(1-z)(1-\gamma)\right], \quad (4)$$

In the same way, the replicator dynamics equation of SNPs and WPs can be obtained. After combining the replication dynamic equations of the three parties, the three-party replication dynamic system (5) can be obtained. In system itself, each of the functions considered depends on all three variables x, y, and z.

$$\begin{cases} F(x) = \dfrac{dx}{dt} = x(1-x)\left[(1-\alpha)G_1 - y(1-z)(1-\gamma)W - zH - C_g\right], \\ F(y) = \dfrac{dy}{dt} = y(1-y)\left[x(1-z)(1-\gamma)W + (1-z)U + P_2 - zK - C_p\right], \\ F(z) = \dfrac{dz}{dt} = z(1-z)\left[xL_1 + \beta L_2 + yK + yU - L_3 - C_l\right]. \end{cases} \quad (5)$$

2.5. Three-Party Strategy Evolution Process. According to Lyapunov stability theorem [29, 30], if the strategy adopted by the government, SNPs, or WPs is a stable strategy, then x, y, and z must satisfy the following conditions [31]:

$$F(x) = 0, \quad \frac{\delta F(x)}{\delta x} < 0, \quad F(y) = 0, \quad \frac{\delta F(y)}{\delta y} < 0, \quad F(z) = 0, \quad \frac{\delta F(z)}{\delta z} < 0. \quad (6)$$

As shown in Figure 1. If we denote $y_0 = (1-\alpha)G_1 - zH - C_g/(1-z)(1-r)W$, when $y = y_0$, $\forall x \in [0,1]$, $F(x) = dx/dt \equiv 0$, and $\partial F(x)/\partial x \equiv 0$, the stable strategy of government is uncertain, as shown in Figure 1(a). When $0 \le y < y_0 \le 1$, only $x = 0$ or $x = 1$, $F(x) = dx/dt = 0$, $\partial F(x)/\partial x|x = 1 > 0$, but $\partial F(x)/\partial x|x = 0 < 0$, so, the stable strategy of government is passive intervention, as shown in Figure 1(b). When $0 \le y_0 < y \le 1$, the stable strategy of government is active prevention, as shown in Figure 1(c).

As shown in Figure 2. If we denote $z_0 = x(1-\gamma)W + U + P_2 - C_p/x(1-\gamma)W + U + K$, when $z = z_0$, $\forall y \in [0,1]$, $F(y) = dy/dt \equiv 0$, and $\partial F(y)/\partial y \equiv 0$, the stable strategy of SNPs is uncertain, as shown in Figure 2(a). When $0 \le z < z_0 \le 1$, only $y = 0$ or $y = 1$, $F(y) = dy/dt = 0$, $\partial F(y)/\partial y|y = 1 > 0$, but $\partial F(y)/\partial y|y = 0 < 0$, therefore, the stable strategy of SNPs is nonsupervision, as shown in Figure 2(b). When $0 \le z_0 < z \le 1$, the stable strategy of SNPs is supervision, as shown in Figure 2(c).

As shown in Figure 3. If we denote $x_0 = L_3 + C_l - \beta L_2 - yK - yU/L_1$, when $x = x_0$, $\forall z \in [0,1]$, $F(z) = dz/dt \equiv 0$, and $\partial F(z)/\partial z \equiv 0$, the stable strategy of WPs is uncertain, as shown in Figure 3(a). When $0 \le x < x_0 \le 1$, only $z = 0$ or $z = 1$, $F(z) = dz/dt = 0$, $\partial F(z)/\partial z|z = 1 < 0$, but $\partial F(z)/\partial z|z = 0 > 0$, hence, the stable strategy of WPs is seeking truth from facts, as shown in Figure 3(b). When $0 \le z_0 < z \le 1$, the stable strategy of WPs is distorting facts, as shown in Figure 3(c).

2.6. Evolutionary Stability Analysis. In replication dynamic system (5), let $F(x) = F(y) = F(z) = 0$, the equilibrium points of this tripartite game can be obtained: E_1 (0, 0, 0), E_2 (1, 0, 0), E_3 (0, 1, 0), E_4 (1, 1, 0), E_5 (0, 0, 1), E_6 (0, 1, 1), E_7 (1, 0, 1), E_8 (1, 1, 1) and E_9 (x^*, y^*, z^*). In real, game objects do not have a completely rational situation in the hypothesis, so the Nash equilibrium cannot be directly realized. Evolutionary game is the process of continuous learning of different game subjects, and repeated games are played in a group composed of bounded rational subjects to achieve evolutionary stable equilibrium. At this time, the strategy of the group is an evolutionary stable strategy (ESS). ESS describes the local dynamic properties of replicating dynamic systems. In an asymmetric game, if the strategy of game evolution is ESS, then it must be a strict Nash equilibrium, but the game strategy is Nash equilibrium strategy but not necessarily ESS [32, 33].

Since this article mainly discusses the governance of network public opinion, in the current society, a responsible government is bound to choose the strategy of active prevention [32]. For this, we make assumptions: $(1-\alpha)G_1 - H - C_g > 0$. That is to say, the benefit of the government's choice of active prevention is greater than that of passive intervention. For the convenience of subsequent work, this article only considers equilibrium points that contain only 0 and 1. In this article, we use Lyapunov

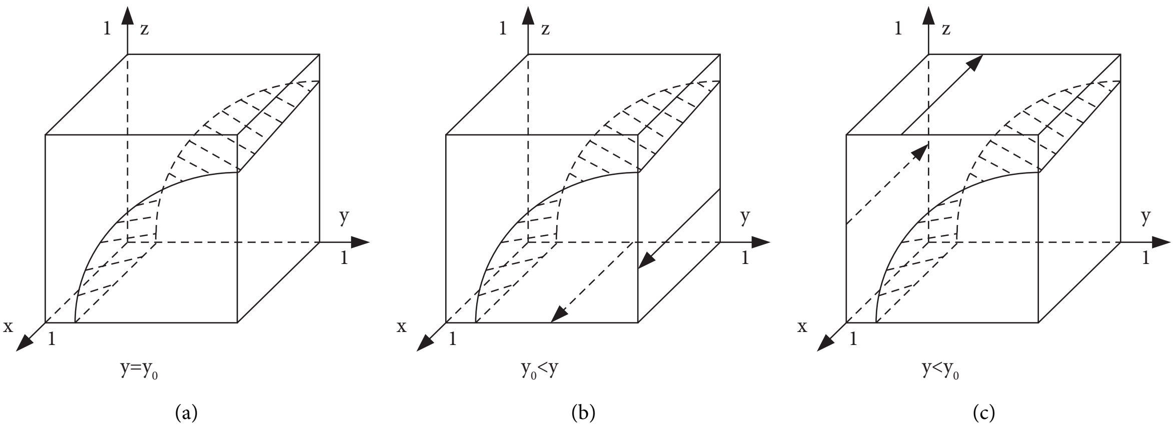


Figure 1: The evolution process of the government.

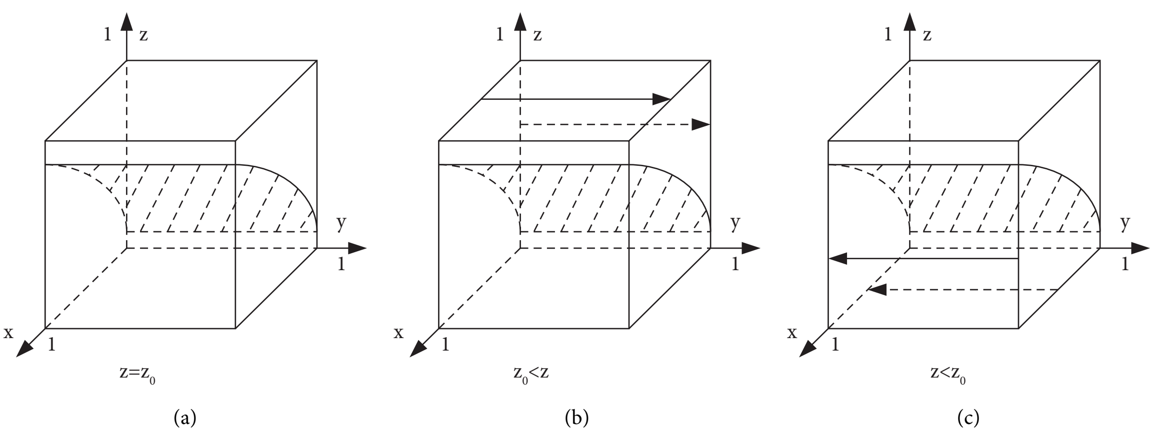


Figure 2: The evolution process of SNPs.

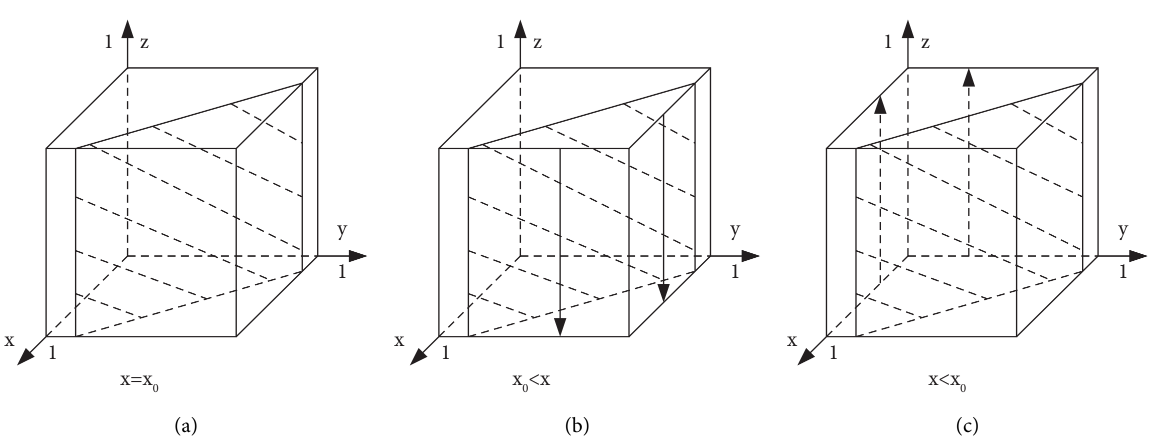


Figure 3: The evolution process of WPs.

stability theory to analyze whether the evolutionary stable strategy combination is true.

The Jacobian matrix of this evolutionary game model is shown as follows:

$$J = \begin{bmatrix} J_{11} & J_{12} & J_{13} \\ J_{21} & J_{22} & J_{23} \\ J_{31} & J_{32} & J_{33} \end{bmatrix} = \begin{bmatrix} \frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y} & \frac{\partial F(x)}{\partial z} \\ \frac{\partial F(y)}{\partial x} & \frac{\partial F(y)}{\partial y} & \frac{\partial F(y)}{\partial z} \\ \frac{\partial F(z)}{\partial x} & \frac{\partial F(z)}{\partial y} & \frac{\partial F(z)}{\partial z} \end{bmatrix}$$
$$= \begin{bmatrix} (1-2x)\left[(1-\alpha)G_1 - y(1-z)(1-\gamma)W - zH - C_g\right] & -x(1-x)(1-z)(1-\gamma)W & x(1-x)[y(1-\gamma)W - H] \\ y(1-y)(1-z)(1-\gamma)W & (1-2y)[x(1-z)(1-\gamma)W + (1-z)U + P_2 - zK - C_p] & y(1-y)[-x(1-\gamma)W - U - K] \\ z(1-z)L_1 & z(1-z)(K+U) & (1-2z)\left[xL_1 + \beta L_2 + yK + yU - L_3 - C_l\right] \end{bmatrix}. \tag{7}$$

Substituting the equilibrium points into the Jacobian matrix of equation (7), respectively, we can get the eigenvalues and stable conditions of 8 equilibrium points, as shown in Table 2.

Under the assumed conditions, the eigenvalues of equilibrium points E_1, E_5, and E_6 exist as positive values, which do not conform to Lyapunov stability theory. Therefore, we will not consider them in the following stability analysis.

Proposition 1. *If $P_2 - K - C_p > 0$ and $\beta L_2 - L_3 - C_l > 0$, only the equilibrium point E_8 (1, 1, 1) is ESS.*

Proof. As shown in case 1 of Table 3. When $P_2 - K - C_p > 0$, the benefit of SNPs choosing supervision is greater than nonsupervision. At this time, the eigenvalues of equilibrium points E_2, E_3, and E_7 exist as positive values and should be excluded. When $\beta L_2 - L_3 - C_l > 0$, the benefit of WPs choosing seeking truth from facts is greater than distorting facts. At this time, the eigenvalues of equilibrium point E_4 exist as positive values and should be excluded. The eigenvalues of equilibrium point E_8 are all negative values. Therefore, only the equilibrium point E_8 (1, 1, 1) is ESS. □

Proposition 2. *If $P_2 - K - C_p > 0$ and $\beta L_2 - L_3 - C_l < 0$, the ESS for the evolutionary game cannot be determined.*

Proof. As shown in case 2 of Table 3. When $P_2 - K - C_p > 0$, the benefit of SNPs choosing supervision is greater than nonsupervision. The eigenvalues of equilibrium points E_2, E_3, and E_7 exist as positive values and should be excluded. When $\beta L_2 - L_3 - C_l < 0$, the benefit of WPs choosing distorting facts is greater than seeking truth from facts. No Equilibrium point will be excluded. Under the condition of case 2, the signs of the eigenvalues of E_4 and E_8 cannot be determined, so their stability cannot be judged.

Under the condition of case 2, the eigenvalue λ_1 of the equilibrium point E_3 and the eigenvalue λ_1 of the equilibrium point E_4 are opposite numbers, and the eigenvalue λ_3 of the equilibrium point E_4 and the eigenvalue λ_3 of the equilibrium point E_8 are opposite numbers. The ESS of equilibrium points E_3 and E_8 wound coexist, if the following conditions are satisfied: $G_1 + \gamma W - C_g < \alpha G_1 + W$, $L_1 + \beta L_2 + K + U > L_3 + C_l > \beta L_2 + K + U$, SNPs chooses the strategy of supervision and WPs chooses the strategy of distorting the facts. Although when the government chooses the passive intervention strategy, the WPs' benefit is greater than the active prevention strategy. However, the government's penalty reduction for SNPs is relatively large, and the government's benefit from active prevention is not as good as passive supervision. At this time, the equilibrium points E_3 and E_8 are both ESS. □

Proposition 3. *If $P_2 - K - C_p < 0$ and $\beta L_2 - L_3 - C_l > 0$, only the equilibrium point E_7 (1, 0, 1) is ESS.*

Proof. As shown in case 3 of Table 3. When $P_2 - K - C_p < 0$, the benefit of SNPs choosing nonsupervision is greater than supervision. The eigenvalues of equilibrium point E_8 exist as positive values and should be excluded. When $\beta L_2 - L_3 - C_l > 0$, the benefit of SNPs choosing seeking truth from facts is greater than distorting facts. The equilibrium

Table 2: Eigenvalues and stable conditions of equilibrium points.

Equilibrium points	Eigenvalues	Stability conditions
$E_1\,(0,\ 0,\ 0)$	$(1-\alpha)G_1 - C_g$ $U + P_2 - C_p$ $\beta L_2 - L_3 - C_l$	$(1-\alpha)G_1 < C_g$ $P_2 + U < C_p$ $\beta L_2 < L_3 + C_l$
$E_2\,(1,\ 0,\ 0)$	$-(1-\alpha)G_1 + C_g$ $(1-\gamma)W + U + P_2 - C_p$ $L_1 + \beta L_2 - L_3 - C_l$	$(1-\alpha)G_1 > C_g$ $(1-\gamma)W + U + P_2 < C_p$ $L_1 + \beta L_2 < L_3 + C_l$
$E_3\,(0,\ 1,\ 0)$	$(1-\alpha)G_1 - (1-\gamma)W - C_g$ $-U - P_2 + C_p$ $\beta L_2 + K + U - L_3 - C_l$	$(1-\alpha)G_1 - (1-\gamma)W < C_g$ $P_2 + U > C_p$ $\beta L_2 + K + U < L_3 + C_l$
$E_4\,(1,\ 1,\ 0)$	$-(1-\alpha)G_1 + (1-\gamma)W + C_g - (1-\gamma)W - U - P_2 + C_p$ $L_1 + \beta L_2 + K + U - L_3 - C_l$	$(1-\alpha)G_1 - (1-\gamma)W > C_g$ $(1-\gamma)W + U + P_2 > C_p L_1 + \beta L_2 + K + U < L_3 + C_l$
$E_5\,(0,\ 0,\ 1)$	$(1-\alpha)G_1 - H - C_g$ $P_2 - K - C_p$ $-\beta L_2 + L_3 + C_l$	$(1-\alpha)G_1 - H < C_g$ $P_2 - K < C_p$ $\beta L_2 > L_3 + C_l$
$E_6\,(0,\ 1,\ 1)$	$(1-\alpha)G_1 - H - C_g$ $-P_2 + K + C_p$ $-\beta L_2 - K - U + L_3 + C_l$	$(1-\alpha)G_1 - H < C_g$ $P_2 - K > C_p$ $\beta L_2 + K + U > L_3 + C_l$
$E_7\,(1,\ 0,\ 1)$	$-(1-\alpha)G_1 + H + C_g$ $P_2 - K - C_p$ $-L_1 - \beta L_2 + L_3 + C_l$	$(1-\alpha)G_1 - H > C_g$ $P_2 - K < C_p$ $L_1 + \beta L_2 > L_3 + C_l$
$E_8\,(1,\ 1,\ 1)$	$-(1-\alpha)G_1 + H + C_g$ $-P_2 + K + C_p$ $-L_1 - \beta L_2 - K - U + L_3 + C_l$	$(1-\alpha)G_1 - H > C_g$ $P_2 - K > C_p$ $L_1 + \beta L_2 + K + U > L_3 + C_l$

Table 3: The condition of evolutionary stability of equilibrium points.

Equilibrium points	Case 1		Case 2		Case 3		Case 4	
	$\lambda_1, \lambda_2, \lambda_3$	Stability	$\lambda_1, \lambda_2, \lambda_3$	Stability	$\lambda_1, \lambda_2, \lambda_3$	Stability	$\lambda_1, \lambda_2, \lambda_3$	Stability
E_1 (0, 0, 0)	+, +, +	Unstable	+, +, −	Unstable	+, \, +	Unstable	+, \, −	Unstable
E_2 (1, 0, 0)	−, +, +	Unstable	−, +, \	Unstable	−, \, +	Unstable	−, \,	Uncertain
E_3 (0, 1, 0)	\, −, +	Unstable	\, −, \	Uncertain	\, \, +	Unstable	\, \, \	Uncertain
E_4 (1, 1, 0)	\, −, +	Unstable	\, −, \	Uncertain	\, \, +	Unstable	\, \, \	Uncertain
E_5 (0, 0, 1)	+, +, −	Unstable	+, +, +	Unstable	+, −, −	Unstable	+, −, +	Unstable
E_6 (0, 1, 1)	+, −, −	Unstable	+, −, \	Unstable	+, +, −	Unstable	+, +, \	Unstable
E_7 (1, 0, 1)	−, +, −	Unstable	−, +, \	Unstable	−, −, −	ESS	−, −, \	Uncertain
E_8 (1, 1, 1)	−, −, −	ESS	−, −, \	Uncertain	−, +, −	Unstable	−, +, \	Unstable

Note: "\" indicates that the sign of the eigenvalue is uncertain.

points E_2, E_3, and E_4 exist as positive values and should be excluded. The eigenvalues of equilibrium point E_7 are all negative values, therefore, only the equilibrium point E_7 (1, 0, 1) is ESS. ☐

Proposition 4. *If $P_2 - K - C_p < 0$ and $\beta L_2 - L_3 - C_l < 0$. The ESS for the evolutionary game cannot be determined.*

Proof. As shown in case 4 of Table 3. When $P_2 - K - C_p < 0$, the benefit of SNPs choosing nonsupervision is greater than supervision. The eigenvalues of equilibrium point E_8 exist as positive values and should be excluded. When $\beta L_2 - L_3 - C_l < 0$, the benefit of WPs choosing distorting facts is greater than seeking truth from facts. No Equilibrium point will be excluded. Under the condition of case 4, the signs of the eigenvalues of E_2, E_3, E_4, and E_7 cannot be determined, so their stability cannot be judged.

Under the condition of case 4, the eigenvalue λ_2 of the equilibrium point E_2 and the eigenvalue λ_2 of the equilibrium point E_4 are opposite numbers. The eigenvalue λ_3 of the equilibrium point E_2 and the eigenvalue λ_3 of the equilibrium point E_7 are opposite number. The eigenvalue λ_1 of the equilibrium point E_3 and the eigenvalue λ_1 of the equilibrium point E_4 are opposite number. When the eigenvalue λ_2 of the equilibrium point E_3 is negative, the eigenvalue λ_2 of the equilibrium point E_2 must be positive. When the eigenvalue λ_3 of the equilibrium point E_4 is negative, the eigenvalue λ_3 of the equilibrium point E_7 must be positive. The ESS of equilibrium points E_3 and E_7 wound coexist, if the following conditions are satisfied: $G_1 + \gamma W - C_g < \alpha G_1 + W$, $L_1 + \beta L_2 - C_l > L_3 > \beta L_2 + K + U - C_l$, $P_2 + U > C_p$, WPs chooses the strategy of distorting the facts. The benefit of government choosing active prevention strategy is lower than that of passive intervention, and the benefit of SNPs

Table 4: The fixed values.

Parameters	C_g	G_1	α	W	γ	H	C_p	P_2	C_1	L_1	L_2	β	L_3	K	U
Fixed values	3	15	0.4	4	0.5	5	2	5	1	3	6	0.5	4	2	3

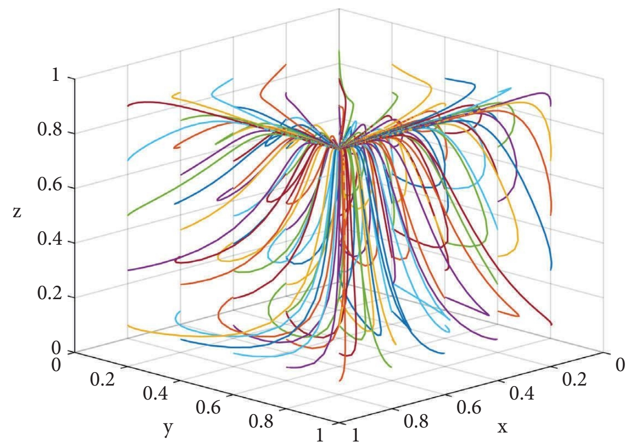
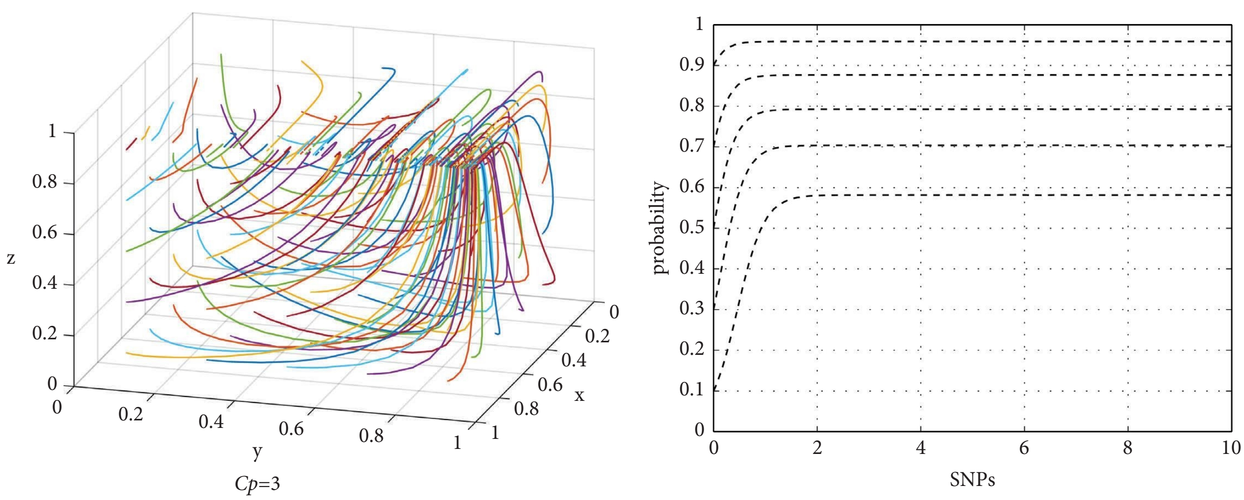


Figure 4: Three-party evolution of fixed values.



(a) (b)

Figure 5: $C_P = 3$ three-party evolution.

choosing supervision is positive. When the initial earning is not included, the benefit of WPs is less than the temptation of interests, and vice versa when the initial earning is included. At this time, the equilibrium points E_3 and E_7 are both ESS. □

3. Numerical Simulation Analysis

What we are pursuing is the social governance system for network public opinion, that is, the government chooses active prevention, SNPs choose supervision and WPs seek truth from facts. Following the above analysis, we use numerical simulations further to analyze the equilibrium point E_8 (1, 1, 1). Before the numerical simulations are performed, the model parameters are assigned with fixed values in Table 4. They must satisfy the condition of Proposition 1. As shown in Figure 4, the strategic evolution of the three-party is stable at E_8 (1, 1, 1).

Under Proposition 1, there is no coexistence of equilibria. We try to explore the evolution of the three-party strategy when the eigenvalue is 0. Therefore, we keep other fixed values unchanged, and simulate the situation where the eigenvalues λ_2 and λ_3 of the equilibrium point E_8 (1, 1, 1) are 0 by changing individual parameters. As shown in Figure 5(a), we set $C_p = 3$ to obtain the three-party evolution diagram when the eigenvalue λ_2 is 0, and there is no stable point at this time. As shown in Figure 5(b), we set 0.1 as the starting point, 0.2 as the step size, and 1 as the end point to explore the willingness change of SNPs when $C_p = 3$. The results show that the willingness of SNPs to choose

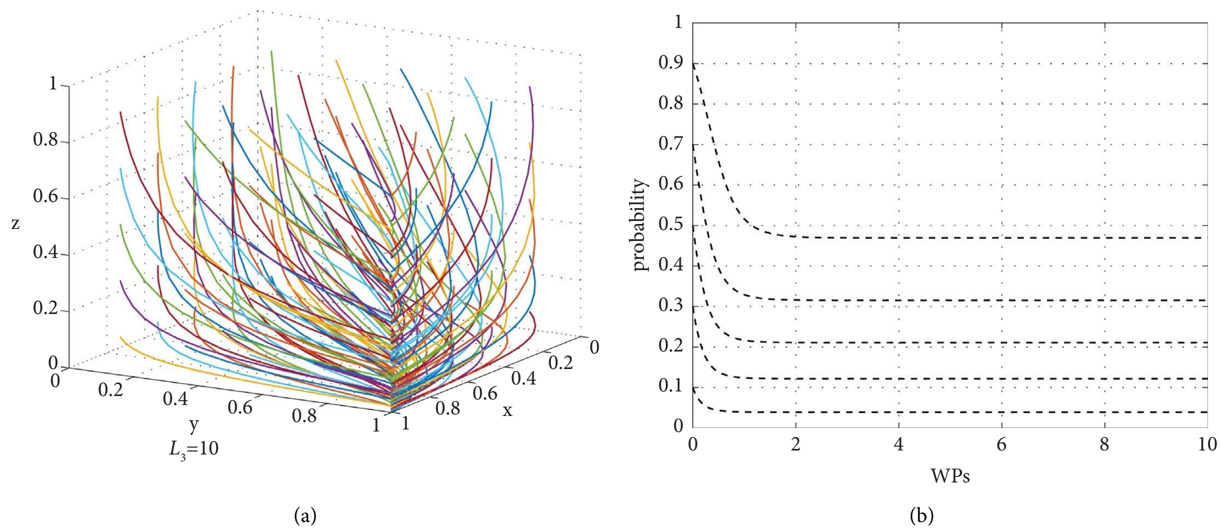


Figure 6: $L_3 = 10$ three-party evolution.

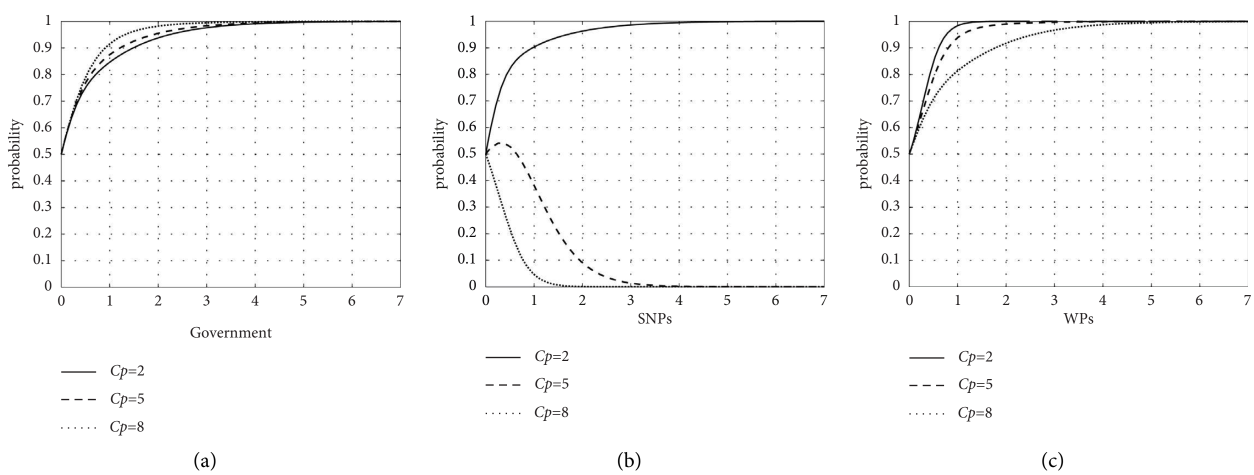


Figure 7: The effect of changing C_P.

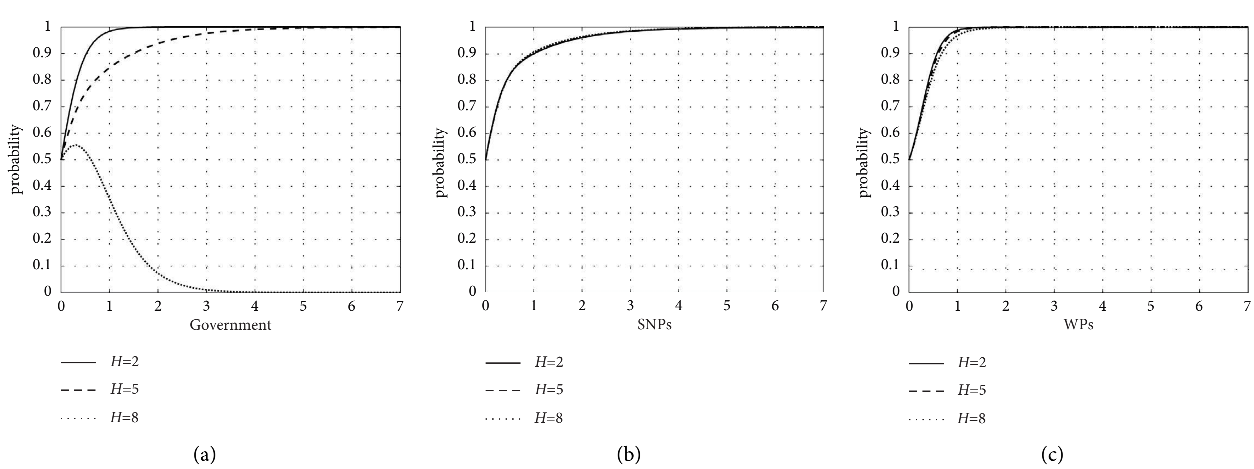
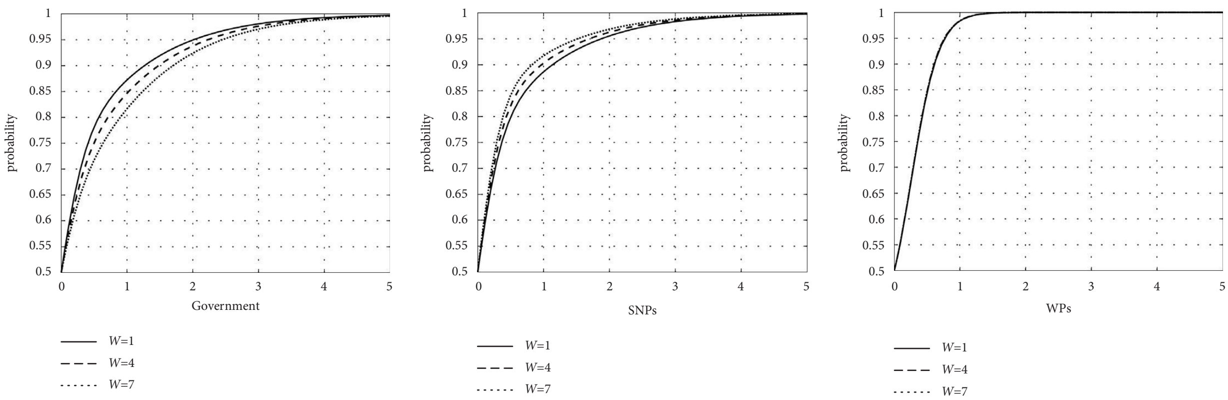
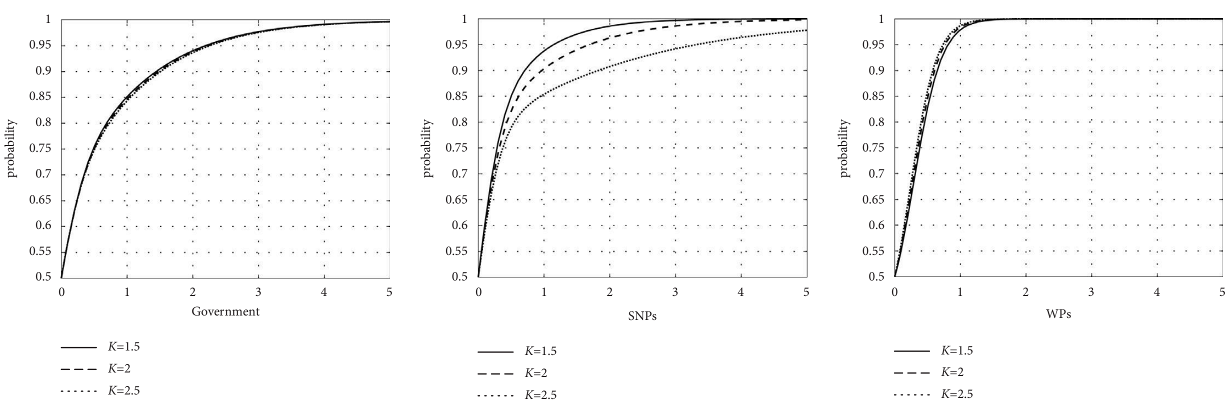


Figure 8: The effect of changing H.



(a) (b) (c)

Figure 9: The effect of changing W.



(a) (b) (c)

Figure 10: The effect of changing K.

supervision increases in the first two games, but then remains constant. As shown in Figure 6(a), We set $L_3 = 10$ to obtain the three-party time. As shown in Figure 6(b), we set 0.1 as the starting point, 0.2 as the step size, and 1 as the end point to explore the willingness change of SNPs when $L_3 = 10$. The results show that the willingness of WPs to choose seeking truth from facts decreases in the first two games, but then remains constant. In the implementation of network public opinion governance, we should be alert to the situation that there is no equilibrium. The willingness of the participating subjects changes from the initial one but cannot be fixed to a certain strategy.

Next, we keep the other fixed values constant and simulate the effect of parameter changes on the evolution results by changing individual parameters. Following, we discussed the influence of the changes of parameters C_P, W, H, K, and U on the evolution results, respectively.

We set C_P as 2, 5, and 8, respectively. As shown in Figure 7(a), in a certain range, the increase of C_P can accelerate the evolution of the government to the active prevention strategy. As shown in Figure 7(b), the increase of C_P may make SNPs give up participating in the social governance of network public opinion. As shown in Figure 7(c), the increase of C_P may slow down the evolution speed of WPs to seek truth from facts. The government can reduce the regulatory cost of SNPs through subsidies, and guide them to join the social governance of network public opinion.

We set H as 2, 5, and 8, respectively. As shown in Figure 8(a), when the government cuts taxes on SNPs too much, it will reduce its own income and change its strategy to passive intervention. As shown in Figure 8(b), we may think that tax cuts will speed up the evolution of SNPs to regulatory strategies; however, the simulation results are different from our imagination under certain conditions. At this time, tax cuts have little effect on the evolution speed of SNPs. As shown in Figure 8(c), tax cuts can slightly increase the evolution rate of WPs towards a pragmatic strategy.

We set W as 1, 4, and 7, respectively. As shown in Figures 9(a) and 9(b), with the increase of W, the evolution speed of the government to the active prevention strategy slows down, and the evolution speed of SNPs to the strategy of supervision increases. The government can guide SNPs to participate in the social governance of network public opinion by setting reasonable penalties. As shown in Figure 9(c), changes in W have almost no effect on WPs.

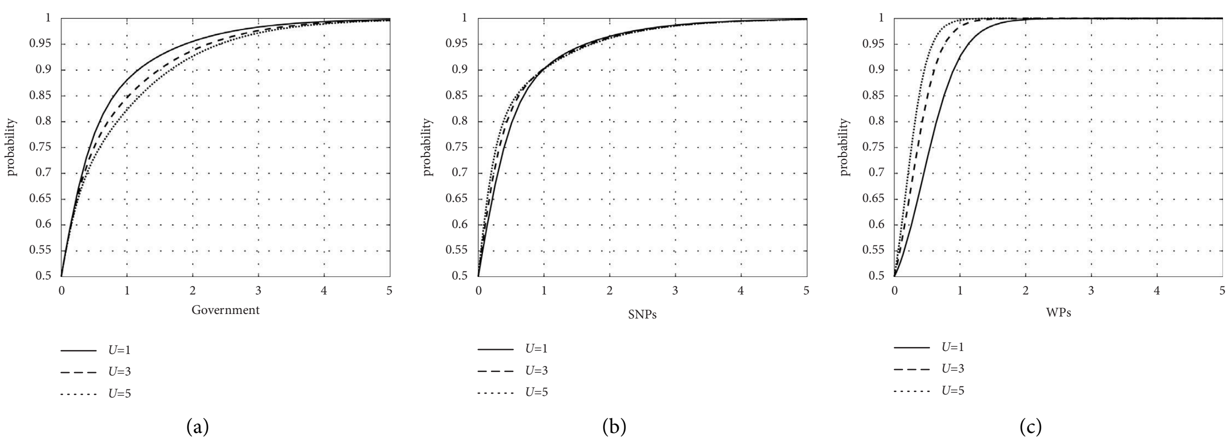


Figure 11: The effect of changing U.

We set K as 1.5, 2, and 2.5, respectively. As shown in Figure 10(a), changes in K have little effect on government. As shown in Figure 10(b), the increase of K can significantly reduce the evolution rate of SNPs to the strategy of supervision. As shown in Figure 10(c), the increase of K can slightly increase the evolution speed of WPs to the strategy of seeking truth from facts. Reasonable reward and punishment measures can help the results develop in a positive direction.

We set U as 1, 3, and 5, respectively. As shown in Figure 11, with the increase of U, the evolution speed of government to active prevention strategy slows down, the evolution speed of SNPs to regulatory strategy and the evolution speed of WPs to realistic strategy increase. The increase of SNPs will punish WPs to distort facts, and it will have a positive incentive effect on both of them at the same time.

4. Conclusions

Through the evolutionary game method, this article focuses on analyzing the strategic changes of the government, SNPs and WPs in the process of network public opinion dissemination. We draw the following conclusions from the model solution and simulation analysis.

The pursuit of SNPs is to maximize the benefit. The government should reasonably set up rewards and punishments for SNPs, and guide them to take corresponding social responsibilities. The government can provide incentives for actively regulated SNPs to offset regulatory cost, thereby incentivizing SNPs to choose regulatory strategies. Building a social governance system for network public opinion will effectively reduce the cost of governance but increase governance efficiency. Compared with SNPs, WPs have less interest correlation with the government and are less affected by the government. The government should establish various ties with WPs, grasp the double-edged sword of WPs, and promote social harmony and stability. In addition, the government should also establish an access system for WPs to increase the cost of mistakes made by WPs. Ban the entire website of WPs with bad records, and award honors to WPs who are positive. This will reduce the impact of online public opinion on social stability.

The government should establish a social governance system for network public opinion and unite the forces of different subjects to jointly resist the damage caused by the spread of network public opinion. This will reduce the impact of online public opinion on social stability.

Data Availability

No underlying data were collected or produced in this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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