# A Sustainable Extension System for Chinese Standard Spoken and Written Chinese Language via Three-party Evolutionary Game

Xianfeng Ding, Xiaolin Yi, Qian Chen, Hanbing Mei, Yiyu Qin, Pengfei Wen, and Qianmei Luo

***Abstract*—This study introduces an innovative model for promoting the standard spoken and written Chinese language through a collaborative approach involving governments, universities, and new media. We integrate these three stakeholders into a unified research framework and apply evolutionary game theory to analyze their strategic decisions and evolutionary paths in cooperative promotion. By formulating an expectation function and replication dynamics for each party, we examine the evolutionary stability strategies, identify key factors influencing interests, and determine the asymptotic stabilization points and their preconditions. Based on simulations of various scenarios, we propose a two-stage development strategy and a sustainable extension system for advancing Chinese Standard Spoken and Written Chinese Language within the context of a three-party evolutionary game model.**

***Index Terms*—promotion of Chinese standard spoken and written Chinese language, evolutionary game, sensitivity analysis, two-stage**

## I. Introduction

Since the 18th National Congress of the Communist Party of China, the Party Central Committee and the State Council prioritized language development. General Secretary Xi Jinping's directives guided language and writing initiatives. Following the implementation of the "13th Five-Year Plan for National Language and Writing Development", significant progress was made in Chinese language and written communication through the collaborative efforts of various sectors. The Living Language Book advocated for research-oriented platforms in universities, research institutes, media organizations, and cultural institutions. These platforms aim to support studying and interpreting Chinese classics, ensure educational continuity, and promote innovative communication initiatives.

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Promoting the Chinese Standard Spoken and Written Chinese Language is crucial. Research has demonstrated that language is closely linked to cultural power, social development, and quality of life [1]. Several studies [2–5] further emphasized the role of language promotion in advancing social development and fostering national unity. For example, [6] argued that promoting the Chinese language could strengthen the national economy. Additionally, [7] highlighted that improving language education could unify ethnic groups, support national rejuvenation, cultivate a skilled workforce, and contribute to shared prosperity.

Universities are pivotal in promoting the Chinese Standard Spoken and Written Chinese Language. Reference [8] emphasized the importance of universities in advancing the Chinese language, while [9] highlighted their ongoing contributions to national language promotion. However, [10] identified the inadequacies of new media in universities, noting its potential to promote Chinese traditional culture in academic settings. Integrating traditional culture with new media could yield mutually beneficial outcomes. Finally, [11] evaluated the current status of national language promotion through a survey and proposed a new collaborative model between universities and new media.

Governments are crucial in promoting the Chinese Standard Spoken and Written Chinese Language. This effort is supported by frameworks like the Living Language Book, which provides contemporary guidelines for language initiatives. Reference [12] advocated integrating new media into educational programs to enhance language promotion. Reference [13] examined governments' role in legitimizing language standards, while [14] detailed its functions as a regulator, participant, and policymaker—especially in markets requiring high initial investments. Reference [15] highlighted governments' strategic role in selecting participants. The Living Language Book also noted that governments collaborated with enterprises to develop applications to promote the language. Reference [16] emphasized reducing collaboration costs to optimize governance outcomes.

New media is key in promoting the Chinese Standard Spoken and Written Chinese Language. Reference [17] highlighted its potential as a primary approach for language promotion. Reference [18] examined the advantages of new media in information dissemination and predicted future trends, including potential negative phenomena. Reference [19] explored challenges in language standardization in new media contexts and identified pathways to address these challenges. However, [14] criticized the entertainment-focused nature of new media, arguing that it hindered effective language promotion. To enhance the role of new media,

[20] proposed strategies for promoting reading, while [21] suggested measures to strengthen governments' credibility on these platforms. Additionally, [22] highlighted the role of social media in tourism, and [23] underscored its advantages in information dissemination, calling for regulatory frameworks to manage its impact. Furthermore, [24–27] explored diverse strategies for advancing new media promotion, emphasizing the potential for collaboration between new media and universities to enhance language promotion. However, [28] identified issues related to "fan circle" public opinion movements on new media, which may trigger large-scale societal responses. Reference [29] highlighted the role of new media in e-commerce, noting its influence on consumer emotions and deception and concerns about substandard products during live-streamed sales. To address these challenges, [30–32] proposed solutions, emphasizing the need for enhanced regulatory oversight.

This suggests that governments, universities, and colleges are the primary agents in promoting the Chinese Standard Spoken and Written Chinese Language, with qualitative analyses being the predominant research method in this field. The existing literature emphasized the importance of universities' and governments' involvement and the need for collaboration with enterprises. It also highlighted the potential of new media in the big data era and the necessity for new collaborative promotion models. However, there is no dynamic analysis examining the willingness to participate in multiparty promotion efforts or evaluating governments' regulatory approaches to determine whether a stable collaborative promotion model existed. Based on this, we propose a three-party collaborative model involving universities, new media, and governments. It examines whether a sustainable extension system for mutual benefit exists among these three parties. A sensitivity analysis is also conducted based on the model to provide recommendations for future collaborative promotion strategies.

In summary, this paper examines the behaviour of governments, universities, and new media in promoting the Chinese Standard Spoken and Written Chinese Language. The evolutionary game model is presented in Section II, focusing on language promotion. Section III analyzes the replicator dynamics equation, the Evolutionary Stable Strategy of three parties, and the model's stability under various conditions. Section IV presents the sensitivity analysis and simulation results, and Section V provides the conclusions.

## II. Evolutionary game model

In promoting Chinese Standard Spoken and Written Chinese Language, governments can actively oversee the initiative or adopt a passive approach. Similarly, universities and new media can choose to participate or opt out. This study develops a three-party evolutionary game model based on the following assumptions:

### A. Parameter setting

**Assumption 1:** All parties are assumed to act with bounded rationality. governments have two strategies: participation ($S_1$) and non-participation ($S_2$), with the probability of participation denoted by $x$. Similarly, universities have two strategies: participation ($P_1$) and non-participation ($P_2$), with the probability of participation denoted by $y$. New media also have two strategies: participation ($Q_1$) and non-participation ($Q_2$), with the probability of participation denoted by $z$. The values of $x$, $y$, and $z$ are constrained to the interval $[0, 1]$.

**Assumption 2:** Governments aim to maximize social welfare, while universities and new media seek to maximize their respective interests. In evolutionary game, all parties act as participants seeking to optimize their benefits. The interactions among the three parties form a closed system without considering external factors or changes.

**Assumption 3:** The initial welfare level of society is denoted by $W_0$, and governments can participate in a collaborative game with universities and new media.

**Assumption 4:** The initial income from universities' independent promotional activities is denoted by $R_1$. If universities participate, governments provide additional funding support of $R_3$ [15], contingent on their participation. If universities opt out, no funding support is provided. Furthermore, universities incur costs associated with collaborative promotion, denoted by $C_1$ [16, 18]. The collaborative gain coefficient for universities is $A_1$ [27], and the degree of collaboration is $A_2$ [12, 27]. A basic income premium is generated when universities and new media collaborate. Without such participation, neither costs nor funding support are incurred.

**Assumption 5:** The initial income from new media' independent promotional activities is denoted by $R_2$. Due to the diverse nature of new media information sources, the transmission of illegal content and undesirable tendencies during information dissemination is inevitable, and this is called new media disorder.

With government participation, measures will be implemented to regulate new media disorder, and fines imposed on new media will be denoted as $C_2$ [10, 30]. These measures will enhance governments' credibility, denoted by $W_1$ [21]. If governments do not participate, their credibility will decrease, denoted by $W_2$ [21].

If new media participate, it must establish a dedicated channel to promote the Chinese Standard Spoken and Written Chinese Language, incurring specific traffic costs. These include the negative impacts of inadequate controlling inappropriate language output and the diversion effects associated with high traffic volumes, resulting in total expenditures of $C_3$ [28].

When universities participate, it will reduce the costs associated with constructing information channels and enhance their public image, leading to a total benefit of $R_5$ [9, 23, 27]. Additionally, sourcing talent and technology will reduce necessary investments, denoted by $C_4$ [23].

If universities or new media opt out of participation, the benefits of collaboration will be diminished, as indicated by the impact coefficient $J_1$ [12]. For new media, the collaborative gain coefficient is $B_1$ [25], and the degree of collaboration is $B_2$ [12]. Additional value for new media's basic income will be generated only through collaboration between universities and new media. When governments participate, they provide financial support, denoted by $R_4$ [15].

Based on the assumptions, the parameters are summarized in Table I, while the game payoff matrix for governments, universities, and new media is shown in Table II.

TABLE I: Parameters

| Player | Parameter | Implication |
|---|---|---|
| governments | $W_0$ | Initial welfare level of society |
| | $R_3$ | Special fund support |
| | $C_2$ | Fine |
| | $W_1$ | Increase in governments credibility |
| | $W_2$ | Decrease in governments credibility |
| | $R_4$ | Financial support |
| | $J_2$ | Influence coefficient of industrial value-added |
| Universities | $R_1$ | Initial income from independent promotion by universities |
| | $C_1$ | Cost of collaborative promotion |
| | $A_1$ | Collaborative gain coefficient of universities |
| | $A_2$ | Degree of collaboration |
| | $C_4$ | Reduction in talent search investments |
| | $W_3$ | Added value |
| New Media | $R_2$ | Initial income from independent promotion by new media |
| | $C_3$ | Cost of collaborative promotion |
| | $J_1$ | Impact coefficient |
| | $R_5$ | Total value of saved information channel construction costs and image gain |
| | $B_1$ | Collaborative gain coefficient |
| | $B_2$ | Degree of collaboration |
| | $W_4$ | Added value |

TABLE II: The payoff matrix

| Gov | University | New Media | |
|---|---|---|---|
| | | $Q_1$ | $Q_2$ |
| $S_1$ | $P_1$ | $W_0+W_1+C_2+(1+J_2)(W_3+W_4)-R_3-R_4$<br>$(1+A_1A_2B_2)R_1-A_2C_1+R_3+R_5$<br>$(1+B_1B_2A_2)R_2-B_2C_3-C_2+C_4+R_4$ | $W_0+W_1+C_2+(1+J_2)W_3-R_3$<br>$R_1-A_2C_1+R_3$<br>$R_2+J_1C_4-C_2$ |
| | $P_2$ | $W_0+W_1+C_2+(1+J_2)W_4-R_4$<br>$R_1+J_1R_5$<br>$R_2-B_2C_3-C_2+R_4$ | $W_0+W_1+C_2$<br>$R_1$<br>$R_2-C_2$ |
| $S_2$ | $P_1$ | $W_0-W_2+W_3+W_4$<br>$(1+A_1A_2B_2)R_1-A_2C_1+R_5$<br>$(1+B_1B_2A_2)R_2-B_2C_3+C_4$ | $W_0-W_2+W_3$<br>$R_1-A_2C_1$<br>$R_2+J_1C_4$ |
| | $P_2$ | $W_0-W_2+W_4$<br>$R_1+J_1R_5$<br>$R_2-B_2C_3$ | $W_0-W_2$<br>$R_1$<br>$R_2$ |

### B. Expectation function

*1) Expected benefits of governments:* Suppose the expected benefit of governments participation is $E_{S_1}$, the expected return on governments non-participation is $E_{S_2}$, and the average expected benefit to governments is $\overline{E_S} = xE_{S_1} + (1-x)E_{S_2}$. Then,

$$\begin{aligned} E_{S_1} =& yz((W_0+W_1+C_2+(1+J_2)(W_4+W_3)- \\ & R_3-R_4)+y(1-z)(W_0+W_1+C_2 \\ & +(1+J_2)W_3-R_3)+(1-y)z(W_0+W_1 \\ & +C_2+1+J_2)W_4-R_4)+(1-y)( \\ & 1-z)(W_0+W_1+C_2) \end{aligned} \tag{1}$$

$$\begin{aligned} E_{S2} =& yz(W_0-W_2+W_3+W_4)+ \\ & y(1-z)(W_0-W_2+W_3)+ \\ & (1-y)z(W_0-W_2+W_4)+ \\ & (1-y)(1-z)(W_0-W_2) \end{aligned} \tag{2}$$

*2) Expected benefits of universities :* Suppose the expected benefit to universities of participation is $E_{P_1}$, the expected return on university non-participation is $E_{P_2}$, and the average expected benefit to universities is $\overline{E_P} = yE_{p_1} + (1-y)E_{P_2}$. Then,

$$\begin{aligned} E_{P_1} =& \mathrm{xz}((1+A_1A_2B_2)R_1 - A_2C_1 + R_3 + R_5) + \\ & \mathrm{x}(1-z)(R_1 - A_2C_1 + R_3) + (1-\mathrm{x})z((1+ \\ & A_1A_2B_2)R_1 - A_2C_1 + R_5) + (1-\mathrm{x})(1-z \\ & )(R_1 - A_2C_1) \end{aligned} \tag{3}$$

$$\begin{aligned} E_{P_2} =& xz(R_1 + J_1R_5) + x(1-z)R_1 + \\ & (1-x)z(R_1 + J_1R_5) + (1-x)(1-z)R_1 \end{aligned} \tag{4}$$

*3) Expected benefits of new media:* Suppose the expected benefit to new media of participation is $E_{Q_1}$. The expected return on new media non-participation is $E_{Q_2}$, and the average expected benefit to new media is $\overline{E_Q} = zE_{Q_1} + (1-z)E_{Q_2}$. Then,

$$\begin{aligned} E_{Q_1} =& xy((1+B_1B_2A_2)R_2 - B_2C_3 - C_2 + C_4 \\ & + R_4) + x(1-y)(R_2 - C_2) + (1-x)y \\ & ((1+B_1B_2A_2)R_2 - B_2C_3 + C_4) + \\ & (1-x)(1-y)(R_2 + J_1C_4) \end{aligned} \tag{5}$$

$$\begin{aligned} E_{Q_2} =& xy(R_2 - B_2C_3 - C_2 + R_4) + x(1-y)(R_2 - \\ & C_2) + (1-x)y(R_2 - B_2C_3) + (1-x) \\ & (1-y)R_2 \end{aligned} \tag{6}$$

### C. Replicator dynamic equation

*1) The replicator dynamic equation of governments is:*

$$\begin{aligned} F_{1(x,y,z)} &= \frac{dx}{dt} = x(E_{S_1} - \overline{E_S}) \\ &= x(1-x)(E_{S_1} - E_{S_2}) \\ &= x(1-x)((J_2W_3 - R_3)y + (J_2W_4 \\ &\quad - R_4)z + W_1 + W_2 + C_2) \end{aligned} \tag{7}$$

*2) The replicator dynamic equation of universities is:*

$$\begin{aligned} F_{2(x,y,z)} &= \frac{dy}{dt} = y(E_{P_1} - \overline{E_P}) \\ &= y(1-y)(E_{P_1} - E_{P_2}) \\ &= y(1-y)(R_3x + (A_1A_2B_2R_1 + (1 \\ &\quad - J_1)R_5)z - A_2C_1) \end{aligned} \tag{8}$$

*3) The replicator dynamic equation of new media is:*

$$\begin{aligned} F_{3(x,y,z)} &= \frac{dz}{dt} = z(E_{Q_1} - \overline{E_Q}) \\ &= z(1-z)(E_{Q_1} - E_{Q_2}) \\ &= z(1-z)((B_1B_2A_2R_2 + (1-J_1)C_4)y + \\ & R_4x - B_2C_3) \end{aligned} \tag{9}$$

## III. Model analysis

### A. Stability analysis of tripartite strategy evolution

According to the stability theorem of differential equations, if the strategy chosen by three parties constitutes the stable state of a single entity, $F_{(n)} = 0, \frac{d_{F(n)}}{d_n} < 0, n = x, y, z$ must be satisfied.

*1) Asymptotic stability analysis of governments:* Equation 7 is calculated, and the results are as follows:

$$x_1 = 0, x_2 = 1, y = \frac{(J_2W_4 - R_4)z + W_1 + W_2 + C_2}{R_3 - J_2W_3} \tag{10}$$

$$\begin{aligned} \frac{d_{F1(x)}}{d_x} =& (1-2x)((J_2W_3 - R_3)y + (J_2W_4 - R_4)z \\ & + W_1 + W_2 + C_2) \end{aligned} \tag{11}$$

(1) If $y = \frac{(J_2W_4 - R_4)z + W_1 + W_2 + C_2}{R_3 - J_2W_3}$, then $F_{(x)}$ always 0. This indicates that all strategy levels are stable, and the proportions of strategy choices made by players will remain stable over time.

(2) If $y \neq \frac{(J_2W_4 - R_4)z + W_1 + W_2 + C_2}{R_3 - J_2W_3}$, then the two stable points for $x$ are $x_1 = 0$ and $x_2 = 1$. There are two possible situations:

**Situation 1:** When the inequality $1 > y > \frac{(J_2W_4 - R_4)z + W_1 + W_2 + C_2}{R_3 - J_2W_3}$ holds, and it is observed that $\frac{dF(x)}{dx}\Big|_{x=1} > 0$ and $\frac{dF(x)}{dx}\Big|_{x=0} < 0$, then $x_1 = 0$ represents an equilibrium state. In this case, if governments reduce financial support for collaborative efforts by universities while increasing penalties for inappropriate behaviour in new media, the incentive for governments to actively participate is likely to increase. This change is expected to positively influence the promotion of the Chinese Standard Spoken and Written Chinese Language, thereby gradually transitioning the conditions to align with those of Situation 2.

**Situation 2:** In this case, the parameter conditions satisfy $0 < y < \frac{(J_2W_4 - R_4)z + W_1 + W_2 + C_2}{R_3 - J_2W_3}$. Consequently, governments' Evolutionary Stability Strategy (ESS) will shift from non-participation to participation.

*2) Asymptotic Stability Analysis of Universities:* The results of Equation 8 are calculated as follows:

$$y_1 = 0, y_2 = 1, x = \frac{-(A_1A_2B_2R_1 + (1-J_1)R_5)z + A_2C_1}{R_3} \tag{12}$$

$$\begin{aligned} \frac{d_{F2(y)}}{d_y} =& (1-2y)(R_3x + (A_1A_2B_2R_1 + (1- \\ & J_1)R_5)z - A_2C_1) \end{aligned} \tag{13}$$

(1) If $x = \frac{-(A_1A_2B_2R_1 + (1-J_1)R_5)z + A_2C_1}{R_3}$, then $F_{(y)}$ is always 0. This result indicates that all levels are stable, and the proportion of strategic choices by universities will not change over time.

(2) If $x \neq \frac{-(A_1A_2B_2R_1 + (1-J_1)R_5)z + A_2C_1}{R_3}$, then $y_1 = 0$ and $y_2 = 1$ are the two stable points of $y$. There are two situations to consider:

**Situation 1:** When $0 < x < \frac{-(A_1A_2B_2R_1 + (1-J_1)R_5)z + A_2C_1}{R_3}$, we find that $\frac{d_{F(y)}}{dy}|_{y=1} > 0$ and $\frac{d_{F(y)}}{dy}|_{y=0} < 0$. In this case, $y_1 = 0$ represents the equilibrium. If governments increase collaborative subsidies to universities, the willingness of new media to participate will increase, thereby reducing participation costs. This condition will be gradually fulfilled in Situation 2.

**Situation 2:** The parameter conditions satisfy $1 > x > \frac{-(A_1A_2B_2R_1 + (1-J_1)R_5)z + A_2C_1}{R_3}$, prompting universities

to transition from non-participation to participation and ultimately evolve into stable evolutionary strategy.

*3) Asymptotic stability analysis of new media:* Equation 9 is calculated, and the results are as follows:

$$y_1 = 0, y_2 = 1, x = \frac{-(A_1A_2B_2R_1 + (1-J_1)R_5)z + A_2C_1}{R_3} \tag{14}$$

$$\begin{aligned}\frac{d_{F2(y)}}{d_y} = (1-2y)(R_3x + (A_1A_2B_2R_1 \\ +(1-J_1)R_5)z - A_2C_1)\end{aligned} \tag{15}$$

(1) If $x = \frac{-(B_1B_2A_2R_2+(1-J_1)C_4)y+B_2C_3}{R_4}$, then $F_{(z)}$ is consistently 0. This outcome indicates that all levels are stable, meaning the proportion of strategic choices by new media will remain constant over time.

(2) Conversely, if $x \neq \frac{-(B_1B_2A_2R_2+(1-J_1)C_4)y+B_2C_3}{R_4}$, then $z_1 = 0$ and $z_2 = 1$ are the two stable points for $z$. This leads to two possible situations:

**Situation 1:** When $0 < x < \frac{-(B_1B_2A_2R_2+(1-J_1)C_4)y+B_2C_3}{R_4}$, if $\frac{dF(z)}{dz}\big|_{z=1} > 0$ and $\frac{dF(z)}{dz}\big|_{z=0} < 0$, then, $y_1 = 0$ is the equilibrium. In this case, if governments increase participation subsidies, both universities and new media are likely to exhibit a higher willingness to participate. This shift would move the parameter conditions toward Situation 2.

**Situation 2:** When the parameter conditions satisfy $1 > x > \frac{-(B_1B_2A_2R_2+(1-J_1)C_4)y+B_2C_3}{R_4}$, ESS of new media shifts towards a participation strategy.

### *B. Model stability analysis*

*1) $Jacobianmatrix$:* Building on concepts such as multiple-population evolutionary stable strategies, steady states, and the stability of solutions to differential equations, we derive the local equilibriums of the system by solving the set of simultaneous differential equations for the variables $x$, $y$, and $z$, as presented in equations 4, 8, and 12. As outlined in [33], the analysis focuses on the pure strategy equilibrium of the system, which is determined by the following combinations of strategy choices:

$E_1(0,0,0)$, $E_2(0,0,1)$, $E_3(0,1,0)$, $E_4(1,0,0)$, $E_5(0,1,1)$, $E_6(1,0,1)$, $E_7(1,1,0)$, $E_8(1,1,1)$

To assess the stability of equilibriums, we apply the Lyapunov criterion. According to this criterion, a linear steady system is considered stable if all eigenvalues of its Jacobian matrix are non-positive. Conversely, the system is considered unstable if any eigenvalue is positive or multiple zero eigenvalues exist.

The stability analysis provides valuable insights into the long-term behavior of the evolutionary game model, identifying which strategy combinations are likely to persist over time under varying initial conditions and player dynamics.

The Jacobian matrix of the three-party dynamic game system is composed of Equations 4,8, and 12.

$$Jacobi = \begin{pmatrix} \frac{d_{F1(x,y,z)}}{dx} & \frac{d_{F1(x,y,z)}}{dy} & \frac{d_{F1(x,y,z)}}{dz} \\ \frac{d_{F2(x,y,z)}}{dx} & \frac{d_{F2(x,y,z)}}{dy} & \frac{d_{F2(x,y,z)}}{dz} \\ \frac{d_{F3(x,y,z)}}{dx} & \frac{d_{F3(x,y,z)}}{dy} & \frac{d_{F3(x,y,z)}}{dz} \end{pmatrix} \tag{16}$$

By putting the $E_1$ into Equation 16, the eigenvalues associated with this equilibrium are derived as follows: $\phi_1 = W_1 + W_2 + C_2$, $\phi_2 = -A_2C_1$, and $\phi_3 = -B_2C_3$. Similarly, putting the remaining seven equilibriums into Equation 16, the eigenvalues of the Jacobian matrix for each equilibrium are summarized in Table III.

*2) Stability of equilibrium:* Under general parameter conditions, the model has five potential ESS summarized in Table IV.

- Scenario 1: When the following conditions are satisfied:

$$\begin{aligned} -J_2W_3 + R_3 - J_2W_4 + R_4 - W_1 - W_2 - C_2 < 0, \\ -R_3 - A_1A_2B_2R_1 - (1-J_1)R_5 + A_2C_1 < 0, \\ -B_1B_2A_2R_2 - (1-J_1)C_4 - R_4 + B_2C_3 < 0, \end{aligned}$$

The governments' involvement implies that the fines imposed to address new media disorder, enhance credibility, and add industry value must exceed the financial support for universities and new media. For universities, the cost of participation should be lower than the sum of governments subsidies, enhanced reputation, cost savings from channel construction, and added value from collaborating with new media. Similarly, the costs incurred by new media should not exceed the sum of government funding, savings from collaboration, and the added value from working with universities.

Table IV shows that there may emerge two ESS under these conditions. To analyze the system's evolutionary process, the path diagram about it is developed, which takes various initial conditions $(x, y, z)$ into account. The initial values of $x$, $y$, and $z$ are selected from the set $\{0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9\}$.

As shown in Fig. 1, when the initial participation levels of each entity vary, most scenarios eventually converge to $E_8$. Convergence occurs at $E_4$ in a few instances. This occurs because low governments participation results in insufficient benefits for universities and new media from promotion to cover the costs of collaboration. Moreover, governments subsidies remain relatively low. As a result, the tripartite strategies evolve toward $E_4$. Conversely, when governments participation is high, the overall subsidies for promotion increase significantly. These subsidies remain within governments' acceptable range, leading to a Pareto optimal equilibrium for society, denoted as $E_8$. At this equilibrium, all parties benefit from participation.

- Scenario 2: When the following conditions are satisfied:

$$\begin{aligned} -J_2W_3 + R_3 - W_1 - W_2 - C_2 < 0, \\ -R_3 + A_2C_1 < 0, \\ B_1B_2A_2R_2 + (1-J_1)C_4 + R_4 - B_2C_3 < 0, \end{aligned}$$

Governments' involvement requires that the fines imposed to address new media disorder, the enhancement of credibility, and the added industry value exceed the financial support for universities. Moreover, governments' financial support should exceed their collaboration costs, and the benefits from collaboration should be lower than the costs incurred by new media. Table IV shows that only one ESS exists in this scenario.

TABLE III: Eigenvalues of the Jacobian matrix

| Equilibrium | $\phi_1$ | $\phi_2$ | $\phi_3$ |
|---|---|---|---|
| $E_1(0,0,0)$ | $W_1+W_2+C_2$ | $-A_2C_1$ | $-B_2C_3$ |
| $E_2(0,0,1)$ | $J_2W_4-R_4+W_1$ $+W_2+C_2$ | $A_1A_2B_2R_1+(1-J_1)R_5$ $-A_2C_1$ | $B_2C_3$ |
| $E_3(0,1,0)$ | $J_2W_3-R_3+W_1$ $+W_2+C_2$ | $A_2C_1$ | $B_1B_2A_2R_2+(1-J_1)C_4$ $-B_2C_3$ |
| $E_4(1,0,0)$ | $-W_1-W_2-C_2$ | $R_3-A_2C_1$ | $R_4-B_2C_3$ |
| $E_5(0,1,1)$ | $J_2W_3-R_3+J_2W_4$ $-R_4+W_1+W_2+C_2$ | $-A_1A_2B_2R_1-(1-J_1)R_5$ $+A_2C_1$ | $-B_1B_2A_2R_2-(1-J_1)C_4$ $+B_2C_3$ |
| $E_6(1,0,1)$ | $-J_2W_4+R_4-W_1$ $-W_2-C_2$ | $R_3+A_1A_2B_2R_1+$ $(1-J_1)R_5-A_2C_1$ | $-R_4+B_2C_3$ |
| $E_7(1,1,0)$ | $-J_2W_3+R_3-W_1$ $-W_2-C_2$ | $-R_3+A_2C_1$ | $B_1B_2A_2R_2+(1-J_1)C_4$ $+R_4-B_2C_3$ |
| $E_8(1,1,1)$ | $-J_2W_3+R_3-W_1$ $+R_4-W_1-W_2-C_2$ | $-R_3-A_1A_2B_2R_1-$ $(1-J_1)R_5+A_2C_1$ | $-B_1B_2A_2R_2-(1-J_1)C_4$ $-R_4+B_2C_3$ |

TABLE IV: System equilibrium stability analysis

| Equilibrium | Scenario 1 | | | | Scenario 2 | | | | Scenario 3 | | | | Scenario 4 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | eigenvalue | | | stability | eigenvalue | | | stability | eigenvalue | | | stability | eigenvalue | | | stability |
| $E_1(0,0,0)$ | + | - | - | **Unstable** | + | - | - | **Unstable** | + | - | - | **Unstable** | + | - | - | **Unstable** |
| $E_2(0,0,1)$ | +/- | +/- | + | **Saddle** | +/- | +/- | + | **Saddle** | + | - | + | **Unstable** | +/- | + | + | **Saddle** |
| $E_3(0,1,0)$ | +/- | + | +/- | **Saddle** | + | + | - | **Unstable** | +/- | + | +/- | **Saddle** | +/- | + | + | **Saddle** |
| $E_4(1,0,0)$ | - | +/- | +/- | **ESS** | - | + | - | **Unstable** | - | - | + | **Unstable** | - | +/- | +/- | **ESS** |
| $E_5(0,1,1)$ | + | +/- | +/- | **Saddle** | +/- | +/- | + | **Saddle** | +/- | + | +/- | **Saddle** | - | - | - | **ESS** |
| $E_6(1,0,1)$ | - | + | - | **Unstable** | +/- | + | +/- | **Saddle** | - | - | - | **ESS** | +/- | + | +/- | **Saddle** |
| $E_7(1,1,0)$ | +/- | +/- | + | **Saddle** | - | - | - | **ESS** | +/- | + | + | **Saddle** | +/- | +/- | + | **Saddle** |
| $E_8(1,1,1)$ | - | - | - | **ESS** | +/- | - | + | **Unstable** | +/- | + | - | **Unstable** | + | - | - | **Unstable** |

As shown in Fig. 2, regardless of the initial participation levels, all parties converge to $E_7$ over time. This convergence is primarily attributed to the relatively high level of governments subsidies, mainly when the costs of collaborative promotion are low. Consequently, increased government financial support results in more favourable outcomes for all involved parties.

- Scenario 3: When the following conditions are satisfied:

$$\begin{aligned} -J_2W_4+R_4-W_1-W_2-C_2<0,\\ R_3+A_1A_2B_2R_1+(1-J_1)R_5-A_2C_1<0,\\ -R_4+B_2C_3<0, \end{aligned}$$

The fines governments impose to address new media disorder, credibility enhancement resulting from government participation, and the added industry value must exceed the financial support for new media. Additionally, the governments' financial support should exceed the costs incurred by universities in collaboration. Conversely, the sum of governments support and the benefits from collaboration must be lower than the costs associated with new media participation. Table IV shows that only one ESS exists under these conditions.

As shown in Fig. 3, regardless of the initial participation levels, all parties ultimately converge to $E_6$ over time. This outcome occurs because universities often face higher costs than the benefits they receive. On the other hand, new media are incentivized to participate due to governments subsidies, which provide more significant benefits. This reflects the governments' policy of strictly promoting the standard spoken and written Chinese language within universities while adopting a more lenient approach toward new media.

- Scenario 4: When the following conditions are satisfied:

$$\begin{aligned} J_2W_3-R_3+J_2W_4-R_4+W_1+W_2+C_2<0,\\ -A_1A_2B_2R_1-(1-J_1)R_5+A_2C_1<0,\\ -B_1B_2A_2R_2-(1-J_1)C_4+B_2C_3<0, \end{aligned}$$

The sum of fines governments impose to address new media disorder, the enhancement of credibility resulting from government participation, and the added industry value lower than the financial support provided to collaborating universities and new media entities. Moreover, the benefits of

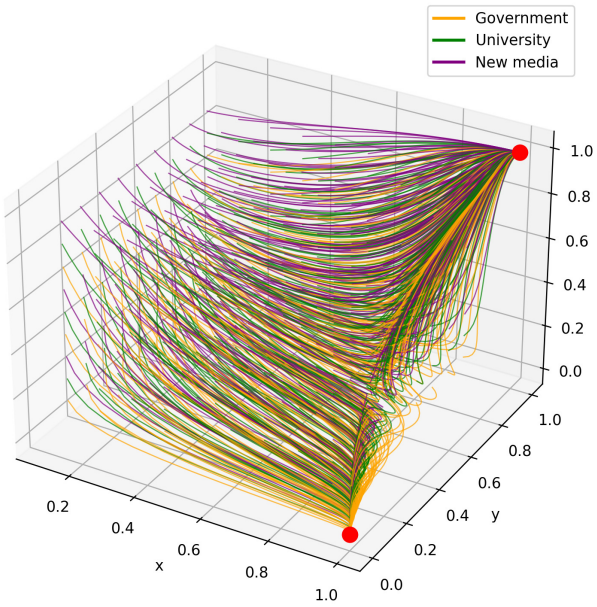



Fig. 1: Evolutionary paths for Scenario 1

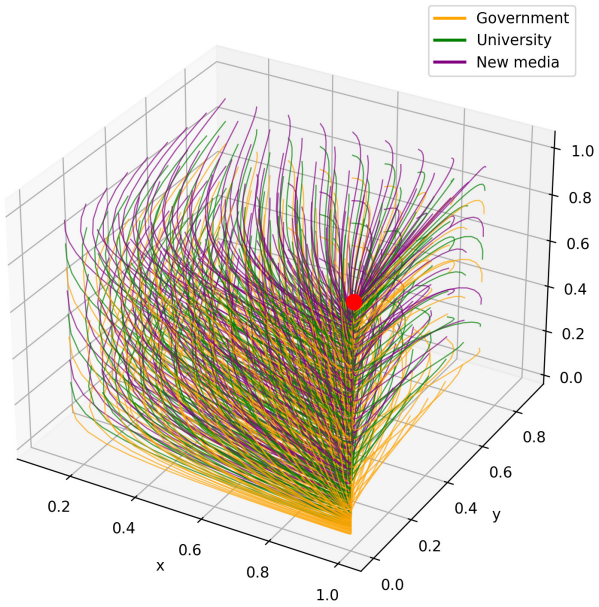



Fig. 3: Evolutionary paths for Scenario 3

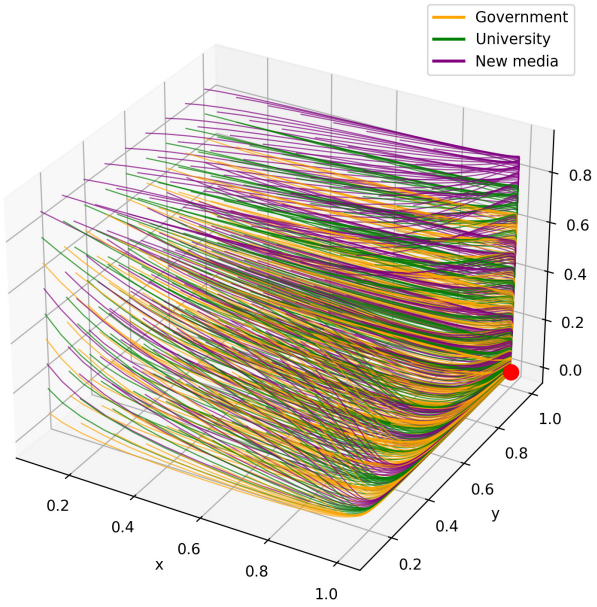



Fig. 2: Evolutionary paths for Scenario 2

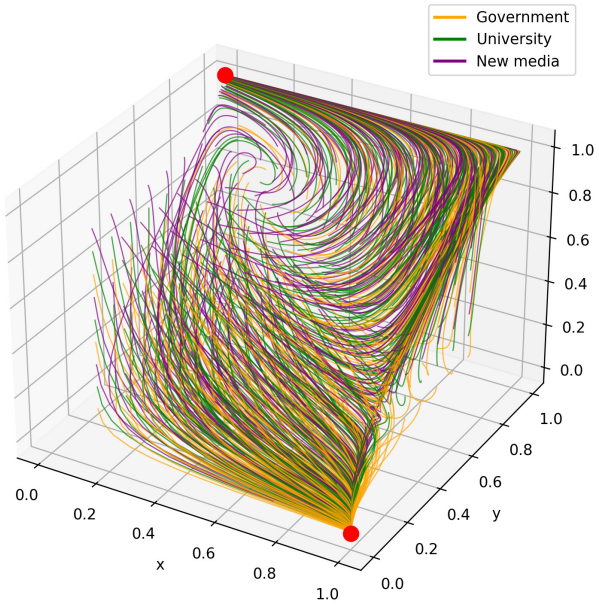



Fig. 4: Evolutionary paths for Scenario 4

university collaboration should exceed the associated costs, while the advantages of new media participation should outweigh the incurred costs. As shown in Table IV, two possible ESS exist under these conditions.

As shown in Fig. 4, two equilibriums may exist under different initial participation levels. Collaborative subsidies cannot cover the associated costs when the governments' initial participation is low. Consequently, universities or new media may face increasing non-coordination, leading to a decline in the positive benefits of their collaboration. This cycle may repeat, ultimately converging to $E_4$. In contrast, when governments' initial participation and the level of collaborative subsidies are high, the benefits of collaboration between universities and new media consistently exceed the benefits of non-collaboration. This further increases the collaboration rate between the two parties. However, as the governments' subsidies gradually surpass their capacity, it begins to withdraw from participation, ultimately causing three parties to converge at $E_5$. At this stage, universities and new media can achieve more significant benefits through collaborative promotion than non-collaborative efforts.

## IV. Sensitivity Analysis

The theme of this paper is to develop a new model for collaborative promotion[1]. In Section III, we identify a potential equilibrium, $E_8$, for tripartite collaboration in Scenario 1. This equilibrium represents a Pareto optimal point, where the expected benefits for all parties at $E_8$ are

[1]Collaborative promotion refers to a scenario in which, after independent strategy selection, all parties eventually reach a stable state of collaboration. Each party's participation probability approaches 1, though it remains below 1 for each individual.

TABLE V: parameter setting

| Parameter | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 |
|---|---|---|---|---|
| $W_0$ | —— | —— | —— | —— |
| $R_3$ | 15 | 10 | 15 | 25 |
| $C_2$ | 10 | 10 | 10 | 10 |
| $W_1$ | 20 | 20 | 20 | 20 |
| $W_2$ | 10 | 10 | 10 | 10 |
| $R_4$ | 25 | 3 | 25 | 35 |
| $J_2$ | 0.2 | 0.2 | 0.2 | 0.2 |
| $R_1$ | 80 | 80 | 80 | 80 |
| $C_1$ | 40 | 3 | 70 | 60 |
| $A_1$ | 0.3 | 0.3 | 0.3 | 0.3 |
| $A_2$ | 0.8 | 0.8 | 0.8 | 0.8 |
| $C_4$ | 20 | 10 | 20 | 50 |
| $W_3$ | 15 | 15 | 15 | 15 |
| $R_2$ | 100 | 100 | 100 | 100 |
| $C_3$ | 35 | 40 | 30 | 50 |
| $J_1$ | 0.7 | 0.7 | 0.7 | 0.7 |
| $R_5$ | 50 | 15 | 15 | 120 |
| $B_1$ | 0.4 | 0.4 | 0.4 | 0.4 |
| $B_2$ | 0.8 | 0.8 | 0.8 | 0.8 |
| $W_4$ | 25 | 25 | 25 | 25 |

greater than others. Moreover, $E_8$ and $E_5$ can shift based on conditions of $E_4$, as shown in Table IV. In practical terms, governments allocate more resources than they receive in return, while new media and universities require continuous guidance.

Therefore, this section focuses on selecting parameters from Scenario 1 and Scenario 4 to explore the impact of key factors on the development of tripartite collaborative promotion. The following sections will analyze the system's sensitivity.

To identify the key factors that significantly influence the evolution process and outcomes at different stages, we analyze all relevant variables in the replicator dynamic equations, including $J_2W_3$, $R_3$, $J_2W_4$, $R_4$, $C_2$, $J_1R_5$, $A_2C_1$, $A_2B_2$, $J_2C_4$, and $B_2C_3$. Based on insights from references [6, 10, 12, 15, 16, 27, 28, 30], the most influential factors ($A_2B_2$, $C_2$, $R_3$, $J_2W_3$, $C_3$) are grouped into five categories for further analysis.

This section presents the results using two-dimensional diagrams. Additionally, the initial point $(x_0, y_0, z_0) = (0.7, 0.4, 0.3)$ is selected for the simulation analysis based on the practical scenario.

TABLE VI: Sensitivity parameter setting

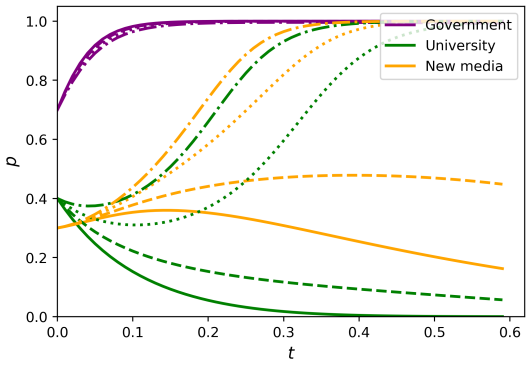
| Parameter | Value_1 | Value_2 | Value_3 | Value_4 |
|---|---|---|---|---|
| $R_3$ | 10/10 | 15/20 | 20/30 | 25/35 |
| $J_2W_3$ | 1/1 | 3/3 | 10/10 | 15/15 |
| $B_2A_2$ | 0.3/0.3 | 0.5/0.5 | 0.7/0.7 | 0.9/0.9 |
| $C_3$ | 50/40 | 55/45 | 60/50 | 65/55 |
| $C_2$ | 3/3 | 10/10 | 17/17 | 24/24 |

### A. *The sensitivity analysis of $R_3$*

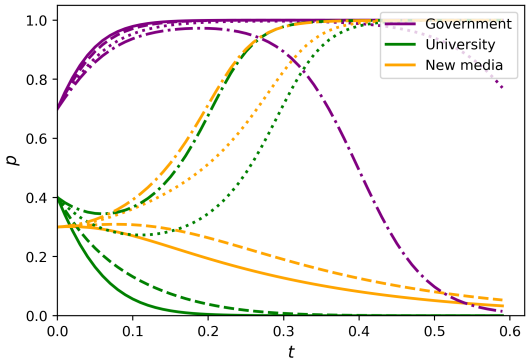
*1) Scenario 1 $R_3$:* In Scenario 1, variations in $R_3$ are shown in Table VI, and the simulation results are presented in Fig. 5a, where the horizontal axis represents evolution time, and the vertical axis shows the proportion of each party involved.

As shown in Fig. 5a, as $R_3$ increases, the governments' strategy remains broadly stable. However, universities and new media exhibit more noticeable shifts in their strategy. When $R_3$ is below 15, universities and new media tend to avoid participating, and the time required for the system to reach ESS increases. When $R_3$ exceeds 15, universities and new media become more inclined to participate, and the time to reach ESS decreases as $R_3$ rises. For the change of $R_3$, the figure shows that universities are more sensitive than new media, with governments being the least responsive. This occurs because, without a tripartite collaboration, increasing governments' resource allocation encourages greater participation from universities and new media.

*2) Scenario 4 $R_3$:* Fig. 5b presents the results of Scenario 4, showing the impact of increasing $R_3$ on the strategies of all parties. When $R_3$ is less than 20, universities and new media are more likely to evolve towards non-participation, while governments' strategy remains relatively stable. However, when $R_3$ exceeds 20, universities and new media favour participation, while governments begin withdrawing from the collaboration. As $R_3$ increases, the time required for all parties to converge to ESS decreases. This is because, as governments' expenditures increase, their willingness to participate diminishes, temporarily increasing participation from universities and new media. Ultimately, as governments reduce their financial support, the tripartite promotion system evolves toward a state where all parties opt out of the collaborative promotion.




(a) Scenario 1 $R_3$




(b) Scenario 4 $R_3$

Fig. 5: Convergence diagram of the evolution of $x - y - z$; The four linearities of '-, –, :, -.' correspond to the values from small to large.

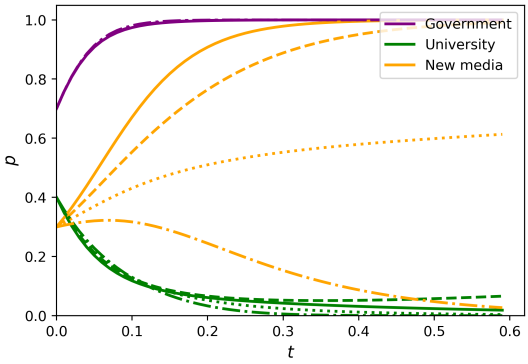
### B. *The sensitivity analysis of $B_2A_2$*

In Equation 15, $B_2A_2$ indirectly influences the convergence rate of governments' participation through its effects

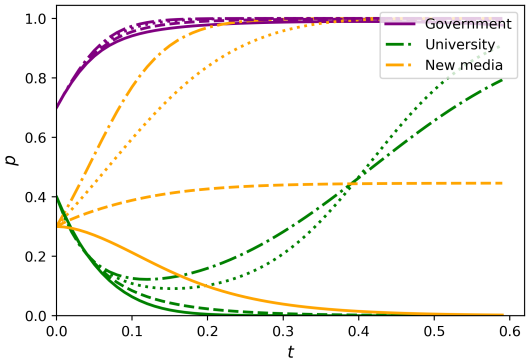
on the strategies of universities and new media. This section analyzes the impact of $B_2A_2$ by treating it as a single parameter, assuming that $B_2 = A_2$.

*1) Scenario 1: $B_2A_2$:* As seen in Fig. 6a, an increase in $B_2A_2$ does not significantly affect governments' strategy, nor does it significantly impact universities. However, new media's strategies shift notably as $B_2A_2$ increases. When $B_2A_2$ is below 0.7, new media tend to participate. However, as $B_2A_2$ exceeds 0.7, new media shift towards non-participation. This shift occurs because, while new media benefit from participation, the associated costs increase, leading universities and new media to opt out in the long run.

*2) Scenario 4 $B_2A_2$:* As illustrated in Fig. 6b, an increase in $B_2A_2$ leads the strategies of universities and new media change, although governments' strategy remains broadly stable. When $B_2A_2$ is below 0.7, universities and new media evolve towards non-participation. However, when $B_2A_2$ exceeds 0.7, they all evolve towards participation. This happens because as universities and new media gradually participate, the mutual benefits for cooperation increase with lower costs for all parties.




(a) Scenario 1 $B_2A_2$



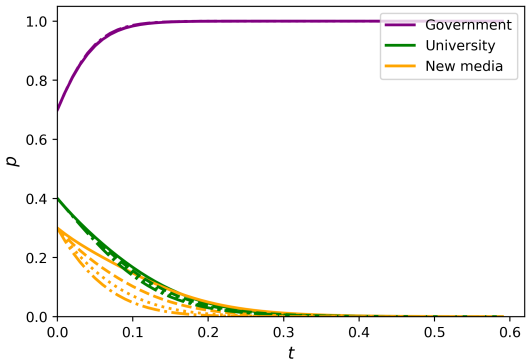

(b) Scenario 4 $B_2A_2$

Fig. 6: Convergence diagram of the evolution of $x - y - z$; The four linearities of '-, –, :, -.' correspond to the values from small to large.

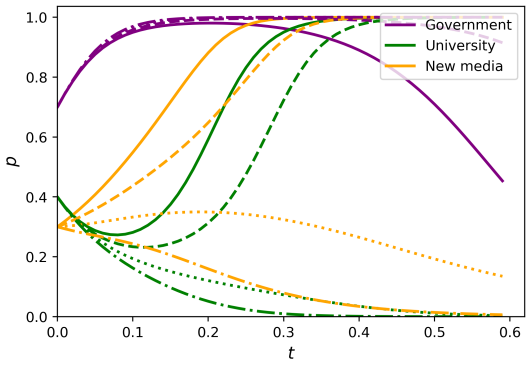
## C. The sensitivity analysis of $C_3$

*1) Scenario 1 $C_3$:* As shown in Fig. 7a, as $C3$ increases, the strategic choices of the three parties remain broadly stable. This is because the degree of collaboration remains relatively low, meaning the collaboration costs are insufficient to alter the evolutionary dynamics of the parties involved significantly.

*2) Scenario 4 $C_3$:* As shown in Fig. 7b, as $C_3$ increases, governments evolve toward higher participation, while universities and new media move towards non-participation. This shift occurs because the collaboration costs for universities and new media are perceived as excessively high under the current external conditions. These costs surpass not only the financial support governments provide but also the potential benefits from cost savings and efficiency gains through collaboration. As a result, both universities and new media opt out of the collaborative promotion. Consequently, as the participation levels of universities and new media decrease, the need for more excellent guidance and incentives increases. So, governments' willingness to participate is enhanced.




(a) Scenario 1 $C_3$




(b) Scenario 4 $C_3$

Fig. 7: Convergence diagram of the evolution of $x - y - z$; The four linearities of '-, –, :, -.' correspond to the values from small to large.

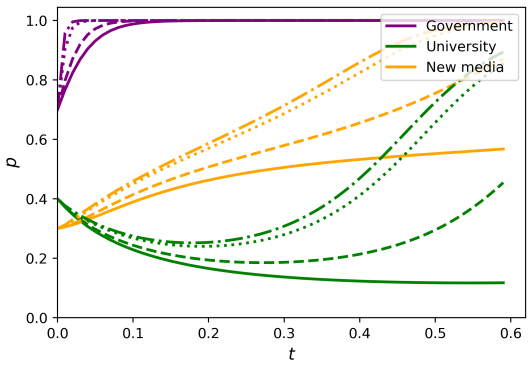
## D. Sensitivity Analysis of $J_2W_3$

Similar to $B_2A_2$, $J_2W_3$ is analyzed as a single entity in this sensitivity analysis. Due to the numerical similarities and consistent trends observed in the analyses of $J_2W_4$ and $J_2W_3$, we focus exclusively on the sensitivity of $J_2W_3$.

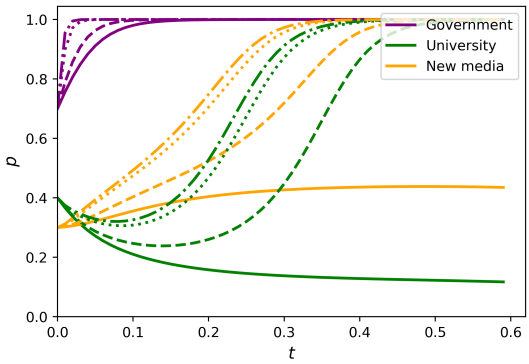
*1) Scenario 1: $J_2W_3$:* As shown in Fig. 8a, as $J_2W_3$ increases, the strategic evolution of the three parties remains broadly stable. This is because, at the initial stages of promotion, the added value from the language and cultural

industry is not significant enough to affect the evolutionary dynamics of the three parties involved meaningfully.

*2) Scenario 4: $J_2W_3$:* As shown in Fig. 8b, as $J_2W_3$ increases, the governments' strategy remains broadly stable. When $J_2W_3$ is less than 1, universities and new media evolve towards non-participation. However, When $J_2W_3$ exceeds 1, universities and new media shift their strategic, evolving towards greater participation. Moreover, as $J_2W_3$ increases, the time required for three parties to converge to ESS decreases. This occurs because the added value from the language and cultural industry encourages governments to more actively guide universities and new media to participate, from which both parties stand to benefit.




(a) Scenario 1 $J_2W_3$

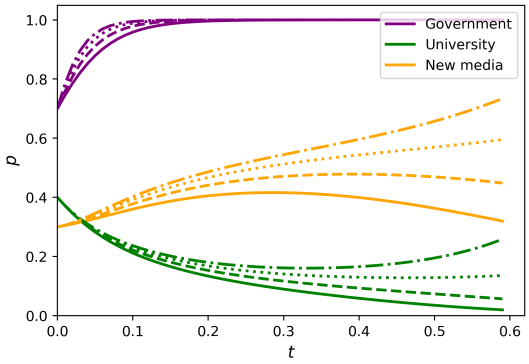



(b) Scenario 4 $J_2W_3$

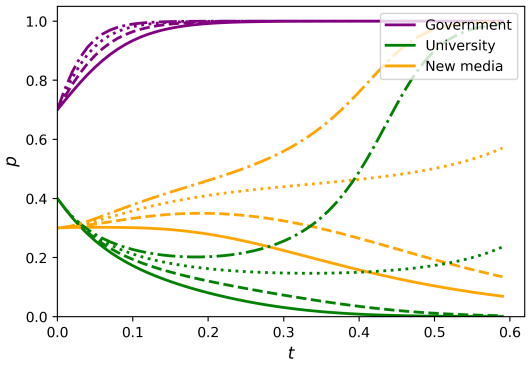
Fig. 8: Convergence diagram of the evolution of $x-y-z$; The four linearities of '-, –, :, -.' correspond to the values from small to large.

### *E. Sensitivity Analysis of $C_2$*

In both Scenario 1 and Scenario 4, the evolutionary trends of all parties exhibit similar patterns. As $C_2$ changes, the governments' strategy remains broadly stable. When $C_2$ is less than 10, universities and new media are reluctant to participate. However, When $C_2$ exceeds 10, universities and new media are more inclined to participate. The only difference between Scenario 1 and Scenario 4 is that under the conditions of Scenario 1, the new media's willingness to participate is less sensitive to penalties. As a result, universities' willingness to participate shows slight variation with changes in penalty severity. This suggests that, regardless of the specific scenario, regulating new media disorder is a key measure to encourage participation from all parties.




(a) Scenario 1 $C_2$




(b) Scenario 4 $C_2$

Fig. 9: Convergence diagram of the evolution of $x-y-z$; The four linearities of '-, –, :, -.' correspond to the values from small to large.

TABLE VII: Significance of parameter effects

| Parameter | Scenario 1 | Scenario 4 |
|---|---|---|
| $R_3$ | Significant | Significant |
| $J_2W_3$ | Significant | Significant |
| $B_2A_2$ | Non-Significant | Significant |
| $C_3$ | Significant | Significant |
| $C_2$ | Significant | Significant |

Based on the analyses presented above, the following conclusions can be drawn:

1) Fund support plays a critical role in the evolutionary dynamics. Adequate financial support is necessary to establish a collaborative promotion model involving all parties. However, excessively increasing $R_3$ beyond a certain threshold may not effectively contribute to the promotion, as the benefits may diminish over time.
2) The level of collaboration between universities and new media is a key factor in successful promotion, particularly in the later stages. The more collaboration, the greater the participation of both universities and new media.
3) The promotional costs of new media significantly impact the evolutionary equilibrium, highlighting the importance of effectively managing these costs.
4) A Development Plan for the language and cultural industry is essential and aligns with the country's

strategic development goals in the new era.

5) Managing disorder within new media is significant in the later stages, as it directly affects the effectiveness of collaborative promotion efforts.

Table VII summarizes the significance of parameter effects.

## V. Conclusions

This study develops a three-party evolutionary game model for a new promotion strategy involving governments, universities, and new media, drawing from existing research and national policies. Moreover, a sustainable extension system is found to be possible. To achieve this sustainable promotion model, we propose to develop a promotion system from $E_4$ to $E_8$, named a two-stage development strategy. Through MATLAB simulations and result analysis, and combined with existing research, the study provides several recommendations. Currently, the promotion is primarily driven by governments [34], with new media and universities playing a guiding role. While a three-party promotion model is emerging, it has not reached stability. As a result, the recommendations mainly focus on actions for governments.

### *A. Distinct Considerations at Each Stage of the Model's Development.*

Governments should prioritize establishing a collaborative promotion framework in the initial stage (as simulated in Scenario 4). In the subsequent stage (as simulated in Scenario 1), the focus should shift to maintaining and enhancing the effectiveness of the promotion. It is important to note that "maintenance" here does not imply additional government intervention but ensures a stable external environment. As shown in Table VI, Scenario 1 cannot transition to Scenario 4, underscoring the irreversibility of the process.

In the initial stage, collaboration among governments, universities, and new media alone cannot establish the new tripartite promotion model. However, by increasing the economic value of the language and culture industry and strengthening penalties for new media disorder, the three parties may transition from spontaneous collaboration to more coordinated efforts. This emphasizes the importance of rational planning for the language and culture industry and strictly control over new media disorder in the early stages to guide the formation of new promotion models.

Governments, universities, and new media can jointly promote the model's development in the subsequent stage. However, simulation results suggest that reduced governments' financial support or participation will hinder the establishment of the tripartite promotion model. Additionally, the model becomes impractical if the promotional costs for new media are prohibitively high. Therefore, to effectively establish the tripartite promotion model, governments must provide sufficient financial support, enforce stricter penalties for new media disorder, and introduce appropriate subsidies to reduce the promotional costs for new media.

### *B. Financial subsidies should be provided to universities and new media involved, within a reasonable range.*

A key strategy to encourage university involvement is developing cultural quality initiatives for college students nationwide. However, [35] indicates that educational resources are insufficient, characterized by inadequate teacher qualifications and ineffective assessment and incentive mechanisms. Moreover, [36] highlights that campus cultural activities often exhibit monotony, low quality, and insufficient student participation. Consequently, financial subsidies should be allocated to universities participating in tripartite promotion efforts to establish a robust foundation for cultural quality, thereby facilitating the promotion of a national standard language. Reference [37] suggests that corruption in universities often stems from the unequal distribution of resources, indicating that excessive financial support should be avoided.

The simulation results indicate that government financial subsidies play a crucial role in encouraging universities and new media to promote the standard Chinese spoken and written language. However, when subsidies exceed a certain threshold, they reduce governments' willingness to continue their involvement in collaborative promotion, leading to instability in the tripartite promotion model. This phenomenon is consistent with findings in the literature. Therefore, while financial support is essential for motivating universities and new media, governments must carefully manage the scale of subsidies. Excessive financial support could jeopardize the promotion model's long-term sustainability.

### *C. governments should prioritize reducing promotional expenses for new media.*

Decreasing traffic and the need for specialized promotional channels are significant factors driving up the costs of new media promotion. Reference [38] emphasizes that collaboration between new and traditional media can utilize the larger audiences of traditional media to increase traffic for new media, thereby enhancing monetization opportunities. In this context, governments can increase the visibility of new media participants by publicly acknowledging their contributions or providing commendations. Increased visibility can lower the promotional expenses for new media.

The simulation results indicate that before establishing a stable tripartite promotion model, efforts should be focused on reducing the collaborative promotion costs for new media. This would encourage greater participation from new media, which is crucial for forming a sustainable tripartite promotion system.

### *D. The development of language and cultural industries should be vigorously promoted.*

As noted by [39], our country's language and cultural industries are still in their nascent stages, presenting substantial potential for growth. Reference [40] emphasizes that the development of these industries could be significantly enhanced through strategic government planning and support. Moreover, the 'Living Language Book' highlights the necessity for innovative approaches in language and writing initiatives. Therefore, planning development trajectories for these sectors in the upcoming stages is crucial. Moreover, advancing information technology is crucial, as [41] indicates that rapid progress in this area can significantly boost the language economy.

The simulation results indicate that the cultural industry's value-added growth significantly impacts the promotion of tripartite collaboration in all phases. At the same time,

its influence diminishes in the second phase. The existing literature suggests that the development of the cultural industry should be prioritized at all stages when establishing a sustainable tripartite collaboration system.

### *E. Measures to address new media disorder should be intensified.*

Reference [31] highlights that new media organizations should hire professionals matching their operational scale, enhance staff training, reinforce management systems, and implement rigorous content supervision.

The simulation results indicate that, in the process of establishing a sustainable tripartite collaboration system, regulating the disorderly behavior of new media is crucial at both the early and later stages. This regulation significantly impacts the formation of the promotion system in both phases.

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