An evolutionary game for governance of Internet audiovisual space

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Abstract
The market size of the Internet audiovisual industry is expanding continuously, which has profoundly affected the ecology of public opinion and the development of the digital culture industry. During the epidemic of Covid-19, it is witnessed that a surge of active online audiovisual users. However, several issues happening in the Internet audiovisual industry, such as spreading rumors, engaging in vulgar performances, which seriously damaged the network environment and social order. For this reason, a tripartite evolutionary game model of Internet audiovisual space governance was established to simulate and analyze the behavior strategies of administrative departments of radio and television, the Internet audiovisual program service agencies, and network audio and video content creators. Moreover, the game model is verified by empirical analysis. Results demonstrate that: only driven by the administrative department of broadcasting and television can the tripartite evolutionary game of Internet audiovisual space governance reach the expected evolutionary equilibrium point. Therefore, administrative departments of radio and television should give full play to the driving role in the process of Internet audiovisual space governance, strengthen the publicity of regulating the creation of Internet audiovisual content and the warning of vulgar creation through government regulation.

Keywords Internet audiovisual industry · Space governance · Tripartite evolutionary game · Stakeholder

1 Introduction
The Internet audiovisual industry includes integrated video, short video, webcast, smart TV (OTT), interactive Internet TV (IPTV) and audiovisual content production. Specifically, Internet audiovisual industry is an emerging industry, which belongs to the cultural and creative sector and makes a significant contribution to the global economy. In the context of commercialization and the complex global-local nexus defining contemporary cultural spheres, audiovisual industry has been defined by an underlying trend towards transnationalization and approximation. The conflicts surrounding Internet governance are the new spaces where political and economic power is unfolding in the twenty-first century [1]. In multiple national and regional contexts, the Internet and media convergence have been key drivers of the need to rethink cultural policies and audiovisual media regulation.

The advancement of new communication technologies and modern phenomena in recent years has influenced the businesses worlds which are still constantly in a new and fast changing area [2]. As 5G enters the commercial stage and the pace of new infrastructure construction acceleration [3], the Internet audiovisual industry is evolving toward wisdom, driving the emergence and growth of a new social economy, which has an impact on Internet cultural issues [4]. Meanwhile, digital technology is reshaping the entire Internet audiovisual system [5]. The technology and product updates of Internet audiovisual rapidly. Be aimed at the demand of different client groups, short video applications and audio applications, such as Tik Tok, Kwai, Shareit, NetEase cloud music and Himalaya, etc., emerge in endlessly [6]. Further, new players emerge in the Internet audiovisual industry and offer unprecedented solutions for aggregating and distributing content. New entrants, especially social networks [7], have been the engines of these changes toward multitasking, multi-
screening behaviors. The way of accessing and interacting with content has changed [8]. All of this increases the complexity of the Internet audiovisual space.

The transformations at work in the audiovisual industry and its regulation are part of global process, namely the digital transition [9]. However, in the exploration stage of Internet audiovisual industry, the regulatory norms and operation mechanism are not perfect which lead to some management gaps and management disarray. For example, online rumors harmed the Internet audiovisual space in various new forms during the outbreak of COVID-19 [10]. Internet rumors were focused on the development of audiovisual industry because of the rumors’ characteristics of wide spread, fast speed, difficult to control, etc., and it is easy to cause the secondary disasters of Internet audiovisual public opinion risks [11]. In order to promote the development of Internet audiovisual industry, a series of regulations of Internet audiovisual industry was issued. In spite of these recent advancements, the space governance of Internet audiovisual still faces some difficulties.

Particularly, the scale of Internet audiovisual industry is huge in China. And it can be argued that the online platforms are aggregating a form of Chinese soft power [12]. The 2021 China Internet audiovisual development research report shows that, in 2020, Internet audiovisual industry market size in China is 600.91 billion yuan, and the number of Internet audiovisual users up to 944 million. During the outbreak of COVID-19, the audiovisual demand of users tilts to the online including short video, live webcast, etc., and Internet audiovisual user scale increases rapidly. However, rumors spread in a wide range and variety of new forms which are difficult to control. The spread of rumor increases the difficulty of the network public opinion control and probably causes serious psychological harm to the public.

Transformative communication technologies have always called for regulatory innovation [13]. The majority of the national authorities have divergent approaches on the economic, social and cultural effects of the digital shift to the audiovisual sector [14]. As a society, cyberspace needs both freedom and order. Given these setbacks, what policies can be implemented to boost the space governance of Internet audiovisual? Three players are involved in any policy game that attempts to answer this question: administrative departments of radio and television, the Internet audiovisual program service agencies, and network audio and video content creators. Based on the above analysis, we attempt to apply an evolutionary game in order to study the policy options of the players. Specifically, the key contributions are as follows:

- Evolutionary game model of Internet audiovisual space governance is built under incomplete information.
- Analyse the evolutionary trajectories of the stakeholders and their sensitivity to parameters.
- There are two evolution paths of tripartite dynamic game.
- Administrative departments of radio and television should be the focus of Internet audiovisual space governance in ideal equilibrium state.

The rest of this paper is organized as follows. In Sect. 2, the related work of this paper is summarized. In Sect. 3, the assumptions of Internet audiovisual space governance are presented. Then, equilibrium analysis of evolutionary game is conducted. Section 4 analyses the evolution path of tripartite dynamic game. In Sect. 5, simulation and empirical analysis are presented to observe the evolutionary trajectories of the stakeholders and their sensitivity to parameters. Finally, in Sect. 6 the achievements of this paper are concluded.

2 Related work

The development of Internet audiovisual industry is closely related to available resources, consumer behavior and national supervision [15]. It becomes clear that the digital shift is a converging reality, insofar as the unprecedented transformation of the audiovisual production, distribution and consumption turns the effectiveness and the goals of audiovisual policies upside down [16]. Kołodziejczyk et al. [17] proposed the new regulates should take into account market and technological changes. Geach [18] argued that without an adequate change in how the law regulates the new resulting audiovisual creative content industry, both in terms of supply and the substance of such content, further harm would also have ensued for the entire industry.

In recent years, studies on Internet audiovisual industry focus on the technical features of the Internet audiovisual industry [19], regulatory choice [20], market trends [21] and industry issues [22]. More particularly, studies on policy options are increasingly concerned. Member States should be aware of the rapid growth of “non-professional” media. Citizens increasingly become their own content creators on virtual individual networks, aggregating their own music or television channels [23]. Besides, Wurff e-t al. [24] argued that in an oligopolistic market structure, destructive competition between manufacturers will reduce the diversity of content product types. Therefore, the government and industry should establish market and platform norms, and actively popularize the knowledge of network ethics and laws and regulations through the media [25].
Relatively studies have analyzed the policy choices of Internet audiovisual space governance. Asongu et al. [26] assessed linkages between social media and governance in Africa. Flew et al. [27] identified the implications of the major digital and social media platforms for twenty-first-century media policy. Gorwa [28] discussed three key dynamics shaping the success of informal governance arrangements: actor competencies, ‘legitimation politics,’ and inter-actor relationships of power and coercion. Regulatory regime will be comprised of a cocktail of different regulatory approaches and the developing concept of co-regulation is likely to be more productive. Besides, the concept of multi-party cooperation emphasizes the cooperation between the government, enterprises, associations. Yang et al. [29] explored the policy-making trends for Internet governance in China. Obviously, new players emerge in the audiovisual industry and offer unprecedented solutions for aggregating and distributing content.

It should be noted that some progress has been made in the space governance of Internet audiovisual through the above-mentioned literature. In addition, Some scholars used neural network [30], social network analysis, Bayesian network analysis etc., to analyze the development of industry, which can be used for reference in this paper. But to the best of our knowledge, there are very few studies to build an evolutionary game model of Internet audiovisual space governance. In order to intuitively observe the evolutionary trajectories of the stakeholders and their sensitivity to parameters, it is necessary to simulate their strategies. Our major contribution to the paper and its results could be more in line with reality and have some significance for future policy.

3 Evolutionary game model and stable analysis

In this section, the evolutionary game model of the Internet audiovisual space governance is designed from the perspective of stakeholders. Game theory is a classical theory applied to the studies of strategic confrontation and competition among stakeholders, or the strategy choice in the face of a situation, and the tripartite evolutionary game model proposed in this paper is based on the classical evolutionary game model [31, 32].

3.1 Assumptions

Considering the reality of Internet audiovisual space governance, we posit the following assumptions:

1. When
   
   2. All three game players have limited rationality, and, because of incomplete information, cannot make a choice that maximizes their own interests.

3. The administrative departments of radio and television can select from two strategies: actively supporting and guiding and inactively intervening. In case of actively supporting and guiding, the administrative department of radio and television provides the subsidies for the Internet audiovisual program service agencies and network audio and video content creators as well as supervises and fines. In case of inactively intervening, the administrative departments of radio and television take no action whatever the other two game players act.

The strategies that can be selected by the Internet audiovisual program service agencies include: actively supervision and inactively intervening. In the case of actively supervision, Internet audiovisual program service agencies regulate network audio and video content creators by means of agenda-setting, content censorship, content creators signing contracts, warning and punishment, closure account and other measures. In case of inactively intervening, network audio and video content creators could create non-standard content without any supervision, such as vulgar content creation, illegal rumor, etc., in order to obtain the short-term traffic and popularity of the platform surge.

Network audio and video content creators also face two choices: creating standardized content and creating vulgar content. In the case of creating standardized content, content creation and distribution shall be conducted in accordance with the regulations of administrative departments of radio and television and Internet audiovisual program service agencies, and vice versa.

For administrative departments of radio and television, the Internet audiovisual program service agencies, and network audio and video content creators under different strategies, the related cost factors are as follows:

Supposing that the administrative departments of radio and television choose the strategy of actively supporting and guiding, the cost which includes human, material and financial expenses is $C_1$. When the Internet audiovisual program service agencies carry out actively management, special fund support and other rewards which from the administrative departments of radio and television is $J$. Once the network audio and video content creators create
vulgar content when the administrative departments of radio and television choose inactively intervening, the society will generate negative emotions. The loss of public credibility of the administrative departments of radio and television is $P$.

Assume that the cost of Internet audiovisual program service agencies when carrying out active supervision is $C_2$. The network audio and video content creators when creating standardized content will be rewarded with part of advertising revenue and home page push from the Internet audiovisual program service agencies, indicated by $g$. When the network audio and video content creators create vulgar content, the Internet audiovisual program service agencies will warn, punish or ban the content creators, meanwhile their own losses are $S_1$. When Internet audiovisual program service agencies select the strategy of inactively intervening, and the network audio and video content creators create vulgar content and cause the chaos of Internet audiovisual space, the agencies will be suffered warnings and fines from administrative departments of radio and television, the losses are $F$.

Supposing that the network audio and video content creators need to pay the cost $C_3$ when creating content. When the Internet audiovisual program service agencies carry out active supervision, the network audio and video content creators who create vulgar content need to bear the losses, such as being warned and shunted down account, which are $S_2$. When Internet audiovisual program service agencies carry out inactively intervening and administrative departments of radio and television carry out actively supporting and guiding, the network audio and video content creators who create vulgar content will bring about the rise of negative social public opinion, and will be severely punished by administrative departments. The losses are $S_3$.

For the administrative departments of radio and television, Internet audiovisual program service agencies and network audio and video content creators under different strategies, the relevant income factors are as follows:

If the administrative departments of radio and television carry out actively supervision, the public credibility of administrative departments will increase and the benefits are $G$. Under the condition of the Internet audiovisual program service agencies carry out inactively intervening, if the network audio and video content creators conduct vulgar creation, the administrative departments of radio and television will fine $F$ from the former.

If the Internet audiovisual program service agencies choose actively supervise, they will be rewarded $J$ by the administrative departments of radio and television. Meanwhile, the strategy of actively supervise contributes to the development of Internet audiovisual program service agencies, and its own profits is $H$. When the network audio and video content creators create vulgar content, the Internet audiovisual program service agencies which carry out inactively intervening will gain additional benefits $R_3$, such as the increase of users and content clicks.

When the network audio and video content creators create content in a standardized way, they can gain benefits $R_1$, such as fans and profits. And the Internet audiovisual program service agencies will reward the former, indicated by $g$. When the network audio and video content creators choose to create vulgar content, they probably obtain more subscribers and other benefits, indicated by $R_2$.

### 3.2 Replicated dynamic equation

Replication dynamic equation is a mechanism to study the dynamic strategy adjustment of the subject in the bounded rational game. So, the replication dynamic equation of the behavior strategy of three parties in the game is further constructed. The strategy combination and pay-off matrix of three players is established in Table 1.

In the initial stage of the three players game, $x, y, z$ are the probabilities of the three parties in the game choosing the strategy of actively supporting and guiding, actively supervising and creating standardized content, respectively, and the probabilities satisfy $0 \leq x \leq 1, 0 \leq y \leq 1, 0 \leq z \leq 1$.

The expected payoffs $E_{11}$ that administrative departments of radio and television gain when they choose the strategy of “actively supporting and guiding” are

$$E_{11} = yz(G - C_1 - J) + y(1 - z)(G - C_1 - J) + (1 - y)z(G - C_1) + (1 - y)(1 - z)(G + F - C_1)$$

The expected payoffs $E_{12}$ that administrative departments of radio and television gain when they choose the strategy of “inactively intervening” are

$$E_{12} = y(1 - z)(-p) + (1 - y)(1 - z)(-p)$$

Accordingly, the average expected payoffs of administrative departments of radio and television are:
Table 1 Strategy combination and pay-off matrix of three players

| Players                                                                 | Network audio and video content creators |
|------------------------------------------------------------------------|------------------------------------------|
| Administrative departments of radio and television                      |                                           |
| $x$ Internet audiovisual program service agencies                       | $y$                                      |
| $1 - y$                                                                | $1 - y$                                   |
| $y$                                                                    | $y$                                      |
| $1$                                                                    | $1$                                      |

$E_1 = xE_{11} + (1 - x)E_{12}$ (3)

The replicator dynamics equation of the proportion $x$ for the administrative departments of radio and television is

$F(x) = dx/dt = x(E_{11} - E_1)$ (4)

The expected payoffs $E_{21}$ that Internet audiovisual program service agencies gain when they choose the strategy of “actively supervising” are

$E_{21} = xz(J + H - C_2 - g) + x(1 - z)(J + H - C_2 - S_1)$
$+ (1 - x)z(H - C_2 - g) + (1 - x)(1 - z)$
$= (H - S_1 - C_2)$ (5)

The expected payoffs $E_{22}$ that Internet audiovisual program service agencies gain when they choose the strategy of “inactively supervising” are

$E_{22} = x(1 - z)(R_3 - F) + (1 - x)(1 - z)R_3$ (6)

Accordingly, the average expected payoffs of Internet audiovisual program service agencies are

$E_2 = yE_{21} + (1 - y)E_{22}$ (7)

The replicator dynamics equation of the proportion $y$ for the Internet audiovisual program service agencies is

$F(y) = dy/dt = y(E_{21} - E_2)$ (8)

The expected payoffs $E_{31}$ that network audio and video content creators gain when they choose the strategy of “creating vulgar content” are

$E_{31} = xy(R_1 - C_3 + g) + x(1 - y)(R_1 - C_3)$
$+ (1 - x)z(R_1 - C_3 + g) + (1 - x)(1 - y)$ (9)

Accordingly, the average expected payoff of network audio and video content creators is

$E_3 = zE_{31} + (1 - z)E_{32}$ (11)

The replicator dynamics equation of the proportion $y$ for the network audio and video content creators is

$F(z) = dz/dt = z(E_{31} - E_3)$ (12)

Due to the limited rationality of the three parties of the game, it is difficult for the three stakeholders to make the best choice in a game. With the continuous evolution of multiple games, the three parties can find the strategy of maximizing interests and finally formulate the evolutionary stability strategy (ESS). Therefore, a three-dimensional dynamic system of the governance game is formed as follows:
Table 2  Strategy combination and pay-off matrix of three players

| Equilibrium points | Eigenvalues |
|--------------------|-------------|
|                   | \( \lambda_1 \) | \( \lambda_2 \) | \( \lambda_3 \) |
| \( D_1(0, 0, 0) \) | \( G + F - C_1 + P \) | \( H - S_1 - C_2 - R_3 \) | \( R_1 - R_2 \) |
| \( D_2(0, 0, 1) \) | \( G - C_1 \) | \( -g + H - C_2 \) | \( R_1 \) |
| \( D_3(0, 1, 0) \) | \( -J + G - C_1 + P \) | \( -H + S_1 + C_2 + R_3 \) | \( g + S_2 + R_1 - R_2 \) |
| \( D_4(0, 1, 1) \) | \( -J + G - C_1 \) | \( g - H - C_2 \) | \( -g - S_2 - R_1 + R_2 \) |
| \( D_5(1, 0, 0) \) | \( -G - F + C_1 - P \) | \( J + F + H - S_1 - C_2 - R_3 \) | \( S_3 + R_1 - R_2 \) |
| \( D_6(1, 0, 1) \) | \( -G + C_1 \) | \( J - g + H - C_2 \) | \( -S_3 - R_1 + R_2 \) |
| \( D_7(1, 1, 0) \) | \( J - G + C_1 - P \) | \( -J - F - H + S_1 + C_2 + R_3 \) | \( g + S_3 + R_1 - R_2 \) |
| \( D_8(1, 1, 1) \) | \( J - G + C_1 \) | \( -J - g + H - C_2 \) | \( -g - S_2 - R_1 + R_2 \) |

According to the system equilibrium points and Jacobian matrix, eigenvalues of each equilibrium point can be obtained to analyze its asymptotic stability, as shown in Table 2. According to Lyapunov stability theory [33], the asymptotic stability at the equilibrium point can be determined by the eigenvalues of the Jacobian matrix. If all the eigenvalues have non-positive real parts, then the equilibrium point is asymptotically stable, indicated by the sink. If all eigenvalues are positive, then the equilibrium point is the unstable point, indicated by the source. If the eigenvalues conclude both positive and negative parts, the equilibrium point will be an unstable point which is called saddle point.

4 Evolution path of tripartite dynamic game

According to the system equilibrium points and Jacobian matrix, eigenvalues of each equilibrium point can be obtained to analyze its asymptotic stability, as shown in Table 2. According to Lyapunov stability theory [33], the asymptotic stability at the equilibrium point can be determined by the eigenvalues of the Jacobian matrix. If all the eigenvalues have non-positive real parts, then the equilibrium point is asymptotically stable, indicated by the sink. If all eigenvalues are positive, then the equilibrium point is the unstable point, indicated by the source. If the eigenvalues conclude both positive and negative parts, the equilibrium point will be an unstable point which is called saddle point.

Obviously, when the evolutionary stability point of the trilateral game is (1, 1, 1), the interests of the community are aligned with the interests of the individual, which is the goal of Internet audiovisual industry space governance. To reach the asymptotic stability point (1, 1, 1), the three stakeholders have gone through 8 combinations of strategies in the evolutionary game process and three policy evolution paths.

Path1 : (0, 0, 0) \rightarrow (1, 0, 0) \rightarrow (1, 1, 0) \rightarrow (1, 0, 1) \rightarrow (1, 1, 1)

Path2 : (0, 0, 0) \rightarrow (0, 1, 0) \rightarrow (1, 1, 0) \rightarrow (0, 1, 1) \rightarrow (1, 1, 1)

Path3 : (0, 0, 0) \rightarrow (0, 0, 1) \rightarrow (1, 0, 1) \rightarrow (0, 1, 1) \rightarrow (1, 1, 1)

In the evolution process of path 2, administrative departments of radio and television adopt the strategy of actively intervening, allowing Internet audiovisual program service agencies to compete and develop freely in accordance with market rules. According to the prisoner’s Dilemma theory, “ inactive intervening ” has become the
absolute dominant strategy of Internet audiovisual program service agencies. Therefore, in reality, path 2 cannot finally reach the asymptotically stable point (1, 1, 1) and path 2 is omitted.

In the evolution process of path 3, both the administrative departments of radio and television and the Internet audiovisual program service agencies adopt the strategy of inactively intervening. In this case, it is impossible for network audio and video content creators to adopt standardized creation strategies in reality. The risk of public opinion in the Internet audiovisual space is universality and generalized. Due to the information supply and demand imbalance, ambiguous evidence and perceptual differences among network audio and video content creators, it is easy to lead the Internet audiovisual space into disorder and chaos. Therefore, this path cannot finally reach the asymptotically stable point (1, 1, 1) in reality, and path 3 is omitted.

This implies that only path 1 can reach the asymptotically stable point (1, 1, 1) in reality. In the evolution process of dynamic game driven by administrative departments of radio and television, the conditions that path 1 needs to meet are shown in Table 3.

### 4.1 Analysis on the initial stage (0, 0, 0)

The products forms of Internet audiovisual content are changing rapidly, and such as short videos and Internet live broadcasts which are equipped with emerging technologies are flooding into the market. This has brought a positive impact on the enrichment of Internet audiovisual space and the prosperity of Internet audiovisual culture, but at the same time, it has also caused a series of Internet audiovisual space governance and unexpected public opinion problems. At this moment, the regulations and administrative supervision of administrative departments of radio and television over the emerging Internet audiovisual products are insufficient, and there are some problems such as unclear regulatory responsibilities, imperfect regulatory laws and regulations, extravagant regulatory costs. When \( G + F - C_1 + P < 0 \), the administrative departments of radio and television tend to choose the strategy of actively supporting and guiding.

Due to the needs of market expansion and lack of ability and experience to judge and dispose of undesirable content, the Internet audiovisual program service agencies choose the strategy of inactively intervening over network audio and video content creators who create vulgar content. When \( H - S_1 - C_2 - R_3 < 0 \), the administrative departments of radio and television choose the strategy of inactively intervening.

Because the network audio and video content creators are in the stage of understanding and exploration of the new creation forms, the cognition of standardized creation has not yet formed. In order to gain popularity and monetary benefits, vulgar creation phenomena may occur, such as the dissemination of false information. When \( R_1 - R_2 < 0 \), the network audio and video content creators choose to create vulgar content.

### 4.2 Analysis on the process of (0, 0, 0) to (1, 0, 0)

When the Internet audiovisual program service agencies and network audio and video content creators choose the negative strategy, the negative social impact is gradually expanding and the social contradictions are gradually emerging. In order to improve credibility and standardize the order of the Internet audiovisual space, administrative departments of radio and television gradually improve the relevant management norms and increase the punishment the Internet audiovisual program service agencies which choosing the strategy of inactively intervening, and investigate the responsibility of the vulgar creation of the network content creators. As Internet audiovisual program service agencies gradually reduce the regulatory cost through the division of responsibilities, the regulatory efficiency is constantly improved, and the image of government regulation is greatly enhanced. When \( -G + F + C_1 + P < 0 \), the administrative departments of radio and television tend to choose the policy of actively supporting and guiding.

The administrative departments of radio and television carry out the active control strategy, but in fact the rewards and punishments for the Internet audiovisual program service agencies are insufficient, and the input cost of the
Internet audiovisual program service agencies choosing actively supervision strategy is still high, which lead to the motivation of active supervision is insufficient. When \( J + F + H - S_1 - C_2 - R_3 < 0 \), the Internet audiovisual program service agencies tend to choose the inactively intervening strategy.

Based on the theory of broken Windows and rule loopholes, the vulgar creation behaviors of network audio and video content creators appear frequently when the Internet audiovisual program service agencies carry out inactively intervening strategy, which cause the result demonstration effect gradually expands. Meanwhile, if the administrative departments of radio and television do not punish the network audio and video content creators creating vulgar content harshly, more and more audiovisual program service agencies tend to choose the inactively intervening strategy.

The initiative of Internet audiovisual program service agencies carrying out the strategy of actively supervise has been enhanced under the actively supporting and guiding strategy. Through active supervision, revenue and government rewards are obtained, and the supervision cost is gradually reduced, and more content creators are attracted and the scale economy effect is created. When \(-J - F - H + S_1 + C_2 + R_3 < 0\), the Internet audiovisual program service agencies choose the strategy of actively supervision. However, when the rewards and punishments for content creators of Internet audiovisual program service agencies are weak, and content creators’ vulgar creations get more visitors and traffic, that is \( g + S_3 + R_1 - R_2 < 0 \), network audio and video content creators choose the strategy of creating vulgar content.

Since then, the active control of administrative departments of radio and television has become a norm, and the regulatory cost has been gradually reduced, the credibility has been significantly improved, and the incentives for Internet audiovisual program service agencies have been gradually weakened. When \( J - G + C_1 < 0 \), The administrative departments of radio and television choose the active control strategy. Under the active control of administrative departments of radio and television, the benefits of active supervision of Internet audiovisual program service agencies have been significantly improved, and the costs of active supervision have decreased year by year. When \( -J + g - H + C_2 < 0 \), Internet audiovisual program service agencies continue to opt for an active supervision strategy. The profit of network audio and video content creators creating standardized content is significantly greater than creating vulgar content in this situation. When \( -g - S_2 - R_1 + R_2 < 0 \), the strategy choice of content creators is creating standardize content.

4.3 Analysis on the stage \((1, 1, 0)\) and the final stage \((1, 1, 1)\)

The administrative departments of radio and television continuously increase their control over the Internet audiovisual space, each regulatory department has a clearer division of responsibilities, the management cost has been effectively controlled, the management and control policies have been improved, the reward and punishment mechanism have become more flexible, and the public credibility of broadcasting and television administrative departments has been greatly improved because of actively supporting and guiding strategy. When \( J - G + C_1 - P < 0 \), The administrative departments of radio and television maintain the actively supporting and guiding strategy.

The initiative of Internet audiovisual program service agencies carrying out the strategy of actively supervise has been enhanced under the actively supporting and guiding strategy of administrative departments of radio and television. Through active supervision, revenue and government rewards are obtained, and the supervision cost is gradually reduced, and more content creators are attracted and the scale economy effect is created. When \(-J - F - H + S_1 + C_2 + R_3 < 0\), the Internet audiovisual program service agencies choose the strategy of actively supervision. However, when the rewards and punishments for content creators of Internet audiovisual program service agencies are weak, and content creators’ vulgar creations get more visitors and traffic, that is \( g + S_3 + R_1 - R_2 < 0 \), network audio and video content creators choose the strategy of creating vulgar content.

4.4 Analysis on the stage \((1, 0, 1)\) and the final stage \((1, 1, 1)\)

For the stage \((1, 0, 1)\), when \( J - G + C_1 - P < 0 \), administrative departments of radio and television maintain active control strategies. At this time, the administrative department of radio and television has a strong punishment and accountability for content creators, that is \(-g - S_2 - R_1 + R_2 < 0\), network audio and video content creators choose to create vulgar content. But when the cost of active supervision by Internet audiovisual program service agencies is high, that is \( J - g + H - C_2 < 0 \), Internet audiovisual program service agencies maintain the strategy of inactively intervening.

Then, under the active control and adjustment of administrative departments of radio and television, the rewards and punishments for Internet audiovisual program service agencies were increased. When \(-J + g - H + C_2 < 0\), the strategic choice of Internet audiovisual program service agencies is the actively supervision.

5 Simulation and empirical analysis

To reach the asymptotic stability point \((1, 1, 1)\), conditions need to be reached as follows: \( J - G + C_1 < 0 \); \( -J + g - H + C_2 < 0 \); \(-g - S_2 - R_1 + R_2 < 0\). In order to intuitively observe the evolutionary trajectories of the stakeholders and their sensitivity to parameters, it is necessary to simulate their strategies. In this study, we implemented this simulation by using MATLAB. In order to meet these conditions, suppose that \( J = 5 \); \( F = 2 \); \( p = \)
1; C₁ = 5; C₂ = 3; C₃ = 10;  S₁ = 1; S₂ = 3; S₃ = 5; R₁ = 10; R₂ = 3; R₃ = 10; G = 15; H = 5; g = 2. And three situations x = 0.2, y = 0.7, z = 0.9, x = 0.5, y = 0.5, z = 0.5, x = 0.9, y = 0.2, z = 0.7 are selected to conduct simulation analysis with MATLAB. The results are shown in Fig. 1.

In this situation, the behavioral strategies of the three parties gradually tend to stabilize at the ideal situation (1, 1, 1), and the choice of strategies will not be changed due to the different initial wishes of the subjects.

Among the relevant parameters of the trilateral game, cost, loss and profit are all objective values. There are 5 subjective parameters: financial support provided by the administrative departments of radio and television when the Internet audiovisual program service agencies choose actively supervise (J), penalty losses of Internet audiovisual program service agencies when choose inactively intervening strategy by the administrative department of radio and television (F), penalty losses incurred by network audio and video content creators who are punished by Internet audiovisual program service agencies for vulgar creation (S₂), penalty losses of network audio and video content creators creating vulgar content who are punished by administrative department of radio and television (S₃), rewards for network audio and video content creators creating standardize content by Internet audiovisual program service agencies (g). Therefore, the sensitivity of the stakeholders to the former 5 parameters is explored in this paper. It is needed to be emphasized that when we analyze the sensitivity of one of the above parameters, the values of the other parameters are the same.

5.1 Financial support provided by administrative departments of radio and television (J)

In order to explore the sensitivity of stakeholders to the financial support provided by administrative departments of radio and television, we let J = 1, J = 5, J = 9. The results are shown in Fig. 2.

The simulation results show that the financial support (J) has a significant impact on the strategic choice of administrative departments of radio and television and Internet audiovisual program service agencies. With the increase of financial support (J), the probability of the Internet audiovisual program service agencies choose actively supervision greatly increases, the willingness of administrative departments of radio and television to support and guide actively has decreased slightly.
5.2 Penalty losses of internet audiovisual program service agencies ($F$)

In order to explore the sensitivity of stakeholders to the penalty losses of Internet audiovisual program service agencies when choose inactively intervening strategy by the administrative department of radio and television, we let $F = 1$, $F = 5$, $F = 15$. The results are shown in Fig. 3.

The simulation results show that the penalty losses ($F$) have an impact on the strategic choice of administrative departments of radio and television and Internet audiovisual program service agencies. With the increase of $F$, the willingness of Internet audiovisual program service agencies to actively supervision increased obviously, the probability of administrative departments of radio and television carry out actively supporting and guiding has increased slightly.

5.3 Penalty losses of network audio and video content creators ($S_2$)

In order to explore the sensitivity of stakeholders to the penalty losses of network audio and video content creators who are punished by Internet audiovisual program service agencies for vulgar creation ($S_2$), we let $S_2 = 1$, $S_2 = 5$, $S_2 = 15$. The results are shown in Fig. 4.

The simulation results show that the penalty loss ($S_2$) has an impact on the strategic choice of the Internet audiovisual program service agencies and network audio and video content creators. With the increase of $S_2$, the

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**Fig. 2** The sensitivity of financial support ($J$) a Probability of administrative departments of radio and television actively supporting and guiding, b Probability of the Internet audiovisual program service agencies actively supervision, c Probability of the network audio and video content creators creating standardize content

**Fig. 3** The sensitivity of penalty losses ($F$) a Probability of administrative departments of radio and television actively supporting and guiding, b Probability of the Internet audiovisual program service agencies actively supervision, c Probability of the network audio and video content creators creating standardize content

**Fig. 4** The sensitivity of penalty losses ($S_2$) a Probability of administrative departments of radio and television actively supporting and guiding, b Probability of the Internet audiovisual program service agencies actively supervision, c Probability of the network audio and video content creators creating standardize content
willingness of Internet audiovisual program service agencies to actively regulate slightly increases, the willingness of network audio and video content creators to standardize their creation has increased significantly.

### 5.4 Penalty losses of network audio and video content creators ($S_3$)

In order to explore the sensitivity of stakeholders to the penalty losses of network audio and video content creators creating vulgar content who are punished by administrative department of radio and television ($S_3$), we let $S_3=1$, $S_3=5$, $S_3=15$. The results are shown in Fig. 5.

The simulation results show that the loss of the penalty losses of network audio and video content creators creating vulgar content who are punished by administrative department of radio and television ($S_3$) has an impact on the strategic choices of Internet audiovisual program service agencies and network audio and video content creators. With the increase of penalty losses ($S_3$), the willingness of Internet audiovisual program service agencies to actively supervision slightly increased, and the willingness of network audio and video content creators to standardize their creation has increased significantly.

### 5.5 Rewards for network audio and video content creators ($g$)

In order to explore the sensitivity of stakeholders to the rewards for network audio and video content creators creating standardized content by Internet audiovisual program service agencies ($g$), we let $g = 1$, $g = 3$, $g = 6$. The results are shown in Fig. 6.

The simulation results show that the rewards for network audio and video content creators creating standardized content by Internet audiovisual program service agencies ($g$) has an impact on the strategic choice of administrative departments of radio and television, Internet audiovisual program service agencies, and network audio and video content creators. With the increase of the rewards, the willingness of administrative departments of radio and television supporting and guiding actively control is slightly increased, the Internet audiovisual program service agencies carry out actively supervision decreased obviously, and the willingness of network audio and video content creators to standardize their creation has increased significantly.

### 5.6 The sensitivity of parameter ($J$) and ($F$)

The above results show that the administrative department of radio and television plays an important role in the dynamic game of Internet audiovisual space governance.
order to explore the sensitivity of relevant parameters of administrative department of radio and television, we select the parameters \( J \) and \( F \) for simulation and analysis. We let \( J = 1, F = 1; J = 5, F = 5; J = 9, F = 15 \). The results are shown in Fig. 7.

The simulation results show that the financial support provided by administrative departments of radio and television \( J \) and the penalty losses of Internet audiovisual program service agencies \( F \) have an obvious impact on the choices of stakeholders. With the increase of the \( J \) and \( F \), the willingness of administrative departments of radio and television supporting and guiding actively control is decreased. The willingness of Internet audiovisual program service agencies carry out actively supervision increased obviously, when the \( J = 1 \) and \( F = 1 \), the probability goes down and then up. The Probability of network audio and video content creators standardizing their creation has decreased slightly.

6 Conclusion

This study established a tripartite evolutionary game model to discuss the space governance of Internet audiovisual from the perspective of the relevant stakeholders. First, the evolutionary game model of the Internet audiovisual space governance is designed from the perspective of stakeholders, and a payoff matrix of the stakeholders under different scenarios is supposed. Then, the replicated dynamic equations of stakeholders are listed, and the evolutionary stable strategies by solving the asymptotic stability of the equilibrium points are explored. Finally, the evolution path of tripartite dynamic game is analyzed and the results of numerical simulation of the ultimate evolutionary stable strategies and of their relevant parameters, together with empirical analysis, are presented.

This paper studies the initial willingness of stakeholders, without considering the factors of stakeholders’ psychological willingness. In the future, we may add psychological willingness as a variable into the game model or introduce prospect theory to improve the evolution.

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