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Research on multiagent governance of the marine ecoeconomic system in China considering marine scientific research institutions and media

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The multiagent governance model of the marine ecoeconomic system requires local governments to actively guide the participation of social subjects. Under the new reality of multiagent governance mechanism, this study proposes an analytical framework for describing the dynamic relation between local governments and marine production enterprises. It uses the analytical tools of evolutionary game theory to establish an evolutionary game system between the two parties and takes China as the specific research object. For doing so, it selects marine scientific research institutions and media with a strong public value representation and discusses the unilateral evolutionary stability strategy of the system by introducing four parameters, namely, the number of marine scientific research institutions, the contribution level of marine scientific research institutions, the participation level of media, and the authenticity level of information released by media. Furthermore, we used MATLAB to simulate and analyze by combining our research data in 14 cities in coastal areas of China. The results demonstrate that: 1) improving the contribution level and number of marine scientific research institutions is conducive to the collaborative governance of the marine ecoeconomic system; 2) the authenticity level of information released by media is positively correlated with the development of the multiagent governance model of the marine ecoeconomic system; and 3) differently biased objects with distorted media report information affect the trend of the governance effect of the marine ecoeconomic system. Thus, a timely improvement or reduction of the participation level of media is necessary.

KEYWORDS

marine ecoeconomic system, multiagent governance, marine scientific research institutions, media, evolutionary game

1 Introduction

Ecologist Mashijun (1984) put forward the theory of economic-social-ecological composite system (hereafter referred to as the ecoeconomic system) on the basis of summarizing the cybernetic principles of ecosystems with integration, coordination, autogenesis, and circulation as the core. Moreover, the author clearly pointed out that the essence of sustainable development is the systematic development of the relationship between an individual and its working, material production, and social and cultural environments. The marine ecoeconomic system is an important component of the global ecoeconomic system. It is a

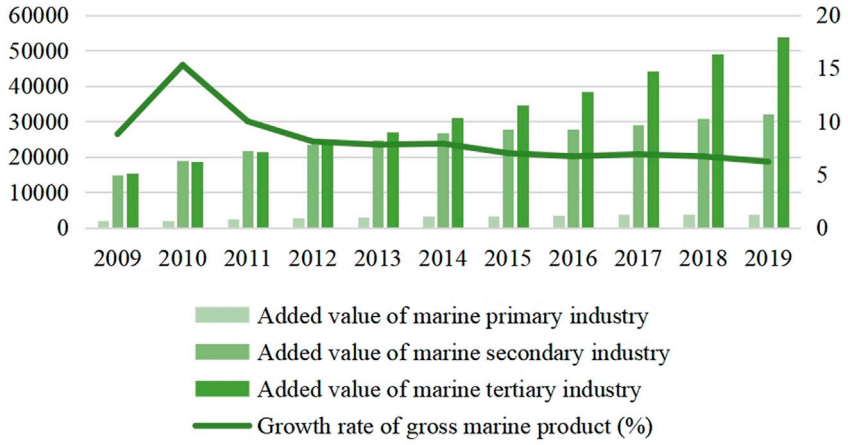

FIGURE 1
Marine economic growth of China from 2009 to 2019.

special composite system with specific structures and functions and is composed of the marine ecosystem, marine economic system, and coastal social system (Gao and Gao, 2012). Under the goal of ecological civilization construction, the key to promoting the coordinated development of the global marine ecoeconomic system lies in the appropriate treatment of the relationship between human economic society and marine ecology. Only by adjusting human values and codes of conduct and enhancing the integration, adaptability, and control of marine ecology, economy, and social governance can the advanced evolution of the marine ecoeconomic system be promoted (Gao, 2021). At present, the trend of the governance of the marine ecoeconomic system at the global scale is to introduce more social subjects under the structures of government guidance and enterprise investment, which, thus, forms a new pattern of multiagent collaborative governance.

Governance of the marine ecoeconomic system is a symbiotic problem faced by coastal countries of the 21st century. Looking at China today, the ocean, as an important position of modern economic development, points out a new path for national development. Figure 1 depicts that gross marine product for China in 2019 was 8,941.5 billion yuan or an increase of 6.2% over the previous year, which accounts for 9.0% of gross domestic product (hereinafter referred to as GDP). Since the 1990's, China's marine economy has rapidly developed; its economic aggregate has risen steadily; and its industrial structure has been gradually optimized. As the largest advantage and potential industry, it has become a new point of growth for China's national economy. However, behind the rapid rise of marine economy, marine ecological problems in China are becoming increasingly prominent, whereas marine ecological civilization is declining (Charfeddine, 2017; Baloch et al., 2019). Today, although the ocean is a breakthrough in China's economic innovation and social development, it may also become a bottleneck and hidden danger, which may backfire on its future (Wang, 2020). Therefore, to ensure the coordinated and sustainable development of the marine ecoeconomic system and to promote the green development of China's marine economy, it is of great significance to study the marine ecoeconomic system from the perspective of multiagent governance.

However, the biggest problem lies in determining the role and mechanism of each subject in the governance of the marine ecoeconomic system to achieve a high degree of synergy in governance and enable the marine ecoeconomic system to operate in a healthy and orderly manner. In recent years, local governments in China, like other countries, have mainly focused on the legal aspect of marine governance and mostly considered legislation as the starting point, supervision as the means, and administrative enforcement as the guarantee (McKinley and Ballinger, 2018; Taljaard et al., 2019). Although the premise of ocean governance is the improvement of the law, it remains insufficient to warrant reliance. A single solution at the legislative level will lead not only to increased social costs but also to detriment in the maintenance of the credibility of the government and even cause the intensification of social contradiction (Qu et al., 2021).

Therefore, this study focuses on marine scientific research institutions and media with strong public value representation as participants of the multiagent governance of the marine ecoeconomic system. The reasons are as follows: For media, there are two ways to participate in governance. Firstly, the media can participate in governance through reputation mechanisms. The reputation mechanism of the media is that the media realizes its supervision function by reporting and then influencing the reputation of the government, enterprises or individuals (Kolbel et al., 2017). Secondly, the media will act as an information bridge connecting the government, enterprises and the public, and disclose information to the government and the public, and introduce administrative penalties from the government (Gao et al., 2018). In particular, the media examines the improvement of local marine ecology and the green production process of enterprises to judge whether marine governance is strictly implemented. The realization of media supervision and participation in governance can not only guide the behavior evolution direction of local governments and marine production enterprises in a "soft direction," but also save governance costs. Marine scientific research institutions are the main driving force of marine science and technology innovation and development in China and the important direction of national marine research capacity construction. At present, under the strategic background of China's building a maritime power, it is of great significance to scientifically plan the behavior decisions and

governance measures of marine scientific research institutions, and rationally allocate marine scientific and technological innovation resources for the governance of marine ecological and economic system. At the same time, as stakeholders are greatly affected by the ocean, marine scientific research institutions and media participate in the governance of marine ecoeconomic system, which helps reduce the loss of public resources caused by market and government failures (Cheng, 2018).

With the transformation of the global governance structure from one-entity to multiagent collaborative governance, the establishment of a mechanism for multiagent collaborative governance and the formation of a new pattern of "mutual building and sharing" of the marine ecoeconomic system are of great significance to the maximization of the governance effect (Xia, 2022). Under the new reality of multiagent governance mechanism, this study proposes an analytical framework for describing the dynamic interaction between local governments and marine production enterprises. It uses the analytical tools of evolutionary game theory to establish an evolutionary game system between the two parties, and discusses the unilateral evolutionary stability strategy (ESS) of the system after introducing the factors of marine scientific research institutions and the media. Based on the sustainable development goals and the coordination of the marine ecoeconomic system, this study analyzes the specific role of various influencing factors to provide strategic support for promoting multiagent collaborative governance of the marine ecoeconomic system.

The study intends to answer the following key questions.

(1) What is the importance of marine scientific research institutions and media on the multiagent governance of the marine ecoeconomic system? What's the impact? From the perspective of overall system stability, special cases, and general cases, when can the two subjects play the best governance utility?
(2) What impact does the behavior evolution of marine scientific research institutions and media exert on the regulatory effect of local governments? How can the optimal behavior choice strategy of local governments be achieved?
(3) How does the behavior evolution of marine scientific research institutions and media influence the governance effect of marine production enterprises? How can the optimal behavior selection strategy be achieved?

2 Literature review

2.1 Marine ecoeconomic system

In the face of the deteriorating marine ecological cycle, the depletion of biological resources, and the continued decline of environmental water quality, the global ocean is undergoing a crisis of rapid consumption of biomass, and the marine ecosystem is gradually forming a "Metabolic Rift" (Clausen and Clark, 2005). Compared with terrestrial ecosystems, the carrying capacity of marine ecosystems is more fragile. The uncontrolled development and utilization and neglect to effectively protect and repair the oceans will inevitably influence the supply capacity of marine products and services and destroy marine ecology (Hall, 2001). To ensure the healthy and sustainable operation of marine ecology while developing marine economy, comprehensive planning should be conducted from the perspective of combining economy and ecology (Kildow and McIlgorm, 2010).

Throughout the research of global scholars, the research on issues related to marine ecological economy has gradually developed from a single to a systematic way. Jin et al. (2003) combined the ecosystem model with the economic analysis model to establish a model of the marine ecoeconomic system, breaking the boundary between a single research ecological model and an economic model. Martinez et al. (2007) believed that we should pay attention to the coordinated development among ecology, economy and society. The past extensive development mode has caused serious damage to the marine ecological environment. Hoagland and Jin (2008) obtained the relationship between marine ecology, social and economic development by collecting a large amount of data and using quantitative methods, and divided their states. Gao and Gao (2012), on the basis of existing research results, gave a precise definition of marine ecoeconomic system. The two scholars referred society to the same dimension as ecology and economy for research. They believed that marine ecoeconomic system includes three aspects, namely, marine ecology, marine economy and marine society. The paper analyzed in detail how the three subsystems operate, how to become a complex marine ecoeconomic system through coupling. Bene et al. (2001) focused on the adaptability and self recovery ability of marine ecoeconomic system under dangerous conditions, and built a dynamic model of marine ecoeconomic system adapting to dangerous conditions on the basis of the research. On the basis of studying the ecosystems of the United States, Canada and Australia, Juda, (2003) discussed the impact of the national marine governance model on a country's marine ecoeconomic system, and believed that changing a country's marine governance methods could achieve the coordinated development of the marine ecoeconomic system and ultimately be conducive to national marine development.

To summarise, as one of the most productive, diverse, and developmental systems on Earth (Souter and Linden, 2000; Sun et al., 2018), the marine ecoeconomic system has attracted the attention of many scholars. In view of the increasingly sharp contradiction between marine economic and social development and marine ecological protection, scholars all over the world pay much attention to their coordinated development at the end of the 20th century, especially in the 21st century. Research topics mainly cover the marine economic transformation of coastal countries and regions (zones) (Liu et al., 2012; Delgado et al., 2021), marine fishery management (Bundy et al., 2017; Gelcich et al., 2019), marine environment governance (Parlee and Wiber, 2018; Devenport et al., 2021), marine protected area management (Carcamo and Gaymer, 2013; Jones et al., 2013), marine biodiversity restoration (Lockwood et al., 2012; Jacob et al., 2018), and marine energy utilization (Castelos, 2014; Goffetti et al., 2018), among others. For example, Sarker et al. (2018) analyzed the sustainable development potential of the marine economy in Bangladesh; Voyer et al. (2020) took Timor-Leste as an example for assessing consistency and coordination between policies and marine economic development; Gerhardinger et al. (2020) formulated a transformation experiment of sustainable development for the marine economy in Brazil; Costello et al. (2012) suggested specific plans for the repair, reconstruction, and income increase of small-scale fisheries in the world that did not undergo assessment; lastly, Vince and Hardesty. (2017) discussed the reduction of plastic pollution on the basis of market strategy and

community participation in governance and put forward suggestions for the coordinated development of the governance and economy of the global marine environment.

2.2 Multiagent governance

As a strategic public goods in the 21st century, governance of the maritime domain involves multiple subjects. In the process of governance, there will be many drawbacks if only relying on a single government governance, as this domain requires the participation of enterprises, the public and other multiple subjects (Savan B et al., 2004). As early as the industrialization period, Sherman and Alexander (1985) proposed the adoption of a method called "multisector overall collaborative governance" to coordinate and optimize the governance of marine ecological economy. Wittman, (1998) suggested that a mechanism of government assessment with economic development as the core will make local governments excessively pursue fiscal revenue and economic growth at the expense of the ecological environment and overlook the due supply and protection of public goods; thus, ensuring the effectiveness of ecological governance policies is difficult. Moreover, Holling and Meffe. (1996); Armitage et al. (2012) believe that the "command and control" governance model, which relies on the mandatory promotion of local governments, is costly and produces unsustainable effects. Therefore, the governance leadership of government departments should be diluted and gradually transferred to the public. Based on this notion, many new governance methods of the marine ecoeconomic system have been proposed such as marine zoning governance, participatory governance, and community governance, among others (Crowder et al., 2006).

"Multiagent governance" is an umbrella term for various public management topics, including cross-sectoral partnerships, intergovernmental and interagency cooperation, public service networks, consensus building, and public participation (Emerson et al., 2012). When a single organization or individual cannot complete a task by itself, then a multiagent governance mechanism is required (Thomson and Perry, 2006). Multiagent governance is a new form of participation in social and political activities for different individuals or organizations. It is also a more effective method for solving the needs of a multiagent modern society and for achieving common goals (Imperial, 2005). Nowadays, in the process of examining the governance issues of different industries, the majority of scholars emphasize the important role of multiagent collaborative governance and propose the acceleration of the construction of a multilevel, cross-sectoral, and mixed collaborative governance model that includes the government, enterprises, the public, and other stakeholders (Ostrom, 2010). In this manner, a transformation from "unified supervision" to "multiagent governance" among local governments can be realized. Combining the mechanisms of multiagent governance and industry governance can not only effectively improve the efficiency of governance and reduce regulatory costs (Song et al., 2010) but also enhance the scale and quality of ecological capital stock (Liu, 2018), and restrict the tendency of local governments to sacrifice the ecological environment to maintain political performance (Zheng and Kahn, 2017). At the same time, multiagent governance can effectively avoid government failure by dividing the social responsibility of the government and partially transferring it to other participants (Arentsen, 2008), which is conducive to optimizing the distribution of social responsibility (Eckerberg and Joas, 2004). Multiagent governance can also improve the acceptance of governance policies by other social subjects and solve the problem of uncoordinated ecological development (Widmer et al., 2019).

The propositions of various disciplines on multiagent governance are shown in Table 1. In different subject areas, the multiagent governance model has been affirmed and recognized in different degrees.

2.3 Multiagent governance with public participation

In recent years, however, certain differences continue to exist in the effect of public participation on collaborative governance. On the one hand, many scholars affirmed the value of public participation in the multiagent governance mechanism using different methods. Among them, Hirschman's "appeal" participation in governance, such as petition, appeal, public opinion, and protest, can effectively promote the effect of environmental governance (2001); Heritier (2010) believes that public participation in governance has become a key concept in global protection and management, which is conducive to the formulation of governance policies and the establishment of participatory democracy. On the other hand, a few scholars remain skeptical about public participation in governance. Pargal et al. (1997) believes that public participation in governance exerts no obvious effect on the behavior of pollutant discharge subjects; Cheyne (2015) believes that although public participation is mandatory in local government planning and decision making, the defects and deficiencies in governance effect should not be underestimated given the changes in national legislation, economy, society, and technology; Marzuki et al. (2011) proposed that decision making processes and operation methods should be optimized to maximize the value of public participation in governance.

In order to ensure the governance effect, many scholars introduce a third party to supervise and constrain. You and Yang. (2017) put public reporting as the source of government supervision into the game between the government and enterprises; Yuan et al. (2019) found that local governments strengthen the governance effect under the pressure of the central government and the public; Li et al. (2018), Ross et al. (2016), Tilt (2019) believe that only the participation of the government, enterprises and the public can effectively control pollution emissions; Zhang et al. (2015) and Liu et al. (2017) believe that whether enterprises comply with pollution control is influenced by regulatory pressure from the government and environmental NGOs. Through literature review, it was found that the above research focused on the supervision role of the public and environmental NGOs. In reality, the channels for the public and environmental NGOs to participate in governance are narrow, not highly recognized, and their power is weak, and their influence on decision-making is obviously insufficient.

However, the media has the advantages of timely dissemination, wide coverage and strong public opinion effect. The disclosure of social bad words and deeds can cause strong public opinion pressure and attract more attention from the society and the government. Some scholars consider the governance role of media, but mainly analyze the

TABLE 1 The propositions of various disciplines on multiagent governance.

Subject involved	Related claims	References
Economics	International environmental investment can solve environmental problems around the world. The multiagent governance model can be carried out through joint consultation among local governments, investors and residents	Forsyth and Xu (2004)
	The multiagent governance model is conducive to a comprehensive consideration of social, environmental and economic development issues, as well as improved investment efficiency and power sharing	Lockwood et al. (2009)
Ecology	Due to the complexity of social and ecological processes, the publicity of environmental resources and the sharing of environmental protection results, the governance model emphasizing one decision-making center can no longer meet the requirements. Only the multiagent governance model based on classical liberalism can meet the requirements of the principle of ecological rationality	Mark, (2008)
	Taking urban and rural communities in the Atlantic Rainforest Reserve around Pernambuco, Brazil as an example, the investigation found that if the reserve wanted to better protect biodiversity and environment, it must find ways to mobilize the initiative of the community subjects, so as to improve the management efficiency	Bento-Silva et al. (2015)
Politics and Law	The multiagent governance model can increase the public's participation in policy and technology choices, thus improving the acceptance of policies	Forsyth (2006)
	The formulation of environmental laws and policies requires the participation of the public and private sectors to exert pressure on the government, and environmental protection requires multi-level cooperation, even international cooperation, and multiagent participation in the decision-making process	Arentsen, (2008)
Sociology	Only relying on a single government to lead, can not meet the needs of public affairs management, but should mobilize the power of multiagent, give play to the different effects of each subject, form a governance force	Held (2001)
	Cooperation between the government and other subjects transfers responsibility to these sectors, so cooperation is conducive to multiagent sharing environmental responsibilities	Eckerberg and Joas, (2004)

impact of media reports on corporate decisions from the corporate level. Shen and Feng. (2012) studied the effects of media reports and government regulation on corporate environmental information disclosure. Wang et al. (2017) analyzed the influence of media on enterprises' environmental protection investment behavior; Jia et al. (2016) studied the impact of media reports on enterprises' pollution behavior on enterprises and proposed that the government should cooperate with the media. Kathuria (2007) took India as the research object and found that media reports on water pollution can reduce the discharge behavior of enterprises.

In addition, multiagent governance needs a large number of professional talents, knowledge and technology, which makes multiagent governance inseparable from scientific research institutions. The main role of scientific research institutions is to govern knowledge, information, technology and talent providers. Some scholars have considered the governance role of scientific research institutions. Duan et al. (2019) compared the advantages and disadvantages of independent and cooperative innovation in digital media enterprises and proposed that enterprises should cooperate with scientific research institutions. Su et al. (2019) studied the tripartite collaborative innovation behavior of the government, enterprises and scientific research institutions, and proposed that the government should improve the incentive mechanism of industry, education and research.

At present, the overall governance awareness of society is not strong, the willingness of enterprises to take the initiative to reduce emissions is not strong, emission reduction and pollution control mainly rely on government supervision and guidance (Al-Rawi et al., 2021). If the government supervision is not strict, it is easy to make enterprises slack off, resulting in pollution problems. Based on this, in order to better urge the government to strictly supervise, to let enterprises assume corresponding responsibilities and reduce pollutant emissions, this paper considers the introduction of media and marine scientific research institutions into governance. Based on evolutionary game theory, this paper studies the evolutionary stability between the degree of local government supervision and the choice of marine production enterprises' governance strategies, as well as the interaction mechanism among them.

2.4 Application of evolutionary game theory to marine governance

Evolutionary game theory is an effective tool for modeling decision-making processes (Hogan, 1997), providing mathematical solutions for stakeholder conflict and cooperation (Leyton-Brown and Shoham, 2008). In addition, due to human bounded rationality and learning mechanisms (Taylor and Jonker, 1978), evolutionary game theory focuses on the decision-making process of multiple players and the analysis of dynamic evolution (Vincent, 1980). Meanwhile, evolutionary game theory can clarify the conflict of interests and allocation among participants, which has high theoretical and practical significance.

Many researchers have used evolutionary game theory to study the decision-making process of governments and enterprises in marine governance. Wang et al. (2019) developed an evolutionary game model to analyze the decision-making process between local governments that control pollution and pollution-producing enterprises, and suggested the use of dynamic penalties to control pollution. Sheng et al. (2019) used evolutionary game theory to analyze the strategic choices of the central government, local governments and enterprises under different governance policies. Moreover, the study claims that increasing default fines and compliance incentives are most effective for governance effects. Gao et al. (2019) used evolutionary game theory to analyze the interaction among upstream governments, downstream governments and the central government in the eastern route of the South-to-North Water Diversion project, and found that without the supervision of the

central government, upstream and downstream governments would not spontaneously and cooperatively implement the basin ecological compensation system. However, these studies all regard the government as the sole supervisor of the governance process. In addition, Gao et al. (2018) studied the role of media in governance event information disclosure through evolutionary game theory. The results show that the media can influence the information disclosure of governance events through top-down intervention and bottom-up reputation mechanism. However, these studies are also a tacit admission that media reports are always true.

However, in fact, when media report news, driven by interests, they often deviate from the facts and blindly pursue sensational effect, which makes it difficult to play an effective governance role (Xiong et al., 2011). Cao et al. (2017) considered the two sides of media participation in governance and believed that media reports were false and misleading, which would hinder the effective supervision of the government. In addition, from the perspective of evolutionary game, some scholars discussed the situation that media reports not only produce positive or negative social effects on enterprises, but also affect the credibility of supervision, and respectively proposed incentive and constraint mechanisms for enterprises and supervision (Zhang et al., 2015; Xiong and Zhang, 2018). Borochin and Cu. (2018) believe that despite the bias in news reporting, media in developing countries can still be used as an alternative channel for governance.

2.5 Summary

Based on the above mentioned literature, one can infer that multiagent governance is an inevitable trend for the sustainable development of the marine ecoeconomic system; however, certain contradictions and difficulties in the governance process remain. Nowadays, when global scholars seek for effective methods for playing the role of the multiagent governance mechanism, the majority attribute the difficulties to boundaries in power and responsibility and relationships among multiple agents. Few scholars consider the impact of the attributes of various subjects on the effectiveness of collaborative governance, which is the value of this paper. Given that the evolutionary game model has been successfully applied to the fields of environmental governance, food safety, and collaborative innovation, among others, this study takes the marine ecoeconomic system as the research subject. On the basis of evolutionary game theory, it selects marine scientific research institutions and media with strong public value representation as public representatives to discuss the promotion of the multiagent governance and sustainable development of the marine ecoeconomic system, alleviation of the regulatory pressure of local governments, and the governance inertia of marine production enterprises to provide theoretical basis and policy recommendations for the innovation of the mechanism for the multiagent governance of the marine ecoeconomic system.

In recent years, coastal local governments in China have established the value orientation of “ecological priority” and interspersed the concept in the organization of policies and regulations, formulation of governance objectives, establishment of governance institutions, improvement of governance capacity, and inheritance of governance culture. As the supporting carrier of the coordinated development of the marine ecoeconomic system, the marine ecosystem subsystem provides resources and environmental protection for the development of the marine economy and coastal society. The current reality of the deterioration of global marine ecology urges countries to focus on the governance of the marine ecoeconomic system, which is also the highlight of this study. However, this paper only discusses marine research institutions and media. In the multiagent governance of marine ecoeconomic system, the coastal public and some non-governmental organizations are also the important bodies that influence the decision-making process of governments and enterprises. Therefore, further research is needed to address the involvement of these agencies and this paper is considered a start point of this future research.

3 Model construction and analysis

This study models the multiagent governance of the marine ecoeconomic system and selects the current governance subjects, namely, local governments and marine production enterprises, to build a dynamic interactive analysis framework. Meanwhile marine scientific research institutions and media with strong public value creativity can be introduced as representatives of coastal social subjects and public interests while building an evolutionary game system between local governments and marine production enterprises. Four parameters are set, namely, number of marine scientific research institutions, level of contribution of marine scientific research institutions, level of participation of media, and level of authenticity level of information released by media.

The reasons are as follows: On the one hand, as an important part of complementing the regulatory role of government departments, the media has the advantages of promoting two-way communication between the public and faster information transmission. On the premise of ensuring the authenticity and reliability of the information released, media reports will serve as a deterrent to marine production enterprises and gradually lead their actions towards active ocean governance (Nguyen, 2015). Meanwhile media participation can form the external governance of an enterprise, which can improve the management decisions of the enterprise by influencing the reputation of senior managers. When a marine production enterprise’s irregular behavior is exposed, it will pay additional violation costs at the cost of reputation loss (Liu B and McConnell, 2013). Therefore, the role of the media in the governance of the marine ecoeconomic system is closely related to the authenticity and participation of the information released by the media.

On the other hand, marine scientific research institutions play an important role in the development of Chinese marine scientific and technological innovation. Their spatial distribution directly affects the allocation and use efficiency of resources for Chinese marine scientific and technological innovation. Based on this, concentrating resources on the construction of marine scientific research institutions in coastal cities and organizing and promoting marine science and technology R&D projects, marine scientific research institutions can provide professional technical reference for local governments to implement efficient marine regulatory measures and reduce regulatory costs (Hou et al., 2021). At the same time, by promoting international cooperation in marine scientific research and government enterprise cooperation, marine scientific research institutions can also provide technical support to marine production enterprises to make their entire production process

TABLE 2 Symbols and meanings of relevant parameters.

Symbol	Meaning and description
α	Probability of local government choosing active supervision
β	Probability of marine production enterprises choosing to manage marine ecology
x	Contribution level of marine scientific research institutions
y	Participation level of media
δ	Number of marine scientific research institutions
φ	Authenticity level of information released by media
s	Ecological, economic and social benefits when local governments choose to actively supervise
c	Total cost paid by the local government in the process of supervision
c_0	Fixed costs paid by local governments in supervision
t	The strength of local government's own regulatory capacity
μ	The total probability of local governments investigating and Punishing Enterprises' damage to marine ecology
ε	Local governments rely on themselves to investigate and deal with the probability of enterprises damaging marine ecology
w	Losses of local governments caused by media exposure of enterprises' destruction of Marine Ecology
d	Economic benefits obtained by marine production enterprises when managing marine ecology
m	Ecological benefits brought by marine production enterprises when managing marine ecology
θ	Social welfare reward probability of local government for the governance behavior of marine production enterprises
Δd	Additional economic benefits obtained by marine production enterprises when they destroy marine ecology
n	Ecological losses caused by marine production enterprises destroying marine ecology
v	Fines and taxes paid to local governments by marine production enterprises when they destroy marine ecology
g	The social reputation and economic losses caused to the marine production enterprises when the damage to the marine ecology is exposed

more efficient and cleaner, and highlight marine economic benefits and ecological benefits (Ning et al., 2021). Therefore, the role of marine scientific research institutions in the governance of marine ecoeconomic system is closely related to the number and contribution level of marine scientific research institutions.

3.1 Parameter description

The subsequent text describes the meanings of parameters involved in the evolutionary game model. Table 2 presents the symbols and meanings of the relevant parameters.

3.2 Model assumptions

On the basis of previous studies, the study makes the following assumptions on the game behavior of multiparty governance subjects.

Hypothesis 1. All participants in the governance of the marine ecoeconomic system are bounded rational economic persons, that is, due to the constraints of their own capabilities and information asymmetry, each party cannot make the most favorable decision for itself at the first time when making decisions. It is often through playing games with the other party and constantly revising its own decisions in the process to maximize its own benefits (Guo et al., 2022). Information among governance entities is asymmetric, and decision-making behavior is independent, that is, the strategy sets of local governments and marine production enterprises are active/passive regulation and governance/non-governance of marine ecology. The probability of corresponding strategy selection is expressed as α, β, $\alpha, \beta \in [0, 1]$.

Hypothesis 2. In the process of the multiagent governance of the marine ecoeconomic system, local governments can actively regulate by means of fines, production restriction, taxation, and other regulatory methods. The probability is $\alpha(0 \le \alpha \le 1)$. At this time, local governments need to spend total cost C, which is expressed as human and financial costs incurred in the supervision process, of which fixed cost C_0 is expressed as administrative costs incurred by the government in establishing special regulatory agencies and in formulating and implementing relevant policies and regulations. As marine scientific research institutions offer local governments with advice and suggestions and participate in governance by transferring professional technology and talents, they help governments reduce regulatory costs, that is, $C = C_0 + \frac{(1-x\delta)}{t}$. At the same time, due to the active supervision of local governments, marine ecological, economic, and social benefits S can be obtained, which are equivalent to the optimization of marine ecology, the increase of investment attraction, and the improvement of the credibility of local governments.

At the same time, local governments may also opt for passive supervision despite the pressure imposed by local economic

TABLE 3 Income payment matrix of local governments and marine production enterprises.

(Local governments, marine production enterprises)	Governance of marine ecology (β)	Non-governance of marine ecology ($1-\beta$)
Active supervision (α)	$s-c+(1-\theta)m-(1-\varphi)yw$ $d+\theta m-(1-\varphi)yg$	$s-c-n$ $d+\Delta d-\mu(v+g)$
Passive regulation ($1-\alpha$)	$(1-\theta)m-(1-\varphi)yw$ $d+\theta m-(1-\varphi)yg$	$-n-yw$ $d+\Delta d-y(v+g)$

development and GDP assessment with a probability of $1-\alpha$. At this time, although governments do not need to pay supervision costs, if the media exposes the acts of enterprises damaging the marine ecology, then the government will suffer economic and social losses yw, which are manifested as decline in public trust, deterioration of the investment environment, and investigation by the central government due to the inaction of local governments.

Hypothesis 3. In the process of the multiagent governance of the marine ecoeconomic system, the goal of marine production enterprises is to maximize their total profits. Thus, they may opt not to govern marine ecology due to marine economic interests and costs. The probability is $1-\beta(0\le\beta\le1)$. At this time, although enterprises will obtain additional economic benefits $\triangle$d, it will also introduce marine ecological losses n. In addition, once local governments investigate and sanction a violation, enterprises will face government fines, additional taxes v, and social reputation and marine economic losses g due to future media exposure.

At the same time, enterprises understand the reward-and-punishment mechanism of the government and will also consider taxation, punishment, and social reputation and choose to govern the marine ecology (probability = β). As a result, marine production enterprises will obtain economic benefits d, improve ecological benefits m, and receive social welfare rewards θm from local governments.

Hypothesis 4. When the media learns that marine production enterprises have incurred damages on marine ecology, it will be exposed and handed over to local governments for treatment. At this time, the probability of enterprises being investigated and sanctioned by local governments is $\mu=\varepsilon+y(1-\lambda)$. Given that information released by the media may only be partially true, this scenario can be classified into two cases. When the media fabricates the truth and reports falsely, that is, it falsely accuses that the marine ecology has not been controlled, then the local government will suffer loss of social reputation $(1-\varphi)yw$, and marine production enterprises will suffer loss of economy $(1-\varphi)yg$. When the media covers up the truth, that is, it does not report that marine ecological damage has occurred and has not been controlled, then local governments and marine production enterprises will gain additional benefits. However, this scenario is inconducive to the marine ecological governance and sustainable development of the marine ecoeconomic system.

3.3 Model building

According to the model assumptions in Section 3.2, Table 3 depicts the income payment matrix of the proposed game model.

According to the results in Table 3, the study concludes that the expected benefits of local governments and marine production enterprises in the choice of different behavior strategies are as follows:

$$\begin{aligned}G_1&=\beta[s-c+(1-\theta)m-(1-\varphi)yw]+(1-\beta)(s-c-n)\\&=s-c-n+\beta m-\beta\theta m-\beta yw+\beta n+\beta\varphi yw\end{aligned}\tag{1}$$

$$\begin{aligned}G_2&=\beta[(1-\theta)m-(1-\varphi)yw]+(1-\beta)(-n-yw)\\&=-v+\beta n+\beta m-yw-\beta\theta m+\beta\varphi yw\end{aligned}\tag{2}$$

$$\begin{aligned}E_1&=\alpha[d+\theta m-(1-\varphi)yg]+(1-\alpha)[d+\theta m-(1-\varphi)yg]\\&=d+\theta m-yg+\varphi yg\end{aligned}\tag{3}$$

$$\begin{aligned}E_2&=\alpha[d+\Delta d-\mu(v+g)]+(1-\alpha)[d+\Delta d-y(v+g)]\\&=d+\Delta d+(v+g)(\alpha y-\alpha\mu-y)\end{aligned}\tag{4}$$

Therefore, the dynamic equation of replication between local governments and marine production enterprises can be obtained as follows:

$$G(\alpha,\beta)=\frac{d\alpha}{dt}=\alpha(1-\alpha)(G_1-G_2)=\alpha(1-\alpha)(s-c-\beta yw+yw)\tag{5}$$

$$\begin{aligned}E(\alpha,\beta)&=\frac{d\beta}{dt}=\beta(1-\beta)(E_1-E_2)\\&=\beta(1-\beta)[\theta m-\Delta d+\varphi yg+yv+(v+g)(\alpha\mu-\alpha y)]\end{aligned}\tag{6}$$

Let $G(\alpha,\beta)=0, E(\alpha,\beta)=0$, the study obtains five local equilibrium points from the evolutionary game system, which are $(0,0)$, $(0,1)$, $(1,0)$, $(1,1)$ and (α^*,β^*):

$$a^*=\frac{\theta m-\Delta d-(1-\varphi)yg+y(v+g)}{(y-\mu)(v+g)}\tag{7}$$

$$\beta^*=\frac{s-c+yw}{yw}\tag{8}$$

3.4 Analysis of stability

To determine the stability of each equilibrium point, the study employs the local stability analysis of the Jacobian matrix. The specific judgment process is derived as follows:

$$j=\begin{vmatrix}\frac{\partial F(x)}{\partial x}&\frac{\partial F(x)}{\partial y}\\\frac{\partial F(y)}{\partial x}&\frac{\partial F(y)}{\partial y}\end{vmatrix}=\begin{vmatrix}a_{11}&a_{12}\\a_{21}&a_{22}\end{vmatrix}\tag{9}$$

$$\begin{aligned}a_{11}&=(1-2\alpha)(s-c+yw-\beta yw)\\a_{12}&=-\alpha(1-\alpha)yw\\a_{21}&=\beta(1-\beta)(v+g)(\mu-y)\\a_{22}&=(1-2\beta)[\theta m-\Delta d-yg+\varphi yg-(\alpha y-y-\alpha\mu)(v+g)]\end{aligned}\tag{10}$$

TABLE 4 Values of local equilibrium points.

Equilibrium point	a_{11}	a_{12}	a_{21}	a_{22}
(0, 0)	$s-c+yw$	0	0	$\theta m-\Delta d+yv+\varphi yg$
(1, 0)	$c-s-yw$	0	0	$\theta m-\Delta d-yg+\varphi yg+\mu(v+g)$
(0, 1)	$s-c$	0	0	$-(\theta m-\Delta d+\varphi yg+vy)$
(1, 1)	$c-s$	0	0	$-[\theta m-\Delta d-yg+\varphi yg+\mu(v+g)]$
(α^*,β^*)	0	X	Y	0

TABLE 5 Model summary.

Subsections	Commentary
Parameter description	It describes the meanings of parameters involved in the evolutionary game model
Model assumptions	Specific hypotheses are made for local governments, marine production enterprises, marine scientific research institutions and media to prepare for the construction of specific models
Model building	Calculate the expected benefits and the dynamic equation of replication. Find the local equilibrium point
Analysis of stability	Determine the stability of the equilibrium point, select the reference value to discuss the situation

Table 4 presents the value of the game system at the five local equilibrium points, namely, a_{11}, a_{12}, a_{21} *and* a_{22}.

Note: X and Y in the Table 4 are divided into the following:

$$X=yw\frac{[\theta m-\Delta d-(1-\varphi)yg+y(v+g)][\theta m-\Delta d+(\varphi-1)yg+(v+g)\mu]}{[(y-\mu)(v+g)]^2} \tag{11}$$

$$Y=\frac{(c-s)(s-c+yw)(v+g)(\mu-y)}{(yw)^2} \tag{12}$$

By judging whether the local stability point meets the two following conditions, whether the equilibrium point obtained is the ESS of the system can be determined.

$$(1)\,trJ=a_{11}+a_{22}<0 \tag{13}$$

$$(2)detJ=\begin{vmatrix}a_{11} & a_{12}\\ a_{21} & a_{22}\end{vmatrix}=a_{11}a_{22}-a_{12}a_{21}>0 \tag{14}$$

The proposed evolutionary game model needs to comprehensively consider the impact of four parameters, namely, x, y, δ *and* φ, on the stable evolution state of the system. By selecting two reference values $s-c_0$ *and* Δd as the judgment intermediary to the analysis of the impact of the change in the range of parameter values on system stability, the value range of parameters can be divided into the following cases:

$$(1)\ \text{If}\begin{cases}s-c_0<\dfrac{1-x\delta}{t}-yw\\ \Delta d>\theta m+y(v+\varphi g)\end{cases},\ \text{then ESS is } (0,0); \tag{15}$$

$$(2)\ \text{If}\begin{cases}s-c_0>\dfrac{1-x\delta}{t}-yw\\ \Delta d>\theta m+y(v+\varphi g)+\varepsilon(1-y)(v+g)\end{cases},\ \text{then ESS is } (1,0); \tag{16}$$

$$(3)\ \text{If}\begin{cases}s-c_0>\dfrac{1-x\delta}{t}\\ \Delta d<\theta m+y(v+\varphi g)\end{cases},\ \text{then ESS is } (0,1); \tag{17}$$

$$(4)\ \text{If}\begin{cases}s-c_0>\dfrac{1-x\delta}{t}\\ \Delta d<\theta m+y(v+\varphi g)+\varepsilon(1-y)(v+g)\end{cases},\ \text{then ESS is } (1,1); \tag{18}$$

$$(5)\ \text{If}\begin{cases}\dfrac{1-x\delta}{t}-yw<s-c_0<\dfrac{1-x\delta}{t}\\ \theta m+y(v+\varphi g)<\Delta d<\theta m+y(v+\varphi g)+\varepsilon(1-y)(v+g)\end{cases},\ \text{then ESS is null.} \tag{19}$$

3.5 Summary

We summarize the summary of Section 3, as shown in Table 5.

4 Analysis of the evolutionary game model

According to the evolutionary game theory, if the benefits of one of the strategies selected by persons of authority exceed those of other strategies, then the model will evolve to the strategy with high benefits independently. The results obtained by copying the dynamic equation can ensure that the evolutionary stability strategies are equivalent to evolutionary equilibrium.

On the basis of the solution results of the model, the study found that the evolution direction of the stable state of the system is dependent on the relative relationship between influence parameters x, y, δ *and* φ and reference values $s-c_0$ and Δd. Specifically, $s-c_0$ refers to the difference among the ecological, economic, and social benefits obtained by local governments and the fixed costs paid when they adopt the active supervision behavior strategy. They can also be expressed as the maximum benefits obtained by local governments when they adopt active supervision without considering the participation of marine scientific research institutions and the media. Moreover, Δd refers to the additional economic

TABLE 6 Parameter value conditions in special cases.

Number	Combinations of parameter settings		Parameter value conditions
4.1.1	When $\delta = 1$ and $\varphi = 1$		$\begin{cases} x > 1 - (s - c_0)t \\ y > \dfrac{\Delta d - \theta m - \varepsilon(v+g)}{(v+g)(1-\varepsilon)} \end{cases}$
4.1.2	When $\delta = 0$ and $\varphi = 1$		$\begin{cases} 0 > 1 - (s - c_0)t \\ y < \dfrac{\theta m - \Delta d + \varepsilon(v+g)}{(v+g)(1-\varepsilon)} \end{cases}$
4.1.3	When $\delta = 1, \varphi = 0$	$v - \varepsilon(v+g) > 0$	$\begin{cases} \varepsilon < \dfrac{v}{v+g} \\ x > 1 - (s - c_0)t \\ y > \dfrac{\Delta d - \theta m - \varepsilon(v+g)}{[v - \varepsilon(v+g)]} \end{cases}$
		$v - \varepsilon(v+g) < 0$	$\begin{cases} \varepsilon > \dfrac{v}{v+g} \\ x > 1 - (s - c_0)t \\ y < \dfrac{\Delta d - \theta m - \varepsilon(v+g)}{[v - \varepsilon(v+g)]} \end{cases}$
4.1.4	When $\delta = 0$ and $\varphi = 0$	$v - \varepsilon(v+g) > 0$	$\begin{cases} \varepsilon < \dfrac{v}{v+g} \\ 0 < (s - c_0)t - 1 \\ y > \dfrac{\Delta d - \theta m - \Delta m - \varepsilon(v+g)}{[v - \varepsilon(v+g)]} \end{cases}$
		$v - \varepsilon(v+g) < 0$	$\begin{cases} \varepsilon > \dfrac{v}{v+g} \\ 0 < (s - c_0)t - 1 \\ y < \dfrac{\Delta d - \theta m - \Delta m - \varepsilon(v+g)}{[v - \varepsilon(v+g)]} \end{cases}$

benefits obtained when marine production enterprises destroy the marine ecology or the opportunity benefits derived when marine production enterprises do not manage the marine ecology without considering the participation of marine scientific research institutions and the media.

Therefore, a change in the system stable equilibrium point within the range of different parameter values can be obtained through a comprehensive analysis of the number (δ) of marine scientific research institutions, the contribution level x of marine scientific research institutions, participation level y of the media, and authenticity level φ of information released by the media.

4.1 Analysis of special cases

To further obtain the threshold range of contribution level x of marine scientific research institutions and participation level y of media, the study first assign values of 0 and one to the number (δ) of marine scientific research institutions and authenticity level (φ) of information released by the media to obtain four combinations of parameter settings. The specific results of the analysis are as follows in Table 6:

4.1.1 When $\delta = 1$ and $\varphi = 1$

The number $\delta = 1$ of marine scientific research institutions indicates that they have sufficient settings in the target areas of governance. The authenticity level $\varphi = 1$ of information released by the media indicates that the media has high information identification ability and professional quality, do not add subjective bias when reporting the news, and do not spread news that inconsistent with facts. At this time, the greater the contribution of marine scientific research institutions and the higher the level of media participation, the better the operation effect of the multiagent governance mechanism of the marine ecoeconomic system. The parameter value range when $\delta = 1$ and $\varphi = 1$ is also the most ideal state in reality.

4.1.2 When $\delta = 0$ and $\varphi = 1$

The number $\delta = 0$ of marine scientific research institutions indicates that the number of marine scientific research institutions established in the target area of governance is small. The authenticity level $\varphi = 1$ of information released by the media indicates that the media can still play a positive role in governance. At this time, if the role of marine scientific research institutions in the governance process is limited, and scientific research achievements cannot be applied to government supervision and corporate governance, then whether or not they participate in the governance process will no longer exert an impact on the final governance effect of the marine ecoeconomic system. At this point, local governments and marine production enterprises need to rely on their capabilities to drive the coordinated governance of the marine ecoeconomic system to set the evolution of the system toward a favorable direction.

By comparing the parameter conditions in Section 4.1.1 and Section 4.1.2, the study found that the following: if the system also evolves to (1, 1), the parameter value range in Section 4.1.1 is easier to meet, which can better realize the effect of multiagent collaborative

TABLE 7 Parameter value conditions in general situation.

Number	Parameters		Parameter value conditions	Results
1	the contribution level of marine scientific research institutions x		$\frac{\partial F(x,\delta)}{\partial x} = -\frac{\delta}{t} < 0$	Improve x
2	the number of marine scientific research institutions δ		$\frac{\partial F(x,\delta)}{\partial \delta} = -\frac{x}{t} < 0$	Improve δ
3	the participation level of media y	$\varepsilon > \frac{\varphi g+v}{v+g}$	$\frac{\partial F(y,\varphi)}{\partial y} < 0$	Reduce y
		$\varepsilon < \frac{\varphi g+v}{v+g}$	$\frac{\partial F(y,\varphi)}{\partial y} > 0$	Improve y
4	the authenticity level of information released by media φ		$\frac{\partial F(y,\varphi)}{\partial \varphi} = yg > 0$	Reduce φ

governance on the marine ecoeconomic system. Simultaneously, the difference between the parameter values of Section 4.1.1 and Section 4.1.2 fully reflects the important role played by the number of marine scientific research institutions δ in the governance process.

4.1.3 When $\delta = 1$ and $\varphi = 0$

The number $\delta = 1$ of marine scientific research institutions indicates that these institutions are adequately set in the target governance area. The authenticity level $\varphi = 0$ of information released by the media suggests that the relevant news reported by the media lacks authenticity; thus, maintaining a neutral and impartial position between governments, enterprises, the public, and themselves is difficult because the media distort reports, fabricate the truth, and confuse the public. At this point, the impact of the level of media participation on the marine governance effect is unstable. Thus, further discussing it in the following situations according to the regulatory capacity of local governments is necessary.

When the ability of local governments to supervise is low, to better achieve the governance effect, the participation level of the media needs to be further improved. Local governments are unable to bear the responsibility of supervising the bad behavior of marine production enterprises due to poor supervision. However, the profit-seeking nature of enterprises makes them neglect marine ecological governance, which leads to the deterioration of marine ecological development. As an important supervisor and disseminator of the negative behavior of marine production enterprises, the media can be more sensitive to the destruction of marine ecology by enterprises than the government can. However, at this time, a false report ($\varphi = 0$) may be a collusion among the media, enterprises, and governments to beautify the report and cover up the truth of the destruction of marine ecology to mislead the public, which is inconducive to marine governance. At this time, media reports have been distorted and colluded with local governments. Only after the central government issues relevant laws and regulations can the level of media participation be improved again. In this manner, the central government can rigidly restrict enterprises and local governments involved in the sea and provide unified guidance, restriction, and rectification of the reporting standards of the media industry. However, this scenario leads to introspection and benign competition in the media industry. However, only when the media is enabled to achieve long-term coexistence and to maximize their interests can an internal supervision mechanism be formulated to better complement the regulatory functions of local governments.

When the ability of local governments to supervise is high, to better achieve the governance effect, the participation level of media needs to be reduced to better achieve the governance effect. In this regard, local governments are in an absolutely dominant position in the governance model of the marine ecoeconomic system. Under the pressure of supervision, enterprises will be forced to enhance the governance of the ocean, and the marine ecology will develop well. Report distortion ($\varphi = 0$) is reflected in the fabrication and defamation by the media of the *status quo* of governments, which resulted in the social reputation and economic losses of local governments and enterprises. To minimize loss, withdrawing from the governance system or reducing the length and frequency of negative reports is necessary for the media to control the radiation of negative public opinion.

Analysis revealed that under the premise that the authenticity of information released by the media cannot be guaranteed, appropriately addressing the positive and negative effects of media participation in governance is necessary to achieve the optimization of the effect of multiple collaborative governance. On the one hand, the central government should take unified measures to improve the participation level and journalistic literacy of the media and compensate for the loopholes of unfavorable local government supervision. On the other hand, when the media strengthen self-regulation, the state and government should legislate to reduce the length and frequency of negative reports and control the radiation of negative public opinion.

By comparing the Δd parameter conditions in Section 4.1.1 and Section 4.1.3, the study found that: In practice, it also makes the system evolve into (1, 1), and the value range of parameter $\triangle d$ in Section 4.1.1 is easier to meet. To better realize the optimization of the multiagent governance of the marine ecoeconomic system, the parameter setting in Section 4.1.1 has more advantages. Comparing the difference between the parameter values of Section 4.1.1 and Section 4.1.3 reflects the important role of the authenticity level φ of information released by the media in the governance process.

4.1.4 When $\delta = 0$ and $\varphi = 0$

The number $\delta = 0$ of marine scientific research institutions indicates that playing a role in the governance process is difficult for them due to the small number established in the target area of governance. The authenticity level $\varphi = 0$ of information released by the media suggests that it distorts reports, fabricates the truth, and confuses the public. At this point, the impact of the level of participation of the media on the governance effect of local governments is unstable; thus, further discussing it in the following scenarios is necessary according to the extent of the regulatory capacity of local governments. In this case, the difference under the same premise between the qualified expression of y in Section 4.1.4 and that of y in Section 4.1.3 is only $\frac{\Delta m}{[v-\varepsilon(v+g)]}$, which is independent of the value of the

number of marine scientific research institutions δ. Therefore, the case-by-case discussion results in Section 4.1.4 are consistent with those in Section 4.1.3. In this study, no words are repeated.

When the ability of local governments is low, to better achieve the governance effect, improving the participation level of media as much as possible is crucial for the maximation of the governance effect.

When the ability of local governments to supervise is high, to improve the governance effect, local governments need to properly guide the media in reducing their participation and the negative impact of negative media reports.

By comparing the fixed value combinations of the four abovementioned parameters, the effect of multiagent governance of marine ecoeconomic system is widely known to be comprehensively affected by many factors. To enable the system to evolve into (1, 1), the number δ of marine scientific research institutions and authenticity level φ of information released by the media play a key role. However, whether or not the media can play a role in the governance of the marine ecoeconomic system is dependent on the regulatory capacity of central and local governments and control of the guidance on public opinion.

4.2 Analysis of the general situation

To better understand the impact of the relevant parameters of marine scientific research institutions and media on the governance effect of the marine ecoeconomic system, the study investigates the general conditions for the evolution of the system into (1.1). The parameters of the system need to meet the following:

$$\begin{cases} s - c_0 > \dfrac{1 - x\delta}{t} = F(x, \delta) \\ \Delta d < \theta m + y(v + \varphi g) + \varepsilon(1 - y)(v + g) = H(y, \varphi) \end{cases} \tag{20}$$

On the premise of avoiding exerting an influence on the conclusion, the analysis is also conducted with $s - c_0$ and Δd as reference values. At the same time, a more general conclusion is drawn by solving the following equations to discuss the influence of parameter changes on function values in Table 7:

4.2.1 Analysis of the influence of contribution level x of marine scientific research institutions

To better meet the parameter value conditions for the evolution of the system into (1, 1), further improving the contribution level of marine scientific research institutions, highlighting the efficient utilization of marine scientific and technological R&D resources that were invested, driving a step-by-step increase in the output level of marine scientific and technological achievements, and focusing on the original innovation and later transformation of marine scientific and technological achievements are important aspects. In this manner, the scientific and technological strength of the governance of the ocean can be improved.

4.2.2 Analysis of the influence of the number δ of marine scientific research institutions

To better meet the parameter value conditions for the system to evolve to (1.1), further increasing the number of marine scientific research institutions is necessary. Through capital investment and introduction of excellent talents, the scale effect can be realized through the expansion of the scale of scientific research scale. At the same time, attention should be given to the improvement of the input–output structure of marine science and technology and to the acceleration of the industrialization of marine science and technology.

4.2.3 Analysis of the influence of the participation level y of the media

When the ability of local governments to supervise is low, further guiding the media to improve its participation level y is necessary to better meet the parameter value conditions to enable the system to evolve into (1, 1). The industry ethics of the media is to strictly abide by the principle of objectivity and impartiality and truthfully and accurately report the state of the sea. However, enterprises become tired of governance, and the media become lazy in reporting due to the lack of supervision by the local government. The interests of the three parties conspire to connive at the destruction of marine ecology, which is contrary to the original intention of governance. At this time, the study suggests the introduction of the central government as the main body and points to unification among local governments, enterprises, and media through legislation. On the one hand, the results imply that the media should be guided in increasing their participation and in forming a "punishment expectation" for enterprises and local governments. On the other hand, this scenario will stimulate benign competition within the media industry; select high-quality media based on the survival of the fittest in the market, give play to its role in supervision and balance, effectively curb the destructive behavior of marine production enterprises and the lazy governance of local governments, and improve the probability and effect of marine ecological governance.

When the ability of local governments to supervise is high, to better meet the parameter value conditions for the system to evolve into (1, 1), further guiding the media in reducing participation level y is necessary when the local government exhibits a high level of regulatory capacity. The participation of the media can urge enterprises to adopt a more serious attitude toward the issue of the moral bottom line. However, in recent years, the commercial media and personal media have reported on the ocean much more than the official media. Alternatively, the high degrees of freedom of speech and insufficient punishment have led to frequent reports of distortion. At present, many uncertainties remain in terms of media supervision (Dyck et al., 2008). Therefore, based on the premise that local governments exercise a high level of regulatory capacity, they should implement media regulation with an objective and neutral attitude, and, if necessary, come forward to correct the guidance of public opinion to avoid adverse losses.

4.2.4 Analysis of the impact of the authenticity level φ of information released by the media

To better meet the parameter value conditions for the system to evolve into (1.1), improving the authenticity level φ of information released by the media is important. When exposing and reporting on marine issues, the media should emphasize the accuracy of content, do not favor any interested parties, interpret the event from an objective perspective, give long-term and all-round attention, explore the interest chain behind the violations and possible consequences. The authenticity of information released by the media has been effectively guaranteed, which can not only avoid social reputation

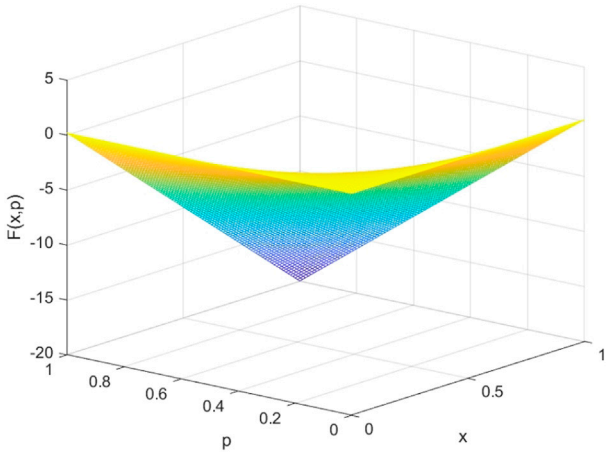

FIGURE 2
Simulation image of local government behavior strategy selection.

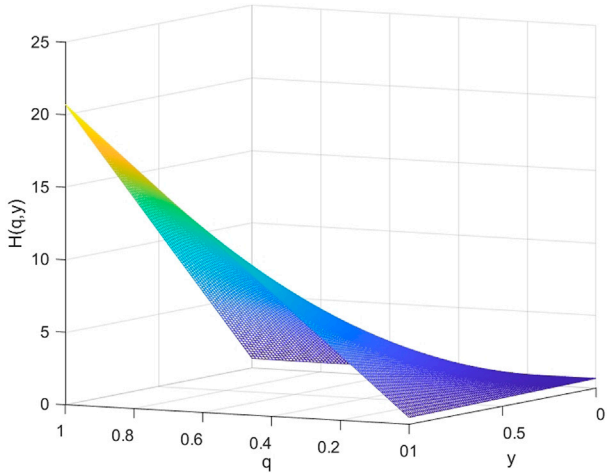

FIGURE 3
Simulation image of behavior strategy selection of marine production enterprises.

and economic losses to government departments and marine production enterprises due to information distortion but also retain the trust of the public in the abovementioned governance subjects. Furthermore, these initiatives can effectively alleviate information asymmetry among local governments, enterprises, and the public.

5 Numerical simulation

To explore the continuous trend of various parameters on the evolution of the system into (1, 1), the study distributed questionnaires on the multiagent collaborative governance of the marine ecoeconomic system across 14 coastal cities (Dalian, Qinhuangdao, Tianjin, Yantai, Qingdao, Lianyungang, Nantong, Shanghai, Ningbo, Wenzhou, Fuzhou, Guangzhou, Zhanjiang, and Beihai) from August 2021 to December 2021 to obtain data. The study then conducted a numerical simulation of the results of the parameter conditions in the general case of the system to obtain simulation images that influence the governance behavior of local governments and marine production enterprises to analyze the influence of the parameters in an intuitive manner.

As certain variables of the survey results are interval values, the average value is used for convenience. The specific survey values are as follows: 1) local governments: the average amount as punishment for illegal enterprises per instance is 44,200 yuan with an average punishment times of 21.6 per year. The annual average number of times of accepting media exposure and supervising enterprises involved is 2.232. 2) Marine production enterprises: the average annual investment for marine ecological governance is 440,200 yuan for a single enterprise, and 30% of the enterprises are rewarded by the government for ecological governance.

To set the simulation parameter values more reasonably, the study consulted with 20 experts in marine ecology and economy through interviews, online dialogs, and other channels based on the data that were not investigated. In combination with the setting of simulation parameter values in the relevant literature (Lu and He, 2020; Du et al., 2021), the parameters were assigned (220,000 is taken as a unit). The details are as follows: 1) local governments: $t = 5$, $\varepsilon = 0.9$, $\theta = 0.3$; 2) marine production enterprise: $v = 0.2$, $g = 0.2$, $m = 2$.

5.1 Analysis of the choice of behavior strategies of local governments

To explore the influence of contribution level x and number δ of marine scientific research institutions on $F(x, \delta)$ of the selection of local governments of their strategy, let $t = 5$ and $x \in (0, 1)$ $\delta \in (0, 1)$. Then, substitute Matlab software for numerical simulation. Figure 2 depicts the obtained image (replace δ with p in Figure 2).

Figure 2 illustrates that function $F(x, \delta)$, which influences the choice of the behavior strategies of local governments is the minus function of contribution level x of marine scientific research institutions and number δ of scientific research achievements. To finally enable the marine ecoeconomic system to evolve toward the direction of (1, 1), improving the values of contribution level x and number δ of marine scientific research institutions is necessary, that is, to further strengthen the status of marine scientific research institutions.

5.2 Analysis of the selection of behavior strategies of marine production enterprises

To explore the influence of participation level y of the media and authenticity level φ of information released by the media on the strategic choice $H(y, \varphi)$ of marine production enterprises and according to the results of the survey and expert consultation, the study obtained $\varepsilon = 0.9$, $v = 0.2$, $g = 0.2$, $\theta = 0.3$, $m = 2$, which was substituted into MATLAB for numerical simulation. Figure 3 provides the resulting image (replace φ with q in Figure 3).

Figure 3 demonstrates that the increase in function $H(y, \varphi)$, which influences the strategic choice of marine production enterprises, can be classified into two types, namely, 1) when the authenticity level φ of information released by the media is relatively balanced with its participation level y, then function $H(y, \varphi)$ is an extremely evident

increase function and 2) when authenticity level φ of information released by the media is relatively different from its participation level y, then function $H(y,\varphi)$ is a minus function. Therefore, comprehensively considering the impact of media on the effect of multiagent collaborative governance is crucial to finally enable the system to evolve toward the direction of (1, 1).

6 Conclusion

By constructing an evolutionary game model of the multiagent governance mechanism of the marine ecoeconomic system, this study selected and analyzed the impact of four relevant parameters of marine scientific research institutions and the media on the stable evolution of the game system. The results indicate that: 1) improving the contribution level and number of marine scientific research institutions is conducive to the collaborative governance of the marine ecoeconomic system; 2) the authenticity level of information released by media is positively correlated with the development of the multiagent governance model of the marine ecoeconomic system; and 3) differently biased objects with distorted media report information affect the trend of the governance effect of the marine ecoeconomic system. Thus, a timely improvement or reduction of the participation level of media is necessary. If information reported by the media is untrue, then the higher the supervision ability of the central and local governments should be, such that they can resist the loss of credibility and compensate for the defects of media participation in governance.

The conclusion provides the following ideas for promoting the multiagent governance mechanism of the marine ecoeconomic system.

6.1 Local governments should reform their supervision and drive the coordinated governance of multiple subjects

On the one hand, for underdeveloped coastal areas, the governments should focus on the allocation of scientific research resources. The government should vigorously guide local resources for high-quality and characteristic scientific to collect data through marine governance research, and improve the efficiency of scientific research achievements in marine governance research in the region. At the same time, the government should strengthen the coordination and integration effect of the allocation structure, allocation mode and allocation environment of scientific research resources, formulate the differentiated matching path and development strategy, and not only consider the impact of a single factor. Even if the marine development in the region is lacking, and the allocation mode and environment of scientific research resources are severely limited, continuing to increase scientific research investment, especially basic research investment, can effectively improve the governance efficiency. For more developed coastal areas, local governments should focus on the utilization of scientific research resources. The government should implement precise policies to promote the full and efficient use of local marine scientific research resources. By making reasonable reference to the output efficiency of various marine scientific research institutions, increase investment in institutions with good performance and further expand the scale of scientific research. At the same time, the government issued relevant policies to build an academic exchange platform between institutions for scientific researchers, encourage them to learn advanced technologies, and effectively improve governance efficiency. On the other hand, local governments should encourage the media to actively disclose the illegal acts and marine ecological conditions of marine production enterprises. As such, the media can play its regulatory role and compensate for regulatory loopholes in the government. At the same time, local governments should also fully utilize their core regulatory functions, actively innovate regulatory methods, adopt appropriate tax credit policies, and establish environmental publicity penalties, among others, to offset the negative impact of deviations in media reports and take the initiative to play active regulatory and guiding roles in the process of long-term multiagent governance.

6.2 The media should deepen publicity and convey real information to society

The media should not only continuously expand the collection and dissemination channels of governance information and disclose high-quality and high-precision information but also continuously increase the intensity and frequency of reports on the conditions of the marine ecology. Moreover, when disclosing governance, the media must make full disclosure, not avoiding the good and not missing the bad. Any judgement by the media must be complemented by reliable information and documentation, and be able to withstand repeated scrutiny in logical arguments. Only in this way can the media give better play to their ability of information transmission and supervision, and encourage marine production enterprises to take the initiative in marine governance. Simultaneously, the media should abide by the principles of objectivity, impartiality, and freedom in the reporting process, take the truth as the yardstick, excavate deep-seated lessons on environmental protection that underlie marine pollution and destruction, and utilize the subjective initiative of social subjects. In this manner, the efficiency of the marine governance of local governments and marine production enterprises can be effectively improved. In addition, the media should follow up on the popularization of knowledge related to the governance of the marine ecoeconomic system in real time to attract and increase public participation in this collaborative governance mechanism.

6.3 Scientific research institutions should devote themselves to output and jointly promote the implementation and progress of scientific research achievements

Marine scientific research institutions should stimulate the work enthusiasm of internal researchers, improve the contribution rate of marine science and technology innovation, rely on independent cultivation and talent introduction policies, and use various differentiated incentive measures and subsidies to provide sufficient material guarantee for marine scientific research talents to perform well in the long-term war of local marine governance research. At the same time, such institutions should give greater autonomy to the internal personnel of marine scientific research institutions, particularly in the aspects of institution setting, post-setting, talent recruitment, and achievement reward, among others; improve development flexibility and enthusiasm; and further promote the combination of marine scientific research output with the work of local governments and the production of marine enterprises to achieve a better effect through diversified and coordinated governance. More importantly, the marine

scientific research institutions in various regions should, according to their own resource endowments and regional characteristics, choose appropriate paths to improve the efficiency of scientific research output, achieve balanced development among regions, finally achieve a better effect through diversified and coordinated governance.

Data availability statement

The datasets presented in this article are not readily available because of the privacy and confidential nature of its respondents, further inquiries can be directed to the corresponding author.

Author contributions

LG provided the direction and given guidance to the paper. HY conducted the construction and analysis of the game model and data simulation, and was a major contributor to the manuscript writing. DC provided some suggestions for writing the manuscript. All authors read and approved the final manuscript.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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