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Research on Sharing Behavior Strategy of Cultural Heritage Institutions Based on Evolutionary Game Theory

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Abstract: With the accelerated digitalization of China's cultural heritage conservation, cultural heritage data sharing has been gaining more and more attention as an essential link in cultural heritage conservation and transmission. However, there are many problems in cultural heritage sharing, one of which is the low willingness of institutions to share among themselves and the seriousness of information silos. To motivate more cultural heritage institutions to participate in platform sharing and promote long-term, stable data sharing behavior, the dynamic evolution process and the law of institutions' sharing behavior in cultural heritage sharing platforms must be further studied. This paper constructs an evolutionary game model based on evolutionary game theory to explore the evolutionary paths of finite rational cultural heritage institutions to reach a stable strategy, discusses the relevant factors affecting these evolutionary paths, and conducts simulation experiments with the help of MATLAB. This paper finds that the sharing behavior of institutions in cultural heritage sharing platforms is affected by the initial state over time. The free-riding penalty of non-sharing parties, the coefficient of synergistic benefit, the data sharing volume, and the proportion of data complementarity have positive effects on the sharing behavior of cultural heritage institutions; meanwhile, the fixed sharing costs and the loss of gains of sharing parties have an adverse impact on the sharing behavior of cultural heritage institutions. The findings of this paper are essential for solving the cultural heritage sharing dilemma, improving the competitiveness of cultural heritage institutions, and promoting the sustainable development of cultural heritage sharing platforms, which can help promote the development of cultural heritage and help the implementation of cultural digitalization strategies.

Keywords: cultural heritage; evolutionary game; data sharing; evolutionary stability strategy

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1. Introduction

Cultural heritage is the expression system of the emotions, beliefs, culture, and identity gradually formed by a nation or a country over long-term historical development. China's extensive and profound cultural heritage includes traditional Chinese culture and reflects the vitality and creativity of the Chinese nation [1]. The development of digital technology has opened up a new road for the protection of Chinese cultural heritage [2]. Adopting digital technology for collecting, storing, processing, displaying, and disseminating cultural heritage is more conducive to sustainable development and inheritance and increases cultural industries' progress and value. Since the 1990s, information technology has been widely applied to protecting cultural heritage, focusing on digitizing cultural relics, ancient books, and archives [3]. With the advancement of science, technology, and society in recent decades, the digital protection of cultural heritage has produced impressive accomplishments, gathering and storing a sizable amount of cultural heritage data resources. In this context, the construction of cultural heritage data sharing platforms realizes an organic integration of information technology and the protection and sharing of cultural heritage, standardizes and organizes cultural heritage data resources, and improves the efficiency of data utilization. Additionally, it allows cultural heritage institutions in different fields and departments to realize the acquisition and flow of data, becoming critical carriers in promoting the extensive and comprehensive sharing of cultural heritage data.

The fair and sufficient sharing and utilization of cultural heritage data are a meaningful way to improve cultural heritage content richness and influence its transmission and inheritance [4]. However, there are still some difficulties in the sharing and interconnectedness of cultural heritage data in China, such as fragmentation and self-control among cultural heritage institutions, varying levels of digital construction, giant barriers to resource interoperability, and severe information silos [5]. Data resource owners lack an understanding of the social value of sharing, have a weak awareness of protection, and are unwilling to share their resources [6]. In addition, the owners of cultural heritage data are dominated by competition, forming the traditional concept of data exclusivity and closure, and regard data as "personal property". "Free riding" may occur in sharing and cooperation, leading to an infringement of data copyright or the loss of competitive advantage [7]. Therefore, how to design a sharing mechanism to motivate more users to participate in cultural heritage data sharing platforms is a question worth thinking about in cultural heritage sharing and transmission.

In sharing platforms, participants can gain certain benefits by sharing the data in their hands. Meanwhile, their essential competitive advantages could be lost if the core data they possess are exposed. As a result, it is challenging to gauge and predict users' willingness to share at various stages because it fluctuates with benefits and losses and is influenced by other players [8]. The opening and sharing of data among the various parties involved in cultural heritage data sharing is not a choice that can be made at once for their benefit but is an iterative game process. In the case of information asymmetry, it is necessary to decide whether to participate in a platform's data sharing based on mutual learning and imitation under the incentive of the data sharing platform, driven by trust and one's interests. Therefore, the evolutionary game method can be used to analyze the process of institutional sharing behaviors changing over time in cultural heritage sharing platforms.

More and more scholars have used the evolutionary game approach to study the sharing process of resources, data, and knowledge in various fields. Li et al. [9] studied the information sharing process of institutional investors by using evolutionary game theory to find a solution for their conflicting interests. They determined the influence of risk, costs, and the free-rider penalty on the stable state of information sharing. Chen et al. [10] investigated the decision process of logistics resource sharing among courier firms based on an evolutionary game, and the effects of the initial state, firm size, revenue allocation coefficient, and default penalty coefficient on the evolutionary path were analyzed. Liu et al. [11] constructed a three-party evolutionary game model of shared manufacturing in manufacturing enterprises under a government regulation mechanism. They analyzed the positive factors for promoting shared manufacturing in enterprises. Zheng [12] constructed an evolutionary game model of network knowledge sharing based on low-carbon industrial network knowledge sharing and a cooperative network environment and explored the influence of reward and punishment mechanisms, profit distribution, and knowledge potential in the collaborative innovation knowledge sharing of low-carbon technologies. However, there are few previous studies on the process and influencing factors of cultural heritage data sharing. To promote cultural heritage institutions' long-term initiatives and sustainability for cultural heritage data sharing, the dynamic evolutionary processes and patterns of inter-institutional data sharing in cultural heritage sharing platforms need to be further investigated. Based on relevant research on cultural heritage sharing and the evolutionary game method, this paper aims to explore the evolutionary path of the strategic selection of institutional sharing behavior in a cultural heritage sharing platform at the micro level and analyze the strategic stability of each participant and the influence of various factors. Based on previous studies, this paper adds related parameters, such as the initial benefit, coefficient of shared benefit, coefficient of synergistic benefit, fixed sharing costs, loss of gain, and free-rider penalty value, and constructs a data sharing payoff matrix of cultural heritage institutions. An evolutionary game model of the sharing strategy of cultural heritage institutions is established by analyzing the payoff matrix of the sharing strategy. Then, based on the dynamic replication equation, this paper discusses the dynamic evolution and stability of cultural heritage institutions' sharing strategy selection. Finally, based on the numerical simulation, the influences of the initial state of the system and various related factors on the evolution results are analyzed. Unlike previous studies, this paper explores the sharing behavior and related influencing factors of cultural heritage institutions from a micro-level analysis of their sharing decision process rather than from a top-level design perspective, which is essential to fill the research gap in the field of cultural heritage. Second, this paper also sets up a case study of the ASEAN Cultural Heritage Digital Archive to support its findings. The research presented in this paper will aid in effectively sharing cultural heritage and serve as a guide for the incentive and punishment mechanisms of platforms that share cultural heritage data, which is crucial for the inheritance and sustainable development of cultural heritage.

The core of evolutionary game theory is the interaction and decision making of individuals which evolves into an equilibrium over time. It can explain the interchange of cooperation, competition, and conflict among institutions in cultural heritage data sharing and analyze the dynamic processes and strategic choices behind cultural heritage data sharing. The remainder of this essay is organized as follows. Section 2 reviews the literature related to cultural heritage sharing, incentives, and the application of evolutionary game theory. The third part establishes the evolutionary game model of cultural heritage institution sharing behavior and analyzes the dynamic evolution process of the model. In Section 4, the different factors influencing the evolution result are simulated and analyzed. Sections 5–7 provide a discussion of the results, an empirical study, and the study's conclusions, respectively. The framework of the paper is shown in Figure 1.

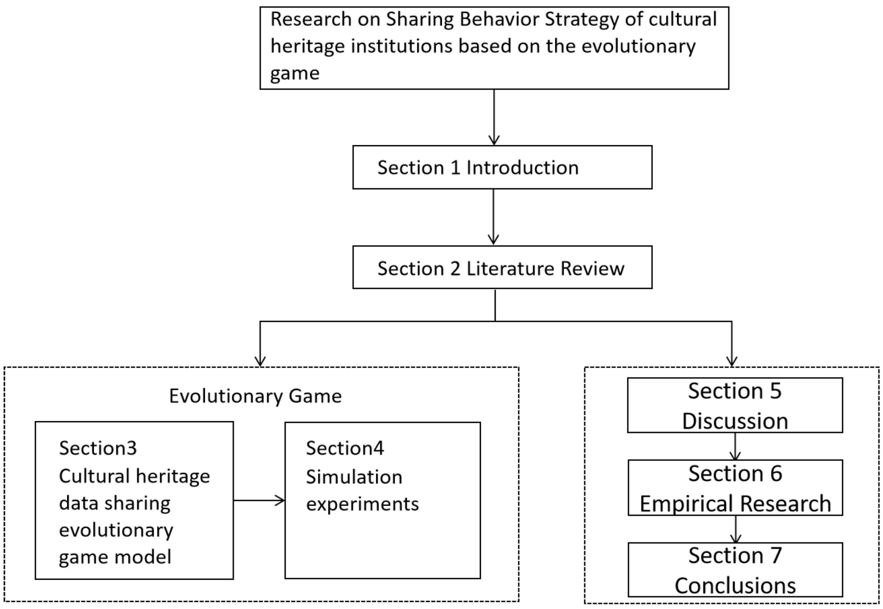

Figure 1. The framework of the paper.

2. Literature Review

One of the goals of digital preservation of cultural heritage is to promote the use of cultural heritage data resources through digitization and to realize the flow of data value by organically combining the high-value content contained in cultural heritage resources with data production elements through creative data exploration and transformation. As an essential link in protecting and transmitting cultural heritage, sharing cultural heritage data has received increasing attention in recent years. This paper sorts out the research related to cultural heritage data sharing and the evolutionary game theory applied to data sharing as follows.

2.1. Research on Cultural Heritage Sharing

Research on cultural heritage data sharing mainly centers on the following aspects. The first is the current state of cultural heritage data sharing. Chen et al. [5] pointed out that in the process of sharing cultural heritage data in China, there are problems such as the difficulty in tracing the source of data utilization, ensuring data quality, protecting the interests of data contributors, and resolving the ownership of data after sharing, which quickly lead to the low motivation of individuals to contribute and use data and make data sharing more difficult. Mou et al. [13] argue that since the protection of cultural heritage in China follows the principle of "government-led and social participation", the main actors in developing cultural heritage resources also show diversified characteristics. Many subjects have different degrees of information mining due to their different industrial backgrounds, so there are many obstacles to cultural heritage sharing. Cao et al. [3] argue that there are various problems in the protection of cultural heritage in China, including unclear property rights, unclear rights and responsibilities of management bodies, a lack of unified planning, and inadequate laws and regulations. The second main research focus is on constructing cultural heritage sharing models and sharing platforms. Dhonju et al. [14] proposed an online geographic crowdsourcing system called "Sharing Our Cultural Heritage" (SOCH) for the large-scale sharing of cultural heritage documents. Gao et al. [15] addressed the problems and challenges faced in constructing digital museums and proposed a digital museum construction scheme based on cloud computing. Zhao et al. [16] have applied blockchain technology to digital museums to protect user privacy and security and to integrate the cultural heritage resources of museums around the world. The third research focus is on factors influencing cultural heritage sharing. Several scholars have explored the factors influencing cultural heritage sharing from different perspectives. Ronra's study identified the factors that influence cultural heritage knowledge (CHK) sharing as "reward[s]" and the "willingness to share" [17]. Han et al. [18] suggested that authenticity and nostalgia are essential to the sharing behavior of cultural heritage travel experiences on social media in the context of cultural heritage tourism. Sun et al. [19] argue that the role of economic factors in the transmission of intangible cultural heritage should not be neglected and that the following all influence the knowledge transfer of intangible cultural heritage: the maximum benefits of the apprentice from the tacit knowledge transfer, the knowledge transmission ability coefficient of the master, the coefficient of the knowledge absorption ability of the apprentice, the environmental support coefficient of the knowledge transfer, and the punishment strategy suffered due to passivity. The studies of the scholars mentioned above found that the factors motivating cultural heritage sharing include incentives, distribution factors, punishment factors, etc. However, cultural heritage sharing is a dynamic process, and while exploring the key influencing factors, more attention should be paid to the participants' sharing decision process. The fourth main line of research is the study of incentive mechanisms for cultural heritage preservation and sharing. Yang et al. [20] studied the preference, value cognition, and protective attitude of landscape professionals and residents towards traditional village landscapes. They found that the protective attitude of the residents was not affected by cultural values but by their perception of the economic benefits and daily utility value. Radzuan et al. [21] studied incentive mechanisms, including loans, tax breaks, and public subsidies, developed in Japan and South Korea to promote cultural heritage conservation. They identified how the incentives work, their limitations, and their constraints. Sun et al. [19] suggested that the improvement of practical benefits, the reinforcement of punishment deterrence, and the reduction in transmission costs are significant incentives for transmitting of intangible cultural heritage.

A review of some scholars' studies has revealed that the problems in cultural heritage data sharing in China can be categorized into several aspects, such as institutional and technical problems, conflicting interests, and cultural perception barriers. Many works in the literature have mentioned the importance of cultural heritage data sharing and have applied emerging technologies, such as cloud computing and blockchains, to cultural heritage sharing to break the dilemma of cultural heritage sharing and seek new development points for cultural heritage protection and inheritance. However, few people have explored the formation of related mechanisms from the sharing strategies of cultural heritage sharing subjects. Therefore, studying sharing strategies among cultural heritage institutions with different interests and interdependence helps fill this current research gap.

2.2. Data Sharing and Evolutionary Game

Traditional game theory often holds that people are entirely rational, require actors to maximize their interests, and have perfect judgment and decision-making abilities in an uncertain game environment [22]. However, the assumption of complete rationality has problems because it is impossible for game players to achieve complete rationality and trust in complex interactions [23]. The evolutionary game is a tool to study the behavioral strategies of various agents and their interaction mechanisms. It has been widely employed in many domains, including biology, economics, politics, and sociology [24]. Unlike the utterly rational assumption of traditional game theory, evolutionary game theory combines traditional game theory with a dynamic evolution process. It holds that human beings have bounded rationality, and each subject can dynamically correct its behavior over time in the process of evolution, that is, throughout a repeated game, finally reaching a stable state [25].

Many works in the literature have used the evolutionary game method to discuss the dynamic interactive process of data sharing. For example, Liu et al. used evolutionary game theory to discuss the evolutionary path of platforms and suppliers in logistics ecological cooperation. They obtained the factors of the evolutionary stabilization strategies that were eventually achieved. Akkaoui et al. [26] verified the influence of blockchain technology on the trust level between different entities in a health data trading system through the evolutionary game model. Based on the evolutionary game model, Xiao et al. [27] studied the behavior patterns of prevention and control between online users and the government in data sharing and information disclosure. Dong et al. [28] introduced evolutionary game theory for cross-departmental sharing in digital government construction and constructed a game model between government data management departments and different government functions involved in cross-departmental data sharing. Zheng et al. [29] completed a three-way dynamic evolutionary game model between core enterprises, small and medium enterprises (SMEs), and financial institutions in the context of blockchains and constructed and compared the dynamic evolutionary game model between core enterprises and financial institutions under the reward and punishment mechanism and the synergistic benefit mechanism, respectively. Lu et al. [30] analyzed the influence mechanisms of data sharing, resource integration, and integrity on collaborative innovation among supply chain enterprises in the digital context based on the evolutionary game method and constructed a dynamic evolutionary game model for supply chain enterprises to participate in collaborative innovation. Pan et al. [31] proposed an evolutionary game model for the data sharing decision behavior of supply chain firms when the value of data changes over time and discussed the impact of the cumulative value of data on the long-term cooperation stability of supply chain firms based on an analysis of the payoff function. Liu et al. [32] proposed a real-time scheme for adjacent nodes on a road to jointly determine their data allocation strategies based on an evolutionary fuzzy game. Chen et al. [33] constructed a dynamic incentive model based on the evolutionary game theory that dynamically adjusted the user's benefits in the data sharing process and promoted the user's willingness to participate in sharing. A small number of scholars have applied evolutionary games to the field of cultural heritage. For example, Sun et al. [19] constructed an evolutionary game model of knowledge transfer between teachers and apprentices to explore how to promote nonheritage inheritance better. Fang [34] focused on the knowledge sharing strategy selection problem of NRM tourism development and constructed an evolutionary game model of NRM tourism community members' participation.

The evolutionary game model has been widely used in government, medical, financial, scientific, and technological service data sharing but is less used in the field of cultural heritage data sharing research. In addition, the research on cultural heritage sharing is mainly about the construction of cultural heritage sharing modes and platforms, etc. There needs to be more research on the choice of cultural heritage institutions in their sharing decision making and the income loss of sharing participants, which needs to be increased. Therefore, this paper draws on the research of evolutionary games in data sharing in other fields, establishes an evolutionary game model to explore the data sharing process among institutional users in a cultural heritage platform, and puts forward optimization suggestions to solve the dilemma of cultural heritage sharing and realize the flow and integration of cultural heritage data.

3. Cultural Heritage Data Sharing Evolutionary Game Model

3.1. Research Hypothesis and Model Construction

Each member in a cultural heritage data sharing platform plays the dual roles of data resource provider and receiver, and data sharing in the platform is a process of the dynamic selection and learning adjustments of participants with finite rationality; i.e., when one institution chooses a certain strategy and obtains higher returns, other institutions may imitate its behavior. The following presumptions are made in this research to build a game model and streamline the calculation:

Hypothesis 1: *In this study, two institutions holding data in the sharing platform are selected as the game subjects, denoted as institution 1 and institution 2. It is assumed that they are both finitely rational and continuously adjust their strategies according to the current returns.*

Hypothesis 2: *Institutions 1 and 2 involved in cultural heritage data sharing have the same strategy space as (Share, Not Share). The probability of institution 1 choosing to share is x, and the probability of not sharing is $1 - x$. The probability of institution 2 choosing to share is y, and the probability of not sharing is $1 - y$, where $0 \leq x \leq 1$, $0 \leq y \leq 1$.*

Hypothesis 3: *From the perspective of participant benefits, the potential benefits to gaming participants are as follows.*

Initial benefit: the normal gains p_i (i = 1, 2) that can be obtained based on its data regardless of whether or not the institution engages in cultural heritage data sharing.

Direct benefit: Thethe benefit obtained by an organization from absorbing and using others' shared resources and converting others' information into its own. This is related to the coefficient of shared benefit α_i (i = 1, 2), the data stock of the other institutions k_i (i = 1, 2), and the institution's independent learning ability to absorb and transform data resources into creation μ_i (i = 1, 2). ($0 \leq \alpha_i \leq 1, k_i > 0, \mu_i > 0$).

Synergistic benefit: The synergistic innovation effect is generated by the institutions participating in the data sharing and the other institutions sharing the resources, realizing the value integration between the two sides and developing new knowledge to obtain the new benefit of "1 + 1 > 2". The size of the synergistic effect depends on three factors. The first factor is the coefficient of the synergistic benefit. The second factor is the degree of data complementarity among the participating parties. As there are various types of data among the participating parties, only the fusion of data with complementary and heterogeneous values can generate new values, i.e., the higher the complementarity of data, the greater the synergistic benefit generated by the fusion of different data during data sharing [35]. The third factor is the amount of data shared between both parties. The more data an organization is willing to share, the greater is the revenue that can be obtained [36]. Thus, the synergistic benefit is related to the proportion of data complementarity n_i (i = 1, 2), the coefficient of synergistic benefit β_i (i = 1, 2) and the data sharing volume d_i (i = 1, 2) $(0 \leq \beta_i \leq 1,\ \beta_1 + \beta_2 = 1;\ d_i > 0;\ 0 \leq n_i \leq 1)$.

Hypothesis 4: *From the perspective of cultural heritage data sharing costs and risks, the possible costs to the game participants are as follows.*

Fixed sharing costs C_i $(i = 1, 2)$ $(C_i > 0)$: these include the technical, material, time, and maintenance costs that are paid for in selecting, organizing, transmitting, analyzing, integrating, and sharing cultural heritage data.

Loss of gain L_i $(i = 1,\ 2)$ $(L_i > 0)$: when an organization chooses data sharing, it also faces a loss of gain, such as the loss of gain from the loss of a core competitive advantage or data leakage.

Hypothesis 5: *Most cultural heritage institutions view data as private property and have a sense of competition in data sharing. They are often willing to obtain resources provided by others but are not willing to share their resources. When one institution chooses to share while another chooses not to share, "free riding" will discourage institutions from sharing data. Therefore, a penalty mechanism is introduced here, in which the party that chooses not to share is subject to a free-rider penalty from a third party (government, organization, platform, etc.) in the form of $F(F > 0)$(including financial losses and non-financial losses, such as in the institution's reputation and image) to reward the party that participates in sharing.*

The relevant parameter settings in the game model in this paper are shown in Table 1.

Table 1. Parameter settings.

Parameters	Meaning
p_i	Initial benefit
α_i	Coefficient of shared benefit
k_i	Other institutional data stock
μ_i	Self-learning capability
β_i	Coefficient of synergistic benefit
d_i	Data sharing volume
n_i	Proportion of data complementarity
C_i	Fixed sharing cost
L_i	Loss of gain
F	Free-rider penalty

The payoff matrix for member participation in the game is displayed in Table 2 based on the study's above-mentioned hypotheses.

Table 2. Payoff matrix of member participation in the game for cultural heritage data sharing.

Institution 1	**Institution 2**	
	Share y	**Not Share 1 − y**
Share x	$p_1 + \alpha_1 k_1 \mu_1 + \beta_1 d_1 n_1 - C_1 - L_1$, $p_2 + \alpha_2 k_2 \mu_2 + \beta_2 d_2 n_2 - C_2 - L_2$	$p_1 - C_1 - L_1 + F$, $p_2 + \alpha_2 k_2 \mu_2 - F$
Not Share 1 − x	$p_1 + \alpha_1 k_1 \mu_1 - F$, $p_2 - C_2 - L_2 + F$	p_1, p_2

The various types of scenarios of the payoff matrix are analyzed.

(1) Both parties choose to share. In this case, institution 1 and institution 2 obtain an initial benefit from their data resources, a direct benefit from the mutual absorption of information, and a synergistic benefit from the fusion of data values. At the same time, sharing costs and a loss of gain are generated. The gain of institution 1 is $p_1 + \alpha_1 k_1 \mu_1 + \beta_1 d_1 n_1 - C_1 - L_1$, and the gain of institution 2 is $p_2 + \alpha_2 k_2 \mu_2 + \beta_2 d_2 n_2 - C_2 - L_2$.

(2) If one party chooses to share and one party chooses not to share, institution 1 shares its data on the platform, but since institution 2 choose not to share, institution 1 can neither obtain the direct benefit of converting others' resources into its resources nor obtain the synergistic benefit and will incur sharing costs and losses. Institution 2 will not receive the synergistic benefit of data complementarity, but only an initial and direct benefit, while being penalized for its free-riding behavior. Therefore, if institution 1 chooses to share and institution 2 chooses not to share, institution 1's gain is $p_1 - C_1 - L_1 + F$ and institution 2's gain is $p_2 + \alpha_2 k_2 \mu_2 - F$. If Institution 1 chooses not to share and institution 2 chooses to share, the benefit to institution 1 is $p_1 + \alpha_1 k_1 \mu_1 - F$ and to institution 2 is $p_2 - C_2 - L_2 + F$.

(3) Both parties choose not to share. Neither party receives the gain from sharing, and no loss is incurred, only an initial benefit. At this point, the gain for institution 1 is p_1 and the gain for institution 2 is p_2.

3.2. Evolutionary Stability Strategy Analysis

3.2.1. Local Equilibrium Analysis

Based on the payoff matrix shown in Table 2, the expected benefits when institution 1 and institution 2 choose to share and not to share are calculated separately, and the dynamic evolution process of data sharing among cultural heritage institutions is described using the replication dynamic equation in evolutionary game theory.

The expected returns for institution 1 choosing to share are as follows:

$$\begin{aligned} U_{1Y} &= y(p_1 + \alpha_1 k_1 \mu_1 + \beta_1 d_1 n_1 - C_1 - L_1) + (1-y)(p_1 - C_1 - L_1 + F) \\ &= y(\alpha_1 k_1 \mu_1 + \beta_1 d_1 n_1 - F) + p_1 - C_1 - L_1 + F \end{aligned} \tag{1}$$

The expected returns for institution 1 choosing not to share are as follows:

$$U_{1N} = y(p_1 + \alpha_1 k_1 \mu_1 - F) + (1-y)(p_1) = y(\alpha_1 k_1 \mu_1 - F) + p_1 \tag{2}$$

The mean returns for institution 1 are as follows:

$$U_1 = xU_{1Y} + (1-x)U_{1N} \tag{3}$$

The expected returns for institution 2 choosing to share are as follows:

$$\begin{aligned} U_{2Y} &= x(p_2 + \alpha_2 k_2 \mu_2 + \beta_2 d_2 n_2 - C_2 - L_2) + (1-x)(p_2 - C_2 - L_2 + F) \\ &= x(\alpha_2 k_2 \mu_2 + \beta_2 d_2 n_2 - F) + p_2 - C_2 - L_2 + F \end{aligned} \tag{4}$$

The expected returns for institution 2 choosing not to share are as follows:

$$U_{2N} = x(p_2 + \alpha_2 k_2 \mu_2 - F) + (1-x)(p_2) = x(\alpha_2 k_2 \mu_2 - F) + p_2 \tag{5}$$

The mean returns for institution 2 are as follows:

$$U_2 = yU_{2Y} + (1-y)U_{2N} \tag{6}$$

The replication dynamic equation is a dynamic differential equation describing the frequency of adoption of a certain strategy in a group, reflecting the choice of different strategies by group members over time and depicting the dynamic process of how the strategy evolves and thus achieves equilibrium stability [37]. The replication dynamic equations for each side are constructed separately.

The replication dynamic equation for institution 1 adopting a shared strategy is as follows:

$$F(x) = \frac{dx}{dt} = x(U_{1Y} - U_1) = x(1-x)[U_{1Y} - U_{1N}] = x(1-x)[y\beta_1 d_1 n_1 - C_1 - L_1 + F] \tag{7}$$

The replication dynamic equation for Institution 2 adopting a shared strategy is as follows:

$$F(y) = \frac{dy}{dt} = y(U_{2Y} - U_2) = y(1-y)[U_{2Y} - U_{2N}] = y(1-y)[x\beta_2 d_2 n_2 - C_2 - L_2 + F] \tag{8}$$

In evolutionary game theory, the equilibrium point of the evolutionary game of the shared participant is obtained when the replication dynamic equation is 0, and its first-order derivative is less than 0 [38]. Taking the replication dynamic equation reflected in Equations (7) and (8), the derivatives for pairs x and y, respectively, are as follows:

$$F\prime(x) = (1-2x)[y\beta_1 d_1 n_1 - C_1 - L_1 + F] \tag{9}$$

$$F\prime(y) = (1-2y)[x\beta_2 d_2 n_2 - C_2 - L_2 + F] \tag{10}$$

According to the replication dynamic equation, the local stability point of the system can be derived, and the evolutionary stability point of the system is finally derived by analyzing the Nash equilibrium of the local equilibrium point. Separately, $F(x) = 0$, $F(y) = 0$. The following local equilibrium points of the evolutionary game model can be obtained: $(0,0), (0,1), (1,1), (1,0), (x^*, y^*)$, where $x^* = \frac{C_2+L_2-F}{\beta_2 d_2 n_2}$, $y^* = \frac{C_1+L_1-F}{\beta_1 d_1 n_1}$.

3.2.2. Local Stability Analysis of the Equilibrium Point

Although the equilibrium points obtained above can make both sides of the game reach the equilibrium decision, they are not necessarily all stable. The game evolutionary stability strategy means that when both parties reach equilibrium, their strategy will remain stable and no longer change. In natural selection, the mutator is either eliminated in evolution or chooses to evolve a stable strategy to adapt to the environment. According to the stability determination criterion proposed in Friedman's study, the local stability analysis of the Jacobian matrix can be used to determine whether the equilibrium point is an evolutionarily stable strategy (EES) [39]. The partial derivatives of x and y for the differential Equations (7) and (8), respectively, give us the Jacobian matrix J of the system of differential equations as follows:

$$J = \begin{bmatrix} (1-2x)[y\beta_1 d_1 n_1 - C_1 - L_1 + F] & x(1-x)\beta_1 d_1 n_1 \\ y(1-y)\beta_2 d_2 n_2 & (1-2y)[x\beta_2 d_2 n_2 - C_2 - L_2 + F] \end{bmatrix} \tag{11}$$

According to the stability criterion of the equilibrium points in the Jacobian matrix, an equilibrium point reaches a stable state when and only when $\det J > 0$ and $trJ < 0$. When $\det J > 0$ and $trJ > 0$, then the equilibrium point is not stable; when $\det J < 0$, the equilibrium point is a saddle point [40].

$$\begin{aligned} \det(J) = {} & (1-2x)(1-2y)[x\beta_2 d_2 n_2 - C_2 - L_2 + F][y\beta_1 d_1 n_1 - C_1 - L_1 + F] - \\ & x(1-x)y(1-y)\beta_1 d_1 n_1 \beta_2 d_2 n_2 \end{aligned} \tag{12}$$

$$tr(J) = (1-2x)[y\beta_1 d_1 n_1 - C_1 - L_1 + F] + (1-2y)[x\beta_2 d_2 n_2 - C_2 - L_2 + F] \tag{13}$$

A local equilibrium point stability analysis is performed based on the aforementioned criteria, and the outcomes are displayed in Table 3.

Table 3. Stability analysis of local equilibrium point.

Local Equilibrium Point	det (J)	tr (J)
$E_1(0,0)$	$(F - C_1 - L_1)(F - C_2 - L_2)$	$(F - C_1 - L_1)+$ $(F - C_2 - L_2)$
$E_2(0,1)$	$(C_2 + L_2 - F)(\beta_1 d_1 n_1 - C_1 - L_1 + F)$	$(C_2 + L_2 - F)+$ $(\beta_1 d_1 n_1 - C_1 - L_1 + F)$
$E_3(1,0)$	$(C_1 + L_1 - F)(\beta_2 d_2 n_2 - C_2 - L_2 + F)$	$(C_1 + L_1 - F)+$ $(\beta_2 d_2 n_2 - C_2 - L_2 + F)$
$E_4(1,1)$	$(\beta_2 d_2 n_2 - C_2 - L_2 + F)$ $(\beta_1 d_1 n_1 - C_1 - L_1 + F)$	$(C_1 + L_1 - F - \beta_1 d_1 n_1)+$ $(C_2 + L_2 - F - \beta_2 d_2 n_2)$
$E_5(x^*, y^*)$		0

The local stability analysis of the game system is performed in the plane region where $R = \{(x,y)|0 \le x \le 1, 0 \le y \le 1\}$ is located according to $0 \le x^* \le 1$, $0 \le y^* \le 1$ and the synergistic benefit $\beta_1 d_1 n_1, \beta_2 d_2 n_2 \ge 0$, $0 \le C_2 + L_2 - F \le \beta_2 d_2 n_2, 0 \le C_1 + L_1 - F \le \beta_1 d_1 n_1$ can be obtained. Under the satisfaction of the above conditions, the stability analysis results of the game system are shown in Table 4; there are two evolutionarily stable strategies (ESS), which are (0, 0) and (1, 1), that is, representing institution 1 and institution 2 choosing the non-sharing strategy and the sharing strategy at the same time.

Table 4. Equilibrium stability analysis of cultural heritage data sharing strategy selection.

Equilibrium Point	det (J)	tr (J)	Stability
$(0,0)$	+	−	Stability point
$(0,1)$	+	+	Unstable point
$(1,0)$	+	+	Unstable point
$(1,1)$	+	−	Stability point
(x^*, y^*)	/	0	Saddle point

According to the results of the local stability analysis of the game system, the evolutionary game phase diagram is drawn, as shown in Figure 2.

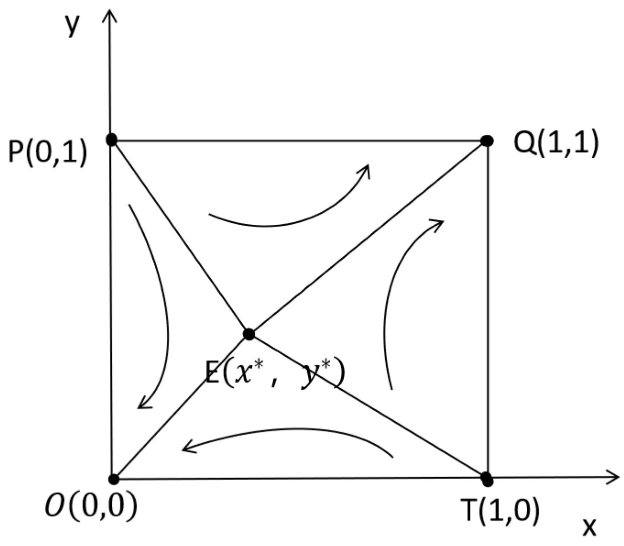

Figure 2. Phase diagram of the cultural heritage data sharing game.

3.2.3. Analysis of Model Parameters

In Figure 2, when the initial point falls in the region S_1 composed of OPET, the evolutionary trajectory of the system will converge to point $O(0,0)$, and both sides of the game choose the non-sharing strategy. When the initial point falls in the region S_2 composed of PQTE, the evolutionary trajectory of the system will converge to point $Q(1, 1)$, and both sides of the game will choose the shared strategy. As shown in Figure 2, when $S_2 > S_1$, the probability of the initial point falling at S_2 increases, then the probability of the system evolving towards a shared strategy increases.

Taking the relevant variables as an example, we analyze their effects on S_2.

$$S_2 = 1 - \frac{1}{2}\left(\frac{C_2 + L_2 - F}{\beta_2 d_2 n_2} + \frac{C_1 + L_1 - F}{\beta_1 d_1 n_1}\right) \tag{14}$$

From Equation (14), it can be seen that: the fixed sharing cost C_i, loss of gain L_i, coefficient of synergistic benefits β_i, data sharing volume d_i, proportion of data complementarity n_i, and free-rider penalty $F(i = 1, 2)$ are the influencing factors of S_2. By taking partial derivatives of each influencing factor based on S_2 separately, the following conclusions can be obtained:

(1) The effect of fixed sharing costs C_I on S_2 (taking C_1 as an example): $\frac{\partial_{S_2}}{\partial_{c_1}} = -\frac{1}{2\beta_1 d_1 n_1} < 0$, S_2 decreases with the increase in the fixed sharing cost C_1, and both sides of the game tend towards the non-sharing strategy. This indicates that the increase in the cost and loss of data sharing will increase the probability of cultural heritage institutions choosing not to share.

(2) The effect of loss of gain L_i on S_2 (taking L_1 as an example): $\frac{\partial_{S_2}}{\partial_{L_1}} = -\frac{1}{2\beta_1 d_1 n_1} < 0$, S_2 decreases with the increase in the loss of gain L_1, and both sides of the game tend not to share as their strategy. This indicates that an increase in revenue loss will increase the probability that cultural heritage institutions will choose not to share.

(3) The effect of free-rider penalty F on S_2: $\frac{\partial_{S_2}}{\partial_F} = \frac{1}{2}\left(\frac{1}{\beta_1 d_1 n_1} + \frac{1}{\beta_2 d_2 n_2}\right) > 0$, S_2 increases with the increase in the free-rider penalty F, and both sides of the game tend to share as their strategies. The free-rider penalty imposed by a third party, such as the government, on cultural heritage institutions for not sharing is binding. Both institutions do not want to be punished, and increasing the free-rider penalty can increase the willingness of both parties to share and reduce hitchhiking sharing.

(4)The effect of the coefficient of synergistic benefit β_i on S_2 (taking β_1 as an example): $\frac{\partial_{S_2}}{\partial_{\beta_1}} = \frac{C_1 + L_1 - F}{2 d_1 n_1 \beta_1{}^2} > 0$, S_2 increases with the increase in the coefficient of synergistic benefit β_1, and both sides of the game tend to share as their strategies. This indicates that increasing the coefficient of the synergistic benefit will increase the probability of cultural heritage institutions choosing to share.

(5) The effect of the data sharing volume d_i on S_2 (take d_1 as an example): $\frac{\partial_{S_2}}{\partial_{d_1}} = \frac{C_1 + L_1 - F}{2\beta_1 n_1 d_1{}^2} > 0$, S_2 increases with the increase in the data sharing volume d_1, and both sides of the game tend to share as their strategy. This means that increases in the data sharing volume will increase cultural heritage institutions' probability of sharing.

(6) The effect of the proportion of data complementarity n_i on S_2 (taking n_1 as an example): $\frac{\partial_{S_2}}{\partial_{n_1}} = \frac{C_1 + L_1 - F}{2\beta_1 d_1 n_1{}^2} > 0$, S_2 increases with the proportion of data complementarity n_1, and both sides of the game tend to share as their strategy. This indicates that the increase in the proportion of data complementarity will increase the probability of cultural heritage institutions choosing to share.

In summary, in the process of data sharing games for cultural heritage institutions, factors such as the fixed sharing costs, free-rider penalty, loss of gain after choosing to share, coefficient of synergistic benefit, data sharing volume, and proportion of data complementarity will all have an impact on both parties' final strategy for the game. Among them, the fixed sharing costs and the loss of gain after choosing to share negatively affect the institutions' sharing strategy choice, and the third-party free-rider penalty when not sharing, the coefficient of synergistic benefit, data sharing volume, and proportion of data complementarity positively affect the institutions' sharing strategy choice.

4. Simulation Experiments

4.1. Parameter Setting

The MATLABR 2021b software is used to simulate the process and outcomes of the dynamic evolution of cultural heritage data sharing strategies of various institutions in a cultural heritage sharing platform in order to further verify and analyze the influence of parameter changes on the strategy selection of cultural heritage institutions. Referring to the research experience and objective facts of [24,35,41], the default values and notes of the given parameters are shown in Table 5.

Table 5. Default initial values of data sharing game model parameters for cultural heritage institutions.

No.	Parameter	Meaning	Assignment
1	β_1	Coefficient of synergistic benefit	0.6
2	β_2		0.4
3	d_1	Data sharing volume	15
4	d_2		16
5	n_1	Proportion of data complementarity	0.7
6	n_2		0.6
7	C_1	Fixed sharing cost	1
8	C_2		1.5
9	L_1	Loss of gain	0.3
10	L_2		0.4
11	F	Free-rider penalty	0.5

The meaning of the variables can be interpreted as follows: "$\beta_i = 0.6$" indicates that the coefficient of the synergistic benefit received by one of the sharing parties is 60%; "$d_1 = 15$" indicates that the amount of data that can be shared by institution 1 is 15 units; "$n_1 = 0.7$" indicates that institution 1 has 70% data complementary to the other participant; "$C_1 = 1$" indicates that the cost to be paid by institution 1 for sharing is 1 unit; "$L_1 = 0.3$" indicates that the loss of gain to be paid by institution 1 for sharing is 0.3 units; and "F = 0.5" indicates that a penalty value of 0.5 units is required for one party not to share. To determine the effect of changes in each variable on the outcome, changing only one variable in each condition is necessary, keeping the other variables constant.

4.2. Simulation Analysis

4.2.1. Effect of Initial Probability on the Choice of Data Sharing Evolution Strategy for Cultural Heritage Institutions

When the initial probability y = 0.6 is chosen by institution 2, the initial probability x is set as 0.4, 0.5, 0.6, 0.7, and 0.8, respectively. The simulation results are shown in Figure 3. When the initial probability y = 0.6 of institution 2 choosing to share is kept constant, the strategies for institution 1 to choose to share eventually converge to 1. Moreover, the larger the value of x is, the shorter the time to converge to sharing. This indicates that institution 1 can converge to sharing more quickly when its initial willingness is strong enough.

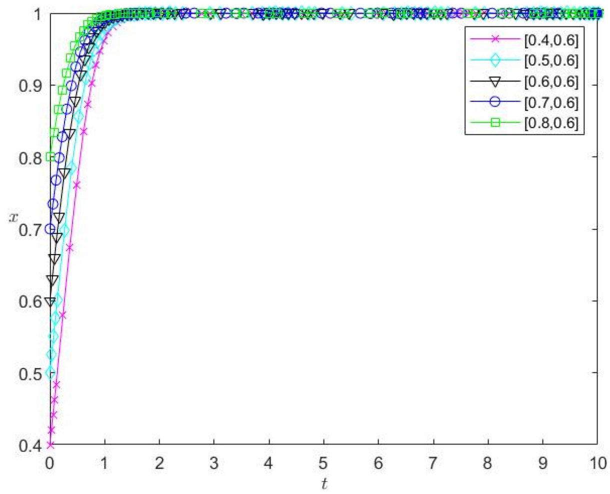

Figure 3. Institution 1 sharing strategy influenced by the initial probability.

When the initial probability of institution 1 choosing to share is x = 0.6, we set the initial probability y of institution 2 choosing to share as 0.4, 0.5, 0.6, 0.7, and 0.8, respectively. The simulation results are shown in Figure 4. When the initial probability (x = 0.6) of institution 1 choosing to share remains constant, the strategies for institution 2 choosing to share eventually converge to 1. Moreover, the larger the value of y, the shorter the time to converge to sharing. This indicates that institution 2 can converge to sharing more quickly when its initial willingness is strong enough.

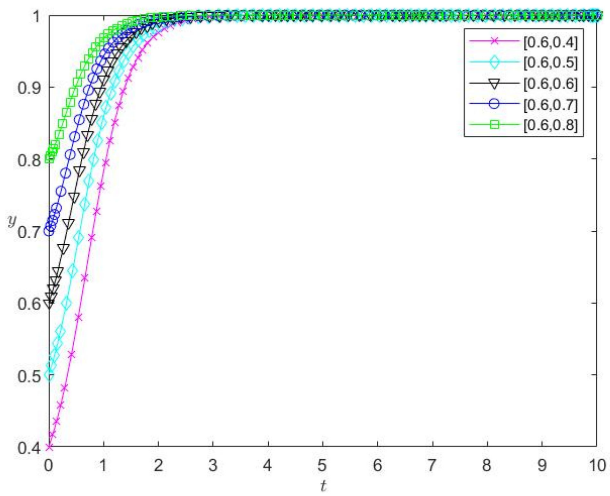

Figure 4. Institution 2 sharing strategy influenced by the initial probability.

This shows that the probability convergence trend and convergence speed of institutions' choice of sharing strategy are related to both the initial probability value of their own strategy choice and the initial probability value of the other game institution's strategy choice. The probability of institutions' choice of sharing reflects their willingness to participate. Only when the initial willingness of cultural heritage institutions to share is strong enough can it lead to inter-institutional data sharing more quickly.

4.2.2. Influence of Related Parameters on the Choice of Data Sharing Evolutionary Strategies for Cultural Heritage Institutions

(1) The influence of the coefficient of synergistic benefit β_i, data sharing volume d_i, the proportion of data complementarity n_i, and free-rider penalty F on the choice of data sharing evolution strategy for cultural heritage institutions

When the other parameters remain constant, the initial sharing probabilities of institution 1 and institution 2 are 0.7 and 0.3, respectively, and the coefficient of synergistic benefit β_1 is 0.3, 0.5, and 0.7, respectively, so the β_2 corresponding values are 0.7, 0.5, and 0.3. The data sharing volume d_1 is 10, 20, and 30; the proportion of data complementarity n_1 is 0.3, 0.6, and 0.9; and the free-rider penalty F is 1, 2, and 3. The simulation results of the effects of the changes in the coefficient of synergistic benefit β_1, data sharing volume d_1, proportion of data complementarity n_1, and free-rider penalty F on the institutional sharing strategies of the two sides of the game are shown in Figures 5–8. From the figures, it can be seen that the final evolution of the strategies of both sides of the game always results in sharing, and with the increase in β_1, d_1, n_1, and F, institution 1 converges to sharing faster, and with the increase in β_2, institution 2 converges to sharing faster. This indicates that as the coefficient of synergistic benefit, data sharing volume, the proportion of data complementarity, and the penalty value increase, both institutions are more willing to choose to share, and the speed of evolution keeps accelerating. In Figure 7, when the proportion of data complementarity is low, the willingness of institution 2 to choose the sharing strategy initially wavers; therefore, the evolution results first to show a decreasing trend, and with the change in time, the willingness of institution 2 to choose sharing starts to rise and finally converges to sharing.

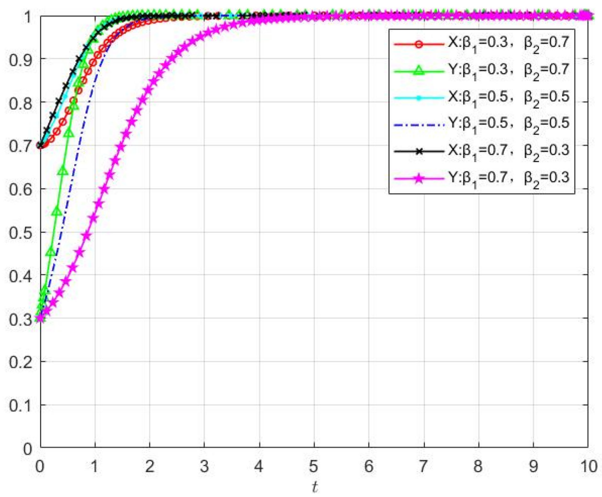

Figure 5. Evolutionary results of β_1 change.

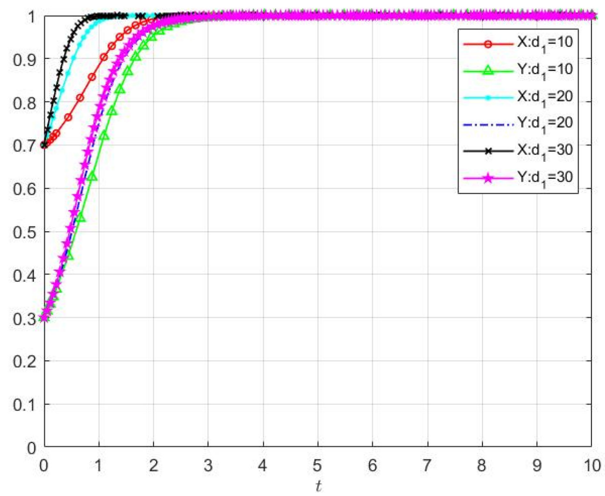

Figure 6. Evolutionary results of d_1 change.

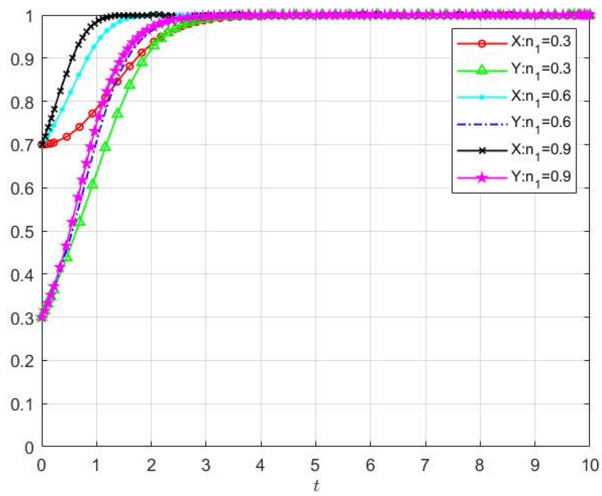

Figure 7. Evolutionary results of n_1 change.

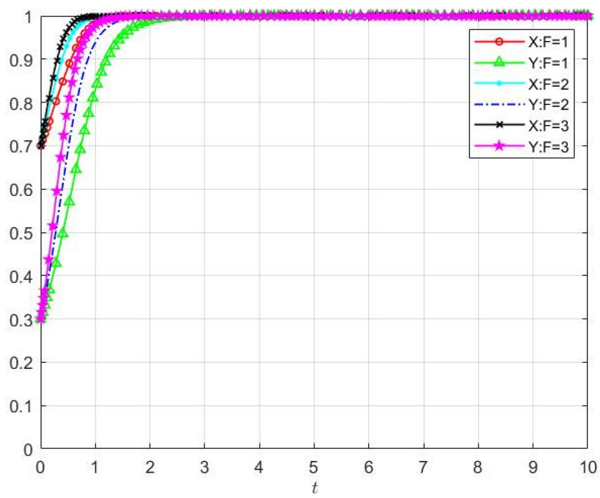

Figure 8. Evolutionary results of F change.

The above analysis shows that the increase in the coefficient of synergistic benefit β_i, data sharing volume d_i, the proportion of data complementarity n_i, and free-rider penalty F will motivate cultural heritage institutions to share. In the cultural heritage data sharing platform, the two parties involved in the data sharing game have the autonomy to decide the amount of data to be shared. In the early stage of the game, the sharing parties will not readily share more of their data due to the asymmetry and incompleteness of information. However, as time progresses, the frequency of cooperation between the sharing parties gradually increases, the level of trust gradually improves, and both parties gradually obtain higher expected benefits, which motivates them to choose the sharing strategy. The differentiation of data among cultural heritage institutions shows a significant asymmetry in the structure and quantity of data between them. This asymmetry forms the intrinsic motivation for data sharing among cultural heritage institutions. Cultural heritage institutions are prone to free-riding behavior when sharing, and this opportunistic behavior tends to discourage institutions from sharing.

(2) The effects of the fixed sharing cost C_i and loss of gain L_i on the choice of data sharing evolution strategy for cultural heritage institutions

The initial sharing probabilities of institution 1 and institution 2 are 0.7 and 0.3, respectively, and the fixed sharing costs C_1 are 1, 3, and 5. The simulation results of the effect of fixed cost changes on the sharing strategies of institutions on both sides of the game are shown in Figure 9. It can be seen from the figure that as the fixed sharing cost

C_1 increases, both sides of the game gradually converge from the sharing strategy to the non-sharing strategy. A threshold value exists between 3 and 5 for the fixed sharing cost C_1. When the fixed sharing cost C_1 of institution 1 is higher than this threshold, the outcome of the strategic evolution of institution 1 and institution 2 is no sharing; when the fixed sharing cost C_1 of institution 1 is less than this threshold, the outcome of the strategic evolution of institution 1 and institution 2 is sharing. This indicates that the pursuit of self-interest maximization is the essence of data sharing behavior of cultural heritage institutions, and with the increase in sharing costs, such as high technical costs and human, material, and financial resources, cultural heritage institutions gain fewer benefits and are significantly less willing to share data; therefore, appropriately reducing sharing costs plays an essential role in attracting cultural heritage institutions to join the sharing platform.

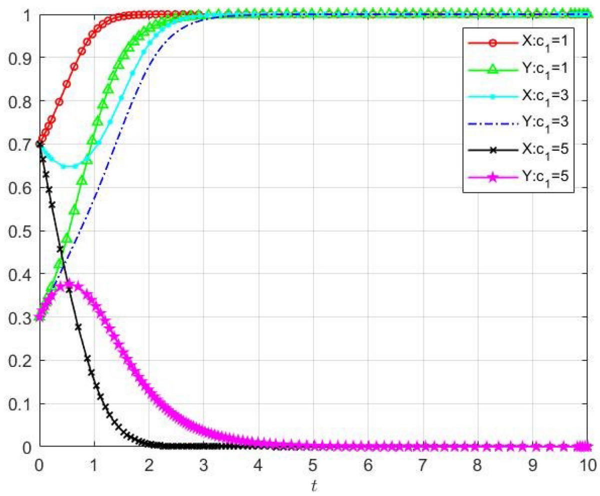

Figure 9. Evolutionary results of C_1 change.

With other parameters unchanged, the initial sharing probabilities of institution 1 and institution 2 are taken as 0.7 and 0.3, respectively, and the loss of gain L_1 is taken as 1, 3, and 5, respectively. The simulation results of the change in the loss of gain L_1 on the sharing strategy of the institutions of both sides of the game are shown in Figure 10. It can be seen from the figure that as the gain loss increases, both sides of the game gradually converge from the sharing strategy to the non-sharing strategy. There is a threshold value between 3 and 5 for the loss of gain L_1. When the gain loss of institution 1 L_1 is more significant than this threshold value, the final result of the strategic evolution of institution 1 and institution 2 is not sharing; when the gain loss of institution 1 L_1 is less than this threshold value, the final result of the strategy evolution of institution 1 and institution 2 is sharing. This indicates that when cultural heritage institutions engage in cultural heritage data sharing with too much risk, they may be less willing to share for fear of data leakage, the loss of their core advantages, and other factors. Therefore, taking practical and reasonable measures to reduce the risk of data sharing among cultural heritage institutions to reduce the loss of gain will make them more willing to participate in sharing cultural heritage platforms.

The above simulation process takes β_1, d_1, n_1, C_1, and L_1 as an example, and the simulation results of β_2, d_2, n_2, C_2, and L_2 are the same, so we will not explain them here.

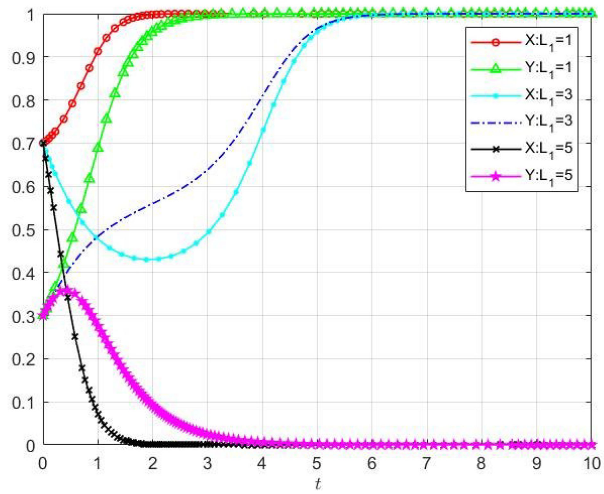

Figure 10. Evolutionary results of L_1 change.

5. Discussion

This paper shows that the increase in the non-sharing party's free-rider penalty, synergistic benefit coefficient, data sharing volume, and data sharing complementary, as well as the decrease in the data sharing cost and loss of revenue of the sharing party have a facilitating effect on the sharing behavior of cultural heritage institutions. One factor in the cultural heritage data sharing process may change the institution's strategy and cause the institution to refrain from sharing. Some researchers [42,43] argue that penalties are more likely to promote sharing behavior than rewards because they stabilize cooperative sharing. Benndorf [44] suggests that financial rewards can significantly impact personal data sharing, and Hui et al. [45] indicate that the public is more willing to share data when the perceived benefits outweigh the perceived risks. The findings show that cultural heritage data sharing behavior is not related to the initial benefit and direct benefit but rather to synergistic benefits, suggesting that institutions are more concerned about the long-term benefits of cultural heritage data sharing and that incentives for them need to focus not only on financial benefits but also on fairness in the distribution of benefits. Data complementarity reflects the integration of unique competitive advantages among different institutions, and only subjects with the right degree of data complementarity can better share and utilize data. Wang et al. [46] mentioned that data-complementary institutions are institutions that gain benefits from sharing, which is positively correlated with the choice of institutions to actively share data. Usually, the higher the cost of data sharing, the lower the willingness to share data. Reducing the data sharing price is mainly achieved by reducing the time cost of the data selection, collation, and delivery in the data sharing process [47]. The risk of privacy breaches is a major cause of lost revenue, and reducing the risk of data breaches will motivate consumers to provide higher-quality data and increase the total income from data sharing. Therefore, these factors can be appropriately adjusted in the evolution of data sharing behavior of cultural heritage institutions to encourage stable institutional participation in sharing over time.

Compared with previous studies, our study broadens the perspective of evolutionary games. It explores the behavioral process of data sharing in cultural heritage institutions at the micro level, enriching the research on cultural heritage with some value. However, there are some shortcomings in this paper, such as the lack of integration of research findings with actual data, which can be verified by accurate cases of cultural heritage data sharing in the future to more accurately reveal the characteristics and process mechanisms of sharing behaviors among cultural heritage institutions.

6. Empirical Research

In 1972, the Convention for the Protection of the World Natural and Cultural Heritage issued by the United Nations Educational, Scientific, and Cultural Organization set off a wave of cultural heritage protection projects [48]. However, the diversity of subjects involved in protecting and transmitting cultural heritage has accelerated the speed of data collection and accumulation but has also made data fragmentation more serious, making it difficult to integrate and widely share cultural heritage resources.

In February 2018, the Association of Southeast Asian Nations (ASEAN) launched the "ASEAN Cultural Heritage Digital Archive" project to explore integrating cultural heritage digital resources in practice [49]. Firstly, the ASEAN Secretariat coordinates the efforts of all parties to carry out coordination, financial support, and technical support, respectively. Secondly, a platform for integrating cultural heritage digital resources has been built independently, with all countries concertedly and actively participating and more than 20 participating institutions adhering to the concept of openness in standardizing and releasing cultural heritage for sharing. Thirdly, it creates unique resources and appropriately applies visualization technology, digital scanning technology, and cloud service technology to the fusion of cultural heritage resources, which improves the core competitiveness of ASEAN cultural heritage and reduces the risk and cost of institutional resource fusion. After the cross-institutional integration project, the platform attracted 60% of young people in Southeast Asia to visit and stimulate their extensive interest in cultural heritage [50]. These developments further expand the access and sharing of ASEAN cultural heritage, strengthen the sense of the cultural identity of ASEAN member countries, and inspire more members of the public and institutions to join the dissemination and sharing of cultural heritage.

Centered on organizational synergy, fusion standards, fusion technologies, and sharing platforms, it is a crucial initiative for cultural heritage sharing in ASEAN countries. Thanks to good environmental policies, the open-mindedness of cultural heritage institutions, proper economic incentives for organizers, distinctive platforms, and the help of emerging technologies, ASEAN cultural heritage digital resource sharing and fusion have achieved tremendous success and significantly contributed to the heritage and sustainable development of cultural heritage in ASEAN countries.

7. Conclusions and Implications

7.1. Conclusions

To solve the problem of the weak motivation and low willingness of institutions to share cultural heritage data, to promote the long-term initiative and sustainability of cultural heritage institutions for cultural heritage data sharing, and to realize the value flow of cultural heritage data, this study applied the theory and method of the evolutionary game theory to explore the long-term evolution law of data sharing among finite rational institutions in a cultural heritage sharing platform at the micro level. We constructed a dynamic evolution model of data sharing by institutions in the cultural heritage sharing platform, analyzed the stability of the system during the game between the two sides of institutions, and focused on various influencing factors that affect the choice of sharing strategies between the two sides. The validity of the results was verified by simulations using the MATLABR 2021b software. The following conclusions were obtained: First, the initial willingness of cultural heritage institutions influences the evolutionary results of their sharing strategies. Second, increasing the non-sharing party's free-rider penalty, the coefficient of synergistic benefit, data sharing volume, and proportion of data complementarity all accelerate the sharing strategy evolution and can effectively promote the sharing willingness of cultural heritage institutions. Third, there is a threshold for the fixed sharing cost and loss of gain. By reducing the loss of gain of sharing parties, we can effectively promote the willingness of cultural heritage institutions to share. Fourth, the initial and direct benefits of sharing do not affect the final evolutionary results.

7.2. Implications

In light of our research's findings, the following paper offers management guidance from the viewpoints of the government and pertinent departments, cultural heritage information platforms, and cultural heritage institutions in an effort to increase the institutions' willingness to share data on the platform and encourage institutions to do so actively:

(1) From the perspectives of the government and related departments:

1. Provide policy support and increase financial investment in cultural industries. While the government places a high value on the preservation and transmission of cultural heritage, it should transfer part of the funds to cultural heritage institutions and enterprises with development potential and provide them with policy support to give impetus to their development.
2. Clear and reasonable incentives and penalties. It is necessary to give full play to the regulatory role of government departments or third-party departments and organizations, and incentives and punishments should be improved to stimulate the willingness of institutions to share by giving them financial or non-financial (reputation, popularity, etc.) diversified incentives. Punish free-riding behavior in the process of data sharing. A perfect punishment mechanism can reduce the occurrence of bad behavior and promote the joint development of the platform and participating institutions.
3. Improve the benefit distribution system. A fair and reasonable distribution of synergistic benefits in sharing can enhance the enthusiasm of both organizations to share and avoid disputes over interests that may lead to a breakdown of cooperation. Heidl et al. [51] suggest that potential free-riding behavior can lead to instability in alliances and that introducing a third party can reduce the opportunistic behavior of alliance members. Therefore, the distribution of collaborative income can be determined through the third-party evaluation agency to comprehensively measure the data sharing amount, contribution input, risk, and other factors of each organization, to ensure openness, transparency, and rationality to protect the interests of each organization and reduce opportunistic behaviors. At the same time, the government and relevant departments need to strengthen supervision and guidance management, such as refining laws and regulations on sharing, formulating sharing standards applicable to different types of data, and clarifying the responsibilities of each stakeholder, in order to optimize the sharing process and promote a good sharing environment and atmosphere among institutions.

(2) From the perspective of cultural heritage institutions:

1. Transform their concepts and strengthen mutual trust in sharing. Increasing the data-sharing volume is also the key to the evolution of sharing strategies. Cultural heritage institutions should adhere to the open concept of "freedom, openness, cooperation, and sharing" and stop considering data as "private property" to increase data sharing. Cooperation among institutions and organizations should be made to establish sharing norms and standards and strengthen mutual trust mechanisms to reduce duplication of efforts and resource waste to reduce the sharing costs. The organization regularly organizes its cultural heritage data to improve its quality and value.
2. Strengthen risk control. Institutions need to enhance their awareness of risk prevention and promptly identify, predict, prevent, and control risks that may arise in the sharing process to reduce risk costs to a certain extent and increase the willingness of both parties to cooperate collaboratively. At the same time, the intellectual property protection system for cultural heritage should be improved to protect the property rights and interests in the sharing and prevent the theft of its core competitive advantages by others. To prevent opportunistic behaviors such as free-riding, institutions can use contracts and agreements as a link between them to clarify the responsibilities and interests of both parties. They can reduce information asymmetry and elimi-

nate opportunistic behaviors by establishing a credit system for cultural heritage institutions.

3. Strengthen technological innovation and personnel training. Relevant skills training is crucial to change individuals' passive awareness of data privacy protection and data value mining in data sharing [52]. Carry out incubation programs that integrate technological innovation and solve technical problems, and encourage institutions to provide technical support for secure data sharing using emerging information technologies such as blockchain, cloud computing, and artificial intelligence. Launch regular training for agency personnel on data collection and processing, data integration and security, infrastructure and technology development and maintenance to improve their sharing capabilities and reduce sharing costs.

(3) From the perspective of cultural heritage information platforms:

1. Construct a mechanism for institutional exchange and dialogue. The trust relationship between institutions is crucial to the cooperation and sharing between the two sides. Therefore, at the early stage of cooperation, the sharing platform can build a scientific and reasonable communication venue for institutions to communicate effectively based on the sharing platform, which can enhance the trust of both sides and reduce the cost of resource sharing.
2. Set up a search mechanism and personalized sharing mode. The degree of data complementarity also determines the degree of sharing between institutions. The stronger the complementarity, the more necessary it is to share to achieve complementary symbiosis and value co-creation between the two sides. Therefore, the platform needs to understand critical information such as institutional background, data type, data volume, and sharing level when selecting institutions to reside in and can set up data retrieval mechanisms for complementary institutions to achieve more efficient sharing and creation of new values. Establish personalized and diversified cultural heritage data-sharing models and mechanisms so that different institutions can find their roles and positioning in the sharing platform to reduce sharing costs.
3. Use emerging technologies to ensure data security. The platform should establish information security and data protection systems, such as strengthening user authentication mechanisms, password access, encryption technology, authority management, and others to realize systematic storage, secure sharing, and complete transformation of relevant data to reduce the risks and profit losses institutions face. Use encryption algorithms, artificial intelligence, virtual reality, and other emerging information technologies to improve the confidentiality and security of data.

The research in this paper has a certain theoretical and practical significance. On the one hand, this paper introduces cultural heritage data sharing into the evolutionary game model, which applies evolutionary game ideas to the data sharing problem and provides a new perspective for research on solving the sharing dilemma and providing reasonable incentives in the cultural heritage field. Furthermore, this paper proposes recommendations from multiple perspectives based on its findings, which can help government departments make policies and reward allocations more scientifically and reasonably. Our recommendations can also help organizers of sharing behavior (sharing platforms and third-party management organizations) provide references for the formulation of sharing-related policies and incentive mechanisms and attract more cultural heritage organizations to join the data sharing of platforms, which is essential for the long-term and stable development of sharing platforms. At the same time, it can provide cultural heritage institutions participating in sharing with guidance on how to implement sharing behaviors in practice, improve the competitiveness of institutions, and contribute to the inheritance and sustainable development of cultural heritage.

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