Evolutionary Game Research on Information Collaboration of River Chief Management Platform from the Perspective of Information Supply Chain

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Abstract: Since the river chief system was implemented, remarkable achievements have been made. However, the river chief management platform also has problems such as information distortion, information lag, and collaboration failure. This paper analyzes the existing problems of the platform, and explores the information collaboration of the management platform from the perspective of the evolutionary game of the information supply chain. Combined with the construction mechanism of information supply chain, the key factors affecting its stable evolution and the equilibrium state that can be reached in the end are obtained. It is of great significance to improve the utilization of information, drive business collaboration through information collaboration, improve the scientific level of decision-making, and finally achieve management collaboration.

1. Introduction

Since the State Council promulgated the Opinions on the Full Implementation of the River Chief System, by the end of 2017, there had been 250,000 river chiefs nationwide. The 31 provinces, municipalities and autonomous regions and the Xinjiang Construction Corps have comprehensively implemented the implementation plan of the rive chief system with remarkable achievements. The "River Chief System" is a major strategy to implement the new development concept and build a beautiful China. It is also an important measure to strengthen the management and protection of rivers and ensure national water security. The river chief system relies on the river chief management platform to play its role. The main body of the river chief system management platform is the river chiefs, river chief office and functional departments. On the basis of making full use of the existing water resources information resources, it appropriately supplements relevant information and develops relevant information services. It is a constructed rive chief information management system and multi-level business application system. There are still many problems in the operation of the river chief management platform. For example, river inspections and projects are not enough. The collected information is used at a low rate. In addition, the incomplete and timely access to information by each department resulted in insufficient information for the river chief to deal with pollution and other issues, making it impossible to make effective decisions. These problems reduce the information transmission and utilization rate to a certain extent, and hinder the implementation of the river chief system.

There are many researches on the river chief system, but most of them focus on the discussion of theoretical issues and the design and implementation of technology. Ren Min pointed out that the inter-departmental coordination of the "River Chief System" is conducive to solving the problems of collaborative failure and fragmentation [1]. Yu Zhenzhen stated that there are problems of inadequate information disclosure and supervision in the river chief system, which limits its implementation [2]. In order to solve the problems and dilemmas in the practice of the river chief system, most scholars focus on the design and implementation of river chief management platform. Feng Jingchun analyzed the construction of the system platform from the aspects of knowledge, technology, and management. It can promote the information construction of the river chief system [3]. Zhou Ji used the Spring framework to design and implement Wuxi's information management platform to promote the

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effective transfer of information and the river chief system to better bring benefits [4].

In order to solve the problem of information collaboration failure in the river chief management platform, this paper studies the information collaboration of the river chief management platform. Information collaboration refers to the deep processing of information using the idea of collaboration. The internal driving force is formed in the information system, so that the information flow has a clear transmission direction, and the various links within the system generate collaboration, which promotes the evolution at the equilibrium critical point and maintains the dynamic balance of the system [5]. Previous studies have mostly applied information systems to areas such as enterprises, government affairs, and urban construction, with little research on water conservancy. Zeng Yuhang used the e-government platform to build a coordinated emergency information mechanism to solve the dilemma of responding to disasters and emergencies [6]. Chen Rui built a smart city information collaboration standard system to ensure the regulation and efficiency of information flow in the management process [7]. Ma Jie built a three-level emergency response information collaboration system in response to problems in China's elderly emergency services [8].

There is an urgent need to improve the efficiency of information transmission between the river chief office and functional departments. In order to improve the information transfer process of the information collaboration subject, this paper studies the information collaboration of the river chief system management platform from the perspective of game analysis of the information supply chain. By analyzing the existing problems of the river chief system management platform, from the perspective of the evolutionary game model of the information supply chain, the construction mechanism of the information supply chain is analyzed. The key factors of the stable evolution of the information supply chain under the river chief system are obtained, and the conditions and possible results of the stable evolution are pointed out. This will help solve existing problems and better implement the river chief system. The river chief office and functional departments of the government need to improve their capabilities, improve information utilization, and promote information collaboration. In addition, it will drive business collaboration, promote the functional transformation of related departments, and finally achieve management collaboration.

2. Construction Mechanism

There is a significant information collaboration between the river chief office and functional departments. Information collaboration is an information activity carried out by two or more subjects to complete a task or solve a problem [9]. Information is asymmetrical. There are differences in information acquisition, transmission, etc. between the river chief office and functional departments. The information supply chain finds missing information and existing problems through the dependency relationship between information subjects. Plan according to the information demand plan proposed by the information demander. Through information acquisition and transmission, balance supply and demand in the process of information sharing to avoid information overload or insufficient information, reduce required costs, and improve information utilization [10]. Effective information organization and coordination promote the sustainable development of information exchange between the subjects. Therefore, the information coordination and overall decision-making of the information supply chain under the river chief system are indispensable. It can improve the utilization rate of information, speed up the decision-making and adjustment of the river chief office and functional departments, and promote the better implementation of the river chief system.

In the information supply chain of river chief system, the river chief office and functional departments are interdependent, and both of them are the information supplier and demander. Information exchange and division of labor can be carried out directly. It can also integrate information under the supervision and incentive mechanism of the government (intermediary), and improve the efficiency of information transmission through indirect cooperation. The river chief information supply chain has the functions of information production, information transmission, information demand and application, and decision-making. The supply chain is mainly composed of three parts: main body layer, activity layer and resource layer, which shows in Figure 1 below.

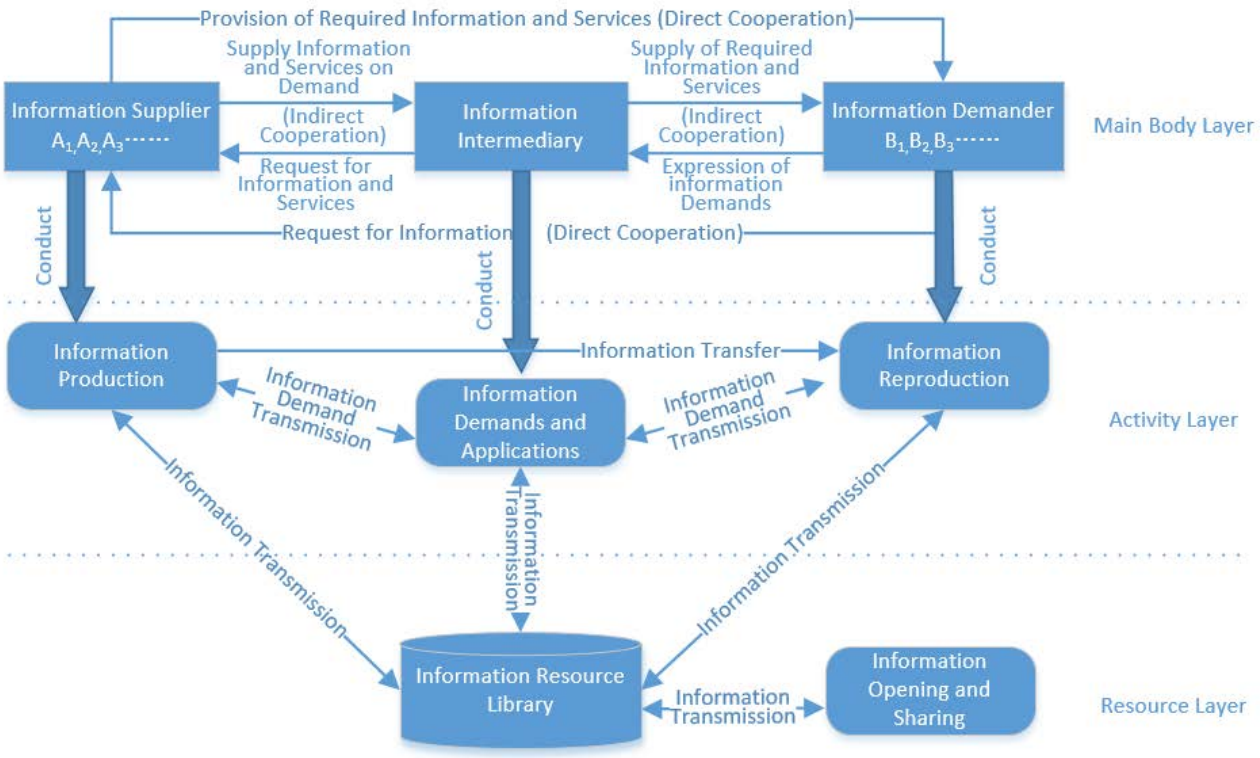

Figure 1 The Basic Structure of the River Chief System Information Supply Chain

In the actual operation mechanism of the river chief system, the organizational structure of the information supply chain presents a network structure model with information intermediation as the core. The information supply chain is multi-layered and interlaced. Each member of the supply chain has multiple channels for obtaining and transmitting information. Through the supervision and incentive of information intermediaries, information can be improved. Members' information can be understood in time to achieve the effect of improving information transmission and utilization. However, closely related subnets also exist within the mesh structure. There is an intricate and ever-changing relationship between members. Different members exchange information in order to achieve common goals. The mesh structure overcomes the problems of information distortion, delay, and fragmentation, strengthens the links between members, and improves information utilization.

3. Evolutionary Game Model

The choice of the structural mode of the river chief information supply chain is the result of the interest game between the information supplier and the information demander. This paper uses evolutionary game theory to analyze the behavioral interaction patterns of members in the information supply chain and the state of the equilibrium structure that the information supply chain can ultimately achieve [11].

The information supply chain consists of three members: information supplier, information demander and information intermediary. A game model with the information supplier and the information demander as subjects of the game was established [12]. The assumptions are as follows. First, both information suppliers and information demanders need to consider their own interests and adjust their strategies according to other members' strategic choices. There are three decision-making options for supply and demand sides: cooperation, non-cooperation, and cooperation with intermediaries. Second, without cooperation, the supplier can obtain the initial information value V_s, the information acquisition cost C_s, the information demander can obtain the initial information value V_d, and the information acquisition cost is C_d. Third, if cooperate, the information communication cost of the supplier is C_s' and the cost of the information communication of the

demander is C_d'. Both of them can get the same information value is V_{sd}, which is an added value formed on the basis of cooperation. It is greater than the cost of information acquisition by them ($V_{sd} > C_s'$, $V_{sd} > C_d'$). Fourth, if the information intermediary participates, its added information value is V_m, and the cost of the required information is C_m ($V_m > C_m$). Both the supplier and demander can obtain additional value V_d' and V_s'. Fifth, in this model, the "cooperation with intermediary" strategy of them is always better than the "non-cooperation" strategy. In reality, the "cooperation with intermediary" strategy always gets more rewards than the "non-cooperation" strategy, so a sane decision-maker will not choose the "non-cooperation strategy". The "non-cooperation" strategy is not considered in this model. In summary, the following Table 1 can be obtained.

Table 1 Payment Matrix of Information Suppliers and Demanders

		Information Suppliers	
		Cooperation with Intermediary (y)	Cooperation with Demanders $(1-y)$
Information Demanders	Cooperation with Intermediary (x)	(A_5, B_5) $A_5 = V_s - C_s + V_m$ $- C_m + V_d'$ $B_5 = V_d - C_d + V_m$ $- C_m + V_s'$	(A_6, B_6) $A_6 = V_s - C_s + V_m$ $- C_m + V_d$ $B_6 = V_d - C_d - C_d'$
	Cooperation with Suppliers $(1-x)$	(A_8, B_8) $A_8 = V_s - C_s - C_s'$ $B_8 = V_d - C_d + V_m$ $- C_m + V_s$	(A_9, B_9) $A_9 = V_s - C_s + V_d$ $+ V_{sd} - C_s'$ $B_9 = V_d - C_d + V_s$ $+ V_{sd} - C_d'$

Assume that the probability that the information supplier chooses the strategy of "cooperating with intermediary" is x, and that of "cooperation with the demanders" is $1-x$. The probability that information demanders choose to "cooperation with intermediary" is y, and that of "cooperation with suppliers" is $1-y$. Available from the payment matrix, the pay of the information supplier choices of "cooperation with intermediary" and "cooperation with the demanders" are $E(S_1)$ and $E(S_2)$. The information demander needs to pay $E(D_1)$ and $E(D_2)$. Formula 1-4 show the function.

$$E(S_1) = A_5 y + A_6(1-y) \quad (1)$$

$$E(S_2) = A_8 y + A_9(1-y) \quad (2)$$

$$E(D_1) = B_5 x + B_8(1-x) \quad (3)$$

$$E(D_2) = B_6 x + B_9(1-x) \quad (4)$$

The total payment function of the supplier and demander is shown in Formula 5-6.

$$E(S) = xE(S_1) + (1-x)E(S_2) \quad (5)$$

$$E(D) = yE(D_1) + (1-y)E(D_2) \quad (6)$$

According to the duplicate dynamic equations of both sides, and substituting Formula 1, 3, 5, and 6, we can get Formula 7.

$$\begin{cases} \dfrac{dx}{dt} = x(1-x)[(A_5 - A_6 - A_8 + A_9)y + A_6 - A_9] \\ \dfrac{dy}{dt} = y(1-y)[(B_5 - B_6 - B_8 + B_9)x + B_8 - B_9] \end{cases} \tag{7}$$

Using Friedman's method [13] to analyze the stability of the equilibrium point of the above function according to the stability of the Jacobian matrix, it can be obtained that the Jacobian matrix is shown in the following Formula 8.

$$J: \begin{bmatrix} (1-2x)[(A_5 - A_6 - A_8 + A_9)y + A_6 - A_9] & x(1-x)(A_5 - A_6 - A_8 + A_9) \\ y(1-y)(B_5 - B_6 - B_8 + B_9) & (1-2y)[(B_5 - B_6 - B_8 + B_9)x + B_8 - B_9] \end{bmatrix} \tag{8}$$

The stability analysis of the five equilibrium points obtained above is performed using the local stability analysis method of the Jacobian matrix, as shown in Table 2 below.

Table 2 Values of $\det j$ and trj of Equilibrium Points

Equilibrium Point	$\det j$	trj
E_1	$(V_m - C_m - V_{sd} + C_s')*$ $(V_m - C_m - V_{sd} + C_d')$	$(V_m - C_m - V_{sd} + C_s') +$ $(V_m - C_m - V_{sd} + C_d')$
E_2	$-(V_m - C_m + C_s')*$ $(V_m - C_m - V_{sd} + C_d')$	$C_s' + V_{sd} - C_d'$
E_3	$-(V_m - C_m - V_{sd} + C_s')*$ $(V_m - C_m + C_d')$	$V_{sd} - C_s' + C_d'$
E_4	$(V_m - C_m + C_s')*$ $(V_m - C_m + C_d')$	$-2(V_m - C_m) - (C_s' + C_d')$
E_5	$\frac{(V_m - C_m + C_s')(V_m - C_m - + C_d')}{(V_{sd})^2} *$ $\frac{(V_m - C_m - V_{sd} + C_s')(V_m - C_m - V_{sd} + C_d')}{(V_{sd})^2}$	0

The stability of the equilibrium point is judged by analyzing the signs of $\det j$ and trj. For discrete systems, if the equilibrium point satisfies $\det j > 0$ and $trj < 0$, the equilibrium point is an evolutionary stability strategy [14-15]. If $\det j > 0$ and $trj > 0$, it is unstable. If $\det j < 0$ then the result is a saddle point. There are four situations: ① $V_m - C_m > V_{sd} - C_s'$ and $V_m - C_m > V_{sd} - C_d'$. ② $V_m - C_m > V_{sd} - C_s'$ and $V_m - C_m < V_{sd} - C_d'$. ③ $V_m - C_m < V_{sd} - C_s'$ and $V_m - C_m > V_{sd} - C_d'$. ④ $V_m - C_m < V_{sd} - C_s'$ and $V_m - C_m < V_{sd} - C_d'$. Based on the above principles, the stability results of the equilibrium points in the four situations in Table 3 can be obtained, and the phase diagram is shown in Figure 2.

Table 3 Stability Results of Evolutionary Games

Equilibrium Point	Situation 1	Situation 2	Situation 3	Situation 4
E_1	Unstable	Saddle point	Saddle point	Stable
E_2	Saddle point	Unstable	Saddle point	Unstable
E_3	Saddle point	Saddle point	Unstable	Unstable
E_4	Stable	Stable	Stable	Stable
E_5				Stable

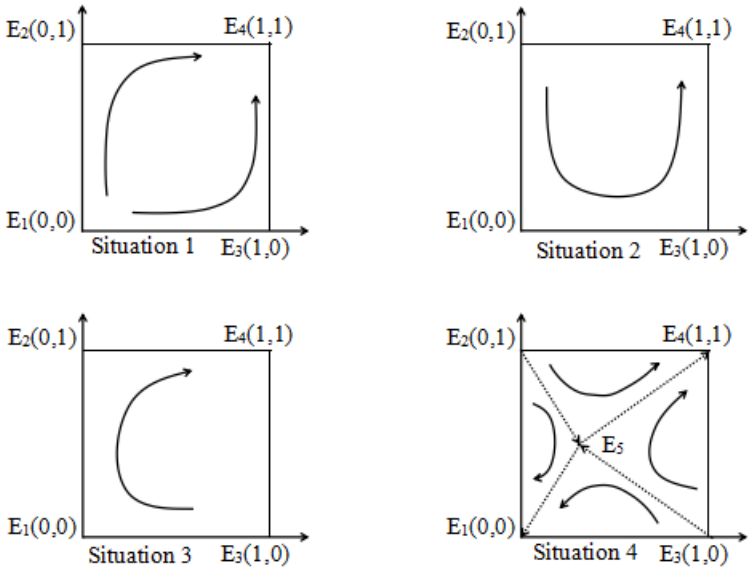

Figure 2 Phase Diagrams for the Four Situations

4. Structural evolution analysis

From the above evolutionary game, in the first three cases, there are two saddle points, one stable point, and one unstable point in the information supply chain of the river chief system. Eventually evolved into a stable strategy of "cooperation with intermediary". If the information benefit $(V_m - C_m)$ that the intermediary organization may provide is greater than the information collaboration benefit $(V_{sd} - C_s')$ or $(V_{sd} - C_d')$ of either member of the information supplier and demander. Regardless of the initial state, the information supply chain of the river chief system will produce an integrated network structure with information intermediary as the core [16]. All members of the information supply chain exchange information with information intermediaries. In order to ensure the smooth flow of information exchange, the information intermediary must process and transmit the acquired information, so as to realize the efficient transmission and utilization of information in the entire information supply chain.

Information intermediaries are mainly government supervision and encouragement mechanisms. It provides professional information services for the river chief office and functional departments, including information production, information transmission, information reproduction, information demands and applications. Government supervision and incentives can improve information transmission and utilization, and achieve information collaboration in information sharing.

From the stability process of case 4, it can be seen that the information benefit $(V_m - C_m)$ obtained by "cooperation with intermediary" is less than the information collaboration benefit $(V_{sd} - C_s')$ or $(V_{sd} - C_d')$ of any member of the information suppliers and demanders. The information supply chain converges to the critical line of various states. If the initial state is in area (E_1, E_2, E_3, E_5), the information supply chain converges to E_1, that is, both suppliers and demanders adopt an evolutionary stabilization strategy of "direct cooperation". If the initial state is in area (E_4, E_2, E_3, E_5), the information supply chain converges to E_4, that is, both of them adopt the evolutionary stabilization strategy of "cooperation with intermediary". It can be seen that the initial state of the game determines the evolutionary game result. The position of the saddle point also affects the results. Assuming that the initial state (x, y) is randomly and uniformly distributed in the area (E_1, E_2, E_3, E_4) shown in Figure 2, the average result after a long-term evolution of the information supply chain is related to the position of the saddle point E_5. If the information

collaboration value V_{sd} is larger, the area (E_1, E_2, E_3, E_5) is larger. The probability of "direct cooperation" between the suppliers and demanders is higher. Conversely, the larger the area of (E_4, E_2, E_3, E_5), the higher the probability of "cooperation with intermediary". In addition, the smaller the value of $V_m - C_m + C_s'$ or $V_m - C_m + C_d'$, the lower the value of information brought by the information intermediary, and the higher the cost of information required. That is, the larger the area of (E_1, E_2, E_3, E_5), the higher the probability of "direct cooperation". Conversely, the probability of "cooperating with intermediary" is higher.

If the suppliers and demanders adopt "direct cooperation", and $C_d + C_d' < C_s + C_s'$, the information demander's information acquisition, organization, and transmission capabilities are strong. In other words, the required information acquisition cost is low, and the information transmission and utilization efficiency is high. Therefore, the information supply chain can establish a demand-driven information exchange mechanism [17]. In the rive chief information supply chain, the rive chief office and functional department are the information supplier and information demander. Identifying the information demands of the information consumer is critical. Mechanisms with clear information demands have higher information utilization. Establishing an information supply chain with government supervision and incentive mechanism as the information intermediary can realize the information collaboration between the suppliers and demanders, thereby driving business collaboration, and then continuously improving the decision-making level to finally achieve management collaboration. Similarly, if $C_d + C_d' > C_s + C_s'$, a supply-driven information exchange mechanism should be established. This requires the information supplier to have a deep understanding of the information demander. It is very necessary to determine information demands based on their characteristics and capabilities, and to forecast and adjust demand changes in a timely manner. By continuously enhancing information acquisition, transmission, and utilization capabilities, the demands of information demanders can be better met.

5. Conclusions

This paper uses the evolutionary game of the information supply chain to analyze the information collaboration of the river chief system management platform. Based on the construction mechanism and structural model of the information supply chain, the key factors affecting the stable evolution of the information supply chain under the river chief system and the equilibrium state that may eventually be reached are analyzed. The main conclusions are as follows.

The evolutionary game of the information supply chain under the river chief system is a complex and constantly changing process. It is affected by the information acquisition, transmission, and utilization capabilities of the river chief system and functional departments, as well as that of information intermediaries. An evolutionary stabilization strategy can be obtained through tripartite coordination. A stable information supply chain is of great significance for the in-depth development of information resources and the promotion of cooperative innovation. The stronger the service capacity of an information intermediary organization, the more it can promote the formation of a network-structured information supply chain with information intermediation as its core. On the contrary, there is a higher probability that the suppliers and demanders choose "direct cooperation". An unstable information supply chain will waste information resources and increase the risk of information transmission. Coordination of information intermediaries is required to reduce information costs, improve information utilization, and then increase information revenue. Finally, the goal of promoting the optimization and adjustment of the information supply chain and forming a sustainable and stable state will be achieved.

It is important to establish an information supply chain with government supervision and incentive mechanisms as the information intermediary. It provides available resources for both suppliers and demanders and adjusts promotion strategies. It is conducive to enhancing the information acquisition, transmission, and utilization capabilities of both suppliers and demanders, and to the greatest extent

possible to solve the existing information distortion, information lag, fragmentation, and collaborative failure of the management platform. By synchronizing information, business collaboration will be driven. Improving the level of business intelligence and scientific decision-making can enhance the development and utilization of information, promote the transformation of related department functions, and management collaboration will be ultimately achieved. However, in order to meet the requirements of environmental change and better implement the river chief system policy, the supervision and incentive mechanism of the river chief office, functional departments and the government must continuously improve the required capabilities and adjust the corresponding information demands according to environmental requirements. It will promote the continuous development of the information supply chain. In addition, there are many research angles and contents of information collaboration under the rive chief system that require further research and exploration.

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