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Information Coordination Strategy in Rolling Stock Manufacturing: An Evolutionary Game Approach

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Abstract: In the rail vehicle manufacturing industry, effective information coordination between manufacturers and suppliers is crucial for supply chain performance. However, the presence of externalities can complicate the strategic choices of these stakeholders. This paper investigates the information coordination strategy between rail vehicle manufacturers and suppliers, considering the impact of externalities. By employing evolutionary game theory, we construct an interest matrix and analyze the equilibrium points and strategic choices under various scenarios. Our findings reveal that the degree of information cooperation, the distribution of cooperation income, and the unilateral opportunity income are the key factors influencing the choice of cooperation strategy. Specifically, a higher degree of information synergy and a more balanced distribution of cooperation benefits promote the adoption of cooperation strategies. Conversely, high unilateral opportunity benefits hinder cooperation. These insights provide valuable guidance for managers and decision-makers in the rail vehicle manufacturing industry to design effective information coordination mechanisms and enhance supply chain performance. By understanding the factors that drive cooperation and the strategic dynamics between manufacturers and suppliers, stakeholders can make informed decisions to foster collaboration and optimize their operations.

Keywords: evolutionary game; externality; information coordination; network type

1 INTRODUCTION

The logistics network of rolling stock manufacturing enterprises mainly includes three nodes and two paths, among which three nodes refer to suppliers, manufacturers (Main Engine Factory) and customers. The two paths refer to the transportation of parts from suppliers to manufacturers (Main Engine Factory) and the transportation of products from manufacturers (Main Engine Factory) to customers, as shown in Fig. 1.

In view of the fact that most of the finished products of rail vehicle manufacturing enterprises are large equipment such as bullet trains and subways, and the delivery method is relatively simple, usually delivered directly to customers for the operation of rail vehicles. Therefore, this paper mainly studies the transportation of parts from the supplier logistics department to the manufacturer (Main Engine Factory) logistics department (hereinafter referred to as "manufacturer" and "supplier"), as shown in Fig. 2. In the process of information coordination, suppliers upload their inventory status, product information, order information, delivery information, order lead time, documents, delivery time and other information to the supplier logistics information platform, while Main Engine Factory upload their maintenance parts logistics information, production plan, inventory information, procurement information and other related information to the manufacturer logistics information platform. Then the information coordination between the supplier and the manufacturer's logistics information platform can realize the information coordination between the two groups. However, the existing problem is how to build the coordination between the two information platforms and under what circumstances the two platforms will realize the information coordination.

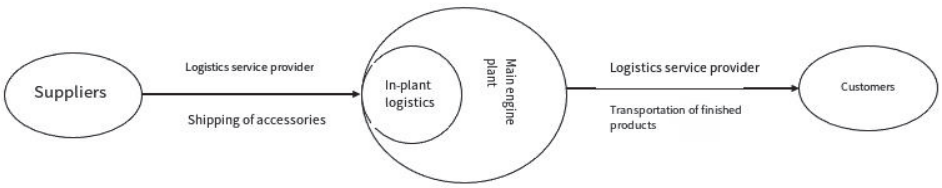

Figure 1 Overall situation of logistics network of network rolling stock manufacturing enterprises

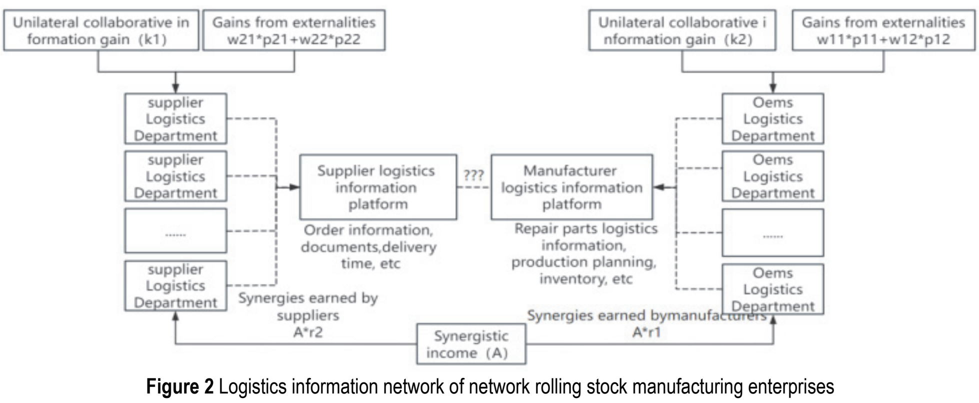

Figure 2 Logistics information network of network rolling stock manufacturing enterprises

Information collaboration plays an extremely important role in improving the operating efficiency and reducing the operating cost of a rolling stock manufacturing enterprise. Take a rolling stock manufacturing in South China and Siemens Group as an example.

A rolling stock manufacturing enterprise in South China, with 21 subsidiaries worldwide, is a typical group structure with cross-region, multi-subsidiary, multi-division and cross-business fields. However, four years ago, the enterprise had the problem of lack of effective coordination and integration among information systems. Each informatization implementation process is an independent behavior, and each department only focuses on its own needs. For example, the implementation of PDM only considers the needs of the design department, the implementation of ERP only focuses on the needs of the business department, which leads to the coordination between organizations and various business areas being very difficult. In the process of production and manufacturing, due to more than 10000 parts of the locomotive, and complex product structure and process, many types and quantities of materials, long processing cycle, often lead to the design, procurement, supply chain, production and other processes being uncontrollable, seriously affecting production efficiency.

Siemens Transportation, a subsidiary of Siemens Group abroad, its subsidiaries, branches and various business units are all over the world, and it is also a typical rolling stock manufacturing enterprise. Before the implementation of the information transformation strategy, there is an isolated information processing plan among various agencies, which leads to the information of each department only uploaded to the information system of each department. Different data sources form an island, the formation of information exchange barriers, communication barriers between departments, unable to carry out information integration, resulting in a quarter of the team's time being used to solve the problem of data integration, time-consuming and labor, but also seriously dragging down the operational efficiency of the enterprise. After the implementation of digital transformation, Siemens Transportation adopts a seamless data access system to break data barriers, and all departments can call the information they need at any time, which greatly improves operational efficiency and reduces production costs.

Evolutionary game breaks the assumption that both sides of the game are completely rational in classical game theory. Based on the perspective of "limited rationality", evolutionary game takes the group as the research object, combines the dynamic evolution process with game theory, and evolves the final strategy combination through repeated games, continuous learning and adjustment in the game process, and the evolutionary principle of "survival of the fittest". However, in the rolling stock manufacturing enterprises, due to the influence of interest relationship, information level and other factors, the participants are bounded rational, and it is difficult to get the final decision in a game, so the traditional Bayesian, differential and incomplete dynamic game models cannot get the optimal equilibrium solution in the information collaborative game decision. Therefore, the evolutionary game method is more suitable for the research of information cooperation strategy under the background of rolling stock manufacturing enterprises.

To sum up, the current information coordination level of network rail vehicle manufacturing enterprises is low, which brings a series of problems such as low logistics efficiency and high logistics cost, which also highlights the importance of information coordination. Therefore, the research questions of this paper are as follows: (1) Under the background of network rail vehicle manufacturing enterprises, under what circumstances will the participants choose the information coordination strategy? (2) What are the factors that affect the information collaboration between manufacturers and suppliers? (3) How do these factors affect the choice of information collaboration strategies of manufacturers and suppliers? In view of the above problems, this paper, from the perspective of information synergy, adopts the method of evolutionary game to study the information synergy strategy between network rail vehicle manufacturers and suppliers. On the one hand, this paper proves that a higher degree of information synergy promotes cooperative behavior, and a more balanced distribution of cooperation benefits ensures the long-term stability of cooperation. On the other hand, high unilateral opportunity income impedes the adoption of cooperative strategies.

The following chapters of this paper are arranged as follows: the second chapter summarizes the existing researches from three aspects: information synergy, evolutionary game and externality effect; the third chapter constructs and analyzes the logistics information cooperation model of rolling stock manufacturing enterprises based on evolutionary game. In the fourth chapter, the sensitivity of each parameter is analyzed. The fifth chapter summarizes and looks forward to the future.

2 LITERATURE REVIEW

2.1 Information Synergy

Different from the traditional research on information resource allocation, the research on information synergy emphasizes the use of the initiative of the subject, and realizes the co-construction and sharing of various information resources through orderly division of labor and cooperation. Francesco et al. believe that information synergy is mandatory and can be divided into four levels: order exchange, operational information synergy, strategic information synergy, and strategic and competitive information synergy [1].

In terms of the application of information synergy theory, the academic circle has also conducted a lot of research. Keyuan Cai et al. studied the information synergy strategy of manufacturer's quality assurance and supplier's quality assurance under the condition of uncertain demand [2]. Yang Man et al. considered Stackelberg game and studied the information coordination strategy of e-commerce sales model in dual-channel supply chain [3]. Wang, T. Y. et al. studied a mixed form of online retail supply chain and established four types of information coordination models [4]; Zili Guan et al. studied the demand information synergy problem in two competing supply chains, and investigated the impact of information synergy on price and service decision making by constructing a multi-level game framework, and explored the value of information synergy to each supply chain [5]. Molin Liu et al. studied the information synergy problem in the supply chain of fresh agricultural products e-commerce, focusing on the impact of freshness elasticity on the information synergy strategy [6]; Yu Man et al. studied the different information synergy modes among supply chain members under the cap and trade supervision, which are no information synergy, partial information synergy and complete information synergy [7]. Yan, K. studied the impact of blockchain technology on supply chain information collaboration and operating costs, combined with retailers' sensitivity to information, developed a three-level supply chain model based on blockchain technology, and found that if the adoption of blockchain is valuable to the supply chain, then the amount of information sensitivity should be moderate [8].

2.2 Evolutionary Game

Based on the conditions of bounded rationality and incomplete information, Nash proposed evolutionary game theory, which holds that game theory agents cannot reach the stable equilibrium of the whole game theory system through one-time decisions, and they must continue to repeatedly game their game theory strategies through continuous learning, adjustment and optimization, and finally achieve the overall game theory balance. At the same time, each game agent can realize repeated game by constantly adjusting his behavior strategy according to the principle of maximizing his own income, so that the system tends to the stable equilibrium state. However, since the equilibrium point of evolutionary game is not the only one, the game system can have multiple evolutionarily stable strategies under various circumstances and conditions.

Evolutionarily stable strategy and replication dynamics are two core contents of evolutionary game theory. With the wide application of evolutionary game, more and more scholars at home and abroad use evolutionary game theory to explain the problems of management economy. Mahmoudi and Rasti-Barzoki (2018) constructed an evolutionary game model of the impact of government subsidies and taxes on the performance of enterprises in the supply chain, and found that the government's tax policy has a significant effect on the performance and behavior of enterprises between its revenue and environmental objectives [9]. Zhu et al constructed an evolutionary pattern among local governments, railway enterprises and residents, and determined the limit conditions for the stability of the stakeholder game system. [10]. Aiming at the quality problem of traditional Chinese medicine, Hu et al established a four-dimensional evolutionary game model between suppliers and manufacturers, obtained the results of the model through the analysis of stability strategy and evolutionary path, and analyzed the influence of supplier selection ratio, rewards and punishments and other parameters on the evolutionary steady state [11]. In order to analyze the behavioral strategies of manufacturers to reduce carbon emissions and the conditions for imposing carbon tax to encourage manufacturers to reduce carbon emissions when consumers are more willing to buy low-carbon products, Guo et al. established an evolutionary game model and analyzed the impact of consumers' low-carbon preference, carbon emission reduction and carbon tax emission reduction on the carbon emission reduction of manufacturing enterprises [12]. Wang, T. Y. combined with evolutionary game theory to construct a tripartite game model of manufacturing capacity sharing, discussed the capacity sharing behavior of manufacturing enterprises from the perspective of blockchain, analyzed the replication dynamics and evolutionary stability of the model by using evolutionary game theory, and used MATLAB software to carry out numerical simulations to analyze the influence of parameter changes on the evolutionary results [13]. Liu et al. used the evolutionary game method to build a tripartite evolutionary game model to study the behavior of community e-commerce platforms under different delay parameters [14].

2.3 Externalities

In economics, externality refers to the phenomenon that after the economic behaviors of market participants have positive or negative impacts on society or other entities, the gains or losses brought by such impacts are not borne by the entities. As for the study of externality effect, most of the existing literature focuses on product pricing strategy, channel power structure and technology research and development.

In terms of product pricing, Yi and Yang studied the relationship between retailers' marketing objectives and manufacturers' wholesale pricing in a market with network externalities [15]. Zhou studied the game model of new products and existing products under the condition of network externalities, and discussed the pricing strategy [16].

In terms of channel power distance, Xu studied the influence of channel contract on pricing strategy and profitability in the case of network externality, compared the channel performance under the two channel contacts, and found that the marginal cost of the manufacturer played a crucial role [17]. Xu et al built a theoretical model to study the government's supervision mechanism on shared bicycles under the condition of externality, and realized the trade-off between the harm of non-users represented by the negative externality cost generated by shared bicycles and the benefits of users represented by user satisfaction [18].

In terms of information coordination of logistics system of network rail vehicle manufacturing enterprises, previous studies focused on the construction of logistics information platform, the application of information network technology to realize supply chain information coordination, the multi-level supply chain information sharing mode, and the evaluation index of supply chain synergy. It cannot fully match the technical requirements of information synergy and the objectivity of the evaluation of synergy effect in the manufacturing enterprises with network supply chain as the framework. In order to realize the information coordination of the logistics system of network rail vehicle manufacturing enterprises, the logistics information coordination must be redefined. Therefore, this paper chooses to adopt the evolutionary game method to build the logistics system information cooperation theory model of network rail vehicle manufacturing enterprises, and considers the influence of externalities to propose effective information cooperation strategy selection (Tab. 1).

Table 1 Comparison of Logistics Information Collaboration Literature

	Information cooperation	Evolutionary game	Externality
Mahmoudi [9]		√	
Xu [17]	√		√
Xu [18]			√
This article	√	√	√

3 MODEL

3.1 Problem Description

The information cooperation of rolling stock manufacturing enterprises mainly has the following characteristics:

(1) Under normal circumstances, member enterprises are both information providers and information recipients. While providing information to others, they will also receive information from others.

(2) There are certain differences and similarities between members in terms of information type and amount of information, etc. Only on this basis can information collaboration bring value to others, thus promoting the development of information collaboration.

(3) After the implementation of information collaboration, because each member enterprise knows the relevant information in advance, its decision-making ability and risk prediction ability will be greatly improved, thus bringing benefits to the enterprise, but the improvement range is different due to the strength of the absorption capacity.

(4) Network enterprises will carry out repeated cooperation and information collaboration on the basis of contract provisions. With the increase of cooperation times, the information relationship between them will be strengthened, and information collaboration will be easier to carry out.

(5) Enterprises will be willing to continue to cooperate only when they obtain satisfactory benefits from information cooperation. If members of the organization think that the benefits brought by information cooperation can cover their costs, they will be willing to continue to cooperate.

(6) When the cooperative enterprise of a member of the network enterprise expires or becomes invalid due to the breach of contract by one of the members, the information collaboration will be terminated. Therefore, when an enterprise withdraws from the organizational network, the entire network organization will face the risk of information loss.

As a group enterprise, the rolling stock manufacturing enterprise has many subsidiaries, branches, third-party logistics enterprises, etc., and a large number of upstream suppliers. These entities have a large amount of information among themselves, and their information systems are independent, and the level of information standardization is low, resulting in low information synergy efficiency and affecting business operations.

Therefore, rolling stock manufacturing enterprises plan to build a unified information cooperation platform, a number of subsidiaries, branches, third-party logistics enterprises and suppliers will upload their own resources and information data to the platform, each enterprise according to their own needs to obtain their own information, improve the level of information coordination, to achieve efficient docking logistics needs. On this platform, manufacturers and many branches upload their demand information, storage information, production planning information and other information to the platform, while suppliers upload their distribution time and inventory information to the platform. Information coordination is formed between the two sides, and each obtains what he needs for win-win cooperation.

In this paper, a two-level supply chain is constructed, including rolling stock manufacturing enterprises (manufacturers) and suppliers, and through evolutionary game analysis, what information coordination strategies will be adopted by the two entities at different stages. In this paper, it is assumed that both parties are not completely rational, and the enterprise group pursues the maximization of enterprise value, that is, while pursuing the maximization of profit, the enterprise also considers the external effects of the decision on the enterprise itself, the society and the environment, which will also lead to the evolution and stability of the two players after a long time of continuous game, and the final information synergy strategy is determined.

3.2 Model Construction

This paper takes rolling stock manufacturing enterprise group and supplier group as the research object. The strategy set of the two groups is {information synergy/information non-synergy}, and divides the externalities suffered by enterprises into two categories of positive and negative externalities. When both parties choose information synergy, the whole group is in the complete information synergy mode. If one party chooses no information coordination, the system is in unilateral information coordination mode.

The parameters of this paper are set as follows.

(1) In this supply chain, there is information asymmetry between the manufacturer and the supplier. During the game, the two sides can only choose two strategies: information coordination and no information coordination. If the manufacturer chooses information coordination, it is denoted as; if the manufacturer chooses no information coordination, it is denoted as $1 - x$ $(0 \le x \le 1)$; If the supplier chooses information coordination as, and chooses not to carry out information coordination, then it is $1 - y$ $(0 \le y \le 1)$.

(2) When both parties make decisions on information collaboration, the first consideration is their own interests, that is, whether they can benefit from the process of information collaboration π_i $(i = 1, 2)$. Therefore, suppose that the normal benefits of both parties are as follows: when one party chooses information synergy, the other party will gain additional information benefits k_i $(i = 1, 2)$.

(3) In the supply chain, with the gradual deepening of cooperation between manufacturers and suppliers, the two parties will become more familiar with each other and have a higher degree of trust in each other, which will lead to an increase in information synergy. In this paper, D_i $(i = 1, 2)$

is used to represent the degree of information collaboration between the two sides.

(4) When both parties adopt the information synergy strategy, both parties will obtain the synergistic value; r_i (i = 1, 2) is the distribution proportion of the total income of both parties. If A is the total synergistic income, the profit shared by the enterprise can be used to express by Ar_i (i = 1, 2), in which $r_1 + r_2 = 1$.

(5) The cost of manufacturers and suppliers participating in information synergy is expressed by C_i (i = 1, 2).

(6) At the same time, in the process of information collaboration, manufacturers and suppliers may have the risk of information disclosure, which will bring losses to enterprises, which is the indirect cost of enterprises participating in information collaboration. If l_i is used to represent the risk brought by the enterprise to adopt the information coordination strategy, $l_i D_i$ can be regarded as the risk cost paid by the enterprise to adopt the information coordination strategy.

(7) The probabilities of positive and negative externality effects of the manufacturer group in the complete information synergy model and unilateral information synergy model are respectively P_{11}, P_{12} and P_{11}', P_{12}' and the corresponding benefits are respectively w_{11} and $-w_{12}$. The probability of producing positive and negative externality effects of the supplier group under the complete information synergy mode and unilateral information synergy mode is P_{21}, P_{22} and P_{21}', P_{22}' respectively, and the corresponding benefits are w_{21} and $-w_{22}$.

Based on the above parameter Settings and assumptions, the profit matrix of manufacturers and suppliers in different decision situations can be obtained, as shown in Tab. 3.

Table 2 Parameter settings

Parameters	Parameters
π_i	Normal earnings
D_i	The degree of information collaboration
C_i	Information collaboration cost
l_i	Risk index
λ_i	Discount factor for future synergies
k_i	Unilateral acquisition of information benefits
r_i	Distribution coefficient of synergistic gain
A	Total synergistic income
P_{ij}	The probability of positive and negative externalities in the perfect information synergy model
P_{ij}'	The probability of positive and negative externalities under unilateral information synergy model
$\pm w_{ij}$	The probability of positive and negative externalities under unilateral information synergy model

Table 3 Payoff matrix of both sides of the game

Both sides of the game		Manufacturers	
		Synergy (x)	Unsynergy ($1-x$)
Vendors	Synergy (y)	$\pi_1 + Ar_1 - C_1 - l_1 D_1 + \lambda_1 \left(w_{11}P_{11} - w_{12}P_{12}\right)$ $\pi_2 + Ar_2 - C_2 - l_2 D_2 + \lambda_1 \left(w_{21}P_{21} - w_{22}P_{22}\right)$	$\pi_1 + k_1 D_1 - C_1 + \lambda_1 \left(w_{11}P_{11}' - w_{12}P_{12}'\right)$ $\pi_2 + l_2 D_2 + \lambda_2 \left(w_{21}P_{21}' - w_{22}P_{22}'\right)$
	Unsynergy ($1-y$)	$\pi_1 + l_1 D_1 + \lambda_1 \left(w_{11}P_{11}' - w_{12}P_{12}'\right)$ $\pi_2 + k_1 D_2 - C_2 + \lambda_2 \left(w_{21}P_{21}' - w_{22}P_{22}'\right)$	π_1 π_2

The expected benefits of manufacturer information collaboration are:

$$U_{11} = y\left(\pi_1 + Ar_1 - C_1 - l_1 D_1 + \lambda_1\left(w_{11}P_{11} - w_{12}P_{12}\right)\right) + \\ + (1-y)\left(\pi_1 - l_1 D_1 + \lambda_1\left(w_{11}P_{11}' - w_{12}P_{12}'\right)\right)$$

The expected benefits when manufacturer information is not synergistic are:

$$U_{12} = y\left(\pi_1 + k_2 D_1 - C_1 + \lambda_1\left(w_{11}P_{11}' - w_{12}P_{12}'\right)\right) + \\ + (1-y)\pi_1$$

The average expected return of the manufacturer is:

$$\overline{U_1} = xU_{11} + (1-x)U_{12}$$

Then the manufacturer chooses the replication dynamic equation of information synergy as:

$$F(x) = \frac{\mathrm{d}x}{\mathrm{d}t} = x\left(U_{11} - \overline{U_1}\right)$$

$$F(x) = x(1-x)\left\{D_1\left(yk_2 + l_1\right) + Ayr_1 - \lambda_1\left[(-1+2y)P_{11}' - \\ -yP_{11}\right]w_{11} + \left[(1-2y)P_{12}' + yP_{12}\right]w_{12}\right\}$$

The expected benefits of supplier information collaboration are as follows:

$$U_{21} = x\left(\pi_2 + Ar_2 - C_2 - l_2 D_2 + \lambda_2\left(w_{21}P_{21} - w_{22}P_{22}\right)\right) + \\ + (1-x)\left(\pi_2 - l_2 D_2 + \lambda_2\left(w_{21}P_{21}' - w_{22}P_{22}'\right)\right)$$

The expected benefits when supplier information does not cooperate are:

$$U_{22} = x\left(\pi_2 + k_1 D_2 - C_2 + \lambda_2\left(w_{21}P_{21}' - w_{22}P_{22}'\right)\right) + \\ + (1-x)\pi_2$$

The average expected return of manufacturers is:

$$\overline{U_2} = yU_{21} + (1-y)U_{22}$$

Then the manufacturer chooses the replication dynamic equation of information synergy as:

$$F(y) = \frac{\mathrm{d}y}{\mathrm{d}t} = y\left(U_{21} - \overline{U_2}\right)$$

$$F(y) = y(1-y)\left\{D_2\left(xk_1 + l_2\right) + Axr_2 - \lambda_2\left[(-1+2x)P_{21}' - \\ -xP_{21}\right]w_{21} + \left[(1-2x)P_{22}' + xP_{22}\right]w_{22}\right\}$$

According to the stability discrimination method, the Jacobian matrix is constructed as:

$$\begin{bmatrix} (1-2x)\{D_1(yk_2+l_1) + Ayr_1 - & x(1-x)\{D_1(yk_2+l_1) + Ayr_1 - \\ -\lambda_1[((1-2y)P_{11}' - yP_{11})w_{11} + & -\lambda_1[((1+2y)P_{11}' - yP_{11})w_{11} + \\ +((1-2y)P_{12}' - yP_{12})w_{12}]\} & +((1-2y)P_{12}' + yP_{12})w_{12}]\} \\ y(1-y)\{D_2(xk_1+l_2) + Axr_2 - & (1-2y)\{D_2(xk_1+l_2) + Axr_2 - \\ -\lambda_2[(1-2x)P_{21}'w_{21} - xP_{21}w_{21} + & -\lambda_2[(-1+2x)P_{21}'w_{21} - xP_{21}w_{21} + \\ +((1-2x)P_{22}' - xP_{22})w_{22}]\} & +((1-2x)P_{22}' + xP_{22})w_{22}]\} \end{bmatrix}$$

Based on the Jacobian matrix, the equilibrium points are analyzed, and Tab. 4 is obtained

$$x^* = \frac{\lambda_2 \left(w_{21}P_{21}' - w_{22}P_{22}'\right) + l_2 D_2}{2\lambda_2 \left(w_{21}P_{21}' - w_{22}P_{22}'\right) - \lambda_2 \left(w_{21}P_{21} - w_{22}P_{22}\right) - k_1 D_2 - Ar_2}$$

$$y^* = \frac{\lambda_1 \left(w_{11}P_{11}' - w_{12}P_{12}'\right) + l_1 D_1}{2\lambda_1 \left(w_{11}P_{11}' - w_{12}P_{12}'\right) - \lambda_1 \left(w_{11}P_{11} - w_{12}P_{12}\right) - k_2 D_1 - Ar_1}$$

Table 4 Stability analysis

Equilibrium Point	J_1	J_2	Results
(0, 0)	-	-	ESS
(0, 1)	Uncertain	Uncertain	Instability
(1, 0)	Uncertain	Uncertain	Instability
(1, 1)	-	-	ESS
(x^*, y^*)	±	0	Saddle Point

4. SIMULATION RESULTS AND DISCUSSION

4.1 Evolution Behavior Path of Both Game Players

According to the analysis in the previous chapter, whether the manufacturer and supplier choose to carry out information collaboration mainly depends on the choice of the other side and the judgment of the enterprise itself on the expected income. According to the parameters

$$x^* = \frac{\lambda_2 \left(w_{21}P_{21}' - w_{22}P_{22}'\right) + l_2 D_2}{2\lambda_2 \left(w_{21}P_{21}' - w_{22}P_{22}'\right) - \lambda_2 \left(w_{21}P_{21} - w_{22}P_{22}\right) - k_1 D_2 - Ar_2}$$

$$y^* = \frac{\lambda_1 \left(w_{11}P_{11}' - w_{12}P_{12}'\right) + l_1 D_1}{2\lambda_1 \left(w_{11}P_{11}' - w_{12}P_{12}'\right) - \lambda_1 \left(w_{11}P_{11} - w_{12}P_{12}\right) - k_2 D_1 - Ar_1}$$

It can be found that the factors affecting enterprise decision-making include the degree of information synergy, the total collaborative income, the distribution coefficient of income, the benefit of unilateral access to information and the risk index, etc. The following will further analyze the influence degree of the above factors.

The initial parameters of this paper are set as follows: $D_1 = 10$, $D_2 = 8$, $C_1 = 20$, $C_2 = 15$, $k_1 = 1.2$, $k_2 = 1.2$, $r_1 = 0.6$, $r_2 = 0.4$, $A = 100$, $l_1 = 0.6$, $l_2 = 0.4$, $P_{11} = 0.7$, $P_{12} = 0.3$, $P_{21} = 0.6$, $P_{22} = 0.4$, $P_{11}' = 0.3$, $P_{12}' = 0.7$, $P_{21}' = 0.4$, $P_{22}' = 0.6$, $w_{11} = 5$, $w_{12} = 10$, $w_{21} = 8$, $w_{22} = 3$.

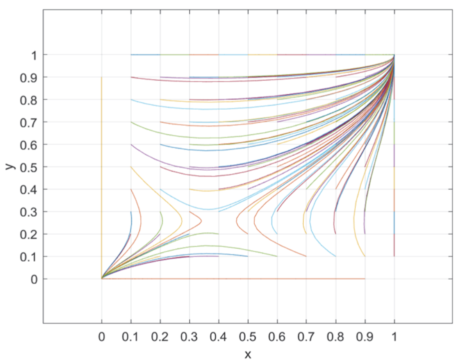

Figure 3 Evolutionary game behavior path of both sides

The initial parameters are substituted into MATLAB to simulate the evolutionary behavior path of both sides of the game, and the results as shown in Fig. 3 are obtained. It is found that the final stable strategy of the evolutionary game of both sides are (0, 0), (1, 1), that is, both sides either choose information coordination or neither chooses information coordination.

4.2 Influence of Information Cooperation Degree on Evolution Result

As can be seen from Fig. 4, when other parameters are fixed and the degree of information synergy is low, there is a high probability that the manufacturer and supplier will choose information dissynergy. Even if the manufacturer chooses information synergy at the beginning, as time goes by, the manufacturer will find that the information synergy cannot meet its expected benefits and even incur losses. Therefore, the manufacturer will adjust its strategy and gradually evolve towards information dissynergy. However, with the increase of information synergy, manufacturers and suppliers gradually find that information synergy will bring them additional benefits, so both sides will tend to choose information synergy. Therefore, for managers, they should focus on improving the degree of information synergy between manufacturers and suppliers by investing in compatible information systems, standardized data formats, and fostering a culture of trust and collaboration.

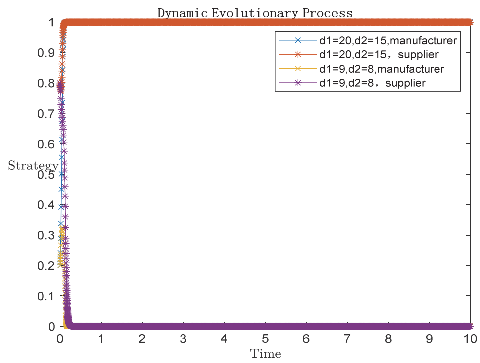

Figure 4 Influence of information synergy degree on evolutionary results

4.3 Influence of Distribution Coefficient of Synergistic Income on Evolutionary Results

As can be seen from Fig. 5, when other parameters are given, when the profit distribution coefficient of the manufacturer is lower than 0.4 or that of the supplier is lower than 0.3, the manufacturer and supplier will find that the benefits they gain in the process of information cooperation are difficult to cover the costs they pay, and then they will be more inclined to choose the strategy of information non-cooperation. On the other hand, when $0.4 \le r_1 \le 0.7$ and $0.3 \le r_2 \le 0.6$,both manufacturers and suppliers are profitable, both of them are more inclined to choose the information synergy strategy. It follows that managers and policymakers should also ensure that the benefits of cooperation are distributed fairly among partners, taking into account their respective contributions and risks, for example by designing fair distribution mechanisms and reward and punishment systems.

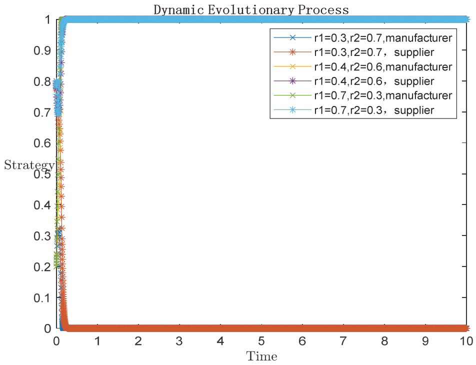

Figure 5 Influence of distribution coefficient of synergistic income on evolutionary results

4.4 Influence of Unilateral Opportunity Return on Evolutionary Outcome

As can be seen from Fig. 6, when other conditions are fixed, when unilateral opportunity return k_1, $k_2 \leq 1.5$, the unilateral opportunity return brought by the manufacturer and supplier only relying on the other party to carry out information synergy alone is too small to meet the demand, while information synergy can bring them more benefits. Therefore, both parties will choose the information synergy strategy.

When $k_1 = k_2 > 5$, the unilateral opportunity return was high enough, and both manufacturers and suppliers believed that information synergy not only could bring enough benefits to themselves, but also would generate costs and bring benefits to the other side. Therefore, both sides were more inclined to the strategy of information dissynergy.

In response to this situation, policymakers can support the adoption of information synergy strategies by providing incentives for information sharing, establishing industry standards, designing reasonable reward and punishment mechanisms, and regulating opportunistic behaviors.

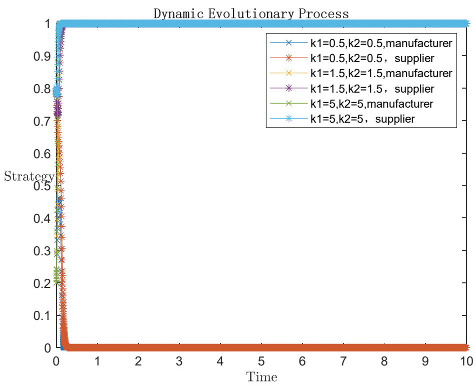

Figure 6 Influence of unilateral opportunity return on evolutionary outcome

5 CONCLUSION

In this paper, evolutionary game method is used to study the information coordination strategy between networked rail vehicle manufacturers and suppliers. The results show that the degree of information cooperation, the distribution of cooperation income and the unilateral opportunity income are the key factors affecting the choice of cooperation strategy. Specifically, we demonstrate that a higher degree of information synergy promotes cooperative behavior, and that a more balanced distribution of cooperative benefits guarantees long-term stability of cooperation. On the other hand, high unilateral opportunity income impedes the adoption of cooperative strategies. Our research has made some contributions to the literature on supply chain management and information coordination. First, we extend the application of evolutionary game theory to the background of rolling stock manufacturing, providing a new perspective for information sharing and cooperation in rolling stock manufacturing. Second, we identify key factors that influence the choice of coordination strategies and provide insights into how these factors interact to shape evolutionary outcomes. Third, we emphasize the importance of designing effective mechanisms to promote information synergy, balance the distribution of cooperative benefits, and reduce opportunistic behavior in supply chain partnerships. Our findings have important implications for managers and decision makers in the rail vehicle manufacturing industry. Managers should focus on increasing the degree of information synergy between manufacturers and suppliers by investing in compatible information systems, standardized data formats, and fostering a culture of trust and collaboration. They should also ensure that the benefits of cooperation are fairly distributed among partners, taking into account their respective contributions and risks. Policymakers can support the adoption of collaborative strategies by providing incentives for information sharing, establishing industry standards, and regulating opportunistic behavior.

Despite this contribution, our study has some limitations that future research can address. First, our model assumes a simplified two-tier supply chain structure, whereas in reality the network of manufacturers and suppliers can be more complex and dynamic. Future research could extend our framework to consider multiple levels of suppliers, competing manufacturers, different types of information flows, etc. Second, our simulations are based on a set of assumptions and parameter values that may not fully capture the diversity and complexity of real-world supply chains. Future research could use empirical data from the rail vehicle manufacturing industry to validate our findings and explore the sensitivity of the results under different assumptions and scenarios. Finally, this study makes a comprehensive analysis of the information cooperation strategy of the rolling stock manufacturing enterprises, focusing on the key factors and mechanisms that affect the evolution results. We hope that our findings will facilitate further research on this important topic and provide effective policies and practices for promoting collaboration and innovation in supply chain management."

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