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EVOLUTIONARY GAME STUDY ON INFORMATION NODES SETTING IN SUPPLY CHAIN TRACING BASED ON COMPENSATION MECHANISM

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Abstract. Consumption compensation is the driving force for motivating each supply chain link to set up information nodes, which is of great significance for promoting informatization, modernization, transformation, and upgrading of the supply chain system. This study simulates the evolution process of strategic selection for each supply chain link to set information nodes independently or collectively under the unconstrained government rewards conditions and punishments. The main conclusions are as follows: (1) When each link in the supply chain provides source tracing information independently, the vendor chooses to set up information nodes for the links with large information cost compensation coefficients. (2) When the vendor provides source tracing information cooperatively if the collaborative benefit is less than the cooperation cost, the information node will be set to the link with the large compensation coefficient. If not, information nodes will be set in each link. (3) Under the government incentive mechanism, enterprises are willing to cooperate. The punishment mechanism helps avoid situations where neither side sets up information nodes. The compensation coefficient is a prerequisite for mechanisms to work.

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1. Introduction

With the continuous improvement of social income and consumption levels, consumers are paying increasing attention to product quality and traceability information in the entire production process. They would like to know the production and delivery from the sources to the end product, including information about the selection, transportation, and processing of raw materials. At this stage, although the consumer market shows a clear willingness to pay for supply chain traceability information [9, 32], the demand momentum is still insufficient. Building a supply chain of information traceability systems will undoubtedly face considerable information costs [22]. Manufacturers do not have enough motivation to participate in the construction of traceability information systems actively. In addition, the phenomenon of 'free-riding' among manufacturers has also caused the government to face numerous obstacles in building the supply chain traceability system. Fundamentally speaking, the core driving force for manufacturers to participate in the construction of the supply chain traceability system comes from the compensation mechanism of consumers. Consumers provide a premium

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for production activities such as providing information, upgrading equipment, and strengthening services for enterprises, so as to provide support for enterprises to set up traceable information nodes. Manufacturers provide consumers with traceability information based on the original final product during the production process. There is a cost to obtain this information. Consumers are willing to pay a corresponding premium for this information based on the product's original selling price. These premiums compensate for the cost incurred by the manufacturer in providing traceability information.

From a practical perspective, China's fresh food supply chain is in a critical period of transformation, and the Chinese government is trying to reduce food safety problems by improving the supply chain traceability system of fresh agricultural products. Take pork consumption as an example. Before the reform and opening up, China's pork supply still belonged to the government's "planned economy". This tradition also led to the passivity of consumption demand in the market economy following up. Consumers' demand for traceability information in the supply chain was insufficient. Most suppliers make decisions independently, and the quality of pork was uneven. This also led to the security issues such as "water injected meat" once becoming a social hot spot. With the rapid development of China's economy in the following four decades, consumers' income has increased, and they pay more attention to food safety. They are willing and able to put forward traceability requirements to pork suppliers. The development of food traceability technology provides an important guarantee for this. Large pork suppliers began to realize collaborative cooperation with farms, slaughterhouses, processing plants and retailers, and gradually built a complete pork supply system from breeding to slaughtering to processing to sales. Based on the cooperation agreement, they improved the supply quality of pork by controlling breeding pigs, ear labeling technology and other methods. In this process, the Chinese government has established a set of reward and punishment mechanisms, which have provided important help for the construction of the traceability information system of China's pork supply chain from the perspectives of laws and regulations, financial compensation, technical support, carrying out the "industry university research" project, and promoting publicity and promotion, and further standardized the collaborative cooperation mechanism of manufacturers in all links of the fresh agricultural products supply chain.

It can be seen that under such a realistic background, it is necessary to explore the determinants of the behaviour of information selection nodes in each supply chain link and its mechanism of action. This explores the core power of consumption compensation in the supply chain traceability system. It has important theoretical and practical significance for encouraging all supply chain links to cooperate and participate in the construction of traceability information system, thereby realising the transformation and upgrading of industrial system informatisation and modernisation.

Many academic studies have focused on the setting of the supply chain of information traceability nodes. This study discusses the following three aspects.

First is the research on the behavioural decision-making of information nodes in each supply chain link of the traceability system. Some scholars have focused on the behaviour of a specific manufacturer in the supply chain. Some analysed the breakdown of cost types and benefits provided by traceability information from the perspective of cost–benefit' [10] or explored technical feasibility issues from information collection, transmission, and processing. Examples include a rice information platform based on radio-frequency identification (RFID) technology for automatic instant identification and information sharing [14], a cold chain logistics temperature and humidity monitoring system based on wireless sensor networks [4]. Other scholars were concerned about the effect on manufacturers' behaviour while constructing the traceability information system, such as the cooperation or conflict of interest among suppliers, consumers, governments, and other parties. Dai [8] pointed out that 'free-rider' behaviour is observed in the supply chain's information traceability system between upstream and downstream manufacturers. Thus, a benefit-sharing mechanism is established to adjust the interests of all the links in the supply chain. Zhu [34] built a dynamic pricing model based on an RFID traceability system for upstream and downstream supply chain manufacturers and explored the cost-sharing problem of perishable food in transportation. Peng and Yang [19] proposed a novel bidirectional risk-sharing contract to coordinate the supply chain with updating demand information. Third, scholars have focused on the role of government regulations. Qian and Yang [21] analysed pricing decisions, anti-epidemic efforts, and cost-sharing under government subsidy measures and coordination strategies. Subsidising manufacturers with cost-sharing can obtain the maximum welfare.

Second, it is the game model research on the behavioural decision-making of each link in the supply chain traceability system. The construction of the supply chain traceability of the information system involves multiple participants' common behaviour and is essentially the result of a game among all parties. For the study of game models and game equilibrium solutions in each supply chain link, some scholars have focused on the theoretical basis of game model construction and algorithms. For example, Haque *et al.* [11,12] further modified the ambiguity theory of game models and multi-criteria group decision-making (MCGDM) based on trapezoidal neutrosophic numbers (TNN) and conducted practical application tests based on this. Chakraborty *et al.* [3] explored different metrics and algorithms for interval-valued pentagon fuzzy numbers (IVPFN) related to categorical membership functions (MF) and analysed their specific applications in game models. Other scholars have paid attention to the specific application of the game model in supply chain traceability. For example, Wang *et al.* [28] used signal games to examine the difference between the role of traceability information in the 'high-quality' and 'poor' food industries in increasing consumers' willingness to pay. High disclosure of traceable information in the sub-optimal industry can result in consumers' willingness to pay for information. Wu *et al.* [30] constructed a traceability game model of an agricultural product supply chain. They pointed out that government intervention could enable all manufacturers to provide traceability information. Shoeleh *et al.* [23] made price and quality levels in a three-echelon supply chain consisting of a supplier, manufacturer, and retailer. The manufacturer prefers to play Stackelberg rather than conflict in the Nash game. While studies of evolutionary game theory, such as Van & García [27] and Cheng *et al.* [7] have important reference significance for constructing the decision model of enterprise information node setting in this study. Liu *et al.* [15] constructed four game models to explore pricing strategies under different government subsidy plans and which groups in production should be the target of subsidy. Nahid and Morteza [18] constructed a game model between manufacturers and their service companies based on price and quality dependence under the supply chain traceability system. They point out that competitive games are beneficial to consumers who seek the best price.

Third, research has been conducted on the influence of consumer compensation mechanisms on the behavioural decision-making of each link in the traceability system. The core of the supply chain of information traceability node setting is based on the separation of costs and benefits. Under the basic assumption of a rational person in economics, the manufacturer's technical and labour costs in providing traceability information will eventually be compensated from market or government actions. The compensation mechanism discussed in this study mainly analyses the effect of consumers' provision of paying premiums for enterprises to provide information, upgrade equipment, and strengthen services on production activities to set traceability information nodes. Manufacturers provide consumers with traceability information about the production process based on the original final product. Obtaining this information entails cost, and consumers are willing to pay a corresponding premium for this information based on the product's original price. These premiums compensate for the costs incurred by manufacturers to provide traceability information. The degree of consumer compensation for the manufacturer's costs directly affects the manufacturer's decision to set the information node. Storoy [24] pointed out that consumers prefer products with high informational levels, and the benefits of traceability information systems mainly come from the premium paid by consumers for traceable information. Cheng [6] pointed out that raising prices is a necessary operating method to compensate manufacturers for the cost of providing traceability information, but too high prices will also reduce product sales. In the short term, rising prices are the main cause of the lack of motivation for many manufacturers to set up the source information node. Although the setup costs are excessively high, they cannot significantly increase the price to obtain sufficient compensation [2]. More studies have confirmed the important role of consumer upgrades in improving product quality and service levels from different perspectives and further explain the important impact of consumer compensation mechanisms on constructing the supply chain of information traceability systems [5, 25].

To summarise, the existing studies have conducted extensive and in-depth analysis on the cost-benefit situation of supply chain manufacturers in terms of the specific behaviour of a link, the cooperation mechanism between links and links, and reward and punishment measures of government departments. The academic community has also been recognised the analytical thinking of multi-party cooperative games. Unfortunately, most of the existing research focuses on the impact of the traceability information premium paid by consumers on corporate profits or costs, and less attention is paid to its role in the evolution of corporate decision-making behaviour. The research on the game closest to this rarely involves the compensation mechanism that consumers pay for the premium information for traceability to the manufacturer and the specific effect of the compensation mechanism on the manufacturer's decision to set up information nodes.

This study focuses on exploring the evolutionary game result of whether to set up information nodes in each supply chain link under the action of the compensation mechanism for the information cost of the manufacturer paid by the consumer's premium information. The main innovations of this study are as follows: First, we build a game model in which each link in the supply chain of information traceability systems sets information nodes independently or cooperatively. We analyse and compare the evolution process of manufacturers' strategic choices under different conditions. Second, based on the above evolutionary game model, an in-depth analysis of the compensation mechanism's effect on constructing the supply chain of information traceability system was carried out. Third, combined with simulation analysis and case studies in different scenarios, we compare the difference and effectiveness of the compensation mechanism of the premium information paid by consumers to enterprises and the government reward and punishment mechanism in influencing the decision-making of traceability information of various manufacturers in the supply chain.

2. Model assumptions

To facilitate the exploration of the influencing factors and action mechanism of the decision-making of traceability information nodes in each link of the supply chain; this study analyses the basic game decision-making model for three scenarios: independent decision-making under unconstrained conditions, cooperative decision-making under unconstrained conditions, and decision-making under the condition of government rewards or punishments. The decision-making mechanism for each link is shown in Figure 1. The information nodes decision in each supply chain link is divided into two types: setting and not setting. The core basis of decision-making is expected income. The main factors affecting expected income are the income conversion coefficient, external effect coefficient, consumption compensation ratio, node setting density, and unit node information degree. The cooperative coordination coefficient embodies the cooperative decision-making mechanism. The government reward and punishment mechanism are embodied by the government reward coefficient and the government punishment coefficient.

Under the existing intra-industry division of labour mode, each production link does not exist independently but runs through the production process to jointly complete a certain final product. Since the production link can be divided into several links, to simplify the analysis, this study abstracts several production links of the supply chain into two game parties, which are set as link 1 and link 2, respectively, in the following text. For example, the pork supply chain can be simplified into two links: link 1 is the pig supplier, and link 2 is the pork processor. At the same time, compared to the entire supply chain, each independent production link belongs to a smaller party. For example, there are many live-pig suppliers and pork processors in the real pork supply chain. All suppliers or processors have group strategy selection determined by the percentage of dominant individuals within the group. It is assumed that there are only two behavioural strategies in each supply chain link. One is to set up traceability information nodes in this production link to provide traceability information to consumers. The other is not to set up traceability information nodes to provide traceability information. For example, live pig suppliers can choose to number each pig and use ear tag technology to provide information on live pigs' growth, vaccines, and diseases during the breeding process. They can use traceability information technology to provide consumers with pork origin, processing process, storage time, and other information.

Other basic assumptions are as follows:

(1) The traceability information provided by the information nodes in each link is valid.

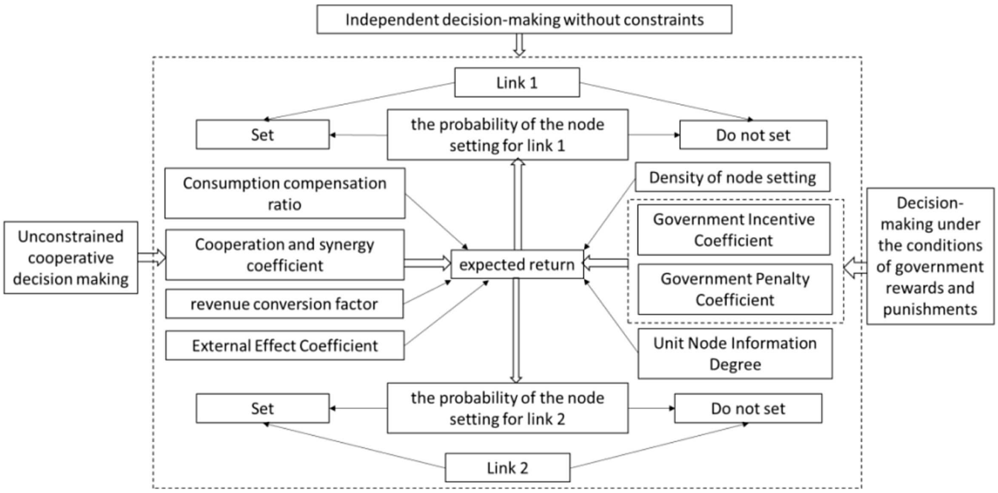


FIGURE 1. Decision-making mechanism diagram of each link in the supply chain.

(2) Considering that consumers consume the final product, assuming that they have no preference for information in each production link, the positive and negative external effects brought by the decisions of link 1 and link 2 in the supply chain are the same for each other.
(3) This study only analyses the game behaviour between link 1 and link 2 in a supply chain, ignoring the impact of other external effects outside this supply chain.
(4) Links 1 and 2 in the supply chain obtain the information premium by providing traceability information, thereby increasing the added value of the corresponding link to increase revenue. Therefore, each link can independently obtain information. The payment of premiums can be assigned to the production link that provides the information.

3. Parameter setting

The parameters and basic formulas used in the theoretical model of this study are as follows:

(1) For a specific production link, the difficulty of setting the source tracing information node is a key factor affecting the level of information provided by the link. The difficulty factor set by the traceability information node of the link in the supply chain is set as $\sigma_i (\sigma_i \in [0,1])$. Combined with Wang *et al.*'s [29] research on the cost function, as the difficulty in setting up the information nodes increases, the effort required by the enterprise to overcome the difficulties also increases, and the setup cost will accelerate. Therefore, this study used the form of a quadratic function[2]. The cost function of the source node with difficulty coefficient σ_i is as follows:

$$C_i(\sigma_i) = \frac{1}{2}\sigma_i^2. \tag{3.1}$$

(2) The supply chain information node mainly obtains information benefits by collecting and providing instant information. Traceability information that is difficult to obtain always has a high market value. In addition to the influence of the node setting difficulty coefficient σ_i, the information gain of setting an information node is mainly affected by the degree of information that the node can provide and the unit income of the information degree. m_i is the information degree that the information node provides at link i in the supply chain. Each unit

[2]Other accelerated functions have no substantial effect on the main conclusions of this study.

of information generates one unit of revenue. Therefore, the revenue function of the information node-set in the supply chain is as follows:

$$R_i = m_i \sigma_i. \tag{3.2}$$

(3) Manufacturers need to replace equipment, upgrade technology, recruit and train workers because of the setting of information nodes, which will cause additional production costs in short to medium term [16]. From the basic economic theory analysis of the short-term flow and fixed costs affecting manufacturers' operating decisions, manufacturers will have the incentive to set up information nodes, at least under the premise of being partially compensated by consumers. For the cost of providing traceability information to manufacturers, $H_i (H_i \in [0, 1])$ is the information premium that consumers are willing to pay. The information premium paid by consumers has a compensation effect of H_i for the information cost of the manufacturer. Under this compensation mechanism, the loss function that manufacturers need to bear to set up information nodes is as follows:

$$L_i = (1 - H_i)\, m_i. \tag{3.3}$$

As pointed out in the previous discussion, the manufacturer has grasped the information conducive to its production and operation because of the information node. This information has a positive effect on reducing the rate of defective products, improving management efficiency, and optimising production modes [20]. k is the information conversion factor, and the available additional functions of the manufacturer's own production and operation owing to the setting of the information node are as follows:

$$G_i = k m_i. \tag{3.4}$$

(4) Setting up information nodes in a link in the supply chain can bring additional benefits to this link and certain positive external effects on the production of upstream and downstream manufacturers in this link because of the consistency of the supply chain. For the sake of analysis, setting information nodes in one link of the value chain is assumed to bring positive external benefits with a coefficient of $\alpha(\alpha_i \in (0, 1))$ to other links. Therefore, for link 1, setting the information node in link 2 can bring the external benefit of $\alpha k m_2$ to link 1, whereas setting the node in Link 1 can also bring external benefits of $\alpha k m_1$to link 2.

(5) In setting up information nodes in cooperation between upstream and downstream links in the supply chain, numerous studies have shown that the cooperation mechanism has a '1 + 1 >2' synergy effect. From the joint efforts of both parties, the benefits of all parties are higher than those of non-cooperation. This mechanism is a strategy optimisation for various actors [1]. Research on supply chain cooperation mechanisms focuses on the role of improving the benefits of each participant based on synergies, focusing on the possible costs of cooperation and the separation of costs and benefits [13, 17, 31, 33]. Research on supply chain cooperation mechanisms has deepened to the level of information sharing. Teunter *et al.* [26] discussed the important role of collaborative innovation in upstream and supply chain links and information sharing for supply chain cooperation and efficient operation. In general, upstream and downstream cooperation in the supply chain helps upstream manufacturers get closer to the consumer market and gain insight into consumer needs. It helps downstream and upstream companies jointly formulate price and sales strategies to improve sales profits. However, it is undeniable that due to the differences in production technology, knowledge systems, and even legal policies in the upstream and downstream links, it takes a lot of workforce and material resources to reach a consensus on cooperation intentions.

However, as stated in the 'prisoner's dilemma', cooperation mechanisms often face obstacles from the 'free-rider' effect; thus, forming a stable dominant equilibrium is difficult. Some scholars have explored the complementarity of cooperation between two sides [29]. The study points out that the benefits of cooperation between regional governments in emission reduction depend on the complementarity of regional governments in emission reduction. Based on this idea, the study uses the product of the emission reduction efforts of regional governments as a performance indicator of cooperative emission reduction. With basic research, the present study replaces the effort of regional governments with the difficulty required to set up information nodes in links 1 and

2 in the supply chain. Therefore, the additional revenue function of each link in the upstream and downstream cooperation of the supply chain is as follows.

$$\Delta R = \phi\sigma_1\sigma_2 \tag{3.5}$$

where $\sigma_1$and σ_2 are the difficulty levels that need to be overcome to set the information nodes for link 1 and link 2 in the supply chain, and ϕ represents the synergy coefficient of cooperation between the two links. The transaction cost function [29] is borne by all parties to achieve cooperation between the two links of the supply chain, as follows:

$$\Delta C = 1 - \sigma_1\sigma_2. \tag{3.6}$$

Equation (3.6) indicates that if the efforts made by the two parties to reach cooperation are great, as the difficulty of the two parties to overcome in setting up the information nodes increases, then the transaction costs that the parties need to bear decrease.

The prerequisite for cooperation between two links of the supply chain is as follows:

$$\phi\sigma_1\sigma_2 - (1 - \sigma_1\sigma_2) > \alpha k m_i$$

The synergistic benefits obtained from the two links are deducted by the transaction costs paid to reach cooperation. Suppose the result is higher than the positive external benefits obtained under non-cooperative conditions. In that case, the participant will choose to set up an information node in cooperation with the other party.

(6) The mechanism of government policy was analysed. There are two common government-control measures. One is to reward manufacturers who actively participate in the establishment of information nodes, and the other is to sanction those who do not set information nodes.

Considering the impact of the difficulty of setting up the information nodes in different links, coefficient λ is the award of the government for the cost of providing traceability information that manufacturers set up the information nodes, and coefficient μ is the manufacturer's free-riding penalty. The setting cost of the information node with the setting difficulty coefficient σ_i is as follows:

$$C_i(\sigma_i) = \frac{1}{2}\sigma_i^2$$

The traceability information provided in link i must overcome the difficulty coefficient of σ_i. Then, the remaining difficulty ratio that does not need to be overcome is considered a 'free ride' on all social resources. $(1 - \sigma_i)$ is the degree of hitchhiking in link i. Therefore, the government's corresponding reward E_i and F_i are as follows:

$$E_i = \lambda C_i(\sigma_i) = \frac{1}{2}\lambda\sigma_i^2 \tag{3.7}$$

$$F_i = \mu(1 - \sigma_i). \tag{3.8}$$

4. Model construction

This section separately constructs three scenarios: an evolutionary game in which each link of the supply chain (1) independently provides traceability information under unrestricted conditions, (2) cooperates to provide traceability information, and (3) provides tracing information under government reward and punishment conditions. The factors that influence the availability of information nodes are extensively analysed to provide traceability information in each supply chain link in each scenario.

Table 1. Evolutionary game payment matrix that independently provides traceability information in each link of the supply chain under unconstrained conditions.

		Link 2	
		Set (r_B)	No set ($1-r_B$)
Link 1	Set (r_A)	$\frac{1}{2}\left[\sigma_1\left(2m_1-\sigma_1\right)+2m_1\left(k+H_1-1\right)\right]+\alpha k m_2$	$\frac{1}{2}\left[\sigma_1\left(2m_1-\sigma_1\right)+2m_1\left(k+H_1-1\right)\right]$
		$\frac{1}{2}\left[\sigma_2\left(2m_2-\sigma_2\right)+2m_2\left(k+H_2-1\right)\right]+\alpha k m_1$	$\alpha k m_1$
	No set ($1-r_A$)	$\alpha k m_2$	0
		$\frac{1}{2}\left[\sigma_2\left(2m_2-\sigma_2\right)+2m_2\left(k+H_2-1\right)\right]$	0

4.1. Evolutionary game: each link of the supply chain independently provides traceability information under unconstrained conditions

Taking Link 1 as an example, the benefits of setting up information nodes come from two parts. The first is the difference between the information benefits and costs obtained by setting up the information nodes in this link and the difference between the additional benefits and costs, which is the sum of formula (2) minus (1) and formula (4) minus (3). This benefit is not affected by whether the information nodes are set up in other links. The other part of income is affected by the behaviour of other links. If information nodes are set up in other links, then the external benefits obtained in this link are $\alpha k m_2$. Suppose no information nodes are set in the other links, this link will not have external revenue. From this, the evolutionary game payment matrix that independently provides traceability information in each supply chain link can be obtained, as shown in Table 1. Links 1 and 2 randomly and independently choose to set or not set information nodes and repeat the entire game process. r_A and r_B, respectively, indicate the probability of setting information nodes in Links 1 and 2, respectively.

Table 1 shows the expected revenue from setting the information node in Link 1 as follows:

$$U_H^{A_1}=\frac{1}{2}r_B\left[\sigma_1\left(2m_1-\sigma_1\right)+2m_1\left(k+H_1-1\right)\right]+r_B\alpha k m_2+\frac{1}{2}\left(1-r_B\right)\left[\sigma_1\left(2m_1-\sigma_1\right)+2m_1\left(k+H_1-1\right)\right].$$

$$U_H^{A_1}=r_B\alpha k m_2+\frac{1}{2}\left[\sigma_1\left(2m_1-\sigma_1\right)+2m_1\left(k+H_1-1\right)\right].$$

The expected revenue of the information node is not set in Link 1, as follows:
$U_H^{A_0}=r_B\alpha k m_2$.
The average revenue is

$$\overline{U}_H^A=r_A U_H^{A_1}+\left(1-r_A\right)U_H^{A_0},$$

$$\overline{U}_H^A=\frac{1}{2}r_A\left[\sigma_1\left(2m_1-\sigma_1\right)+2m_1\left(k+H_1-1\right)\right]+r_B\alpha k m_2.$$

According to the dynamic replication equation, $\dot{r}_A/r_A$ is the information nodes growth rate to the overall proportion that link1 chooses to set, whereas $\dot{r}_B/r_B$ is the growth rate of nodes to the overall proportion that Link 2 chooses to set. The two-dimensional dynamic system comprising the Malthusian equation can be obtained as follows:

$$\dot{r}_A=dr_A/dt=r_A\left(U_H^{A_1}-\overline{U}_H^A\right)=\frac{1}{2}r_A\left(1-r_A\right)\left[\sigma_1\left(2m_1-\sigma_1\right)+2m_1\left(k+H_1-1\right)\right].$$

$$\dot{r}_B=dr_B/dt=r_B\left(U_H^{B_1}-\overline{U}_H^B\right)=\frac{1}{2}r_B\left(1-r_B\right)\left[\sigma_2\left(2m_2-\sigma_2\right)+2m_2\left(k+H_2-1\right)\right].$$

TABLE 2. Evolutionary game payment matrices that cooperate to provide traceability information in various links of the supply chain under unconstrained conditions.

		Link 2	
		Set (r_B)	No set ($1-r_B$)
Link 1	Set (r_A)	$\frac{1}{2}\left[\sigma_1\left(2m_1-\sigma_1\right)+2m_1\left(k+H_1-1\right)\right]+\left(\phi+1\right)\sigma_1\sigma_2-1$	$\frac{1}{2}\left[\sigma_1\left(2m_1-\sigma_1\right)+2m_1\left(k+H_1-1\right)\right]$
		$\frac{1}{2}\left[\sigma_2\left(2m_2-\sigma_2\right)+2m_2\left(k+H_2-1\right)\right]+\left(\phi+1\right)\sigma_1\sigma_2-1$	$\alpha k m_1$
	No set ($1-r_A$)	$\alpha k m_2$	0
		$\frac{1}{2}\left[\sigma_2\left(2m_2-\sigma_2\right)+2m_2\left(k+H_2-1\right)\right]$	0

where $\dot{r}_A=0$ and $\dot{r}_B=0$, $r_A=0$, $r_A=1$; $r_B=0$, and $r_B=1$ are obtained.

This notion leads to the following proposition (see appendix for proof).

Proposition 4.1. *The strategic equilibrium points of the dynamic evolution game between the upstream and downstream sides of the supply chain in different states is as follows:*

$$(r_A, r_B) = (0,0), (0,1), (1,0), (1,1).$$

Proposition 4.2. *The local stability of each equilibrium point is as follows:*

When $\overline{H}_1 < H_1 < 1$, $\overline{H}_2 < H_2 < 1$, the stable equilibrium strategy is $\{set, set\}$. When $0 < H_1 < \overline{H}_1$, $\overline{H}_2 < H_2 < 1$, the stable equilibrium strategy is $\{noset, set\}$. When $\overline{H}_1 < H_1 < 1$, $0 < H_2 < \overline{H}_2$, the stable equilibrium strategy is $\{set, noset\}$. When $0 < H_1 < \overline{H}_1$, $0 < H_2 < \overline{H}_2$, the stable equilibrium strategy is $\{noset, noset\}$.

Amongst them,

$$\overline{H}_1 = 1+\frac{\sigma_1^2}{2m_1}-\sigma_1-k; \quad \overline{H}_2 = 1+\frac{\sigma_2^2}{2m_2}-\sigma_2-k.$$

4.2. Evolutionary game: all links in the supply chain cooperate to provide traceability information under unconstrained conditions

Similar to the above, the benefits of setting information nodes come from the following sources: The first is the independent income obtained by setting the information node in Link 1, the same as in Scenario 1. The second is the synergistic benefits obtained by setting the information nodes in cooperation with other links. The difference between the cooperation benefit and the transaction cost determines the revenue, which is the difference between formulas (5) and (6). Third, if no information nodes are set in Link 1, and other links are set, the external benefits $\alpha k m_2$ will also be obtained in Link 1. If no information node is set on either side, then the revenue of both sides is zero. r_A and r_B represent the probability of setting an information node in Link 1 and Link 2, respectively. Thus, the evolutionary game payment matrix of cooperation in each supply chain link to provide traceability information can be obtained, as shown in Table 2.

It can be seen from Table 2 that the expected benefit of setting the information node in Link 1 is

$$U_H^{A_1} = \frac{1}{2}r_B\left[\sigma_1\left(2m_1-\sigma_1\right)+2m_1\left(k+H_1-1\right)\right]+r_B\left[\left(\phi+1\right)\sigma_1\sigma_2-1\right]+\frac{1}{2}\left(1-r_B\right)\left[\sigma_1\left(2m_1-\sigma_1\right)+2m_1\left(k+H_1-1\right)\right]$$
$$U_H^{A_1} = r_B\left(\phi+1\right)\sigma_1\sigma_2-r_B+\frac{1}{2}\left[\sigma_1\left(2m_1-\sigma_1\right)+2m_1\left(k+H_1-1\right)\right].$$

The expected benefit of not setting the information node in Link 1 is:

$$U_H^{A_0} = r_B\alpha k m_2.$$

The average return is:

$$\overline{U}_H^A = r_A U_H^{A_1} + (1 - r_A) U_H^{A_0}$$
$$\overline{U}_H^A = \frac{1}{2} r_A [\sigma_1 (2m_1 - \sigma_1) + 2m_1 (k + H_1 - 1)] + r_A r_B (\phi + 1) \sigma_1 \sigma_2 - r_A r_B + r_B (1 - r_A) \alpha k m_2$$

According to the dynamic replication equation, $\dot{r}_A/r_A$ and $\dot{r}_B/r_B$ are the growth rates of information nodes to the overall proportion that Link 1 and Link 2 choose to set. The two-dimensional dynamic system comprising the Malthusian equation can be obtained as follows:

$$\dot{r}_A = r_A (1 - r_A) \left\{ \frac{1}{2} [\sigma_1 (2m_1 - \sigma_1) + 2m_1 (k + H_1 - 1)] + r_B [(\phi + 1) \sigma_1 \sigma_2 - \alpha k m_2 - 1] \right\}$$
$$\dot{r}_B = r_B (1 - r_B) \left\{ \frac{1}{2} [\sigma_2 (2m_2 - \sigma_2) + 2m_2 (k + H_2 - 1)] + r_A [(\phi + 1) \sigma_1 \sigma_2 - \alpha k m_1 - 1] \right\}$$

where $\dot{r}_A = 0$ and $\dot{r}_B = 0$, $r_A = 0$, $r_A = 1$; $r_B = 0$, and $r_B = 1$ are obtained. As well as:

$$r_{BD} = \frac{\sigma_1 (m_1 - \sigma_1/2) + m_1 (k + H_1 - 1)}{1 + \alpha k m_2 - (\phi + 1) \sigma_1 \sigma_2}; \quad r_{AD} = \frac{\sigma_2 (m_2 - \sigma_2/2) + m_2 (k + H_2 - 1)}{1 + \alpha k m_1 - (\phi + 1) \sigma_1 \sigma_2}.$$

This leads to the following propositions:

Proposition 4.3. *The strategic equilibrium points of the dynamic evolution game between the upstream and downstream sides of the supply chain in different states is as follows:*

$$(r_A, r_B) = (0, 0), (0, 1), (1, 0), (1, 1), (r_{AD}, r_{BD}).$$

Proposition 4.4. *The local stability of each equilibrium point is as follows:*

(1) When $\overline{H}_1 < H_1 < 1$, $\overline{H}_2 < H_2 < 1$, the stable equilibrium strategy is $\{set, set\}$. When $0 < H_1 < \overline{H}_1$, $\overline{H}_2 < H_2 < 1$, the stable equilibrium strategy is $\{noset, set\}$. When $\overline{H}_1 < H_1 < 1$, $0 < H_2 < \overline{H}_2$, the stable equilibrium strategy is $\{set, noset\}$. When $0 < H_1 < \overline{H}_1$, $0 < H_2 < \overline{H}_2$, the stable equilibrium strategy is $\{noset, noset\}$.

Amongst them:
$\overline{H}_1 = 1 + \frac{\sigma_1^2}{2m_1} - \sigma_1 - k - \frac{(\phi+1)\sigma_1\sigma_2 - \alpha k m_2 - 1}{m_1}$, $\overline{H}_2 = 1 + \frac{\sigma_2^2}{2m_2} - \sigma_2 - k - \frac{(\phi+1)\sigma_1\sigma_2 - \alpha k m_1 - 1}{m_2}$.

(2) Further, it is based on synergistic benefits and transaction costs. Under the condition that the synergistic benefit is higher than the transaction cost, that is: Under the condition of $(\phi + 1) \sigma_1 \sigma_2 - 1 > 0$, in the whole range of $0 < H_1 < 1$, $0 < H_2 < 1$, the stable equilibrium strategy is: $\{set, set\}$. Under the condition that the synergistic benefit is lower than the transaction cost, that is, under the condition of $(\phi + 1) \sigma_1 \sigma_2 - 1 < 0$, there are the following possible stable equilibrium strategies: When $\overline{H}_1 < H_1 < 1$, $\overline{H}_2 < H_2 < 1$, the stable equilibrium strategy is $\{set, set\}$. When $0 < H_1 < \overline{H}_1$, $\overline{H}_2 < H_2 < 1$, the stable equilibrium strategy is $\{noset, set\}$. When $\overline{H}_1 < H_1 < 1$, $0 < H_2 < \overline{H}_2$, the stable equilibrium strategy is $\{set, noset\}$. When $0 < H_1 < \overline{H}_1$, $0 < H_2 < \overline{H}_2$, the stable equilibrium strategy is $\{noset, noset\}$.

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

It can be seen from the image that the coordinate of the saddle point is $S(r_{AD}, r_{BD})$, and the area of the quadrilateral OMSN in the figure can reflect the position of the saddle point on the OP. The larger the area of OMSN, the closer the saddle point is to the equilibrium point P, that is, the evolution of the equilibrium point of each link decision-making direction. The area of the OMSN is shown in formula (4.1).

$$G = \frac{1}{2} (r_{AD} + r_{BD})$$
$$G = \frac{1}{2} \left[\frac{\sigma_1 (m_1 - \sigma_1/2) + m_1 (k + H_1 - 1)}{1 + \alpha k m_2 - (\phi + 1) \sigma_1 \sigma_2} + \frac{\sigma_2 (m_2 - \sigma_2/2) + m_2 (k + H_2 - 1)}{1 + \alpha k m_1 - (\phi + 1) \sigma_1 \sigma_2} \right]. \tag{4.1}$$

The derivative of equation (4.1) with respect to each parameter, we obtain:

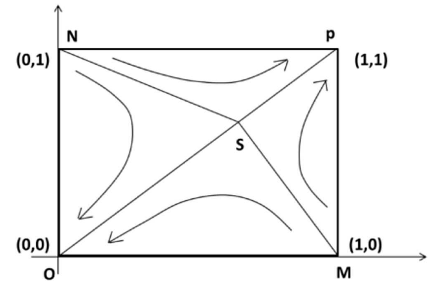
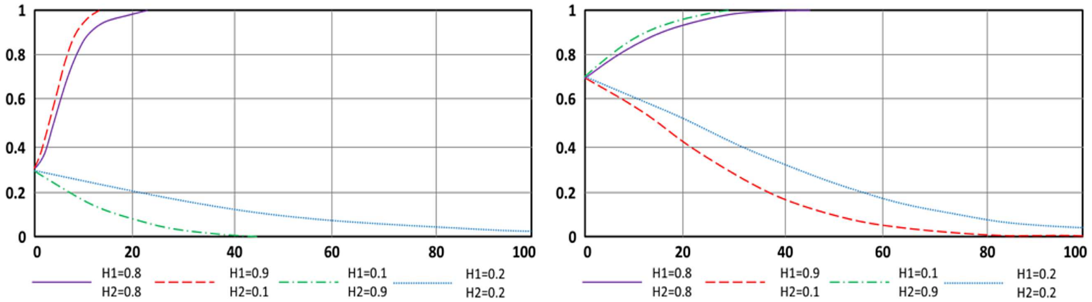


FIGURE 2. (a) Dynamic phase diagram of game equilibrium.



(1) Probability of node setting in Link 1 (2) Probability of node setting in Link 2

FIGURE 2. b) Stable decision-making in an evolutionary game system with independent traceability information provided by each link of the supply chain under unconstrained conditions.

Proposition 4.5. *The sensitivity analysis of the parameter changes to the evolution of the equilibrium point is as follows:*

(1) Under the premise that the unit information degree is higher than the difficulty of setting traceability nodes, the increase in the difficulty of setting information nodes will still promote the evolution of the equilibrium point $\{set, set\}$ *of decision-making in each link of the supply chain.*

Proof. Calculate the derivative of the difficulty of setting the traceability node σ_1, σ_2 to equation (4.1), respectively, and obtain

$$\frac{\mathrm{dG}}{\mathrm{d}\sigma_1} = \frac{\sigma_2(\phi+1)\left[2m_1(H_1+k-1)-\sigma_1(\sigma_1-2m_1)\right]}{4\left[\alpha k m_2-\sigma_1\sigma_2(\phi+1)+1\right]^2} + \frac{\sigma_2(\phi+1)\left[2m_2(H_2+k-1)-\sigma_2(\sigma_2-2m_2)\right]}{4\left[\alpha k m_1-\sigma_1\sigma_2(\phi+1)+1\right]^2} + \frac{2(m_1-\sigma_1)}{4\left[\alpha k m_2-\sigma_1\sigma_2(\phi+1)+1\right]}$$

$$\frac{\mathrm{dG}}{\mathrm{d}\sigma_2} = \frac{\sigma_1(\phi+1)\left[2m_1(H_1+k-1)-\sigma_1(\sigma_1-2m_1)\right]}{4\left[\alpha k m_2-\sigma_1\sigma_2(\phi+1)+1\right]^2} + \frac{\sigma_1(\phi+1)\left[2m_2(H_2+k-1)-\sigma_2(\sigma_2-2m_2)\right]}{4\left[\alpha k m_1-\sigma_1\sigma_2(\phi+1)+1\right]^2} + \frac{2(m_2-\sigma_2)}{4\left[\alpha k m_2-\sigma_1\sigma_2(\phi+1)+1\right]}.$$

According to the above analysis, when $m_1 > \sigma_1, m_2 > \sigma_2$, $\frac{\mathrm{dG}}{\mathrm{d}\sigma_1}$, and $\frac{\mathrm{dG}}{\mathrm{d}\sigma_2}$ must be greater than 0, that is, the difficulty of setting traceability nodes is not a key factor restricting the setting of information nodes in each link of the supply chain. Technical-level limitations are not considered here. □

(2) The degree of information is uncertain for the evolutionary path of the balanced decision-making of traceability information nodes. Under the condition of low externalities, the improvement of the information

degree will help to promote the evolution of the equilibrium point $\{set, set\}$ of decision-making in each supply chain link. Under the condition of high externality, the improvement of information degree is not conducive to the evolution of the equilibrium point $\{set, set\}$of decision-making in each supply chain link.

Proof. Calculate the derivative of the information degree of the traceability node m_1, m_2 respectively with respect to formula (4.1), we can get:

$$\frac{\mathrm{dG}}{\mathrm{d}m_1} = \frac{-\alpha k\left[2m_2\left(H_2+k-1\right)-\sigma_2\left(\sigma_2-2m_2\right)\right]}{4\left[\alpha k m_1-\sigma_1\sigma_2\left(\phi+1\right)+1\right]^2} + \frac{\left(\sigma_1+H_1+k-1\right)}{2\left[\alpha k m_2-\sigma_1\sigma_2\left(\phi+1\right)+1\right]}$$
$$\frac{\mathrm{dG}}{\mathrm{d}m_2} = \frac{-\alpha k\left[2m_1\left(H_1+k-1\right)-\sigma_1\left(\sigma_1-2m_1\right)\right]}{4\left[\alpha k m_2-\sigma_1\sigma_2\left(\phi+1\right)+1\right]^2} + \frac{\left(\sigma_2+H_2+k-1\right)}{2\left[\alpha k m_1-\sigma_1\sigma_2\left(\phi+1\right)+1\right]}.$$

Combining the above analysis, it can be seen that when the external effect coefficient α is large, $\frac{\mathrm{dG}}{\mathrm{d}m_1}$ and $\frac{\mathrm{dG}}{\mathrm{d}m_2}$ may have negative values, and when the external effect coefficient α is small, $\frac{\mathrm{dG}}{\mathrm{d}m_1}$ and $\frac{\mathrm{dG}}{\mathrm{d}m_2}$ may have positive values. In other words, the evolution effect of the information degree of traceability nodes on the decision-making of information node-set in each supply chain link is uncertain. This is because the larger external effect is more conducive to the 'free-rider' behaviour between each link. The higher the degree of information, the greater the effect on this. Each link of the supply chain is also more motivated to choose the decision not to set up information nodes to promote this effect. □

(3) An increase in the proportion of consumer compensation will help the decision-making of each link of the supply chain to evolve toward the equilibrium point of $\{set, set\}$.

Proof. Calculate the derivative of the consumer compensation ratio H_1, H_2 with respect to equation (4.1). We obtain:

$$\frac{\mathrm{dG}}{\mathrm{d}H_1} = \frac{m_1}{2\left[\alpha k m_2-\sigma_1\sigma_2\left(\phi+1\right)+1\right]} \quad \frac{\mathrm{dG}}{\mathrm{d}H_2} = \frac{m_2}{2\left[\alpha k m_1-\sigma_1\sigma_2\left(\phi+1\right)+1\right]}.$$

According to the above analysis, $\frac{\mathrm{dG}}{\mathrm{d}H_1}$ and $\frac{\mathrm{dG}}{\mathrm{d}H_2}$ must be greater than 0; that is, the higher the compensation ratio of consumers to the supply chain traceability information of node setting, the more conducive it is to promote the setting of information nodes in each link of the supply chain. □

(4) The improvement of external conditions will promote the evolution of decision-making in each supply chain link towards the equilibrium point of $\{noset, noset\}$.

Proof. Calculate the derivative of the externality coefficient with respect to equation (4.1), respectively, we obtain

$$\frac{\mathrm{dG}}{\mathrm{d}\alpha} = \frac{-k m_1\left[2m_2\left(H_2+k-1\right)-\sigma_2\left(\sigma_2-2m_2\right)\right]}{4\left[\alpha k m_1-\sigma_1\sigma_2\left(\phi+1\right)+1\right]} + \frac{-m_2\left[2m_1\left(H_1+k-1\right)-\sigma_1\left(\sigma_1-2m_1\right)\right]}{4\left[\alpha k m_2-\sigma_1\sigma_2\left(\phi+1\right)+1\right]}.$$

Based on the above analysis, $\frac{\mathrm{dG}}{\mathrm{d}\alpha}$ must be less than 0. The greater the external effect of the supply chain traceability information node setting, the stronger the free-rider behaviour of each link in the supply chain, and the less conducive it is to set information nodes for decision-making. □

(5) The improvement of the synergy coefficient is conducive to the evolution of the equilibrium point $\{set, set\}$ of decision-making in each supply chain link.

Proof. Calculate the derivative of the synergy coefficient ϕ with respect to equation (4.1), respectively, we obtain

$$\frac{\mathrm{dG}}{\mathrm{d}\phi} = \frac{\sigma_1\sigma_2\left[2m_1\left(H_1+k-1\right)-\sigma_1\left(\sigma_1-2m_1\right)\right]}{2\left[\alpha k m_2-\sigma_1\sigma_2\left(\phi+1\right)+1\right]} + \frac{\left[2m_2\left(H_2+k-1\right)-\sigma_2\left(\sigma_2-2m_2\right)\right]}{2\left[\alpha k m_1-\sigma_1\sigma_2\left(\phi+1\right)+1\right]}.$$

TABLE 3. Evolutionary game payment matrix that provides traceability information at various links in the supply chain under government rewards and punishments.

		Link 2	
		Set (r_B)	No set ($1-r_B$)
Link 1	Set (r_A)	$\frac{1}{2}\left[\sigma_1\left(2m_1-\sigma_1\right)+2m_1\left(k+H_1-1\right)\right]+\frac{1}{2}\lambda\sigma_1^2+\left(\phi+1\right)\sigma_1\sigma_2-1$	$\frac{1}{2}\left[\sigma_1\left(2m_1-\sigma_1\right)+2m_1\left(k+H_1-1\right)\right]+\frac{1}{2}\lambda\sigma_1^2$
		$\frac{1}{2}\left[\sigma_2\left(2m_2-\sigma_2\right)+2m_2\left(k+H_2-1\right)\right]+\frac{1}{2}\lambda\sigma_2^2+\left(\phi+1\right)\sigma_1\sigma_2-1$	$\alpha k m_1-\mu\left(1-\sigma_2\right)$
	No set ($1-r_A$)	$\alpha k m_2-\mu\left(1-\sigma_1\right)$	$-\mu\left(1-\sigma_1\right)$
		$\frac{1}{2}\left[\sigma_2\left(2m_2-\sigma_2\right)+2m_2\left(k+H_2-1\right)\right]+\frac{1}{2}\lambda\sigma_2^2$	$-\mu\left(1-\sigma_2\right)$

Based on the above analysis, $\frac{\mathrm{dG}}{\mathrm{d}\phi}$ must be greater than 0. The greater the coordination coefficient set by the supply chain traceability information node, the more conducive it is to promote the setting of information nodes in each link of the supply chain. □

(6) The evolution path of the income conversion coefficient for the balanced decision-making of traceability information nodes is uncertain. Under the condition of lower externalities, the improvement of the cooperation and synergy coefficient will help to promote the evolution of the decision-making in each supply chain link towards the equilibrium point $\{set, set\}$. In contrast, under the condition of higher externality, the increase in cooperation and synergy coefficient is not conducive to the evolution of the equilibrium point $\{noset, noset\}$of decision-making in each link of the supply chain.

Proof. Calculate the derivative of the income conversion coefficient with respect to formula (4.1) respectively, we get:

$$\frac{\mathrm{dG}}{\mathrm{d}k}=\frac{-\alpha m_1\left[2m_2\left(H_2+k-1\right)-\sigma_2\left(\sigma_2-2m_2\right)\right]}{4\left[\alpha k m_1-\sigma_1\sigma_2\left(\phi+1\right)+1\right]^2}+\frac{-\alpha m_2\left[2m_1\left(H_1+k-1\right)-\sigma_1\left(\sigma_1-2m_1\right)\right]}{4\left[\alpha k m_2-\sigma_1\sigma_2\left(\phi+1\right)+1\right]^2}$$
$$+\frac{m_1}{2\left[\alpha k m_2-\sigma_1\sigma_2\left(\phi+1\right)+1\right]}+\frac{m_2}{2\left[\alpha k m_1-\sigma_1\sigma_2\left(\phi+1\right)+1\right]}.$$

Combining the above analysis, when the external effect coefficient α is large, $\frac{\mathrm{dG}}{\mathrm{d}k}$ may have negative values; when the external effect coefficient α is small, $\frac{\mathrm{dG}}{\mathrm{d}k}$ may have positive values. In other words, the evolutionary effect of the revenue conversion coefficient on the information node setting decision of each supply chain link is uncertain. Since a larger external effect is more conducive to the 'free-rider' behaviour between each link, it will reduce the revenue conversion coefficient and promote the traceability of the information node setting effect. □

4.3. Evolutionary game of providing traceability information in each link of the supply chain under conditions of government rewards and punishments

In the context of introducing government policy intervention, when cooperating to set up information nodes, Link 1 can obtain the benefits of setting information nodes individually, and the synergy benefits from cooperation and government subsidies based on the cost of the setting. When the information node is set in Link 1 and not in Link 2, link 1 obtains the benefits of setting the information node separately and the government reward. When Link 1 does not set the information node and Link 2 does, Link 1 will receive the external benefit of $\alpha k m_2$ and accept the punishment given by the government according to the degree of 'free ride' as shown in formula (8). When both parties do not set up information nodes, the two parties cannot obtain external benefits and accept the corresponding punishment of the government according to their 'free-rider' levels. Table 3 shows the evolutionary game payment matrix that provides traceability information for each supply chain link under government reward and punishment conditions.

It can be seen from Table 3 the expected benefit of setting the information node in Link 1 is:

$$U_H^{A_1} = r_B \left\{ \frac{1}{2} \left[\sigma_1 \left(2m_1 - \sigma_1 \right) + 2m_1 \left(k + H_1 - 1 \right) \right] + \frac{1}{2} \lambda \sigma_1^2 + \left(\phi + 1 \right) \sigma_1 \sigma_2 - 1 \right\}$$
$$+ \left(1 - r_B \right) \left\{ \frac{1}{2} \left[\sigma_1 \left(2m_1 - \sigma_1 \right) + 2m_1 \left(k + H_1 - 1 \right) \right] + \frac{1}{2} \lambda \sigma_1^2 \right\}$$
$$U_H^{A_1} = r_B \left(\phi + 1 \right) \sigma_1 \sigma_2 - r_B + \frac{1}{2} \left[\sigma_1 \left(2m_1 - \sigma_1 \right) + 2m_1 \left(k + H_1 - 1 \right) \right] + \frac{1}{2} \lambda \sigma_1^2.$$

The expected benefit of not setting the information node in Link 1 is:

$$U_H^{A_0} = r_B \alpha k m_2 - \mu \left(1 - \sigma_1 \right).$$

According to the dynamic replication equation, the information nodes growth rate selected to set the information nodes in the setting links 1 and 2 to the overall proportion are $\dot{r}_A / r_A$ and $\dot{r}_B / r_B$. The two-dimensional dynamic system composed of the Malthusian equation is:

$$\dot{r}_A = r_A \left(1 - r_A \right) \left\{ \frac{1}{2} \left[\sigma_1 \left(2m_1 - \sigma_1 \right) + 2m_1 \left(k + H_1 - 1 \right) \right] + \frac{1}{2} \lambda \sigma_1^2 + \mu \left(1 - \sigma_1 \right) + r_B \left[\left(\phi + 1 \right) \sigma_1 \sigma_2 - \alpha k m_2 - 1 \right] \right\}$$

$$\dot{r}_B = r_B \left(1 - r_B \right) \left\{ \frac{1}{2} \left[\sigma_2 \left(2m_2 - \sigma_2 \right) + 2m_2 \left(k + H_2 - 1 \right) \right] + \frac{1}{2} \lambda \sigma_2^2 + \mu \left(1 - \sigma_2 \right) + r_A \left[\left(\phi + 1 \right) \sigma_1 \sigma_2 - \alpha k m_1 - 1 \right] \right\}$$

Set $\dot{r}_A = 0$, $\dot{r}_B = 0$

$$r_A = 0, r_A = 1, r_{BD} = \frac{\sigma_1 \left(m_1 - \sigma_1 / 2 \right) + m_1 \left(k + H_1 - 1 \right) + \lambda \sigma_1^2 / 2 + \mu \left(1 - \sigma_1 \right)}{1 + \alpha k m_2 - \left(\phi + 1 \right) \sigma_1 \sigma_2}$$
$$r_B = 0, r_B = 1, r_{AD} = \frac{\sigma_2 \left(m_2 - \sigma_2 / 2 \right) + m_2 \left(k + H_2 - 1 \right) + \lambda \sigma_2^2 / 2 + \mu \left(1 - \sigma_2 \right)}{1 + \alpha k m_1 - \left(\phi + 1 \right) \sigma_1 \sigma_2}.$$

This leads to the following proposition.

Proposition 4.6. *The strategic equilibrium points of the dynamic evolution game between the upstream and downstream sides of the supply chain in different states is as follows:*

$$\left(r_A, r_B \right) = \left(0, 0 \right), \left(0, 1 \right), \left(1, 0 \right), \left(1, 1 \right), \left(r'_{AD}, r'_{BD} \right).$$

Proposition 4.7. *The local stability of each equilibrium point is as follows:*

When $\overline{H}_1 < H_1 < 1$, $\overline{H}_2 < H_2 < 1$, the stable equilibrium strategy is $\{set, set\}$. When $0 < H_1 < \overline{H}_1$, $\overline{H}_2 < H_2 < 1$, the stable equilibrium strategy is $\{noset, set\}$. When $\overline{H}_1 < H_1 < 1$, $0 < H_2 < \overline{H}_2$, the stable equilibrium strategy is $\{set, noset\}$. When $0 < H_1 < \overline{H}_1$, $0 < H_2 < \overline{H}_2$, the stable equilibrium strategy is $\{noset, noset\}$.

Amongst them,

$\overline{H}_1 = 1 + \frac{\sigma_1^2}{2m_1} - \sigma_1 - k - \frac{(\phi+1)\sigma_1\sigma_2 + \mu(1-\sigma_1) - \alpha k m_2 - 1}{m_1}$,

$\overline{H}_2 = 1 + \frac{\sigma_2^2}{2m_2} - \sigma_2 - k - \frac{(\phi+1)\sigma_1\sigma_2 + \mu(1-\sigma_2) - \alpha k m_1 - 1}{m_2}$.

(2) Based on the government rewards perspective and punishments. Under the condition that the sum of government compensation and synergistic benefits is higher than the transaction cost, that is: under the condition of $\frac{1}{2}\lambda\sigma_1^2 + (\phi+1)\sigma_1\sigma_2 - 1 > 0$, within the range of $0 < H_1 < 1$, $0 < H_2 < 1$, the stable equilibrium strategy is:$\{set, set\}$. Under the condition that the sum of government compensation and synergistic benefits is lower than the transaction cost, $\frac{1}{2}\lambda\sigma_1^2 + (\phi+1)\sigma_1\sigma_2 - 1 < 0$, there are the following possible, stable equilibrium

strategies: if $\overline{H}_1 < H_1 < 1$, $\overline{H}_2 < H_2 < 1$, then the stable equilibrium strategy is; $\{set, set\}$ When $0 < H_1 < \overline{H}_1$, $\overline{H}_2 < H_2 < 1$, the stable equilibrium strategy is $\{noset, set\}$. When $\overline{H}_1 < H_1 < 1$, $0 < H_2 < \overline{H}_2$, the stable equilibrium strategy is $\{set, noset\}$. When $0 < H_1 < \overline{H}_1$, $0 < H_2 < \overline{H}_2$, the stable equilibrium strategy is $\{noset, noset\}$.

Under the condition of government reward and punishment, the coordinates of the saddle point are $S\left(r'_{AD}, r'_{BD}\right)$, and the area of the quadrilateral OMSN is shown in formula (10):

$$G' = \frac{1}{2}\left[\frac{\sigma_2\left(m_2 - \sigma_2/2\right) + m_2\left(k + H_2 - 1\right) + \lambda\sigma_2^2/2 + \mu\left(1 - \sigma_2\right)}{1 + \alpha k m_1 - (\phi + 1)\,\sigma_1\sigma_2} + \frac{\sigma_1\left(m_1 - \sigma_1/2\right) + m_1\left(k + H_1 - 1\right) + \lambda\sigma_1^2/2 + \mu\left(1 - \sigma_1\right)}{1 + \alpha k m_2 - (\phi + 1)\,\sigma_1\sigma_2}\right] \tag{4.2}$$

In equation (4.2), the sensitivity analysis of other parameters is consistent with Proposition 4.5 except for the difficulty of setting traceability nodes $\sigma_1, \sigma_2$and the reward coefficient λ and penalty coefficient μ.

Proposition 4.8. *The sensitivity analysis of the parameter changes to the evolution of the equilibrium point is as follows:*

(1) When the conditions of $m_1 + \sigma_1\lambda > \sigma_1 + \mu, m_2 + \sigma_2\lambda > \sigma_2 + \mu$ are met, the increase in the difficulty of setting up each link will still promote the evolution of the decision-making in each supply chain link towards the equilibrium point of $\{set, set\}$.

Proof. Calculate the derivative of the difficulty of setting the traceability node σ_1, σ_2 to equation (4.2), respectively, we obtain

$$\begin{aligned}\frac{\mathrm{d}G'}{\mathrm{d}\sigma_1} &= \frac{\sigma_2(\phi+1)\left[2m_1(H_1+k-1) - \sigma_1(\sigma_1 - 2m_1) + \sigma_1^2\lambda - 2\mu(\sigma_1 - 1)\right]}{4\left[\alpha k m_2 - \sigma_1\sigma_2(\phi+1) + 1\right]^2} \\ &\quad + \frac{\sigma_2(\phi+1)\left[2m_2(H_2+k-1) - \sigma_2(\sigma_2 - 2m_2) + \sigma_2^2\lambda - 2\mu(\sigma_2 - 1)\right]}{4\left[\alpha k m_1 - \sigma_1\sigma_2(\phi+1) + 1\right]^2} + \frac{2(m_1 - \sigma_1 + \sigma_1\lambda - \mu)}{4\left[\alpha k m_2 - \sigma_1\sigma_2(\phi+1) + 1\right]} \\ \frac{\mathrm{d}G'}{\mathrm{d}\sigma_2} &= \frac{\sigma_1(\phi+1)\left[2m_1(H_1+k-1) - \sigma_1(\sigma_1 - 2m_1) + \sigma_1^2\lambda - 2\mu(\sigma_1 - 1)\right]}{4\left[\alpha k m_2 - \sigma_1\sigma_2(\phi+1) + 1\right]^2} \\ &\quad + \frac{\sigma_2(\phi+1)\left[2m_2(H_2+k-1) - \sigma_2(\sigma_2 - 2m_2) + \sigma_2^2\lambda - 2\mu(\sigma_2 - 1)\right]}{4\left[\alpha k m_1 - \sigma_1\sigma_2(\phi+1) + 1\right]^2} + \frac{2(m_2 - \sigma_2 + \sigma_2\lambda - \mu)}{4\left[\alpha k m_1 - \sigma_1\sigma_2(\phi+1) + 1\right]}.\end{aligned}$$

Combined with the above analysis, when $m_1 + \sigma_1\lambda > \sigma_1 + \mu, m_2 + \sigma_2\lambda > \sigma_2 + \mu$, $\frac{\mathrm{dG}}{\mathrm{d}\sigma_1}$, and $\frac{\mathrm{dG}}{\mathrm{d}\sigma_2}$ must be greater than 0, the increase in the difficulty of setting traceability nodes will promote each supply chain link to increase the setting ratio of traceability information. □

(2) The improvement of the reward coefficient will help the decision-making of each supply chain link to evolve toward the equilibrium point of $\{set, set\}$.

Proof. Calculate the derivative of the reward coefficient λ, respectively, with respect to equation (4.2), we obtain:

$$\frac{\mathrm{d}G'}{\mathrm{d}\lambda} = \frac{\sigma_1^2}{4\left[\alpha k m_2 - \sigma_1\sigma_2(\phi+1) + 1\right]} + \frac{\sigma_2^2}{4\left[\alpha k m_1 - \sigma_1\sigma_2(\phi+1) + 1\right]}.$$

Based on the above analysis, $\frac{\mathrm{dG}}{\mathrm{d}\lambda}$ must be greater than 0; the larger the reward coefficient set by the government for the supply chain traceability information node, the more conducive it is to promote the establishment of information nodes in each supply chain link. □

(3) The improvement of the penalty coefficient will help the decision-making of each supply chain link to evolve toward the equilibrium point of $\{set, set\}$.

Proof. Calculate the derivative of the penalty coefficient μ with respect to Eq. (10), we obtain

$$\frac{\mathrm{dG}}{\mathrm{d}\mu} = \frac{(1-\sigma_1)}{2\left[\alpha k m_2 - \sigma_1\sigma_2\left(\phi+1\right)+1\right]} + \frac{(1-\sigma_2)}{2\left[\alpha k m_1 - \sigma_1\sigma_2\left(\phi+1\right)+1\right]}.$$

Based on the above analysis, $\frac{\mathrm{dG}}{\mathrm{d}\mu}$ must be greater than 0; the greater the government penalty coefficient for not setting up supply chain traceability information nodes, the more conducive it is to promote the information nodes establishment in each supply chain link. □

5. Simulation

Combined with the previous mathematical analysis, this section uses Vensim PLE software to assign values to the influencing factors of the decision-making mechanism in each supply chain link set in Figure 1. The parameter settings are as follows: The probability r_A of setting the information node in Link 1 and the probability r_B of setting the information node in Link 2 are set as $\{0.3, 0.7\}$. The setting difficulty coefficient σ_1 and σ_2 of the information nodes in Links 1 and 2 are set as $\{0.5, 0.2\}$. The information degrees m_1 and m_2 of the unit information nodes of links 1 and 2 are set as $\{0.5, 0.2\}$. The information conversion coefficient k was set to 0.5, and the external effect coefficient α was set to 0.5.

On this basis, the three scenarios of setting up information nodes independently under unconstrained conditions, setting up information nodes cooperatively, and setting up information nodes under the government reward and punishment mechanism for each supply chain link, conversely, simulate the system stability and equilibrium results of different scenarios. In contrast, specific cases are introduced to analyse each scenario's characteristics and compare and analyse the decision-making differences in each supply chain link under different scenarios.

5.1. Evolutionary game: each link of the supply chain independently provides traceability information under unconstrained conditions

Combining Propositions 4.1 and 4.2, $H_1 = 0.8$, $H_2 = 0.8$; $H_1 = 0.1$, $H_2 = 0.9$; $H_1 = 0.9$, $H_2 = 0.1$; $H_1 = 0.2$, $H_2 = 0.2$ are taken separately. Figure 2b depicts the evolution results of the information node setting decision in Links 1 and 2.

Figure 2b shows that the system stability decision of the evolutionary game in each link simulated by the simulation is logically consistent with the theoretical result when independently setting information nodes without constraints. When the consumption compensation level of both parties is low, neither party has an incentive to set up information nodes. When the consumption compensation reaches a certain level, the information node is set at the link with a higher consumption compensation level, and the other side is not set. When the consumption compensation level continues to increase, both parties will have an incentive to set up information nodes simultaneously.

Most of the decisions in each link of China's traditional fresh food supply chain belong to this basic model. The domestic consumption level was low in the early stage of reform and opening up, taking pork consumption as an example. It was difficult for the market to provide sufficient consumption compensation to the pork supply chain. In addition, the technical conditions were not mature enough, and each link of the pork supply chain made independent decisions and had no motivation. When setting up traceability information nodes in the pork market at that time, retailers were unable to provide consumers with pork traceability information, which led to many quality problems such as 'water-injected meat'.

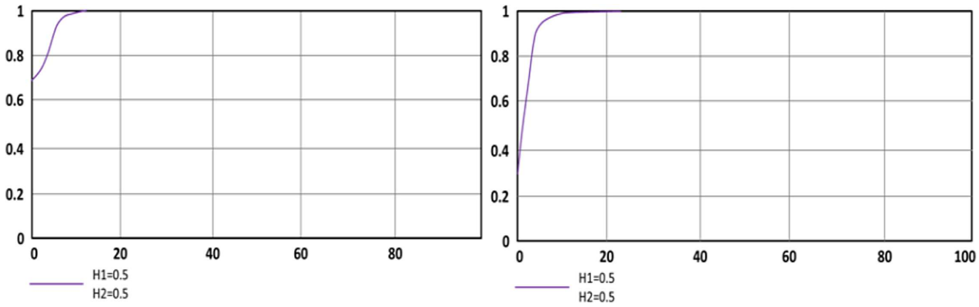


FIGURE 3. Stable decision-making in an evolutionary game system with independent traceability information provided by each link of the supply chain under unconstrained conditions.

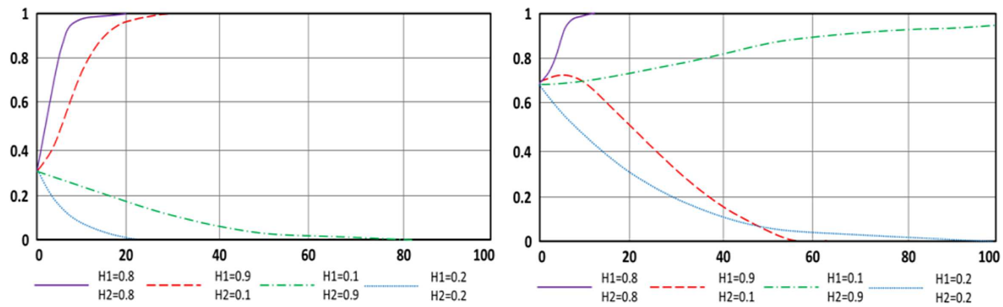


FIGURE 4. Stable decision-making in an evolutionary game system where the synergy benefits are higher than the transaction cost and each link provides traceability information.

5.2. Evolutionary game: all links in the supply chain cooperate to provide traceability information under unconstrained conditions

Combining Propositions 4.3 and 4.4, the synergy coefficient ϕ is set to eight when synergy benefits are lower than transaction costs, that is, $(\phi+1)\,\sigma_1\sigma_2 - 1 < 0$. $H_1 = 0.9$, $H_2 = 0.9$; $H_1 = 0.4$, $H_2 = 0.8$; $H_1 = 0.05$, $H_2 = 0.95$; $H_1 = 0.95$, $H_2 = 0.05$; $H_1 = 0.1$, $H_2 = 0.1$; $H_1 = 0.1$, $H_2 = 0.5$ are taken separately. Figure 3 illustrates the evolution results of the information node-setting decision in Links 1 and 2. The synergy coefficient ϕ is set to 15 when synergy benefits are higher than transaction costs, that is, $(\phi+1)\,\sigma_1\sigma_2 - 1 > 0$. $H_1 = 0.5$, $H_2 = 0.5$ are taken. Figure 4 shows the simulation results.

Figures 3 and 4 show that the simulation results are logically consistent with the theoretical conclusions when information nodes are set in unconstrained cooperation. Synergistic benefits and transaction costs are important conditions that affect the decision-making of information nodes in each link under the conditions of cooperation. When the synergy benefit is greater than the cooperation cost, without considering the influence of other factors, each link chooses to set up information nodes to provide traceability information. When the synergy benefit is less than the cooperation cost, if the consumption compensation of both parties is low, neither party has an incentive to set up information nodes. With the increase in consumption compensation, the game will provide traceability information to the information nodes set up in the link with a larger compensation degree. The evolution of the link that requires less compensation does not provide traceability information.

Continued analysis of the Chinese pork supply chain. With the continuous improvement of China's per capita income level, consumers' requirements for pork quality have become increasingly stringent, and they have begun to demand information on pork origin and quality. They are willing and able to provide 'information on pork

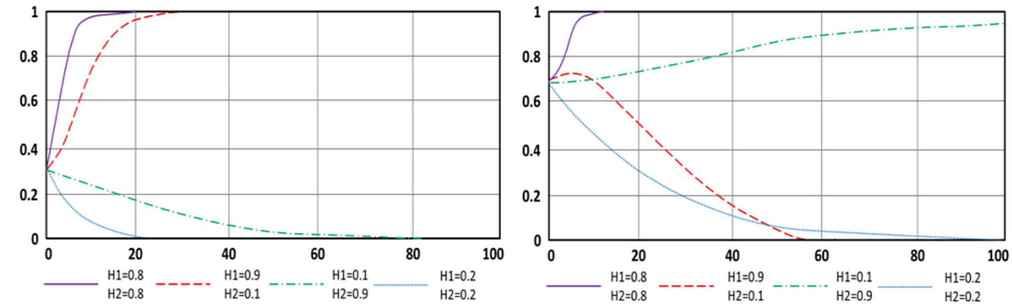


FIGURE 5. Stable decision-making in an evolutionary game system where the synergy benefits are lower than the transaction cost and each link provides traceability information.

prices higher than average Premium' and the current brand pork on the market basically adopts the company's exclusive pig supply chain, and through signing contracts with farmers to ensure the quality of the company's purchase of live pigs. Tianbang Food Co., Ltd., which was listed in 2007 as an example. The company has its own dedicated pig breeding farm and signs a special purchase agreement with farmers. The farmers must breed live pigs according to the company's requirements and only sell live pigs of this variety to Tianbang Foods and shall not be sold privately. The Tianbang Food Company uses ear tag technology to identify and monitor the growth of each pig to ensure the breed and quality of pigs. Similarly, Suzhou Sutai Enterprise Co., Ltd. also controlled the quality of live pigs through targeted cooperation with farmers. It also has a commercial pig production base and a meat processing plant, and ensures the quality of pork at the end of the sales by joining a franchised store. Consumers are willing to pay a higher premium for high-quality pork that can provide traceability information. Companies that receive consumer compensation are more willing to use ear tag technology to add traceability information nodes, provide consumers with more accurate product traceability information and increased brand awareness and market share.

5.3. Evolutionary game of providing traceability information in each link of the supply chain under the government reward and punishment

Combining Propositions 4.5 and 4.6, the government reward coefficient λ and punishment coefficient μ are set as $\{1, 0.7\}$ when the sum of government compensation and synergistic benefits is lower than transaction costs, which is, under the condition of $\frac{1}{2}\lambda\sigma_1^2 + (\phi+1)\,\sigma_1\sigma_2 - 1 < 0$. The synergy coefficient ϕ is 3.5, and $H_1 = 0.8$, $H_2 = 0.8$; $H_1 = 0.1$, $H_2 = 0.9$; $H_1 = 0.9$, $H_2 = 0.1$; $H_1 = 0.2$, $H_2 = 0.2$; $H_1 = 0.55$, $H_2 = 0.25$ are taken separately. Figure 5 depicts the evolution results of the available information node setting decisions. When $\frac{1}{2}\lambda\sigma_1^2 + (\phi+1)\,\sigma_1\sigma_2 - 1 > 0$, the government reward coefficient λ and punishment coefficient μ are set as $\{5, 0.7\}$. ϕ is set as 3.5, and $H_1 = 0.5$, $H_2 = 0.5$ are taken.

Figures 5 and 6 show that the simulation results confirm the theoretical propostion in the presence of the government compensation and punishment mechanism. The government's reward mechanism is similar to the cooperation mechanism, which further supplements cooperation benefits. The existence of the punishment mechanism induces the decision-making of links that are unwilling to set up the information nodes. Consistent with previous findings, the sum of government compensation and synergistic benefits and the size of transaction costs are important conditions that affect the decision-making of information nodes in each link under the conditions of cooperation. When the sum of government compensation and synergistic benefits is higher than the transaction costs, each link chooses to set up information nodes. Under the condition that the sum of government compensation and synergistic benefits is lower than the transaction cost, information nodes are set up in the links with higher consumption compensation. In contrast, those with lower consumption compensation are not set up, but this behaviour is gradually set up to improve consumption compensation. Information Node Evo-

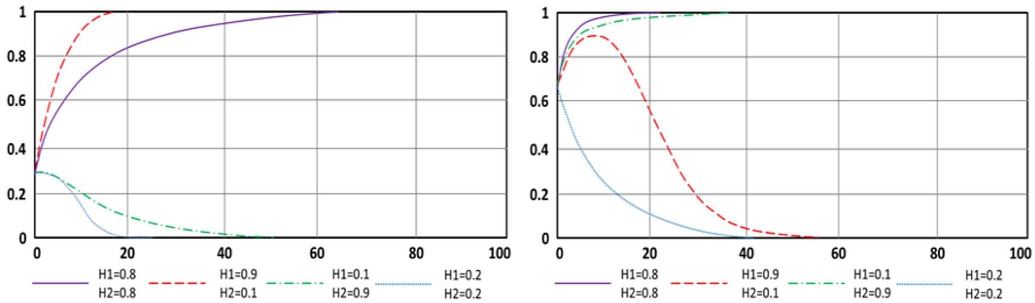


FIGURE 6. Stable decision-making in an evolutionary game system that provides traceability information when the sum of government compensation and synergistic benefits is higher than transaction costs.

lution. The government's punishment mechanism further supplements the effect of the reward mechanism, and there is no longer a stable equilibrium that neither side sets.

The Chinese government has made significant efforts to fresh foord safety. Taking the pork market as an example, from the perspective of incentives, it encourages merchants to adopt high-quality operations that are stricter than the basic norms through publicity, provides financial incentives and technical support for manufacturers with traceability systems, encourages related enterprises and scientific research institutions. Cooperate to carry out "industry-university-research" projects and provide certain funds and policy support for them. It is also under the support of government scientific research projects that Suzhou Sutai Enterprise Co., Ltd. has realised the application of some patent technologies for pig information traceability in actual production through cooperation with scientific research institutions. They have added traceability information nodes to improve the quality of traceability information. From the perspective of punishment, the Chinese government has promulgated many laws and regulations and introduced some pork food safety systems of management. This includes strict requirements for retailers to publicise pork purchase information, standardise pork transportation and storage conditions, and strictly prohibit the sale of spoilt pork. There are corresponding penalites for behaviours that do not meet the sales conditions such as fines, rectification, and revocation of licences. In recent years, the Chinese government has greatly promoted the construction of China's supply chain of information traceability system by combining rewards and punishments, leading enterprises to construct the traceability information system actively, and continuously improving informatisation and modernisation level of China's supply chain system.

6. Concluding remarks

With the continuous upgrading of production technology and consumer demand, production links far away from the consumer market can provide detailed information on the downstream production process. Consumers need to understand the production information of the final product and gradually have the willingness to pay and the ability to pay for traceability information. With the help of evolutionary game theory, this study simulates the strategy evolution process of each supply chain link, cooperatively setting up information nodes under the government reward and punishment mechanism and under unconstrained conditions, focusing on the compensation provided by consumers for information premiums for manufacturers' information costs, and explores the evolution path of the manufacturer's decision to set up information nodes under the consumer information compensation mechanism. With the help of system dynamics simulation tools and real case analysis, the robustness of the model was verified.

6.1. Conclusion

This study mainly draws the following research conclusions:

(1) When each link independently sets up information nodes under unconstrained conditions, if the level of consumer compensation is low, each link has no incentive to set up information nodes. With the increase in the consumer compensation proportion, the supply chain link that obtains greater compensation is selected, set up an information node, and the other party chooses not to set up an information node and obtains external benefits by 'free riding'. After the consumer compensation reaches a certain level, both parties will evolve to a balanced strategy in which both information nodes are set. The evolutionary path is related to the initial state and willingness to pay during this process.
(2) When each link cooperates to set up information nodes under unconstrained conditions, the cooperation mechanism strengthens the effect of consumption compensation, and the core mechanism is the size of synergistic benefits and transaction costs. When the synergy benefit is large, each link cooperates to set up information nodes, and when the synergy benefit is small, the 'free-rider' behaviour is chosen. With the continuous improvement of cooperative and synergistic benefits, the evolution direction of the game results is as follows: set the traceability information node for the link with greater compensation, and do not set the traceability information node for the link with less compensation. After the synergy benefit exceeds the cooperation cost, the game achieves a steady-state where both parties set up information nodes.
(3) When information nodes are set up in each link under government rewards and punishments, the government's reward mechanism is similar to the cooperation mechanism, and synergy can be achieved. A larger reward mechanism will increase the willingness of each link to cooperate in setting up information nodes, and punishment measures can effectively avoid the 'prisoner's dilemm' in which both parties are unwilling to set up information nodes. However, the effect of reward and punishment policies is still affected by consumption compensation, which must be based on a higher compensation ratio.

6.2. Research Outlook

This study analyses the evolutionary game results of the consumer compensation mechanism's decision to set up information nodes in each supply chain link under the conditions of independence and cooperation, as well as government rewards and punishments. The research conclusions have certain theoretical and practical significance for constructing a supply chain traceability information system. In practical work, the focus should be on promoting consumption upgrades improving the level of consumption compensation set by traceability information nodes in each supply chain link. The focus should also be on strengthening win-win cooperation among various links and supplementing the government's reward and punishment mechanism. The research results pointed out that in the early stage of the construction of the traceability information system, when the supply chain manufacturers received low compensation from consumers and made it difficult for enterprises to cooperate, it is indeed an effective method to guide the evolution path with the help of the government reward and punishment mechanism. However, this policy cost is huge and difficult to last. Therefore, to ensure good and long-term operation, it is necessary to promote the implementation and play of the information cost compensation mechanism for manufacturers.

As far as the pork supply chain cases are concerned, from the perspective of live pig suppliers, the focus should be on strengthening the traceability of each live pig, focusing on detailed information on various indicators such as different growth and development, feed environment, vaccination, infectious diseases, and treatment. Therefore, pigs of different quality classes are distinguished in detail. From the perspective of pork processors, strict standards for different quality levels of pork should be formulated in detail. Information should be marked on the source, slaughter and processing time, storage and transportation conditions, and time of each piece of pork to provide consumers with detailed product production information. From the government's perspective, cooperation and exchanges between manufacturers should be guided step-by-step; policy, financial, and technical support should be provided for manufacturers participating in the construction of the traceability information system, and enterprises that violate food safety regulations should be punished. From the consumers' perspective, it can guide consumers to transform to green and healthy consumption habits. At the same time establish a feedback mechanism for direct consumer opinions to ensure that consumers have suggestions, questions, or requirements for any link in the supply chain. This can be the first time feedback is given to the corresponding links and manufacturers, thereby promoting the construction of the supply chain system to better meet the needs of consumers.

The research in this study only draws relevant conclusions through mathematical model derivation and proof. In the future, empirical data and empirical methods need to be verified. In addition, this study does not analyse horizontal game decision-making between different links in the supply chain, nor does it consider the impact of other industries on decision-making. It is hoped that the following ideas can be extended for follow-up research: first, conduct more targeted empirical analysis and empirical testing based on specific cases or data. Second, we explore the game mechanism of competition or cooperation between horizontal links in different supply chains. Third, we explore the evolution of traceability information decision-making in each link in a multi-industry supply chain network system.

Appendix A.

A.1. Proposition 1 proves: (Others are same)

Table A.1. Local stability of each equilibrium point under the condition of independently setting information nodes.

	Condition 1: $\overline{H}_1 < H_1 < 1$; $\overline{H}_2 < H_2 < 1$		
$(0,0)$	$trJ > 0$	$\det J > 0$	Point of instability
$(0,1)$	–	$\det J < 0$	Saddle point
$(1,0)$	–	$\det J < 0$	Saddle point
$(1,1)$	$trJ < 0$	$\det J > 0$	Stabilisation strategy ESS
	Condition 2: $0 < H_1 < \overline{H}_1$; $\overline{H}_2 < H_2 < 1$		
$(0,0)$	–	$\det J > 0$	Saddle point
$(0,1)$	$trJ < 0$	$\det J > 0$	Stabilisation strategy ESS
$(1,0)$	$trJ > 0$	$\det J > 0$	Point of instability
$(1,1)$	–	$\det J > 0$	Saddle point
	Condition 3: $\overline{H}_1 < H_1 < 1$; $0 < H_2 < \overline{H}_2$		
$(0,0)$	–	$\det J < 0$	Saddle point
$(0,1)$	$trJ > 0$	$\det J > 0$	Point of instability
$(1,0)$	$trJ < 0$	$\det J > 0$	Stabilisation strategy ESS
$(1,1)$	–	$\det J < 0$	Saddle point
	Condition 4: $0 < H_1 < \overline{H}_1$; $0 < H_2 < \overline{H}_2$		
$(0,0)$	$trJ < 0$	$\det J > 0$	Stabilisation strategy ESS
$(0,1)$	–	$\det J < 0$	Saddle point
$(1,0)$	–	$\det J < 0$	Saddle point
$(1,1)$	$trJ > 0$	$\det J > 0$	Point of instability

$dr_A/dt = 0$; $dr_B/dt = 0$; $(r_A, r_B) = (0,0), (0,1), (1,0), (1,1)$ are the balance points.

A.2. Proposition 2 proves: (Others are same)

Constructing the Jacobian matrix J of the system and judging the local stability,

$$J = \begin{bmatrix} \dot{r}_A/r_A & \dot{r}_A/r_B \\ \dot{r}_B/r_A & \dot{r}_B/r_B \end{bmatrix},$$

$\dot{r}_A/r_A = \frac{1}{2}\left(1-2r_A\right)\left[\sigma_1\left(2m_1-\sigma_1\right)+2m_1\left(k+H_1-1\right)\right];\dot{r}_A/r_B = 0;\dot{r}_B/r_A = 0;$
$\dot{r}_B/r_B = \frac{1}{2}\left(1-2r_B\right)\left[\sigma_2\left(2m_2-\sigma_2\right)+2m_2\left(k+H_2-1\right)\right].$

Combining Friedman (1998)[3] to determine the trace condition ($trJ < 0$) and the determinant condition ($\det J > 0$),

$\frac{1}{2}\left[\sigma_1\left(2m_1-\sigma_1\right)+2m_1\left(k+H_1-1\right)\right]+\alpha k m_2-\alpha k m_2 > 0,$

Obtain: $H_1 > 1+\frac{\sigma_1^2}{2m_1}-\sigma_1-k$

Set: $\overline{H}_1 = 1+\frac{\sigma_1^2}{2m_1}-\sigma_1-k$; $\overline{H}_2 = 1+\frac{\sigma_2^2}{2m_2}-\sigma_2-k$

When $\overline{H}_1 < H_1 < 1$, $\overline{H}_2 < H_2 < 1$, the stable equilibrium strategy is $\{set, set\}$. When $0 < H_1 < \overline{H}_1$, $\overline{H}_2 < H_2 < 1$, the stable equilibrium strategy is $\{noset, set\}$. When $\overline{H}_1 < H_1 < 1$, $0 < H_2 < \overline{H}_2$, the stable equilibrium strategy is $\{set, noset\}$. When $0 < H_1 < \overline{H}_1$, $0 < H_2 < \overline{H}_2$, the stable equilibrium strategy is $\{noset, noset\}$.

Table A.1 shows the judgment of the local stability of the equilibrium point in each case.

Appendix B.

A dynamic system model for the decision-making of the information nodes in Link 1 and 2 of supply chain is established through the system dynamics analysis method, as shown in Figure B.1.

The model contains two variables (probability of setting the source tracing information node Link 1 and probability of setting the source tracing information node in Link 2); two flow rate variables (the probability change rate of the traceability information node is set in Link 1 and the probability change rate of the traceability information node is set in Link 2); four auxiliary variables (the expected return of the information node is set Link 1, the expected return of the information node is not set in Link 1, the expected return of the information node is set in Link 2 and the expected return of the information node is not set in Link 2) and several external variables (the remaining variables). The flow level variable is an integral function of the convection rate variable over time. The relationship between the flow rate and auxiliary variables is determined by replicating dynamic equations of different subjects in the evolutionary game.

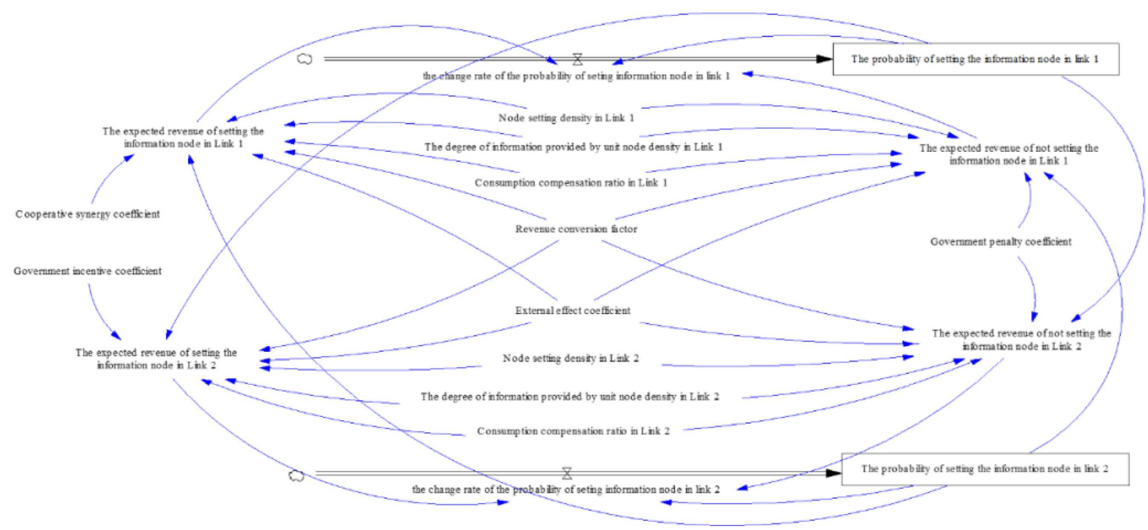


Figure B.1. Power system model of supply chain traceability information node setting.

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