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Study of the Game Model of E-Commerce Information Sharing in an Agricultural Product Supply Chain based on fuzzy big data and LSGDM

Luo ming [a,b], Zhou GuoHua [a,*], Wei Wei [c]

[a] School of Economics and Management, Southwest Jiaotong University, Chengdu 610031, China
[b] School of Economics and Management, Tibet University, Lhasa 850012, China
[c] School of Computer Science and Engineering, Xi'an University of Technology, Xi'an 710048, China

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ABSTRACT

Information asymmetry is the root of agricultural product quality problems. Generally speaking, the common problems related to agricultural products are solved by effective supply chain management. From the perspective of agricultural supply chain management, this paper analyzes the shortcomings of the traditional supply chain management process by using fuzzy big data and LSGDM (Large scale group decision making), and puts forward a new method of supply chain management. In addition, from the perspective of asymmetric information sharing regarding agricultural products, an asymmetric information sharing model for agricultural products based on the evolutionary rule theory is established. Combined with fuzzy big data and LSGDM, this paper puts forward the hypothesis of each variable in the process of the information sharing game. On this basis, a mathematical model of the "pool equilibrium" of the high and low prices in the agricultural products market is put forward. Finally, a case study of products of different quality in the sea cucumber market is carried out. The results show that high quality sea cucumber products occupy a large market share in the supply chain of agricultural products. The research of this paper is of great significance, because it can increase the reliable theoretical data available for the research of the agricultural supply chain.

1. Introduction

China is a major agricultural producer. Agriculture has always been an important part of China's national economy. At present, China is in the process of transforming from an agricultural society to an industrial society; however, the basic guarantee of people's material life is still agriculture. Introducing contract thinking into agricultural economic activities is an important channel for agricultural development. Through practical research, it has been proven that contract agriculture can effectively solve various contradictions in the agricultural market. However, in real-life situations, there are some shortcomings in the actual development of contract agriculture. These shortcomings are related to the inherent shortcomings of the supply chain in the operation process. Because of asymmetric information regarding agricultural products in the operational process of the supply chain, there is great uncertainty in the supply chain itself. This leads to the strong sensitivity of other components in the supply chain, which makes the actual operations of the agricultural supply chain difficult to coordinate (Cui, 2015).

With the accelerating process of global economic integration, the level of science and technology and the level of the economy have been improved to a certain extent. The current commodity circulation has been analyzed from the perspective of the supply chain. Supply chain management ideas have penetrated into various industries and injected increased competitiveness into individual businesses and enterprises. In real-life situations, as an important part of the supply chain system, the supply chain of agricultural products is different from other forms of supply chains (Jiang et al., 2019). For the agricultural supply chain, there is information flow transmission between upstream farmers and downstream sellers. However, due to their different positions, there are some differences in the integrity and timeliness of the information they are able to access and control (Jiang et al., 2015). Information is an important element that shapes each role in the supply chain and enables different players to make decisions. The production of agricultural products will directly affect the quantity decisions of the seller. The downstream sales enterprises of the supply chain are the last link in the flow of agricultural products to the client side; therefore, these downstream sales enterprises have direct access to the market demand

* Corresponding author.
E-mail address: jielu4395fanlu@163.com (Z. GuoHua).

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information of the customers. This market information is an important basis for farmers as they seek to formulate their production volume in the upstream of the supply chain, which is also the main factor that determines the farmers' income. Therefore, it is necessary to coordinate the mechanism of information transmission and information sharing in the supply chain of agricultural products. If the information sharing of each member in the supply chain is very symmetrical, the operation of the supply chain of agricultural products will be smooth, and members of both the upstream and downstream of the supply chain can achieve the best income; this is the ideal of a healthy agricultural supply chain operation. However, in real-life situations, both the upstream farmers and the downstream sales enterprises operate from their own situation. The upstream farmers hope that the downstream enterprises can receive an unlimited amount of their agricultural products and maximize the sales prices, while the downstream sales enterprises hope that the upstream farmers can provide accurate quantity and good quality agricultural products; however, sales enterprises typically consider that the lower the purchase price, the better. In the process of communication between the two sides, some important information will be concealed, which leads to the distortion of information transmission in the agricultural supply chain, and the appearance of bilateral effects. In this context, effectively solving the information asymmetry of the agricultural product supply chain and improving the operational efficiency of the entire agricultural product supply chain has become the key to the development of e-commerce in the agricultural product supply (Tang et al., 2015).

In this paper, we use the game model to examine information asymmetry. The essence of the game theory is to coordinate the distribution of interests among the members of the supply chain so that each party can benefit from each of the others. The goal is to reduce the distortion of information transmission and maximize the elimination of the conflicts of interest among the members of the supply chain, so as to optimize the operation of the supply chain. To promote the effective cooperation of supply chain members, experts and scholars have begun to apply game theory to the supply chain, and have achieved certain results (Li et al., 2010; Guo et al., 2011; Sošić, 2010). The adjustment method combined with a game model has become a research focus of supply chain management scholarship and provides references for decision-making across the entire range of supply chain operations (Hamari, 2013; Inderfurth et al., 2013; Rahayu et al., 2015).

Food is an essential element of every person's life, and agricultural products are inseparable from daily life. With the continuous improvement of people's living standards, increasing attention has been focused on the issues concerning the quality and safety of agricultural products (Raghunathan, 2003). The frequent problems with food safety are concerning, as food safety affects people's health and can impede the stable development of a country (Shnaiderman et al., 2014). The government monitors food safety, and more and more scholars are doing research in this field (Cheng, 2005). In view of the existing agricultural safety issues, the Chinese government has introduced a series of measures to safeguard the quality of agricultural products, and the agricultural sector has improved its quality and safety supervision from all aspects (Zhuping et al., 2013; Lambert et al., 2013). Traditionally, China has been a fundamentally agricultural country. China's agricultural production is affected by many variables, including seasonality, degree of freshness, regionality, and decentralization (He et al., 2014; Ahmad et al., 2015). The production of agricultural products is affected by natural factors. Fresh products are necessities in people's daily lives and consumption elasticity is low (Zhang et al., 2010). The benefits of studying supply chain management in manufacturing have been recognized by academics, governments, and businesses (Tian et al., 2011). Considerable achievement has been made in the research on supply chain management in manufacturing; however, to date, little attention has been paid to supply chain management in the agricultural field (Soto-Acosta et al., 2016). As research of the supply chain generally has developed, scholars have now begun to examine the supply chain of the agricultural field specifically (Hartono et al., 2014).

Most scholars believe that the level of agricultural products is closely related to the quality and safety of food. With the development of international agricultural trade, the ecological chain of agricultural products and the quality assurance of agricultural products have been extended from China to many foreign countries (Hopewell et al., 2015). In order to make the extended agricultural supply chain operate efficiently, partnerships should be established that benefit each party, and certain conditions should be achieved so that the parties operate consistently, exchange mutually, trust each other, and consider food safety to be their responsibility (Kurnia et al., 2015). Management of the ecological chain—strengthening each node of that chain—is vital to ensuring the safety and quality of agricultural products (Agarwal et al., 2015). The core content of agriculture product eco chain management is traceability management and a quality and safety certification system (Arunpraparut, 2015). In this paper, a distance based LSGDM method that considers group influence is proposed. The method designs a generalized distance measure between two points of information, which overcomes the limitations of existing distance measures (Zhan et al., 2021). It proposes a new cohesion measurement method of LSGDM based on a restricted equivalence function, which is used to measure the cohesion of expert sub groups, so as to promote the consensus process of majority groups and reduce the influence of internal divergence that may occur with a majority group driven CRP approach (RM et al., 2021). The proposed model is applied to solve a practical LSGDM problem that involves the evaluation of the influencing factors of network venture capital (X et al., 2021). This study considers the influence of trust relationships on CRP in large-scale group decision-making and proposes a consensus model based on behavior analysis; this model comprehensively considers leadership behavior and non cooperative behavior (C Zhang et al., 2021). Large scale group decision-making problems usually involve a large number of decision-makers. This paper proposes a T-SSGDM process to account for the heterogeneity between groups. Compared with the traditional LSGDM method, the framework does not need a cluster process to reduce the size of DMS alternatives to a manageable level (C Zhang et al., 2021).

The classic game theory is based on the assumption that the game participants are completely rational. However, in the agricultural industry, because each party seeks to maximize its own benefits and there is considerable information asymmetry among parties, the participants are not completely rational. Therefore, using evolutionary game theory to study the behavior of different players in the agricultural industry is more realistic and meaningful (Himes et al., 2016; Liang et al., 2017). The specific actions of the members of the current product safety management system have the characteristics of having a high cost and no obvious effect; this situation cannot effectively guarantee the quality and safety of products (García et al., 2016). In the study of the quality and safety management of the agricultural supply chain, there are still some problems: most of the literature does not combine product information management with supply chain management (Aulkemeier et al., 2016). China has vast territory and abundant resources, and the agricultural supply chain information asymmetry is serious and has impeded the development of a sound information management system (Chen et al., 2015). Many scholars use the classic game theory in their research, which does not fully reflect the reality that participants are not completely rational. Therefore, in this paper, based on the assumption of incompletely rational participants and fuzzy big data and LSGDM, evolutionary game research is carried out on the agricultural supply chain signal transmission mechanism. The aim of this research is to identify ways to ensure the quality and safety of supplied products through the control of signal transmission. This study of the safety supply mechanism of agricultural products has great theoretical and practical significance.

The main contributions of this paper include the following.

In view of the problem of information asymmetry in the process of agricultural product supply, it is concluded that the modern agricultural supply chain with online and offline supermarkets as the core can better serve the public and adapt to the current economic development.

Aiming at the complexity of the agricultural supply chain, fuzzy big data and large scale group decision making technology are proposed. To accomplish information sharing in the supply chain, the evolutionary game theory is established.

Taking sea cucumber products as an example, fuzzy big data and large scale group decision making technology are applied in practice, and an electronic information classification method of sea cucumber products is constructed. At the same time, the appropriateness of the proposed evolutionary game model is verified.

The rest of this paper is structured as follows. The first part analyzes the advantages of fuzzy big data and large scale group decision making technology in solving the problem of information asymmetry regarding agricultural products. This section also discusses the feasibility of the algorithm in solving problems related to agricultural products, which is very effective (Giri et al., 2020). The second part analyzes the principle and implementation process of fuzzy big data and the large scale group decision making technology. The third part puts forward the optimization strategy of using fuzzy big data and the large scale group decision making technology to solve the problem of information asymmetry regarding agricultural products. In the fourth part, the electronic information classification of sea cucumber agricultural products is carried out, and the appropriateness of the proposed evolutionary game model is verified (Biswas, 2020). The fifth part summarizes the research content of the asymmetry problem regarding agricultural products, summarizes the performance test results of the LSGDM method, and summarizes the application effect of the proposed technical model for a specific agricultural product (the sea cucumber).

2. Research on relevant theoretical models

2.1. Supply chain theory

The supply chain is a complex system composed of many elements. Consumer goods undergo an entire process consisting of many steps: raw material production and purchase, parts production and processing, product assembly molding, product distribution, and retail to the final consumer. This process includes the production and consumption of product materials, as well as the production and consumption of non-material products. Various product production, distribution, trade, and consumer links form a complete supply chain system.

This section discusses the theory of the ecological chain management of the supply of agricultural products supply. The agricultural product SCM is also known as the agricultural chain management, according to the overall planning and improvement of the flow of materials, information, and funds between food and agricultural production sectors. The participants in the supply chain can coordinate and promote each other through a reasonable and fair cooperation mechanism, benefit distribution mechanism, and performance evaluation mechanism. A supply chain strategic alliance of agricultural product producers and sellers can be established that will naturally improve the operational efficiency of the product supply chain, better meet the needs of consumers, and realize the dynamic equilibrium state of minimizing the total cost of agricultural products.

Considering the characteristics of management itself, combined with the particularity of each link of agricultural production and the nature of demand for agricultural products, we can identify the characteristics of product supply chain. The behavior of this supply chain depends on changes in market information. As national macroeconomic regulations and controls adjust and market positions changes, the supply chain will adjust its strategy to ensure that the total cost of the entire supply chain is minimized. Agricultural products have obvious and complex dynamics. Due to the different processing procedures of different crops, crop processing links are variable, and the links involved in processing, transportation, and marketing also have their own characteristics. Due to the seasonal, perishable, and regional characteristics of agricultural products, the process of crop operations is more complex than that of other industrial products and requires complicated and timely management. Due to the timeliness and perishability of crops, products must be delivered to consumers within a specified time, which creates higher requirements for crop management methods and techniques. At the same time, to establish a rapid response to customer needs, coordination requirements are higher. The structure of agriculture is complex, and the nodes in its supply chain belong to different supply chains; therefore, cooperation and communication between partners must run smoothly. Risk is hard to control. Each enterprise's risk comes from the market and its partners; agriculture also involves risks related to nature. Production is heavily dependent on climate, and the regional nature of information asymmetry regarding the crops themselves makes the risks in the crop supply chain particularly acute and difficult to control.

The flow charts of "supply chain of modern crop products" and "traditional agricultural product supply chain" are shown inFigs. 2 and 3, which show the difference between the modern and traditional supply chains. The cooperative relationship among enterprises in the supply chain of agricultural products is relatively long-term and stable, and in the process of the production and circulation of crops, enterprises are responsible for supervision and management. The core business of the "supply chain of modern crop products" is the supermarket; at the same time, the core enterprises are responsible for managing the suppliers and farms, and for contracting with the farmers to ensure quality and safety.

In a supply chain contract, through reasonable information disclosure, the buyer and the seller formulate a framework to ensure the effective operation of the supply chain process and improve the performance of the supply chain. A supply chain contract generally refers to the development of the supply chain in the direction of maximizing revenue through reasonable means of regulation and planning. In essence, a supply chain contract is a kind of game method, in which each member of the supply chain reaps the best profit. This kind of contract is based on the Pareto optimal solution. The common contract formalism includes wholesale price contracts, quantity discount contracts, quantity transfer payment contracts, revenue sharing contracts, option contracts, repurchase contracts, minimum purchase quantity contracts, and stock contracts. The research results of this common supply chain coordination contract are summarized as follows. (1) The wholesale price contract. This kind of contract can also be called a price contract; that is, the supplier first determines a benchmark wholesale price in the supply chain. Then, the retailers make purchasing plans according to market conditions and wholesale prices. Next, the supplier combines the retailer's purchasing plan to produce the products needed by the retailer, and the retailer bears all of the risks in the process. Therefore, in this contract mode, the supplier does not need to face the market risk directly; rather, all risks are borne by the retailer, and the supplier's own benefits are certain. (2) The quantity discount contract. From the formal point of view, the quantity discount contract can be divided into two

Fig. 1. A wide variety of agricultural products.

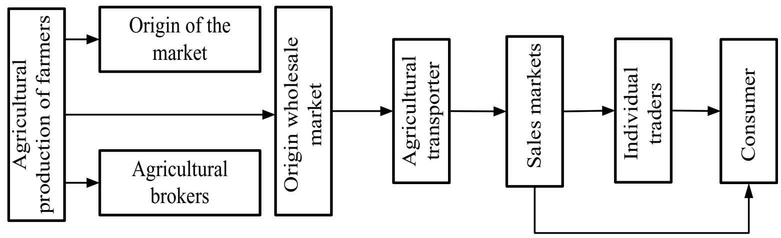

Fig. 2. Traditional agricultural supply chain.

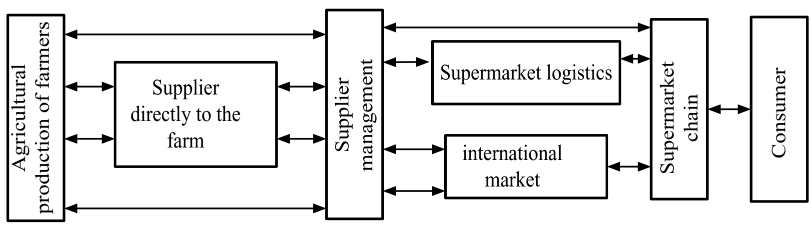

Fig. 3. Modern agricultural supply chain.

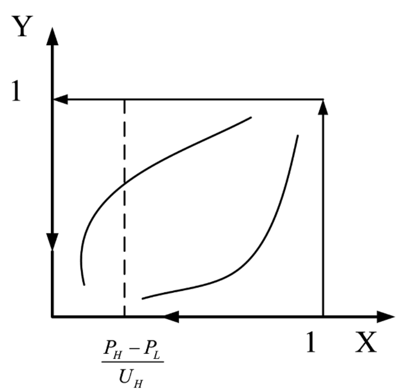

Fig. 4. Evolution phase diagram.

types: the full quantity discount model and the incremental discount model. The total quantity discount model mainly shows that if the retailer's current order quantity exceeds a certain limit, the supplier needs to give the retailer a certain degree of discount after exceeding the limit. If the retailer's order quantity is within this period, the supplier will provide products to the retailer at the original price. If the quantity of the order exceeds the contract limit, the retailer will give a discount according to the contract. (3) The quantity transfer payment contract. In this form of contract payment, the leader of the supply chain needs to set corresponding payment points for different orders. The payment principle is that the leader of the supply chain determines a benchmark supply threshold. If the current order quantity exceeds the payment benchmark, the leader of the supply chain needs to transfer part of the payment amount from the total amount. If the order quantity does not exceed the payment benchmark, the leader of the supply chain will There is no need to give in. (4) The revenue sharing contract. The revenue sharing contract is another form of contract in which the supplier first needs to provide the seller with a lower benchmark price, so as to obtain part of the revenue agreement from the seller; this improves the efficiency of the information flow and effectively coordinates the supply chain information. The principle of this contract is that the supplier can provide a sufficient quantity of goods to the retailer at a lower price in the process of the supply chain while also ultimately obtaining part of the income from the retailer; this increases the profits of the retailer. (5) The option contract. In this form of contract, the seller purchases a planned or specified quantity of bulk goods from the supplier. This option allows the seller to purchase a certain quantity of goods at an agreed price in the future. Therefore, this contract mode is an effective means for both parties to share the risks. (6) The buy back contract. This kind of contract means that the seller buys back the unsold goods at a reasonable price near the end of the selling season, which is lower than the original selling price. It is also a risk sharing mechanism, and the risk can be adjusted according to the repurchase price, which can be agreed upon by both supplier and retailer. (7) The minimum purchase quantity contract. In the minimum quantity contract, the seller needs to establish the minimum order quantity to reduce the market demand risk. Within this quantity range, the seller needs to give the seller a certain degree of concession. With the increase in the quantity, the revenue will gradually increase. (7) The inventory contract. This kind of contract means that in the early stage of the peak sales season, the supplier needs to book an order of goods from the seller according to the plan, and the remaining goods are considered inventory. After the peak sales season arrives, the supplier can protect the wholesale goods according to the agreement and then quickly obtain the required access. If there is no purchase of the remaining goods, the seller needs to pay the corresponding liquidation damages.

2.2. Evolutionary game theory based on fuzzy big data and lsgdm

In the process of agricultural product supply chain e-commerce information sharing, it is necessary to establish a complete information sharing game model, and its components should be fully considered in the process of constructing the model. This mainly includes information sharing cost, information sharing risk, information absorbing capacity, information sharing amount, information sharing synergy effect, reward and punishment mechanism, and information sharing commitment. These parts are elements and variables. In the actual situation, in the process of building the model, we need to consider the information sharing of the agricultural product supply chain, specify the reward and punishment mechanism for the weak part of the link, coordinate the part of the supply chain that has insufficient awareness of the information sharing commitment, and regard this as a risk element link. From the aspects of information sharing cost and risk, information absorption capacity, information sharing amount, and information synergy effect, this paper constructs an e-commerce information sharing game model of the agricultural product supply chain. The two sides of the game are not completely rational in the actual operation process of the supply chain, so we need to make the following assumptions.

First, we need to assume that the two sides of the game are opposite parties in the model, which can be expressed as a combination form {shared, not shared}, and we assume that the variables are set as follows: (1) the two sides of the supply are manufacturers and suppliers. (2) Assuming that there is a long-term cooperation between the two sides, the game relationship exists all the time in the process, and it does not terminate because of the existence of information sharing. The normal returns of player 1 and player 2 are represented by B1 and B2, respectively. (3) If the two sides of the game share information according to the agreement, they need to share the risk brought by the supply operation, and the two sides will obtain higher profits by playing together. On this basis, it can be assumed that RI ($I = 1{,}2$) is the information absorption capacity, and enterprises with strong absorption capacity have greater profits. Qi ($I = 1{,}2$) is the amount of information shared, and the greater the amount of information shared by one party, the greater the benefit of the other party.

The biggest difference between the evolutionary game theory based on fuzzy big data and LSGDM and the traditional game theory is the abandonment of the rational human hypothesis in the traditional theory. Traditional game theory assumes that all participants in the game are completely rational, and each participant understands the process of the game and understands all the information. This assumption is too rational and idealized. The evolutionary game process assumes that the game process is repetitive, and participants are assumed to have the same limitedly rational. The participant is one or two of a large number of individuals. At the beginning, the participant understands some to none of the game process, each participant is randomly selected, they conduct the game repeatedly with each other, and they have no specific opponents. At this point, the participant's choices and judgment come mainly from his own experience; the participant may obtain information by observing the decision-making process of other participants, and many participants continue to learn and evolve in the process of participating in the game.

According to the number of research groups, the evolutionary game theory based on fuzzy big data and the LSGDM model can be divided into a single-group model and a multi-group model. A single-group model refers to treating all populations in an environment as a large group, so that biological behavior can be uniquely determined, and the behavior of each group in an environment can be treated as a specific pure strategy. Thus, the groups in the whole environment can be treated as individuals who choose different pure strategies. Two individuals can be randomly selected for the game, because their strategies are the same (this may also be called symmetric games). When the behavior of different groups in the traditional single-group model is divided, the whole group can be regarded as a multi-group model. The whole group can be divided into many small groups, and the individuals randomly selected in the group are paired, and the repeated game is carried out for them; in this case, the game changes from a symmetric game to an asymmetric game.

In the course of the game, assuming there are two different participant groups, the participants choose a pure strategy from the pure strategy set S, and the participant in the t stage is expressed by using the pure strategy$s \in S$. Then, $\theta_t(S)$ is defined as the proportion of participants who adopt the pure strategy S accounting for the total number of groups at the t stage, as shown below:

$$\theta_t(S) = \phi_t(s) \Big/ \sum_{r \in S} \phi_r(r) \tag{1}$$

The expected utility of the participant in adopting the pure strategy S at the t stage is shown as follows:

$$u_t(s) = \sum_{r \in S} \phi_r(r) u(s, r) \tag{2}$$

In the above formula, $u(s, r)$ refers to the expected benefits of the former participants who use pure strategy S while another type of participants use pure strategy R. The expected effect is defined as follows:

$$\overline{u}_t = \sum_{s \in S} \phi_r(r) u_t(s) \tag{3}$$

In general, there are two factors involved in determining the game participants' learning speed. (1) The level of success of the learning object in the group. This is related to the size of the learning incentive for the other participants. For the size of the learning object, the higher the proportion of the corresponding type of participants in the group, the faster the learning speed of the whole group. The dynamic change of the type of game participant strategy with the change of time can be expressed by the following formula (the dynamic differential equation):

$$d\theta_t(s) / d_t = \theta_t(s) \left[u_t(s) - \overline{u}_t \right] \tag{4}$$

The replication dynamic mechanism is used to conduct the simulation analysis of participants' learning and improvement process. After repeated games, the two sides will reach a stable and balanced state—the evolutionary stability strategy. Even if there is deviation and interference caused by rationality, the two sides will soon return to a stable and balanced state.

3. Construction and analysis of the evolutionary game model of the signal sharing of the agricultural product supply chain based on fuzzy big data and lsgdm

3.1. Assumptions about model variables

China's agricultural product supply chain has distinctive characteristics: the supply chain is long and complex, the business maturity of the supply chain is low, the construction of a business information system across the supply chain lags behind, and the logistics system among enterprises in the product chain is relatively backward. From the perspective of links and organizational carriers, the structure of China's agricultural product supply chain can be divided into three types. 1) The wholesale market type: this kind of agricultural product supply chain has many and scattered participants; the transaction price of agricultural products is opaque; and the transaction information of agricultural products is difficult to query and is easily distorted, which makes it difficult to monitor the quality of agricultural products. 2) The company farm type: the whole supply chain of the company carries out information collection and centralized processing, farmers carry out production according to the requirements of the company, and the company continuously supervises and manages the production process of the whole supply chain. This type of supply chain operation can effectively improve the quality of crop products. 3) The chain distribution type: in this type of agricultural product supply chain, the distribution center is the core of information management, and perfect information management at the distribution center is conducive to information collection, analysis, and processing for the whole market.

According to the quality of the provided products, suppliers develop a corresponding price strategy P_H, P_L for the products. After consumers observe the external information of products in the consumer process, and according to the information θ of the products, these consumers make judgments. Then, according to the Bayesian formula, the a posteriori probability of consumers deciding about whether the product is of good quality product is obtained. If the consumer judges that the product is a good quality product, the product is purchased at a high price P_H provided by the supplier. If the consumer judges that the product is an inferior quality product, the product is purchased at a low price P_L. When the consumer offers a low price for a product of good quality, the supplier will not sell the product to the consumer. The supplier may not be able to sell the product later to another consumer, and there will be the risk of losing the production cost of the product. If the supplier sells inferior quality products to consumers in a high price, the supplier will suffer credit losses. The assumption is shown as follows:

A_1 represents suppliers that provide good quality products, and the probability is x; A_2represents suppliers that provide inferior quality products, and the probability is 1-x; A_{21} represents suppliers of inferior quality agricultural products past the safety label based on probability u; A_{22} represents suppliers of inferior quality agricultural products that are not past the safety label based on probability 1-u; B_1 represents consumers that pay a high price P_H to buy the product; B_2 represents consumers that buy the product at a low price P_L; C_H indicates the marginal cost of production of the high quality agricultural products; C_L is the marginal cost of production of the inferior quality agricultural products; U_h represents the utility of high quality products with a low price; U_L represents the utility of inferior quality products with a low price; Y is the probability of consumers paying a high price; the probability of a low price is 1-y; Q indicates the credit losses of the inferior quality suppliers who provide false information; θ indicates the degree of information symmetry between the supplier and the consumer, $0 \leq \theta \leq 1$; and $\frac{U_H}{P_H}, \frac{U_L}{P_L}$ represents standard normal distribution.

3.2. Evolutionary game model based on fuzzy big data and lsgdm analysis – a "mixed equilibrium" supply market for agricultural products

In the "mixed equilibrium" supply market conditions, regardless of the product quality provided by suppliers, suppliers will post security labels on the product. In this model, the establishment condition of the supply market is $C_H - C_L > Q$, which is a calculation of the inferior quality product suppliers' credit loss vis a vis the marginal cost in production. If the "production cost" of inferior quality products is lower than the marginal production cost of good quality products, then the inferior quality product suppliers will adopt a strategy of posting security labels. According to the hypothesis in the model, the probability of consumers to buy good quality products at a high price is $P(A_1B_1)$, the probability of buying inferior quality products at a high price is $P(A_2B_1)$, the probability of purchasing good quality products at a low price is $P(A_1B_2)$, the probability of buying inferior quality products at a low price is $P(A_2B_2)$, and the probability y of a consumer buying a product at a good price can be obtained, as shown in Eq. (5). From Table 1, the expected benefit π_{A1} ,π_{A2}, as well as supplier groups' expected benefit $\overline{\pi}$ in the production of good quality and inferior quality products can be calculated, as shown in formulas (6), (7) and (8):

B(1-y) represents that B_1 brings the products at a high price based on probability y; B (2-y) represents that B_2 brings the products at a low price based on probability 1-y; A (1-x) represents that A_1 produces high quality products based on x; A (2-x) represents that A_2 produces inferior quality products based on 1-x.

$$y = P(B_1) = P(A_1B_1) + P(A_2B_1) = x + (1-\theta)(1-x) \tag{5}$$

$$\pi_{A1} = y(P_H - C_H) + (1-y)(-C_H) \tag{6}$$

$$\pi_{A2} = y(P_H - C_L - Q) + (1-y)(P_L - C_L - Q) \tag{7}$$

$$\overline{\pi} = x\pi_{A1} + (1-x)\pi_{A2} \tag{8}$$

From Table 1, the expected utility U_{B1}, U_{B2} and the expected utility $\overline{U}$of the consumer group purchasing the product at high prices and low prices can be calculated, as shown in Eqs. (9), (10) and (11).

$$U_{B1} = x[U_H - (P_H - P_L)] + (1-x)[U_L - (P_H - P_L)] \tag{9}$$

$$U_{B1} = (1-x)U_L \tag{10}$$

Table 1
Benefit matrix of agricultural producers and consumers.

Consumer	B(1-y)	B(2-y)
A(1-x)	$P_H - C_H$, $U_h - (P_H - P_L)$	$-C_H, 0$
A(2-x)	$P_H - C_L - Q$, $U_L - (P_H - P_L)$	$P_H - C_L - Q, U_L$

$$\overline{U} = yU_{B1} + (1-y)U_{B_2} \tag{11}$$

According to the replication dynamics analysis of the asymmetric evolution game of the supplier and the consumer, the obtained replicator dynamic equation of supplier groups is shown in formula (12):

$$\frac{d_x}{d_t} = x(\pi_{A1} - \overline{\pi}) = x(1-x)(\pi_{A1} - \pi_{A2}) = x(1-x)[yP_L - (C_H + P_L - C_L - Q)] \tag{12}$$

The dynamic equation for the replication of consumer groups is shown in Eq. (13):

$$\frac{d_y}{d_t} = y\left(U_{B1} - \overline{U}\right) = y(1-y)(U_{B1} - U_{B2}) = y(1-y)[xU_H - (P_H - P_L)] \tag{13}$$

This paper analyzed the replication dynamic equation of the two game groups of the supplier and the consumer, because in the case of this supply chain, the local equilibrium point of the system could be obtained by the above formula. Based on this, the information sharing game model was analyzed.

$x^* = 0, y^* = 0$ is the evolutionary stability strategy (ESS) of this game system. When low-quality products in the market are passed off as high-quality products, high-volume product suppliers are damaged and there is a reduction in the number of high-quality product suppliers. In this situation, the information symmetry θ is 1, which indicates that consumers fully understand the situation of the market, and consumers are only willing to buy the product at low prices. At this point, the agricultural supply market is a "Zimeng market", and the consumer's agricultural products' quality and safety cannot be guaranteed. Therefore, the government must impose the punishment Q to the agricultural product supplier that provided false information, and cause $Q > C_H - C_L$, so that the false information provided by low-quality agricultural products suppliers will be unprofitable.

There are many nodes in the supply chain, which need to share information. In practice, the operation process of a supply chain is a dynamic balancing process. Every enterprise in the supply chain needs to communicate with information. However, there is frequently an information imbalance and inconsistent information sharing, which will lead to problems in the operation of the supply chain. If the supply chain information sharing is carried out as planned, it will reduce the information distortion caused by communication barriers and different ways of thinking. If the information sharing of each node in the supply chain can be realized, the contradictions between nodes will be coordinated, balancing the interests of enterprises in the supply chain and ensuring the long-term stable operation of the supply chain. In the e-commerce environment, the information sharing process of the supply chain is mainly a stable flow of information from the source supplier to the final sale to the customer. In the different nodes of the supply chain, enterprises can calculate information timely and effectively. With the support of network technology, each node can share information timely, which can promote closer contact between enterprises, ease problem solving, reduce the overall risk of the system, and improve the operational level of the entire supply chain system. The information dissemination process model can be expressed in the form shown in Fig. 5 below.

Before the construction of an information sharing mode, we need to formulate three principles: openness and absorption, balance between confidentiality and sharing, and coordination. In essence, the agricultural product supply chain is not only a simple commodity circulation link, but also a comprehensive link from the source to consumers, including logistics, information, and capital. This process includes not only the circulation of agricultural products, but also the processing, packaging, and transportation of agricultural products. In this process, the added value of agricultural products is increasing. Therefore, the circulation supply chain of agricultural products can also be regarded as a value-added chain. The premise of value-added agricultural products

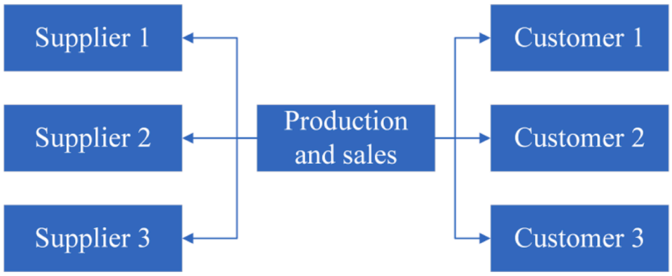

Fig. 5. Information dissemination model of supply chain in e-commerce environment.

is to ensure that all nodes of the agricultural product supply chain maintain synchronous operations and coordinate with each other. The current e-commerce operation mode can effectively realize the information sharing of the entire agricultural product supply chain; establish real-time information transmission; reduce the cost of information sharing; and improve the relationship between farmers, suppliers, suppliers, end retailers and customers. At present, the Internet can realize the online sales of domestic agricultural products, and also realize the import sales of foreign agricultural products. However, in this process, the speed of information flow is slow, which conflicts with the real-time information sharing proposed in this paper. In the actual operational process, there will be information delay and distortion in the process of e-commerce information sharing. Therefore, to reduce the impact of this kind of information distortion, we need to adopt more scientific and effective information network technology to speed up the effect of logistics information transmission. For the development of this arrangement and the status quo of the supply chain and information sharing, the effective model of e-commerce information sharing in the agricultural product supply chain can be expressed as shown in Fig. 6.

As shown in Fig. 6, in the game model of e-commerce information sharing in the agricultural product supply chain, the information sharing mode needs to establish two information bases. As the source of agricultural production, farmers need to establish an information base with the support of government departments and relevant social departments, while the middle link requires the government departments and supply chain nodes to jointly establish an information base. In the process of information transmission, information can be transmitted to all nodes via one to many modes, and information can be transmitted and shared through the information receiving module in the network. Farmers and processors need to be authorized to process sensitive data and timely comprehend supply, production, and marketing information (Fig. 7).

4. Case study

In the sea cucumber market, there are many high-quality "light dried sea cucumbers" and poor quality "sugar dry sea cucumbers". Many businesses use the inferior sea cucumbers to replace the high-quality ones and sell "sugar dry sea cucumbers" to consumers at high prices. Because of the high sugar content contained in the sea cucumbers and the unscientific production process, "sugar dry sea cucumbers" cause a series of harms to humans. According to the "National Wholesale Market Price Information Network of Agricultural Products", the following assumptions may be made, and the measuring unit is the "Yuan/jin". The price of a "dried sea cucumber" was $P_H = 3600$, the marginal cost was $C_H = 2500$, the “sugar dry sea cucumber" price was $P_L = 1650$, and the marginal cost was $C_L = 950$. The probability of suppliers supplying high-quality sea cucumbers was "light dried sea cucumber" market share $x = 0.4$, and the probability that "sugar dry sea cucumber" suppliers used inferior sea cucumbers to replace high-quality sea cucumbers was $u = 0.5$. After receiving product information, the probability of consumers being willing to pay a high price according to their own judgments and the presence of the "light dried sea cucumbers" in the market was the same, which was $y = 0.4$. The utility of consumers in purchasing the high-quality sea cucumbers was $U_H = 3600 \pm \sigma$, and the utility for purchasing the high-quality sea cucumbers was $U_L = 1650 \pm \sigma$; σ was a minimum number.

Therefore, after the behavior of the suppliers of inferior quality sea cucumbers was monitored, the loss $Q = C_H - C_L < 1550$; in other words, the punishment of the seller after providing false information was less than the price difference between the two types of sea cucumbers. The evolution direction of the market was (0, 0), and $x^* = 0, y^* = 0$ was the evolutionary stability strategy (ESS) of this game system.

When $Q = C_H - C_L = 1550$, the seller’s punishment for delivering

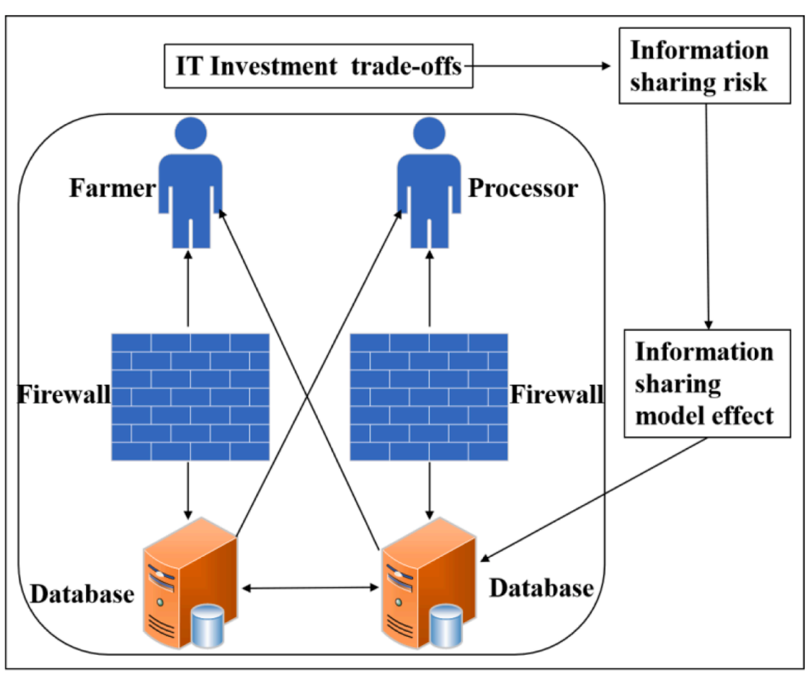

Fig. 6. Information sharing model of agricultural products supply chain under E-commerce.

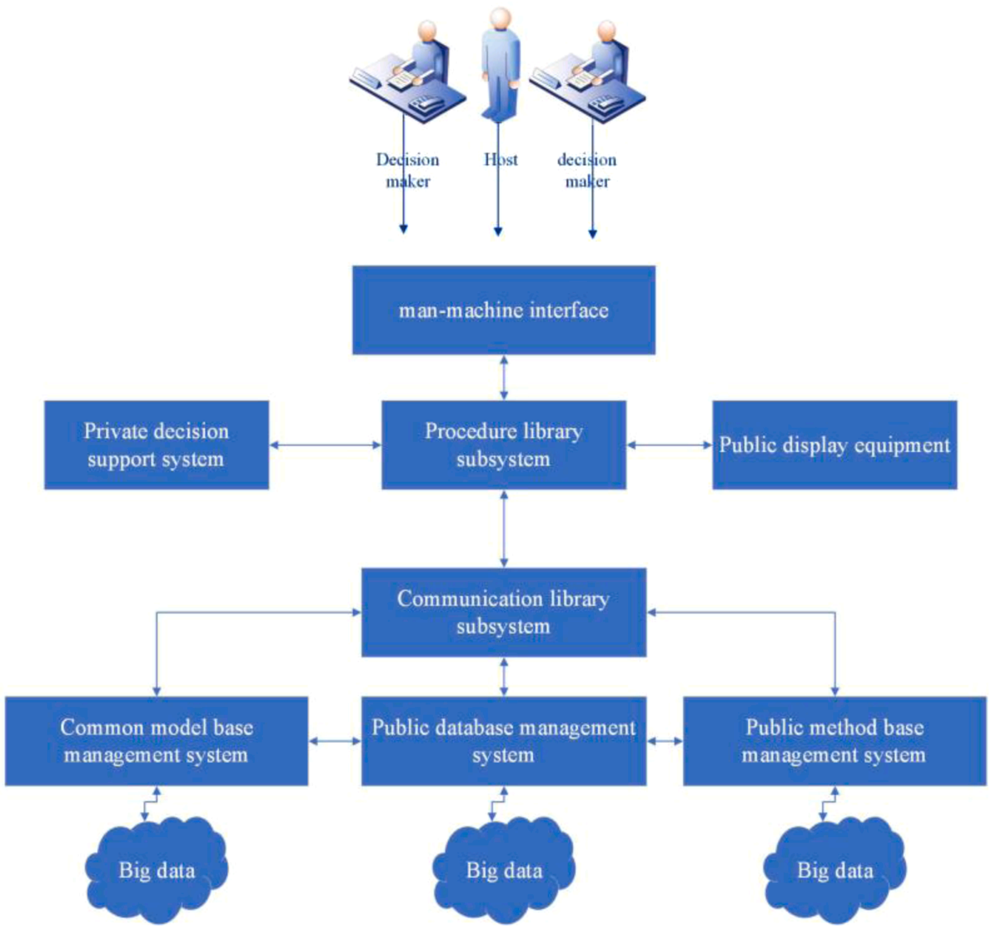

Fig. 7. Large scale group decision making system.

false information was the same as the price of the two species of sea cucumber, $x^* = 0, y^* = 0$, and $x^* = 1, y^* = 1$ was the evolutionary stability strategy of this game. The evolution results of the C, D areas were beneficial for everyone, and it was therefore desirable to increase the ratio of regions C and D in the entire area. Supposing one of the factors of the variable, the other factors were the same.

Using Excel, according to the change in the "light dried sea cucumber" manufacturing marginal cost C_H in district [950, 2735.87] of the above formula, the $t = \frac{S_{CD}}{S_{ABCD}}$ change trend is shown in Fig. 8. With the increase in marginal cost, the area ratio of the C and D districts gradually decreased, and because the high cost in the market was not competitive, suppliers of high-quality sea cucumbers gradually withdrew from the market, resulting in a large number of low-quality sea cucumbers in the market.

With the change in the manufacturing marginal cost of the "sugar dry sea cucumber" in the C_L area [714.13, 2500], the $t = \frac{S_{CD}}{S_{ABCD}}$ change trend is shown in Fig. 9. With the increase in the marginal cost of the "sugar dried sea cucumber", the proportion of areas C and D gradually increased, and suppliers of inferior quality sea cucumbers gradually withdrew from the

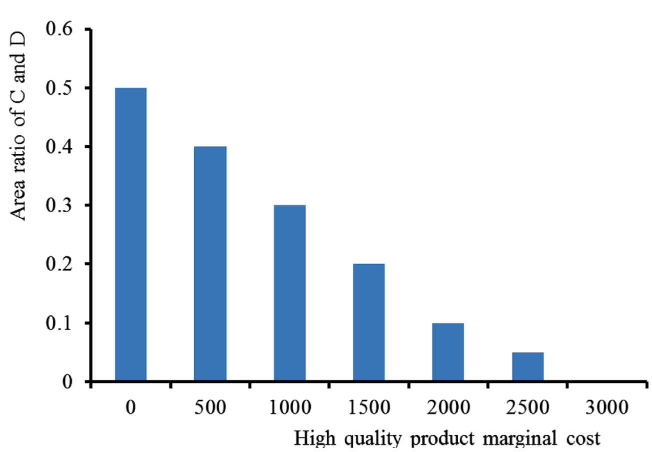

Fig. 8. High-quality product marginal cost evolution trend.

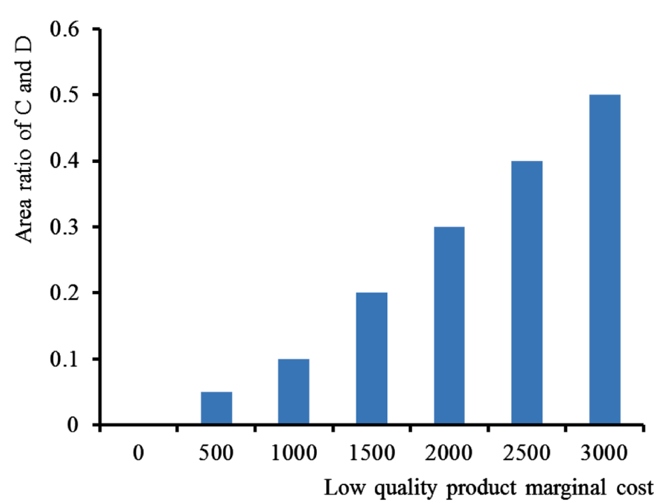

Fig. 9. Low-quality product marginal cost evolution trend.

market due to high costs.

With the change in the P_H "light dried sea cucumber" selling price in area [2500, 5857], the $t = \frac{S_{CD}}{S_{ABCD}}$ change trend is shown in Fig. 10. As the "light dried sea cucumber" prices increased, the area ratio of the C and D areas decreased, because consumers could not pay the high prices. The cheap "sugar dry sea cucumber" was purchased, and the "light dried sea cucumber " lost competitiveness in the market.

With the change in the price P_L "sugar + sea cucumber" in region [950, 3600], the $t = \frac{S_{CD}}{S_{ABCD}}$ change trend is shown in Fig. 11. With the increase in the price of "sugar + sea cucumber", consumers were more inclined to buy the "light dried sea cucumber", so the area ratio of the C and D areas increased, and the "light dried sea cucumber" market share increased.

Information asymmetry is the main source of the quality and safety problems of the agricultural product supply chain. After a long period of study and strategy adjustment, the information symmetry of suppliers and consumers will gradually improve, but the stable state of the agricultural product supply market is different. The evolution of the supply market depends on the starting point of the market state and the significance of various factors. The government and market supervision departments should take measures such as price control and strong supervision to improve the information symmetry of supply and demand parties, as well as implementing corresponding measures to ensure that the agricultural product supply market is in a state of "complete Bayesian equilibrium separation" according to the actual situation of China's agricultural product market. According to the characteristics of information sharing, a game theory model based on agricultural information sharing is constructed. Through the analysis of the information sharing process of upstream and downstream enterprises, it is found that the main factors influencing the information sharing process include information sharing cost, risk, information absorption capacity, information sharing amount, and information sharing synergy factors, which all affect the information sharing process. From the process and results of the game, the stability of the information sharing of both sides is key to determining whether the two sides can cooperate and achieve a long-term win-win situation. Therefore, the single node enterprises in the agricultural product supply chain must improve their ability to collect, process, and transmit information. In addition, it is necessary for each node enterprise of the supply chain to cooperatively establish an information sharing system that includes transparent information collection, information sharing, information processing, risk prediction, and risk resistance capability in order to improve the income of the supply chain. For the entire supply chain, each node enterprise needs to strengthen communication, establish the information sharing guarantee mechanism of the supply chain, and improve mutual trust and information transmission efficiency. Effective incentive measures and long-term cooperative relationships are key to improving the information sharing of the entire agricultural product supply chain. Local governments should strengthen guidance and supervision, encourage the cultivation of information sharing in the agricultural supply chain, and reduce the cost and risk of enterprises participating in information sharing.

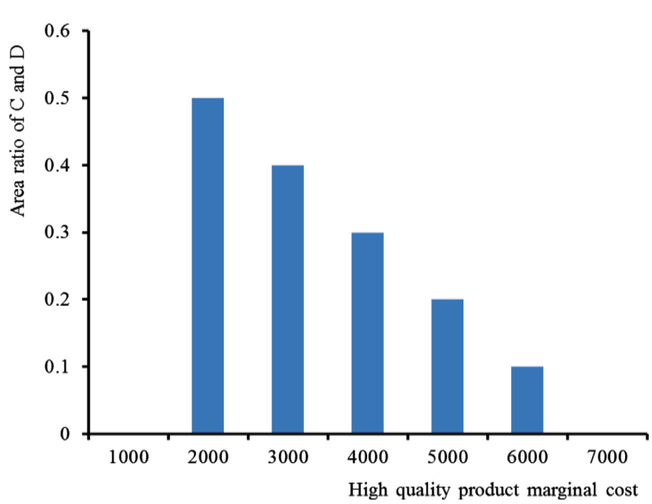

Fig. 10. High quality product sales price changes trend.

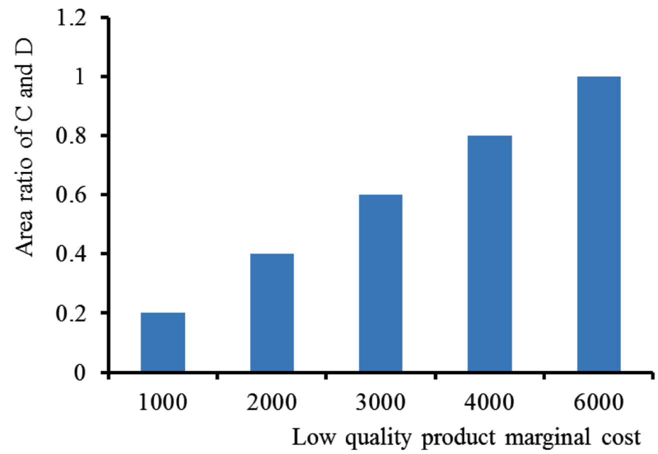

Fig. 11. Inferior quality product sales price changes trend.

5. Conclusions

At present, the brand awareness of agricultural producers in China is not strong, product quality is declining, and the industry is facing a crisis. Therefore, the sustainable development of an agricultural product market and the information sharing regarding the agricultural products ecological supply chain is a research focus. In this context, based on electronic information sharing in the process of agricultural product supply, this paper analyzes the dynamic, complex, regional, and seasonal characteristics of agricultural product supply chain management. By comparing and analyzing the differences between traditional the agricultural product ecological supply chain and the modern agricultural product ecological supply chain, it is concluded that the modern agricultural product supply chain with supermarkets (online or offline) as the core can better adapt to the current complex economic situation. In view of the complexity of the agricultural product supply chain, evolutionary fuzzy big data and LSGDM technology are proposed. The purpose is to realize the information sharing of the supply chain, establish an evolutionary game mathematical model of a mixed equilibrium of the agricultural products market, and verify the correctness of the theoretical model. Taking sea cucumber products as an example, the sustainable development characteristics of high-quality sea cucumber products were analyzed from the perspective of evolutionary fuzzy big data and LSGDM. The electronic information classification method of sea cucumber products was proposed, and the appropriateness of the evolutionary game model proposed in this paper was verified. The research described in this paper is of great significance for the realization of e-commerce information sharing and the improvement of product quality in the ecological supply chain of modern crop products, and this study provides a theoretical basis for the sustainable development of agriculture.

CRediT authorship contribution statement

Luo ming: Conceptualization, Formal analysis, Data curation, Writing – original draft, Writing – review & editing. **Zhou GuoHua:** Conceptualization, Data curation, Formal analysis, Project administration, Writing – original draft, Writing – review & editing. **Wei Wei:**

Conceptualization, Formal analysis, Software.

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Luo Ming: Lang zhong, Sichuan, China, graduated from the Master of Business Administration of Kunming University of Science and Technology in 2011. He is a lecturer in the School of Economics and Management at University of Tibet, an is currently attending a Ph.D. in Management Science and Engineering at the School of Economics and Management at Southwest Jiao Tong University.

Zhou GuoHua (Corresponding Author): Zhang Jia Gang,Jiangsu, China, graduated from the Ph.D. in Management of Southwest Jiao Tong University. He is a professor of the School of Economics and Management of Southwest Jiao Tong University and a doctoral supervisor.

Wei is an associate professor in the School of Computer Science and Engineering at the Xi'an University of Technology in China. He has received his Ph.D from the Xi'an Jiaotong University in 2010. His-research interests include wireless networks, sensor networks, image processing, mobile computing, distributed computing, pervasive computing, Internet of Things, sensor data and cloud computing. He has over 100 papers published or accepted by international conferences and journals. He ran many funded research projects as principal investigator and technical members. He is a senior member of IEEE and CCF.