

Study on Supply Chain Finance System of Agricultural Product Based on Symbiosis Theory

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Abstract. Agriculture, countryside and farmers have always been hot issues in academia and industry. The solution of three agricultural problems requires the strong cooperation of rural finance. Based on symbiosis theory, the study combines agricultural product supply chain with financial institutions to construct supply chain finance system of agricultural product. It clarifies the roles of symbiosis units in the supply chain finance system, analyses the symbiosis interface of the supply chain finance system, discusses the symbiosis relationship in the supply chain finance system and expounds the impact of external environment on the symbiosis relationships. This study has theoretical guiding significance for reducing the financial risk of agricultural products supply chain and optimizing symbiosis relationships in the supply chain finance system, which is conducive to achieving harmonious development of agricultural product supply chain financial system.

1. Introduction

In 2019, the “Central Document No. 1” regards the issue of “agriculture, countryside and farmers” as the top priority of the national work again, and the solution of the “three agricultural problems” needs the strong cooperation of rural finance, in order to meet the capital demand in the process of promoting structural reform of agricultural supply side, and leading modern agriculture to accelerate development^[1]. Difficulty in financing is a general problem faced by farmers and small and medium-sized agricultural enterprises for a long time because of the lack of guarantees in china^[2]. Supply chain finance system of agricultural product is a new financing mode that supply chain finance is applied in the agricultural chain to solve the financing dilemma of farmers and small and medium-sized agricultural enterprises by bundling core enterprises with upstream and downstream. At present, scholars mainly use the theory of organizational fairness, game theory, relationship governance theory and modern contract theory to analyze the research on agricultural supply chain finance^[3]. Some scholars also study from the perspective of law, psychological contract, integrated governance and transaction cost^[4]. We intend to build a financial system of agricultural supply chain based on Symbiosis theory. Symbiosis theory was presented by Aotn de Bary (1879). Actually, symbiosis is not only a biological phenomenon, but also a social phenomenon. It includes both biological identification mechanism and social science methods. Symbiosis theory provided a new way to ensure it stable and lasting^[5]. Therefore, based on symbiosis theory, we try to combine agricultural supply chain and financial institutions to construct and study supply chain finance system of agricultural product, so as to promote the cooperative development, benefit sharing, risk sharing of the symbiotic units in the supply chain finance system, and finally establish a mutually beneficial symbiosis relationship.

2. Supply chain finance system of agricultural product from the perspective of symbiosis

Agricultural Supply Chain Finance has the characteristics of self-compensation, closure and continuity. Self-repayment refers to the cash flow generated by agricultural trade itself; closeness

refers to the bank to ensure the special use of special funds by setting up a closed loan operation process; continuity refers to the continuous occurrence of similar trade behavior between the upstream and downstream of agricultural supply chain. In the perspective of symbiosis, agricultural supply chain finance system involves symbiosis unit, symbiosis interface and symbiosis relationship. The symbiosis unit is the foundation, the symbiosis interface is the medium, and the symbiosis relationship is the link. Symbiosis relationships among symbiosis units in agricultural supply chain finance are also affected by the external environment from the government, agricultural industry associations, and end consumers. Accordingly, we constructed the symbiosis model of agricultural product supply chain finance system, as shown in Figure 1. The symbiosis of agricultural product supply chain finance system is based on agricultural products supply chain and financial institutions. It extends the upstream and downstream of agricultural products supply chain vertically and horizontally. Through logistics symbiosis, capital flow symbiosis and information flow symbiosis among entities, the material integration, information integration and energy integration of the whole agricultural products supply chain finance system are finally realized.

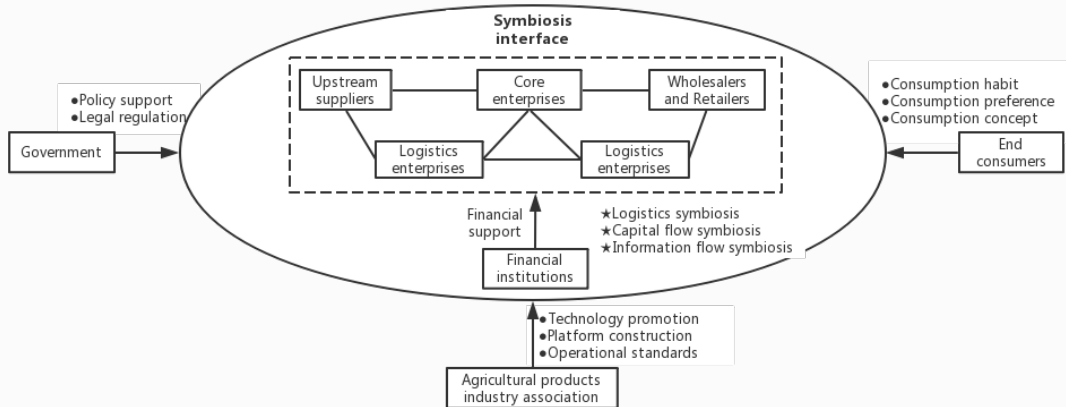


Figure 1 Symbiosis model of agricultural product supply chain finance system.

3. Symbiosis units of agricultural product supply chain finance system

3.1. Analysis of symbiosis units

The symbiosis unit is the foundation of energy production and exchange that constitutes the symbiosis relationship. Symbiosis units of agricultural supply chain finance system involve: (1) Core enterprises. As the dominator of the supply chain, core enterprises are generally large group enterprises engaged in breeding, standardized feeding and planting, processing of products, production of feed and pesticides, and bioengineering business. Most of them are state key leading enterprises. Credit level and credit rating of core enterprises are important for developing agricultural supply chain finance. Through agricultural supply chain financial services, core enterprises can obtain lower prices, more convenient delivery and shorter settlement cycle from upstream and downstream. Therefore, core enterprises are willing to provide certain credit resources support for the financing of upstream and downstream, such as providing counter-guarantee for farmers in guaranteed loans.

(2) Upstream suppliers. Agricultural suppliers are the source of the supply chain, which also is the riskiest part of the chain^[6]. Characteristics of agricultural products affect the supply mode, the choice of equipment and manufacturers, as well as the operation efficiency of supply chain finance. Most of agricultural products suppliers are farmers in our country. They are affected by the small-scale agricultural economy, having the characteristics of “small, scattered and weak”. There are more than 230,000 agricultural business enterprises and more than 100 million individual farmers in

China^[7], and the total demand for funds is relatively bulky. However, as far as each farmer is concerned, his capital demand is urgency, few and frequent. Traditional financing process lacks effective financing risk mechanism and guarantee mechanism. Farmers' repayment ability is limited and default rate is high. Commercial financial institutions do not regard farmers as ideal financing targets^[8]. By introducing supply chain finance, farmers can apply for loans from financial institutions with the help of credit resources of core enterprises, such as orders and accounts receivable. At the same time, they can obtain financing through warehouse receipt pledge.

(3) Wholesalers and retailers. They are located in the middle of the supply chain, mainly including large supermarkets, chain stores, agricultural markets and catering services enterprises. Their degree of centralization, the way of transaction between others, and the scope of transaction have a certain impact on the scale and financing mode of the agricultural supply chain finance. Through services of supply chain finance, wholesalers and retailers can obtain loans from financial institutions under the supervision of logistics enterprises by means of repurchase guarantee of core enterprises, thus effectively alleviating the pressure of insufficient purchasing funds, reducing transaction costs, expanding sales volume and improving market competitiveness.

(4) Logistics enterprises. They go through the whole process of agricultural supply chain finance and are the bridge between suppliers, core enterprises, wholesalers and retailers. In the supply chain finance of agricultural products, logistics enterprises play agent role of financial institutions and become channels for financial institutions to sell financial products. As assessors and regulators of the pledged chattels, they are mainly responsible for transportation, warehousing and supervision in supply chain finance. With the deepening of cooperation between logistics enterprises and financial institutions, they form long-term cooperative alliances, such as establishing logistics banks, so as to realize the continuous interaction of logistics, information flow and capital flow in the financing process^[9], ensure the normal production and operation of financing enterprises under the premise of controllable risk, and create new profit growth points.

(5) Financial institutions. They are the managers and leaders of the entire supply chain financial business, involving banks, insurance companies, guarantee companies, trust companies and fund companies. Financial institutions provide tailor-made financing services for small and medium-sized enterprises(SMEs) and retail investors in the agricultural supply chain by evaluating the credit status of core enterprises, the close relationship between other enterprises and core enterprises in the supply chain, and the operation, risk tolerance and trading mode of the entire agricultural supply chain. By developing supply chain finance, financial institutions cannot only develop diversified financial products for SMEs and retail customers in the supply chain, but also broaden the customer base, and promote the development of other business such as deposit and settlement.

3.2. Quality parametric compatibility

Qualitative parameters are factors that determine intrinsic properties and changes of symbiosis units in supply chain finance system. They can be used to describe intrinsic relationship and intrinsic properties of symbiosis units^[10]. The qualitative parameters of symbiosis units are not single, but a group, which together determine their intrinsic properties. The quality parameters of core enterprises include the industry influence, commercial reputation, production capacity, and cooperative sense. The quality parameters of upstream suppliers include production performance, vocational skills, daily income, deposit amount, social status and relations. The quality parameters of wholesalers and retailers include the size and income, sales ability and channels, and market share. The quality parameters of logistics include the technological level, scale, delivery capacity, and comprehensive degree of services. The quality parameters of financial institutions involve the assets scale, return on assets, capital adequacy ratio, total loans and deposits, and user satisfaction.

The quality parameter compatibility of symbiosis units in agricultural supply chain finance system means that for any symbiosis unit $S_i, (i = 1, 2, 3, \dots, n)$, its quality parameter is Z_{S_i} , which could be expressed by the quality parameter $Z_{S_{-i}}$ of other symbiosis units S_{-i} , namely $Z_{S_i} = f(Z_{S_{-i}})$. The concept of set can be expressed as $Z_{S_1} \cap Z_{S_2} \cap \dots \cap Z_{S_n} = \phi$. For example, the performance level of upstream

suppliers depends on the orders and cooperative sense of core enterprises, the total loan and loan policy of financial institutions, the service ability and technical level of logistics, and the sale channels and ability of wholesalers and retailers. Upstream suppliers can apply for financing from financial institutions by using orders from core enterprises, and financial institutions send cooperative logistics enterprises to evaluate and supervise agricultural pledges. Banks can judge whether the pledges have broad market according to sales situation of downstream, so as to decide whether to lend or not, and how much to lend. The compatibility of the quality parameters of the symbiosis units in the agricultural supply chain finance system means that the symbiosis units are closely related and interact with each other, which determines that they must keep consistency in asset specificity, market awareness, corporate culture and cooperation spirit.

3.3. Selection of Symbiosis Objects

The selection of symbiosis objects by symbiosis units is based on the recognition of each other according to definite rules. Under the condition of incomplete information, the selection of symbiosis objects is relative. For example, there is an asymmetry between the choice of contracted farmers by enterprises and the willingness of farmers to participate in contract agriculture. Enterprises hope to establish cooperative relations with large-scale farmers, while small-scale farmers prefer to participate in contract agriculture^[11]. Symbiosis units can only select symbiosis objects according to their own information and quality parameters. Enterprises with information advantages take the lead in entering the symbiosis system of supply chain finance. With the increase of information, some symbiosis units with low degree of relevance and intimacy will be replaced by symbiosis units with high degree of relevance and intimacy^[12], and a more stable symbiosis relationship is forming. As China's agricultural product supply chain finance started late, the selection of symbiosis objects is mainly reflected in the selection of core enterprises, farmers, wholesale retailers and logistics enterprises by financial institutions, as well as the selection of farmers, wholesale retailers and logistics enterprises by core enterprises.

Finance symbiosis theory refers that any symbiosis unit, even if it has all the conditions of symbiosis, cannot be incorporated into the symbiosis system indefinitely. Because if the symbiotic density is increased blindly, the loss of symbiotic energy will be larger than the increase energy when it exceeds the critical state. This critical state is symbiotic density equilibrium, that is, the number of symbiosis objects when the marginal symbiotic loss equals the marginal symbiotic energy. In practice, in terms of upstream, there are many farmers and SMEs with financial need. It is impossible for financial institutions and core enterprises to integrate all dispersed farmers into the supply chain finance system, and the number of suppliers that can be used as symbiosis objects is limited. Large growers, breeders and SMEs with large scale are easier to be integrated into the supply chain finance system, because they have larger production, stronger production capacity and higher asset specificity. Therefore, they have higher solvency, weaker opportunism tendency and stronger sense of cooperation. Moreover, in order to solve the contradiction between the large number of farmers and the balance of symbiotic density, measures such as establishing farmers' joint guarantee mode, entrusting agricultural brokers, using agricultural cooperative organizations are adopted to connect financial institutions, core enterprises and farmers. In terms of core enterprises, because of their good credit and strong repayment ability, financial institutions usually enlarge the credit of core enterprises by 10%-20%. If 10 financial institutions give similar credit to the same core enterprise at the same time, the core enterprise's credit will be increased by 100%-200%, which enlarges the credit risk. Therefore, when choosing symbiosis objects, financial institutions should evaluate the credit level of credit-granting enterprises in advance, actively construct the evaluation index system of financial credit risk in supply chain^[13], and investigate whether there exists duplicate credit. It is better to cooperate with fixed core enterprises and logistics enterprises, so as to form a long-term and stable mutually beneficial symbiosis relationship, which is conducive to reducing the cost of information search and financing risk.

4. Symbiosis interface of agricultural product supply chain finance system

The financial symbiosis interface of agricultural supply chain is the contact medium, channel or carrier between upstream and downstream, enterprises and financial institutions, self-organization of supply chain finance and environment. It holds the functions of material exchange, information transmission and energy transmission. Symbiosis interface is the basic support for the formation of symbiosis relationships in agricultural supply chain financial system, and it is also the necessary condition for the operation of the system. There are many symbiosis interfaces the system of agricultural supply chain finance, and these interfaces are combination of various forms, involving capital, information, market, technology, etc., as shown in Table 1. On these interfaces, the symbiosis units in the system of agricultural supply chain finance can exchange material, energy and information through symbiotic media, making the relationship between symbiosis units closer.

Table 1 Symbiosis interface's effect on the symbiosis of agricultural supply chain finance system.

Medium of symbiosis interface	Role in system symbiosis
Financing, fund management and settlement	Preventing the fracture of capital chain Increasing new profit points
Agricultural brokers, agricultural professional cooperative organizations	Realizing symbiotic density balance Reducing transaction costs
Reputation	Promoting trust and cooperation Enhancing visibility
Contracts, stock	Guaranteeing the equality of rights and obligations Ensuring the symmetry of interests
Category and quality of agricultural products	Setting the loan ratio Reducing the risk of pledge
Agricultural electronic transaction platform	Establishing trading carrier Improving trading efficiency
Technical training	Strengthening interaction and integration Improving the attraction of financiers

5. Symbiosis relationship of agricultural product supply chain finance system

5.1. Symbiosis relationship between financing subjects and financial institutions

The symbiosis relationship of agricultural supply chain finance depends on the positive interaction brought by symbiosis media such as financing and settlement, information, credit, contract, equity, agricultural cooperative organization. Within system of agricultural supply chain finance, financial institutions, as capital providers, are indispensable symbiosis units, while SMEs and farmers in the agricultural supply chain, as capital demanders, rely on the loan support of financial institutions. Their symbiosis relationship is shown in Table 2.

Table 2 Symbiosis relationship between financing subjects and financial institutions.

financing subjects	positive	negative
positive financial institutions	Mutual encouragement (Relationship optimization)	Financial institutions restrain financing subjects (Relationship deterioration)
negative	Financing subjects restrain financial institutions (Relationship deterioration)	Mutual inhibition (Relationship breakdown)

As shown in Table 2, When both of financing subjects and financial institutions make positive efforts, they encourage each other and intend to cooperate further. Their symbiosis relationship is constantly optimized, gradually developing to the continuous and reciprocal symbiosis relationship. For example, Nongjiang bank provides credit support to farmers engaged in agricultural and animal

husbandry production with Jinsui huinong card as the carrier and 3-5 household joint insurance as the guarantee. When core enterprises purchase agricultural products from farmers at normal market prices, farmers pay interest on loans to Nongjiang bank according to a certain proportion of sales, thus forming a virtuous financing cycle. When financing subjects make positive efforts while financial institutions do not, financial institutions restrain financing subjects, which leads to the deterioration of their symbiosis relationship. It is a symbiosis relationship of partial benefit. For example, in order to transfer financing risks to the maximum extent, some financial institutions unilaterally request to reduce the loan amount, or increase the guarantee amount, and use their advantages to pressure the financing subjects to sign some unreasonable overlord clauses. Similarly, when financial institutions make positive efforts while financing subjects do not, financing subjects restrain financial institutions, which leads to the deterioration of their symbiosis relationship. This is also a symbiosis relationship of partial benefit. About 400 billion yuan of agricultural contracts has not been fulfilled every year in China. In order agriculture, the fulfilment rate of orders is less than 20%, which shows that the phenomenon of breach of agricultural contracts in China is very serious. Therefore, financial institutions are facing a huge risk of farmers' default. At the same time, financing subjects may take advantage of information asymmetry to apply for loans with low-quality agricultural products as collateral, which increases the risk of financial institutions. When both of financing subjects and financial institutions are unwilling to make efforts, they restrain each other and do not need to continue to cooperate. Their relationship is a point symbiosis relationship. For example, financing subjects cannot guarantee the fulfilment of the order requirements, the quantity and quality of pledged agricultural products, and the authenticity and validity of accounts receivable. At the same time, financial institutions cannot provide a reasonable loan ratio, or they may ask for high margin and guarantee fees with the threat of suspension of financing.

Therefore, the first kind of mutual incentive is conducive to the further development of symbiosis relationship, while the other three do not contribute to the maintenance, consolidation and optimization of symbiosis relationship. Under the condition of mutual incentive, the entire agricultural supply chain finance system has formed a benign interactive situation, in which all the symbiosis units' benefit. Under the condition of single restraint and mutual restraint, the whole agricultural supply chain finance system is confused, which easily breeds a large number of speculative and opportunistic tendencies. As a result, financial institutions "want to lend but dare not lend", and financing subjects "want to borrow but cannot borrow".

5.2. Symbiosis relationship between logistics enterprises and financial institutions

The relationship between agricultural supply chain logistics and financial institutions is a principal-agent relationship. Financial institutions do not understand logistics enterprises, which can easily lead to adverse selection risks and moral hazards, making it impossible to form a symbiosis relationship. Considering the information asymmetry between them, a principal-agent model of incentive mechanism for logistics enterprises under asymmetric information is constructed to better clarify the relationship and promote the formation of symbiosis relationship between them.

5.2.1. Model hypothesis

(1) Assuming that there are only two parties in the principal-agent relationship of agricultural supply chain finance: the logistics enterprise (agent) and the financial institution (principals). (X, Y) separately indicates the efforts of the logistics enterprise and the financial institutions. The maintenance of principal-agent relationship between them requires their joint efforts. When the efforts of the financial institution in supervision are improved, the efforts of the logistics enterprise are also improved. However, due to technical and economic constraints on the financial institution, the increment of its efforts will be less and less. At (X_0, Y_0) , no matter how the financial institution improves its efforts, the logistics enterprise will hardly improve its efforts, as shown in Figure 2.

(2) Assuming that both parties are risk-neutral and aim to maximize their own interests.

(3) Both parties need certain cost to make efforts. For simplification, assume that the effort cost of the logistics enterprise is $C_X = \frac{k_1}{2} X^2$, and the effort cost of the financial institution is $C_Y = \frac{k_2}{2} Y^2$. k_1, k_2 represent their cost coefficients respectively, and $k_1 > 0, k_2 > 0$

(4) The output income shall be shared by both parties. Assuming that the total return function of output is a linear function

$$\pi_{X,Y} = \lambda_1 X + \lambda_2 Y + \theta.$$

θ represents exogenous uncertainties, and $\theta \sim (0, \sigma^2)$. λ_1, λ_2 represent their contribution coefficients to output income respectively, and $\lambda_1 > 0, \lambda_2 > 0$. The net profit function is:

$$\overline{\pi_{X,Y}} = \pi_{X,Y} - C_X - C_Y.$$

Suppose that the income function of the logistics enterprise is:

$$\pi_X = \alpha + \beta \pi_{X,Y} - C_X.$$

α is the fixed income. β is the incentive reward coefficient, indicating the shared output, and $\beta \in [0, 1]$. The income function of the financial institution is:

$$\pi_Y = \pi_{X,Y} - \pi_X = (1 - \beta) \pi_{X,Y} - \alpha - C_Y.$$

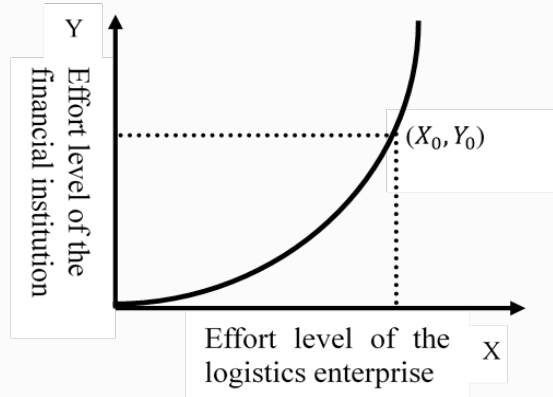


Figure 2 The relation between the logistics enterprises (agents) and the financial institution (principals) in effort level.

5.2.2. Model

The real monetary income of the logistics enterprises is as follows:

$$\pi_X = \alpha + \beta \pi_{X,Y} - C_X = \alpha + \beta(\lambda_1 X + \lambda_2 Y + \theta) - \frac{k_1}{2} X^2$$

Because the logistics enterprise is risk-neutral and its expected utility is equal to the expected income, the expected utility of the logistics enterprise is as follows:

$$E\pi_X = E(\alpha + \beta \pi_{X,Y} - C_X) = \alpha + \beta(\lambda_1 X + \lambda_2 Y) - \frac{k_1}{2} X^2$$

Similarly, the real monetary income of the financial institution is as follows:

$$\pi_Y = (1 - \beta) \pi_{X,Y} - \alpha - C_Y = (1 - \beta)(\lambda_1 X + \lambda_2 Y + \theta) - \alpha - \frac{k_2}{2} Y^2$$

Its expected utility is as follows:

$$E\pi_Y = E((1 - \beta) \pi_{X,Y} - \alpha - C_Y) = (1 - \beta)(\lambda_1 X + \lambda_2 Y) - \alpha - \frac{k_2}{2} Y^2$$

In the whole principal-agent process, the net profit generated by the joint efforts of the logistics enterprises and the financial institution is as follows:

$$\overline{\pi_{X,Y}} = \pi_{X,Y} - C_X - C_Y = \lambda_1 X + \lambda_2 Y + \theta - \frac{k_1}{2} X^2 - \frac{k_2}{2} Y^2$$

In order to sign the principal-agent contract and form a symbiosis relationship, it is necessary to maximize the profits generated by the joint efforts of the two parties. Namely,

$$MAX: \overline{\pi_{X,Y}} = \pi_{X,Y} - C_X - C_Y = \lambda_1 X + \lambda_2 Y + \theta - \frac{k_1}{2} X^2 - \frac{k_2}{2} Y^2 \quad (1)$$

In order to make the logistics enterprise accept the principal-agent contract, the financial institution must satisfy two conditions: 1) participation constraints (IR). The expected utility of the

logistics enterprise when accepting the contract cannot be less than the maximum expected utility when not accepting the contract, that is, it must guarantee $E\pi_X \geq \overline{\pi_X}$. 2) Incentive compatibility constraints (IC). Because of information asymmetry, the logistics enterprise may make less effort by using information advantages in order to maximize its own interests. In order to observe, maximizing the effort of the logistics enterprise is necessary. Namely,

$$IR: E\pi_X = \alpha + \beta(\lambda_1 X + \lambda_2 Y) - \frac{k_1}{2} X^2 \geq \overline{\pi_X} \quad (2)$$

$$IC: MAX: E\pi_X = \alpha + \beta(\lambda_1 X + \lambda_2 Y) - \frac{k_1}{2} X^2 \quad (3)$$

In the case of information asymmetry, the logistics enterprise will pursue to maximize its own interests. For formula (3), let $\frac{\partial E\pi_X}{\partial X} = 0$, then $X = \frac{\beta}{k_1} \lambda_1$. Considering $\frac{\partial^2 E\pi_X}{\partial X^2} = -k_1 < 0$, when the efforts level of the logistics enterprise satisfies $X = \frac{\beta}{k_1} \lambda_1$, its interests is maximized.

The financial institutions can choose to supervise the pledge agricultural products by itself or outsource them to the logistics enterprise. Outsourcing relationship is closely related to relationship quality^[14]. If outsourcing is chosen, two conditions must also be met: 1) Participation constraints (IR). The cost of the financial institutions choosing logistics enterprises is lower than the cost of supervision by itself, namely, $E\pi_Y \geq \overline{\pi_Y}$. 2) Incentive compatibility constraints (IC), namely,

$$IR: E\pi_Y = (1 - \beta)(\lambda_1 X + \lambda_2 Y) - \alpha - \frac{k_2}{2} Y^2 \geq \overline{\pi_Y} \quad (4)$$

$$IC: MAX: E\pi_Y = (1 - \beta)(\lambda_1 X + \lambda_2 Y) - \alpha - \frac{k_2}{2} Y^2 \quad (5)$$

Similarly, the financial institution will seek to maximize its own interests. For formula (5), let $\frac{\partial E\pi_Y}{\partial Y} = 0$, then $Y = \frac{1-\beta}{k_2} \lambda_2$. Considering $\frac{\partial^2 E\pi_Y}{\partial Y^2} = -k_2 < 0$, when the efforts level of the financial institution satisfies $Y = \frac{1-\beta}{k_2} \lambda_2$, its interests is maximized.

However, $X = \frac{\beta}{k_1} \lambda_1, Y = \frac{1-\beta}{k_2} \lambda_2$ are only the effort level of both sides when they make their own interests maximize. It's a Nash equilibrium solution, which does not achieve the maximization of the overall interests of logistics outsourcing in the agricultural supply chain financial system. That is to say, the efforts of both sides did not reach the Pareto optimal level at this time.

Bring $X = \frac{\beta}{k_1} \lambda_1, Y = \frac{1-\beta}{k_2} \lambda_2$ into $\overline{\pi_{X,Y}}$, then,

$$\overline{\pi_{X,Y}} = \lambda_1 X + \lambda_2 Y + \theta - \frac{k_1}{2} X^2 - \frac{k_2}{2} Y^2 = \frac{\beta}{k_1} \lambda_1^2 + \frac{1-\beta}{k_2} \lambda_2^2 + \theta - \frac{\beta^2}{2k_1} \lambda_1^2 - \frac{(1-\beta)^2}{2k_2} \lambda_2^2$$

Let $\frac{\partial \overline{\pi_{X,Y}}}{\partial \beta} = \frac{1-\beta}{k_1} \lambda_1^2 - \frac{\beta}{k_2} \lambda_2^2 = 0$, then $\beta = \frac{k_2 \lambda_1^2}{k_1 \lambda_2^2 + k_2 \lambda_1^2}$. The maximum total revenue can be achieved, but at this time both sides still have not reached the Pareto optimal level of effort.

Let $\frac{\partial \overline{\pi_{X,Y}}}{\partial X} = 0, \frac{\partial \overline{\pi_{X,Y}}}{\partial Y} = 0$, then $X^* = \frac{k_1}{\lambda_1}, Y^* = \frac{k_2}{\lambda_2}$. Both sides achieved Pareto's optimal level of effort. Obviously, when the level of efforts of the logistics enterprise and the financial institutions raise from X, Y to X^*, Y^* , Pareto optimum is achieved. And in order to reach X^*, Y^* , redeploying to compensate both sides for their extra efforts is essential.

For the logistics enterprise, when its effort level rises from X to X^* , the income compensation is:

$$\Delta C_1 = C_{X^*} - C_X.$$

For the financial institution, when its effort level rises from Y to Y^* , the income compensation is:

$$\Delta C_2 = C_{Y^*} - C_Y.$$

When both sides' efforts level raise from X, Y to X^*, Y^* , the increment of net income is:

$$\Delta \overline{\pi_{X,Y}} = \overline{\pi_{X^*,Y^*}} - \overline{\pi_{X,Y}}.$$

Benefits allocation is the key and prerequisite for the cooperation and development of supply chain^[15]. According to contribution coefficient λ_1, λ_2 , the increment is allocated twice. The increment of the logistics enterprise is:

$$\Delta \overline{\pi_X} = \frac{\lambda_1}{\lambda_1 + \lambda_2} \Delta \overline{\pi_{X,Y}},$$

The increment of the financial institution is:

$$\Delta \overline{\pi_Y} = \frac{\lambda_2}{\lambda_1 + \lambda_2} \Delta \overline{\pi_{X,Y}}.$$

Therefore, $(\frac{k_1}{\lambda_1}, \frac{k_2}{\lambda_2})$ is the best strategy for the logistics enterprise and the financial institution to make efforts. At this time, the two parties in agricultural supply chain can achieve a continuous and mutually beneficial symbiosis relationship, while other effort levels are not conducive to the maintenance, consolidation and optimization of the symbiosis relationship.

5.3. Symbiosis content of agricultural product supply chain finance system

(1) Logistics symbiosis. Logistics symbiosis is the foundation of symbiosis units to maintain symbiosis relationship. In the agricultural supply chain finance system, the transportation, packaging, handling and storage of financing pledge are inseparable from logistics support. Modern logistics of agricultural products is an important celling to the development of Chinese agriculture^[16]. Some logistics enterprises have established financing mode of logistics bank through alliance with financial institutions, which makes their symbiosis relationship more closely. In addition, compared with general industrial logistics, agricultural products have higher requirements for logistics because of their own characteristics. Therefore, it is necessary for logistics enterprises to realize the integration and complementarity of superior resources and form strong competitive advantages by means of symbiosis, so as to win the favor of financial institutions to ensure the effective operation of supply chain finance system. Moreover, the agricultural logistics information system based on the Internet of Things can be constructed to promote the co-existence of logistics and information flow in the whole agricultural supply chain financial system^[17].

(2) Capital flow symbiosis. Capital flow symbiosis is the guarantee for symbiosis units to develop symbiosis relationship. Firstly, symbiosis units in the system are independent of each other. Relationships among symbiosis units are only simple supply-demand relationships, and they are unstable and cannot adapt to the operation of supply chain funds, which requires promoting the synergy of symbiosis units in the system in terms of capital flow, such as continuously developing the financial service model of agricultural products supply chain, establishing the financial service model of platform finance, logistics finance and internet finance, etc. The symbiosis units should match the circulation mode of agricultural products with the financial service mode according to their own characteristics of supply and demand, so as to activate the funds in supply chain and maximizing the operation efficiency of the capital flows in supply chain finance system.

(3) Information flow symbiosis. Information flow symbiosis is the key for symbiosis units to consolidate symbiosis relationship. There are plenty of information in the agricultural supply chain finance system, such as business information of symbiosis units, competitiveness information core enterprises, technical information logistics enterprises, and loan information financial institutions, as well as information about credit level and comprehensive competitiveness of the whole supply chain. With the deepening cooperation of symbiosis units in supply chain finance, the information island is gradually broken, and the degree of information sharing among symbiosis units is constantly improving. Significance of sharing information is undisputed for the success of supply chain collaboration^[18]. At this time, financial institutions through logistics enterprises can not only grasp the type, price and quality of pledge information, and monitor the entry and exit of pledge, but also control the loan ratio, margin amount and account balance of the financing subject, which can reduce the financing risk of the entire supply chain financial system.

5.4. Impact of external environment on symbiosis relationships of agricultural product supply chain finance system

Agricultural supply chain finance system is open. With the continuous exchange of information, material and energy between symbiosis units and the external environment, symbiosis relationships

of symbiosis units are affected by the external environment. Good external environment can promote symbiosis units of system to improve efficiency, reduce costs and generate positive symbiosis energy. On the contrary, it would affect symbiosis relationships within symbiosis units and produce negative energy, thus hindering the healthy development of agricultural supply chain finance system. Therefore, it is necessary to clarify the impact of external environment on the symbiosis relationships among symbiosis units of supply chain finance.

(1) Government's impact on symbiosis relationship. The symbiosis of agricultural supply chain finance cannot be separated from government support, guidance and regulation. Government policies and regulations will induce changes in the internal relationships of symbiosis units. Firstly, the upstream and downstream of agricultural supply chain have financing need, while financial institutions need to broaden their business scope and customer groups, which initially promotes the formation of symbiosis relationships between them. But most of these symbiosis relationships belong to point symbiosis or intermittent symbiosis. With the continuous implementation of the “three agricultural” support policy and the SMEs’ financing policy, the interaction between SMEs and financial institutions in the agricultural supply chain have been strengthened. The symbiosis relationship has been strengthened and consolidated, and gradually transit from point symbiosis or intermittent symbiosis to continuous symbiosis. Finally, the relevant laws and regulations about the agricultural supply chain finance are constantly optimized. Banks pay more attention to the symbiotic cooperation with upstream and downstream of agricultural supply chain, and their continuous symbiosis relationships are closer and more stable. In Table 2, when symbiosis units of agricultural supply chain finance encourage each other, the government should encourage financial institutions to provide loans to SMEs and farmers of agricultural supply chain from the perspective of policy support, so as to promote symbiosis relationships of symbiosis units to continue to consolidate and optimize. When symbiosis units are unilaterally restrained or mutually restrained, the government should punish non-standard financing and lending behaviors from the perspective of legal regulation to prompt symbiosis units to adjust symbiosis relationships in time.

(2) Impact of agricultural association on symbiosis relationships. Agricultural product association is a non-profit economic organization established voluntarily by farmers, processing enterprises, sellers, intermediary, cooperative economic organizations and relevant scientific researchers. The agricultural product association will influence on the symbiosis units. Firstly, association provides members with scientific and technological knowledge of agricultural products. And it also guides members to adopt advanced agricultural machinery and introduces excellent varieties, so as to expand the scale of production and ensure the quantity and quality of pledged agricultural products in the supply chain. Secondly, by publishing the information of products production, processing and quality safety to outside in a unified format, the association improves the transparency of members' information, which reduces risks caused by information asymmetry and helps members to obtain more loan opportunities and amount. Finally, through recommending members adopt unified production technologies, the association standardizes the agricultural production and processing, so as to improve the standardization of agricultural products. These measures provide a basis and possibility for classifying agricultural products and defining their quality and price. In this case, when agricultural products are pledged, the procedures of testing, auditing and evaluating will be greatly simplified, which facilitates the development of agricultural supply chain finance and deepening symbiosis relationships of symbiosis units.

(3) Impact of end consumers on symbiosis relationships. Solving the contradiction between supply and demand between production and consumption due to space-time differences is one target of agricultural supply chain finance. Habits, preferences and ideas of consumers will affect the agricultural supply chain finance. Financial institutions can determine the type of agricultural products that can be pledged according to the market demand and price, as well as the loan proportion, repayment time and the amount of deposit. For agricultural products with stable consumption and little price fluctuation, financial institutions may appropriately relax the loan conditions and increase the loan quota. On the contrary, for some flexible consumption of agricultural products, financial institutions will fully examine their market demand to assess

whether to accept the financing applications. In addition, with the increase of consumers' income and the improvement of living conditions, the concept of consumers has also changed. Their demand for agricultural products has shifted from meeting their physiological need to low-carbon, ecological, and green, which promotes the symbiotic cooperation of farmers, logistics enterprises, core enterprises, wholesale retailers and financial institutions in low-carbon economy. For example, when selecting suppliers, core enterprises would choose suppliers with high quality and low pollution, and they may also recommend them to financial institutions to help address their loan problems. And financial institutions can incorporate environmental protection indicators and credit rating into the evaluation of financing objects, increasing the financing amount of “green credit” for upstream and downstream of the agricultural supply chain^[19], so as to better promote the long-term sustainable development of symbiosis relationships of agricultural product supply chain finance.

6. Conclusion

Lacking funds has been a major problem faced by most SMEs. Potential risks in turbulent and dynamic agricultural supply chain finance systems make it even more complicated to solve the SMEs' financing problems, especially in developing countries^[20]. The symbiosis of agricultural supply chain finance system depends not only on the coordination among symbiosis units of supply chain finance, but also influenced by the external environment. In the agricultural supply chain financial system, symbiosis units interact with each other to achieve the continuous and reciprocal symbiosis of the whole system through logistics symbiosis, capital flow symbiosis, and information flow symbiosis. Symbiosis units in the system connect with the outside through symbiosis media such as fund management and settlement, reputation, contract and stock, transaction platform. They transform the material, energy and information of the external environment into the symbiotic force and source for self-development, and ultimately achieve the survival of the fittest through continuous games. In addition, affected by the external environment, symbiosis relationships of symbiosis units of agricultural supply chain finance are affected by the government's guidance and regulation, the coordination and unification of agricultural associations, and the demand constraints of end consumers. Overall, through the construction of the agricultural product supply chain finance system, we can further clarify the role and position of each symbiosis unit in system, and actively build the symbiosis interface of the system, and rationally use the external environment to promote the optimization of symbiosis relationships in the system, which provides theoretical guidance for reducing the financial risk of agricultural supply chain and realizing the orderly development of agricultural product supply chain finance system.

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