An Experimental Research on the Game of Industry Choice by Farmers Embedded in the Value Chain

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Abstract. Industrial prosperity is an important foundation for rural revitalization and a prerequisite for solving all rural problems. In order to explore the main factors that affect the value chain embedded farmers' choice of industry, this paper selects six indicators including industrial policy support as the influencing factors. By constructing a cooperative game model of value chain embedded farmers and enterprises and conducting numerical simulation analysis, it is found that: industrial policy Support, intellectual and technical support, infrastructure support, logistics system support, and market demand support have a positive impact on the industry selection of value chain embedded farmers, and embedded risk has a negative impact on the value chain embedded farmers' industry selection. Finally, according to the research results, this paper also puts forward relevant suggestions.

Keywords: Value Chain Embedding · Industry Choice · Cooperative Game

1 Introduction

The rural revitalization strategy puts forward the general requirements of "prosperous industry, livable ecology, civilized rural customs, effective governance, and prosperous life", among which industrial prosperity is the cornerstone of this strategy. However, the actual situation that China is facing is that the small-scale peasant economy is still the mainstream in most rural areas of our country, and farmers in most areas still adopt small-scale independent operations.

In this context, farmers are facing problems such as unstable income and weak ability to resist risks, and enterprises are facing development obstacles such as farmers increase the price at will, difficult to guarantee profits, and unstable supply of goods. Domestic and foreign scholars have made many useful explorations on how to break through this real dilemma. But at the same time, the new reality is that farmers often deviate from their cooperative relationship with the company in order to pursue short-term benefits or resist market risks. For example, the qualified products are substituted for defective ones, and when the market is good, farmers are willing to "sell in the field", and when the market is bad, they are willing to deliver the products to the company that signed the cooperation agreement. At the same time, many scholars' studies have proved that

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individual characteristics such as poverty status and poverty perception affect individual decision-making. For the above reasons, farmers tend to choose short-term, less risky and relatively less beneficial options.

Based on the reasons above, this paper intends to construct a cooperative game model of value chain-embedded farmers and enterprises and conduct simulation analysis to explore the influencing factors of value chain-embedded farmers' industrial selection, in order to provide reference for relevant departments to formulate effective policies.

2 Literature Review

2.1 Related Research on Value Chain Embedding

Amighini divides the value chain embedding methods into upward embedding and downward embedding [1]. Wang et al. found that the embedded index has a positive relationship with GDP, and the higher the backward embedded index, the greater the impact on GDP growth [2]. Compared with other industries, China's agriculture is at the bottom of the "smile curve", suffering from unequal benefits and unequal distribution. Therefore, China should accelerate the promotion of the upgrading of the agricultural industry chain and enhance China's position in the global agricultural value chain [3]. As China's agriculture joins the development of global value chains, more and more agricultural products enter the international market, occupy a certain position in the global value chain and gradually increase, and the added value obtained is also gradually rising [4].

Production activities embedded in the value chain can promote the development of agriculture through independent innovation or absorption of external knowledge and technology. If agriculture is embedded in the value chain of other industries in the form of OEM, in the long term, agriculture will be locked in simple agricultural production links, leading to a phenomenon similar to industrial "low-end lock-in" [5]. Liu Zhibiao and Zhang Jie believe that when low value-added industries climb to high value-added industries in participating in value chain activities, they will be double-squeezed and suppressed by high value-added industries [6]. Gao Yue et al. found that the scale of the industry and R&D expenditures promote the rise of the status of China's agricultural product processing industry in the value chain [7].

2.2 Related Research on the Influencing Factors of Industry Selection

There are many factors influencing enterprise decision-making in the process of industry selection, such as policy support, infrastructure construction, and market demand [8]. Wang Kemin et al. found that companies encouraged or supported by industrial policies have higher investment levels [9]. Compared with companies that are not supported by industrial policies, companies supported by industrial policies are more likely to obtain more bank loans, and thereby improve the efficiency of corporate investment [10–14]. Intellectual capital has an important impact on the technological innovation capabilities of China's SMEs. Therefore, China's SMEs should focus on the improvement of these two capabilities [15, 16]. Technological capital has an indirect impact on corporate financial performance by affecting human capital, structural capital, and invested capital [17]. The leading role of the logistics industry in economic development should be fully utilized, the construction of logistics infrastructure should be accelerated, and the coordinated development of the logistics industry and the regional economy should be realized [18, 19]. Under the conditions of a buyer's market for agricultural products, market demand is an important inducing factor for farmers' technology adoption behavior [20]. The issue of interest linkage mechanism under multi-participation is the core issue of enterprises participating in the process of rural tertiary industry integration, which may cause various risks [21, 22].

2.3 Literature Review

A review of relevant papers found that China's agricultural industry chain is still in a relatively backward situation, and it is urgent to promote the upgrading of the agricultural industry chain in an all-round way. At the same time, there are many researches on the factors that influence the industry selection of enterprises, but few related researches on the factors that affect the farmers' industry choices, and even fewer researches on the factors that influence the farmers' industry choices on the value chain. Based on this, this paper intends to explore in detail the main factors that affect the value chain embedded farmers' industrial choice through a combination of evolutionary game and numerical simulation.

3 Model Constructing

On the basis of previous scholars' research, this paper intends to construct an evolutionary game model of value chain embedded farmers and enterprises, choosing six indicators of industrial policy support, intellectual technical support, infrastructure support, logistics system support, market demand support, and embedded risk as the main explanatory variable, the income of farmers and enterprises is included as the explained variable into the game analysis model, and numerical simulation analysis is carried out on the basis of evolutionary game. Combined with the results of evolutionary game and numerical simulation, this paper analyzes the main factors that affect the industrial choice of value chain embedded farmers. The specific process is as follows:

1) Assuming that the investments of enterprises and farmers when they are not cooperating are x_1, x_2 respectively, and their investment efficiencies are m_1, m_2 respectively. It can be obtained that the income of enterprises and farmers in the value chain embedded industry without mutual selection is m_1x_1, m_2x_2 respectively. Suppose the cooperation cost coefficients are c_1 and c_2 respectively. Then the cooperation cost of enterprises and farmers is $C_1 = c_1x_1, C_2 = c_2x_2$.

2) Assuming that the conversion rate of industrial policy support income is δ_1, δ_2, when the investment of enterprises and farmers is x_1, x_2, the income derived from industrial policy support is δ_1x_1, δ_2x_2 respectively. In the same way, assuming that the conversion rate of intellectual technical support income is λ_1, λ_2, the conversion rate of infrastructure support income is α_1, α_2, the conversion rate of logistics system support income is β_1, β_2, and the market demand support income conversion rate is γ_1, γ_2. Then the benefits of enterprises and farmers due to industrial policy support are $\lambda_1x_1, \lambda_2x_2$, the

benefits derived from infrastructure support are $\alpha_1 x_1$ and $\alpha_2 x_2$; the benefits derived from logistics system support are $\beta_1 x_1$ and $\beta_2 x_2$; the benefits derived from market demand support are $\gamma_1 x_1$ and $\gamma_2 x_2$.

3) Embedded risk F means that enterprises and farmers will also face certain risks in the process of choosing cooperation. Assume that the risk coefficient of the enterprise is ε_1 and the risk coefficient of the farmers is ε_2. The trust level of the enterprise to the farmers is represented by μ_{12}, and the trust level of the farmers to the enterprise is represented by μ_{21}. From this, the embedded risks of the enterprise and the farmers are as follows:

$$F_1 = (1 - \mu_{12})\varepsilon_1 x_1 \tag{1}$$

$$F_2 = (1 - \mu_{21})\varepsilon_2 x_2 \tag{2}$$

In summary, when enterprises and farmers adopt cooperative strategies, their respective benefits are:

$$\Pi_1 = m_1 x_1 + \delta_1 x_1 + \lambda_1 x_1 + \alpha_1 x_1 + \beta_1 x_1 + \gamma_1 x_1 - c_1 x_1 - (1 - \mu_{12})\varepsilon_1 x_1 \tag{3}$$

$$\Pi_2 = m_2 x_2 + \delta_2 x_2 + \lambda_2 x_2 + \alpha_2 x_2 + \beta_2 x_2 + \gamma_2 x_2 - c_2 x_2 - (1 - \mu_{21})\varepsilon_2 x_2 \tag{4}$$

The income payment matrix of cooperative game between enterprises and farmers can be obtained as shown in Table 1.

Assume that the probability of cooperation and non-cooperation of enterprises in the value chain embedded industry are respectively p, $1 - p$; The probability that farmers adopt cooperation and non-cooperation are respectively q, $1 - q$.

From Table 1, it can be obtained that the expected benefits of enterprises in the value chain embedded industry choosing cooperation are:

$$\begin{aligned} E_1^y = q\big[&m_1 x_1 + \delta_1 x_1 + \lambda_1 x_1 + \alpha_1 x_1 + \beta_1 x_1 + \gamma_1 x_1 - c_1 x_1 \\ &-(1 - \mu_{12})\varepsilon_1 x_1\big] + (1 - q)(m_1 x_1 - c_1 x_1) \end{aligned} \tag{5}$$

The expected benefits of companies choosing not to cooperate are:

$$E_1^n = q m_1 x_1 + (1 - q) m_1 x_1 = m_1 x_1 \tag{6}$$

The average expected income of the enterprise is:

$$\begin{aligned} \overline{E_1} &= pE_1^y + 1 - pE_1^n \\ &= \mathrm{p}q\delta_1 x_1 + pq\lambda_1 x_1 + pq\alpha_1 x_1 + pq\beta_1 x_1 + pq\gamma_1 x_1 - pq\varepsilon_1 x_1 \\ &\quad + pq\mu_{12}\varepsilon_1 x_1 - pc_1 x_1 + m_1 x_1 \end{aligned} \tag{7}$$

The same can be obtained:

Table 1. The income payment matrix of the cooperative game between two types of subjects in the selection of the value chain embedded industries

Cooperative behavior of two types of subjects		Subject 2: Farmers	
		Cooperation	Non-cooperation
Subject 1: Enterprise	Cooperation	$m_1x_1 + \delta_1x_1 + \lambda_1x_1 + \alpha_1x_1 + \beta_1x_1 + \gamma_1x_1 - c_1x_1 - (1 - \mu_{12})\varepsilon_1x_1$	$m_1x_1 - c_1x_1$
		$m_2x_2 + \delta_2x_2 + \lambda_2x_2 + \alpha_2x_2 + \beta_2x_2 + \gamma_2x_2 - c_2x_2 - (1 - \mu_{21})\varepsilon_2x_2$	m_2x_2
	Non-cooperation	m_1x_1	m_1x_1
		$m_2x_2 - c_2x_2$	m_2x_2

The expected benefits of farmers choosing cooperation are:

$$E_2^y = p\big[m_2x_2 + \delta_2x_2 + \lambda_2x_2 + \alpha_2x_2 + \beta_2x_2 + \gamma_2x_2 - c_2x_2 - (1 - \mu_{21})\varepsilon_2x_2\big] + (1 - p)(m_2x_2 - c_2x_2) \tag{8}$$

The expected benefits of farmers who choose not to cooperate are:

$$E_2^n = pm_2x_2 + (1 - p)m_2x_2 = m_2x_2 \tag{9}$$

The average expected income of farmers is:

$$\begin{aligned}\overline{E_2} &= qE_1^y + (1 - q)E_1^n \\ &= pq\delta_2x_2 + pq\lambda_2x_2 + pq\alpha_2x_2 + pq\beta_2x_2 + pq\gamma_2x_2 \\ &\quad - pq\varepsilon_2x_2 + pq\mu_{21}\varepsilon_2x_2 - qc_2x_2 + m_2x_2\end{aligned} \tag{10}$$

In summary, the dynamic differential equations of replication when enterprises and farmers adopt cooperative strategies are as follows:

$$\begin{cases} dp/dt = F_1(p) = p\big(E_1^y - \overline{E_1}\big) = p(1 - p)x_1\big[q(\delta_1 + \lambda_1 + \alpha_1 + \beta_1 + \gamma_1 - \varepsilon_1 + \mu_{12}\varepsilon_1) - c_1\big] \\ dq/dt = F_2(q) = q\big(E_2^y - \overline{E_2}\big) = q(1 - q)x_2\big[p(\delta_2 + \lambda_2 + \alpha_2 + \beta_2 + \gamma_2 - \varepsilon_2 + \mu_{21}\varepsilon_2) - c_2\big] \end{cases}$$

The five local equilibrium points of the system are as follows:
O(0, 0), A(0, 1), B(1, 0), C(1, 1) and D(p*, q*)
After calculation, we can get:

$$(p^*, q^*) = \left(\frac{c_1}{\delta_1 + \lambda_1 + \alpha_1 + \beta_1 + \gamma_1 - \varepsilon_1 + \mu_{12}\varepsilon_1}, \frac{c_2}{\delta_2 + \lambda_2 + \alpha_2 + \beta_2 + \gamma_2 - \varepsilon_2 + \mu_{21}\varepsilon_2}\right)$$

The Jacobian matrix of the system is:

$$J = \begin{bmatrix} (1 - 2p)x_1\big[q(\delta_1 + \lambda_1 + \alpha_1 + \beta_1 + \gamma_1 - \varepsilon_1 + \mu_{12}\varepsilon_1) - c_1\big] & p(1 - p)x_1(\delta_1 + \lambda_1 + \alpha_1 + \beta_1 + \gamma_1 - \varepsilon_1 + \mu_{12}\varepsilon_1) \\ q(1 - q)x_2(\delta_2 + \lambda_2 + \alpha_2 + \beta_2 + \gamma_2 - \varepsilon_2 + \mu_{21}\varepsilon_2) & (1 - 2q)x_2\big[p(\delta_2 + \lambda_2 + \alpha_2 + \beta_2 + \gamma_2 - \varepsilon_2 + \mu_{21}\varepsilon_2) - c_2\big] \end{bmatrix}$$

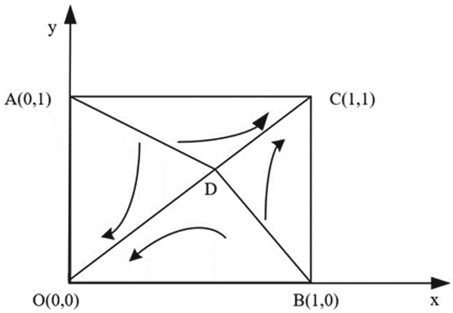

Fig. 1. Evolutionary game trend diagram of value chain embedded farmers and enterprises

The determinant and trace of matrix J are:

$$\det J = (1-2p)x_1\left[q(\delta_1+\lambda_1+\alpha_1+\beta_1+\gamma_1-\varepsilon_1+\mu_{12}\varepsilon_1)-c_1\right] \times (1-2q)x_2\left[p(\delta_2+\lambda_2+\alpha_2+\beta_2+\gamma_2-\varepsilon_2+\mu_{21}\varepsilon_2)-c_2\right]$$

$$-p(1-p)x_1(\delta_1+\lambda_1+\alpha_1+\beta_1+\gamma_1-\varepsilon_1+\mu_{12}\varepsilon_1) \times q(1-q)x_2(\delta_2+\lambda_2+\alpha_2+\beta_2+\gamma_2-\varepsilon_2+\mu_{21}\varepsilon_2)$$

$$\mathrm{trJ} = (1-2p)x_1\left[q(\delta_1+\lambda_1+\alpha_1+\beta_1+\gamma_1-\varepsilon_1+\mu_{12}\varepsilon_1)-c_1\right] + (1-2q)x_2\left[p(\delta_2+\lambda_2+\alpha_2+\beta_2+\gamma_2-\varepsilon_2+\mu_{21}\varepsilon_2)-c_2\right]$$

The evolution process of the evolutionary game between enterprises and farmers is shown in Fig. 1. S_{ADBC} and S_{ADBO} respectively represent the probability of the final outcome of the evolution being (cooperation, cooperation) or (non-cooperation, non-cooperation). In summary, S_{ADBC} can be expressed as follows:

$$S_{ADBC} = 1-\frac{1}{2}\left[\frac{c_1}{\delta_1+\lambda_1+\alpha_1+\beta_1+\gamma_1-\varepsilon_1+\mu_{12}\varepsilon_1}+\frac{c_2}{\delta_2+\lambda_2+\alpha_2+\beta_2+\gamma_2-\varepsilon_2+\mu_{21}\varepsilon_2}\right]$$

4 Simulation Analysis

It can be seen from the above formula that the cooperation cost coefficients (c_1, c_2), industrial policy support income conversion rate (δ_1, δ_2), intellectual technology support income conversion rate (λ_1, λ_2), infrastructure support income conversion rate (α_1, α_2), logistics system support revenue conversion rate (β_1, β_2), market demand support revenue conversion rate (γ_1, γ_2), cooperation risk coefficient $(\varepsilon_1, \varepsilon_2)$, and the trust level of both parties (μ_{12}, μ_{21}) have an impact on the evolution of the system. According to the above formula, the influence of the above factors on the probability of choosing cooperation strategy is discussed respectively.

The value ranges of the above factors are all (0,1), at the same time, $\mu_{12}+\mu_{21}=1$, set the initialization parameter values to $c_1=0.3$, $c_2=0.2$; $\delta_1=0.7$, $\delta_2=0.6$; $\lambda_1=0.9$, $\lambda_2=0.8$; $\alpha_1=0.8$, $\alpha_2=0.7$; $\beta_1=0.7$, $\beta_2=0.6$; $\gamma_1=0.9$, $\gamma_2=0.8$; $\varepsilon_1=0.6$, $\varepsilon_2=0.5$; $\mu_{12}=0.4$; $\mu_{21}=0.6$. Matlab2019a was used for simulation analysis, as follows:

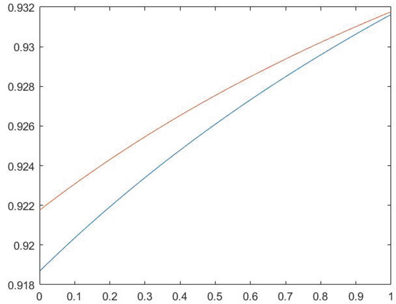

Fig. 2. Simulation diagram of industrial policy support transition changes

4.1 The Impact of Industrial Policy Support Income Conversion Rate (δ_1, δ_2) on S_{ADBC}

It is not difficult to see from Fig. 2 that S_{ADBC} has a positive correlation with the conversion rate of industrial policy support income. Regarding this point, this paper believes that the main reasons are as follows: in order to improve resource utilization, the government will generally continue to increase its support in industrial policies, thereby encouraging farmers and enterprises to cooperate; In order to respond to the policy call and obtain more government support and financial subsidies, enterprises and farmers are more inclined to make choices that meet the policy requirements. This also explains why with the increase in industrial policy support, the probability that both enterprises and farmers choose to cooperate is constantly increasing.

4.2 The Impact of Intellectual Technical Support Income Conversion Rate (λ_1, λ_2) on S_{ADBC}

After simulation analysis, it is found that the area of the quadrilateral ADBC is also positively correlated with the intellectual technical support. This means that with the increase of intellectual and technical support, the probability of enterprises and farmers choosing cooperation is gradually increasing. This is because after receiving more intellectual and technical support, farmers and enterprises will obviously feel the dividends brought by external support. Under the influence of such factors, they will be more convinced that cooperation will bring more external support, and thus obtain more profits than their own production and sales, so they are more willing to choose cooperation (Fig. 3).

4.3 The Impact of Infrastructure Support Income Conversion Rate (α_1, α_2) on S_{ADBC}

With the continuous increase in infrastructure support, both enterprises and farmers will benefit from it. At the same time, the cost of inputting production by enterprises and farmers will also be reduced, and enterprises and farmers will free up a certain cost for cooperation. Under the common influence, enterprises and farmers will also have a stronger willingness to cooperate (Fig. 4).

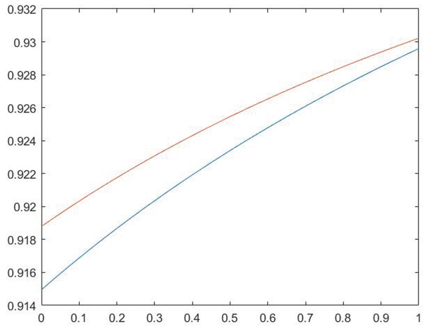

Fig. 3. Simulation diagram of changes in intellectual technical support

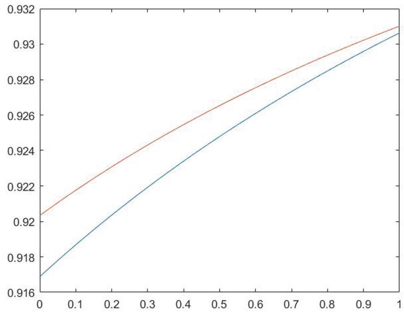

Fig. 4. Simulation diagram of infrastructure support changes

4.4 The Impact of Logistics System Support Income Conversion Rate (β_1, β_2) on S_{ADBC}

The logistics system support and S_{ADBC} have a positive correlation, that is, as the logistics system support increases, the probability of cooperation between enterprises and farmers will also increase. This is because when the logistics system is not perfect, the products produced by farmers generally need to find a way to transport and sell them, and the cost itself will be relatively high, so they are not willing to invest more costs to cooperate; The improvement of the logistics system will greatly reduce transportation costs. Therefore, farmers will choose to cooperate to increase product sales while ensuring profits. Enterprises will also choose to cooperate with farmers in order to maintain stable operations (Fig. 5).

4.5 The Impact of Market Demand Supports Income Conversion Rate (γ_1, γ_2) on S_{ADBC}

With the increase in market demand support, the probability of cooperation between enterprises and farmers will also increase significantly. This is because with the increase in market demand, the market will have greater demand for products. To meet market demand, companies will choose to cooperate with more farmers to increase supply,

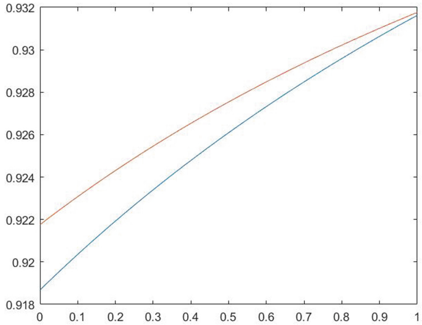

Fig. 5. The simulation diagram of logistics system support changes

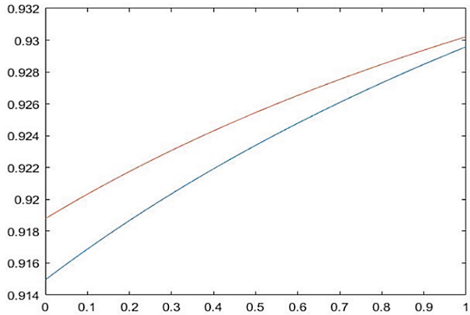

Fig. 6. The simulation diagram of market demand support changes

and farmers will also choose to cooperate with enterprises in order to obtain more profits, which also explains the phenomenon that the probability of cooperation between enterprises and farmers will increase with the increase in market demand support (Fig. 6).

4.6 The Impact of Cooperation Risk Coefficient (ε_1, ε_2) on S_{ADBC}

With the increase of cooperation risks, the probability of cooperation between enterprises and farmers has decreased to a certain extent, and the probability of enterprises choosing not to cooperate has dropped even faster. The reason for the above phenomenon is that with the increase of cooperation risks, under the premise that cooperation does not necessarily bring about a significant increase in profits, enterprises and farmers will choose to adopt their own original models for production and sales in order to avoid risks, instead of taking a certain risk to cooperate, which will make enterprises and farmers feel that the gain is not worth the loss (Fig. 7).

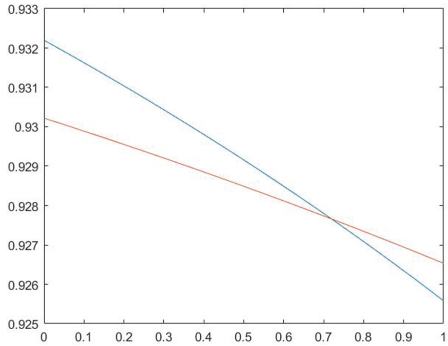

Fig. 7. Simulation diagram of changes in cooperation risk coefficient

5 Conclusions and Suggestions

Through the above simulation analysis, it is found that industrial policy support, intellectual and technical support, infrastructure support, logistics system support, market demand support, and mutual trust levels are positively correlated with the probability of cooperation between farmers and enterprises embedded in the value chain, that is, with the increase of these support, farmers will tend to choose industries; and the cost of cooperation and embedded risks are negatively related to the probability of value chain-embedded farmers and enterprises cooperating. That is, with the increase of cooperation costs and embedded risks, farmers tend not to make industry choices. Based on this conclusion, this paper believes that in order to enhance the willingness of farmers to make industrial choices and promote the win-win cooperation between farmers and enterprises, the following improvements can be considered:

5.1 Increase Policy Support

Increasing industrial policy support will increase the willingness of farmers and enterprises to cooperate. At the same time, policy support will also bring more intellectual and technical support and a reduction in cooperation costs. Under the combined effect of factors such as the increase in industrial policy support, the increase in intellectual and technical support and the reduction in costs, the willingness of farmers and enterprises embedded in the value chain to cooperate will be greatly increased.

5.2 Extensively Attract Talents to Participate in the Agricultural Value Chain

Adopt methods such as improving welfare benefits and granting certain policy subsidies to talents who are willing to engage in work related to the agricultural value chain to attract more talents to participate in the agricultural industry, therefore, provide more complete intellectual and technical support for promoting the transformation and upgrading of the agricultural industry chain.

5.3 Improve Infrastructure Construction

Improve the infrastructure construction of roads, communications, networks, etc. The improvement of infrastructure will bring more convenient cooperation methods and lower cooperation costs for farmers and enterprises, which can effectively increase the probability of industrial selection by farmers and enterprises embedded in the value chain, and promote farmers and enterprises cooperate for a win-win situation.

5.4 Promote the Construction of a Modern Logistics System

Expand the current logistics coverage and gradually realize express delivery in every village. Build a modern logistics system, use big data, 5G and other technologies to promote the construction of a more scientific and efficient logistics system, and provide a more reliable logistics guarantee for the sales of agricultural products.

5.5 Establish an Official Third-Party Trading Platform

The establishment of an official platform can not only provide guarantee for transactions between farmers and enterprises, enhance the trust level of farmers and enterprises, relieve farmers and enterprises from worries, but also reduce cooperation risks and cooperation costs, which will affect the willingness of farmers embedded in the value chain to make industry choices, and promote cooperation between farmers and enterprises.

5.6 Promote Supply-Side Reforms and Expand Market Demand for Agricultural Products

Improve the production and marketing channels of agricultural products, solve the problems of farmers' difficulty in selling agricultural products, and focus on the supply-side structural reforms, establish a more reasonable and complete production and sales system, provide farmers with stronger market demand support, and solve farmers' worries.

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