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Reciprocal and Symbiotic: Family Farms' Operational Performance and Long-Term Cooperation of Entities in the Agricultural Industrial Chain—From the Evidence of Xinjiang in China

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Abstract: The family farm is an important entity in the modern agricultural industrial chain. It is of great significance to empirically study its operational performance improvement and sustainable development. This paper introduces symbiosis theory to establish a symbiosis system framework of the family farm industrial chain and analyzes family farms' operational performance from the view of industrial symbiosis cooperation. We selected 552 agricultural planting family farms in China's Xinjiang Production and Construction Corps as samples to measure the operational environment and performance of family farms using factor analysis and examining the effects of long-term cooperation among the industrial chain entities on family farms' operational performance using the ordered probit model. The results show that the long-term cooperation of the family farms with other entities has a significant positive impact on the family farms' operational performance, which can be enhanced by the improvement of cooperation and moderated by the external environment. Therefore, it is suggested to promote the long-term cooperation between family farms and other industrial chain entities, as well as the industrial environment optimization, to accelerate the healthy and sustainable development of family farms with a continuous, symmetrical, and reciprocal symbiotic model.

Keywords: symbiosis theory; family farm; industrial chain entities; operational performance

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1. Introduction

In the process of promoting the efficient development of agriculture, the weak nature of the traditional agricultural production sector, generated by the natural and social attributes of agriculture, is naturally existing, and its inherent vulnerability and instability are difficult to eliminate. Through the agricultural industrial chain, agriculture can be transformed into an integrated management entity covering pre-production and post-production links, thereby improving the core competitiveness of agriculture [1]. Actually, the future competition of agriculture is the competition of the agricultural industrial chain [2]. In recent years, the family farm, as one of the representative new agricultural management entities, has become the key force to promote the efficient development of China's agriculture [3]. By the end of September 2021, the number of family farms in China exceeded 3.8 million. Scholars have defined the family farm industry chain in accordance with the development and expansion of family farms and industrial chains. Carried out by a number of interconnected industrial clusters, the production and management of family farms forms the foundation of the family farm industry chain. Family farms play an undeniably central role in the industrial chain, while other industrial entities active in different sectors of the chain,

such as the production, processing, preservation, and sale of agricultural products, serve as auxiliary supporters for family farmers [4]. The development and optimization of the family farms industrial chain can be attributed to the modernization of China's agricultural industrial chain [5]. However, the development of the family farms industrial chain still faces multiple bottlenecks in China, such as imperfect benefit distribution mechanisms, a low degree of informatization, high transaction costs [6], and financing difficulties [7]. This leads to a low operational performance level of family farms. To solve these problems, "Central Document No. 1" of 2018 and 2021 clearly emphasized building and improving the agricultural industrial chain, which created a good policy environment for the family farm industrial chain. Meanwhile, this also guided a path to explore the optimization of symbiotic relationships among management entities of the family farm industrial chain.

A family farm's operational performance refers to the final achievements and results of family farm production and operation management [8]. Many scholars have studied in-depth research on family farm operation performance, and an evaluation system based on economic, social, ecological, and other aspects has been constructed [9]. From the perspective of symbiosis theory, the current bottlenecks of improving operational performance of the family farm are rooted in the low level of symbiotic relationships between family farms and other relevant industrial entities. The symbiotic mode of the family farm industrial chain and the degree of continuous symbiosis and mutualism are relatively simple and on a low level with few symbiotic media. Meanwhile, the symbiotic environment needs to be improved. Family farms are not fully compatible with their symbiotic environment. They still face serious problems such as weak support policies, high financial credit thresholds, and imperfect markets [3]. Based on the development background of the family farm industrial chain in China, it is necessary to introduce the symbiosis theory into the family farm industrial chain.

The symbiosis theory was first proposed by Debbie, a German mycologist, to analyze the natural phenomena of interdependence and co-existence between organisms under different environmental conditions. The symbiosis theory has gradually been applied to social science research. In recent years, scholars focused on industrial symbiosis and elaborated on its positive impact on industrial economies, such as the performance of eco-industrial parks [10] and industrial collaboration behaviors [11], and built a relatively complete evaluation framework for industrial symbiosis outcomes [12]. Considering China's unique situation, scholars introduced the symbiosis theory into the field of agricultural economy and further elaborated on the application of the core elements of symbiosis theory (such as symbiotic unit, symbiotic environment, symbiotic relationship, symbiotic mode, etc.), constructed different symbiotic systems under a variety of scenarios, and then further discussed the evolution process of the agricultural industrialized operation organization [10], the development of agricultural industrial integration [13], the collaborative behavior of the agricultural product supply chain [14], and the safety of the agricultural product quality mechanism [15]. Focusing on the family farm industrial chain, scholars believe that there is a certain mechanism for the symbiotic relationship of the entities of the family farm industrial chain, and its development process is the process of gradually realizing mutual symbiosis [4]. The above research introduced the symbiosis theory into the relevant fields and gradually refined it to the family farm industrial chain. They discussed the symbiotic relationship and symbiotic mode between the symbiotic units, laying a theoretical foundation for subsequent research. However, it is still rare to introduce the symbiosis perspective into the family farm industrial chain, for which the construction of the corresponding symbiosis system should be improved. In particular, the essence of symbiosis lies in cooperation [16]. Long-term cooperation is the typical symbol of a continuous symbiotic relationship. The long-term cooperative behavior, mode, and level of other entities in the family farm industrial chain reflect the symbiotic mode and symbiotic relationship among symbiotic units, which is the key issue that the family farm industrial chain symbiotic system needs to contain. Meanwhile, uncertainty is a prevalent factor in every real problem, especially in a symbiotic relationship [17]. The economic impact of the symbiotic relationships on

symbiotic units, and the moderating effect of symbiotic environments, need to be further analyzed based on the scientific statistical methods.

The Xinjiang Production and Construction Corps (XPCC), located in the northwest of China, is the main grain and cotton base of China. The XPCC is at the national leading level in terms of intensification, scale, agricultural equipment, promotion of modern agricultural practical technology, agricultural production technology, and mechanization. It is a key area to promote the development of agricultural modernization in China. Its family farms are characterized by a high degree of specialization, average land scale, obvious organizational advantages, and a low level of industrial chain extension. Compared with the characteristics of production and the operation of family farms in other areas, the production activities of family farms in the XPCC need to take into account economic and social responsibilities at the same time. They have strong adaptability to the symbiosis theory in terms of operation mode, production characteristics, operational environment, etc.

Taking the XPCC's family farm as the research object, this paper studies the influence of the long-term cooperation between a family farm and other entities in the industrial chain on the family farm's operational performance from the perspective of symbiotic subjects of the family farm industrial chain. Firstly, this paper constructs the symbiotic system framework of the family farm industrial chain, then measures the family farm's operating performance and operating environment by using the field survey data and empirically tests the influence of cooperation between the family farm and other entities in the industrial chain on its operating performance by using the ordered probit model (OPM). In addition, we investigate the regulating role of the operational environment in it so as to provide scientific reference for the harmonious symbiosis and performance improvement of other entities in China's family farm industrial chain.

The main contributions of this paper include: (1) introducing symbiosis theory into the family farm industrial chain, further improving the construction of the symbiosis system of the family farm industrial chain, and quantifying its core element (symbiotic environment); and (2) using OPM, based on the symbiosis system framework, the positive impact of long-term cooperation between family farms and other industrial chain entities on their operating performance is empirically analyzed, and the heterogeneous effects of different degrees of cooperation and the positive impact are discussed.

2. Theoretical Analysis and Assumptions

From the perspective of symbiosis, the symbiotic unit of the family farm industrial chain is composed of the family farm and other symbiotic units in the industrial chain (such as agricultural materials supply, agricultural technology services, agricultural machinery services, agricultural collectives, sales departments, etc.). The symbiotic units cooperate with each other to form a stable symbiotic system. With society gradually entering the era of "multi symbiosis", cooperation, mutual benefit, complementarity, and harmony have become the core of symbiosis theory [18], among which cooperation is the essential feature of symbiosis. There are three symbiotic modes among symbiotic units: point symbiosis, intermittent symbiosis, and continuous symbiosis. Among them, point symbiosis and intermittent symbiosis are mostly referring to relatively simple cooperation modes, such as purchase and sale relationships, and order transactions, where the symbiosis mode is inefficient. In contrast, continuous symbiosis is a necessary condition to form a harmonious symbiosis system. The long-term cooperation between the family farm and other entities in the industrial chain is the specific manifestation of the continuous symbiosis mode between the symbiotic units. The continuous process with a clear direction can promote the multiple entities' participation and consultation dialogue. Entities can fully inherit and retain their advantages, complement and promote each other, and create a space of mutual benefit and reciprocity [19,20]. The existing literature, based on different perspectives, discusses the economic benefits of long-term cooperation between family farms and other entities in the industrial chain. Long-term cooperation with other entities is conducive to improving the voice of family farms, also helping to build an efficient service system based on the

demand characteristics of family farms [21]. Farmers can be more likely to make optimal decisions such as save transaction costs related to object search, price negotiation, and service quality supervision [7]. In this way, it can also help successful coordination in the industrial chain [22]. Meanwhile, farmers are enabled to learn new agricultural production technologies to enhance the added value of agricultural products and their awareness of brand and culture [23]. In general, long-term cooperation between family farms and other entities in the industrial chain can make up for each other's functional defects, as well as achieve mutual incentives and adaptation. Therefore, Hypothesis 1 (H1) is proposed.

Hypothesis 1 (H1). *Family farms' long-term cooperation with other entities in the industrial chain significantly positively affects the operational performance of family farms.*

With the improvement of the degree of cooperation, the joint dependency between symbiotic units increases, which drives symbiotic units to increase their respective investment levels in the relationship. While enhancing the dependency of both parties in the relationship, the investment of both parties is close to parity and the dependency tends to be symmetrical, which not only helps to reduce conflicts and transaction costs, but also helps to produce higher resource sharing and synergy effects. In this way, the marginal revenue of joint value creation increases [14]. According to the symbiosis theory, when the degree of cooperation is low, the symbiotic medium between symbiotic units only stays in a single, low-level medium (such as business transactions, order transactions, etc.), and the joint dependence is limited to a relatively low level, which hinders the maintenance and development of their symbiotic relationship. In contrast, the high degree of cooperation can continuously deepen symbiotic units' cooperation contents, enhance their symbiotic relevancies, and close their interest connections. In this way, it can accelerate the formation of all-around interaction, complementation, and sharing including business transactions, information sharing, interest sharing, and risk sharing, then transform into a full exchange of energy flow, material flow, and information flow, bringing the family farm to operational capacity. The improvement of efficiency and income will eventually lead to mutual benefit and harmonious symbiosis [24,25]. Accordingly, Hypothesis 2 (H2) is proposed.

Hypothesis 2 (H2). *The higher the degree of cooperation, the greater the positive effect of long-term cooperation between family farms and other entities in the industrial chain on the operational performance of family farms.*

The establishment of a modern agricultural management system environment and agricultural management public facilities provide an environment for the symbiotic system of agricultural management organizations, including hardware facilities and software conditions such as modern market systems and market economy consciousnesses [13]. This paper focuses on the latter's moderating role in the impact of family farms' long-term cooperation with other entities in the industrial chain on the operational performance of family farms. Compared with symbiotic unit and symbiotic mode, symbiotic environment is external. The ideal logic should be that the symbiotic environment gives play to its positive external functions, speeds up the metabolism and optimization of symbiotic relationships, and then generates positive incentives for the symbiotic system [26]. The superior symbiotic environment has become an important variable on which the family farm industrial chain can operate well and generate symbiotic effects continuously. In the symbiotic system of China's family farm industrial chain, the symbiotic environment is specifically manifested as a comprehensive operational environment covering policy-serving, financial helping, marketing, vocational education, etc. [27]. Among them, the institutional environment is the key driving force for the development of family farms needing suitable market systems and social service systems that match with it to create a specific operational environment [28]. The existing literature shows that the operating environment has a multi-dimensional impact on the operational performance of family farms, among which moderating factors (policy support environment) and market factors

(financial credit environment and marketing environment) can play a positive moderating role to promote family farms' operating performance [29]. Accordingly, Hypothesis 3 (H3) is proposed.

Hypothesis 3 (H3). *In the process of long-term cooperation between family farms and other entities in the industrial chain affecting the operational performance of family farms, the external environment plays a moderating role.*

Based on symbiosis theory and the characteristics of the family farm industrial chain, in combining the hypotheses in this part the framework diagram of the symbiosis system of the family farm industrial chain is constructed (Figure 1).

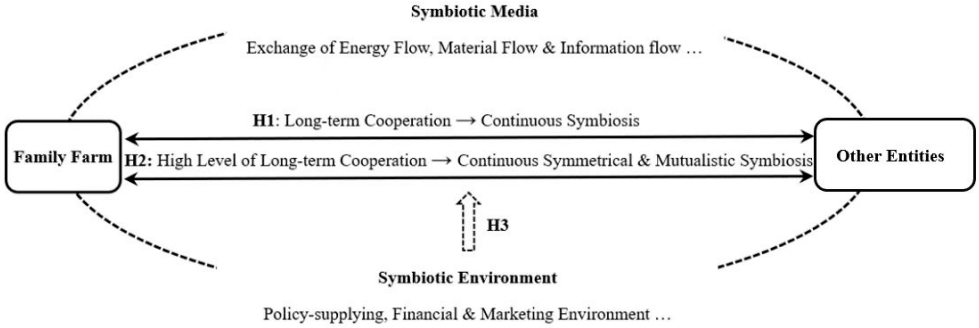

Figure 1. The framework of the family farm industrial chain symbiotic system.

3. Methodology

3.1. Data Source

The data in this paper are from the field survey data of family farms in the XPCC in 2021. The survey area includes the XPCC's 6th, 8th, 10th, and 12th divisions. The survey method is a one-to-one household interview involving the basic situation of the farm, business situation, industry distribution, participation in the secondary and tertiary industries, policy support, product subsidies, financial support, etc. There were 552 questionnaires collected in all. According to the statistical analysis specification, 497 valid samples were finally obtained after removing the samples with missing important variables and qualifying conditions, with an effective rate of 90.04%. To avoid the impact of extreme values on the estimation results, all continuous variables have been shrunk by 99%.

3.2. The Evaluation Indicator System of Family Farms' Operational Performance and External Environment

3.2.1. The Evaluation Indicator System of Family Farms' Operational Performance

According to existing research [29–31], we evaluate the operational performance of family farms from the three dimensions involving economic performance (EP), ecologic performance (ECP), and social performance (SP). Each dimension is divided into several secondary indicators (Table 1).

Table 1. The Evaluation Indicator System of Family Farms' Operational Performance.

Indicator	Secondary Indicator	The Design of the Questionnaire
EP	Comparison with Expectation	Do you think your farm has earned more than expected at the beginning of this year? (Yes = 1, about the same = 2, no = 3)
	Comparison with Experience	Do you think your farm has earned this year is more than the past 2 years? (Yes = 1, about the same = 2, no = 3)
	Comparison with Peers	Do you think your farm has earned this year is more than your peers? (Yes = 1, about the same = 2, no = 3)

Table 1. *Cont.*

Indicator	Secondary Indicator	The Design of the Questionnaire
ECP	Demonstration Farm	Is your family farm a Demonstration Farm (DF)? (Group level of DF = 1, division level of DF = 2, provincial level of DF = 3, no = 4)
	Social Influence	How many farmers are driven by your family farm?
SP	Agri-product Certification	Does your family farm get Agri-product Certification (pollution-free, green, or organic Agri-product)? (Yes = 1, no = 2)
	Use of Pesticides and Fertilizers	Is your family farm strictly controlling the use of pesticides and fertilizers? (Very lax = 1, lax = 2, normal = 3, strict = 4, very strict = 5)

3.2.2. The Evaluation Indicator System of Family Farms' External Environment

Based on the above theoretical analysis, we selected the policy-supporting environment (PSE), financial credit environment (FCE), and marketing environment (ME) to build the external environment system of the family farm industrial chain. Concerning the existing literature [32–34], the external environment of the family farm industrial chain is measured from three dimensions: policy support environment, financial credit environment, and marketing environment. Each dimension is further divided into different secondary indicators (Table 2).

Table 2. The Evaluation Indicator System of Family Farms' External Environment.

Indicator	Secondary Indicator	The Design of the Questionnaire
PSE	Receiving of Policy	Does your family farm receive special government subsidies? (Yes = 1, no = 2)
	Diversity of Policy-supporting	The number of social public services your family farm has received.
	Degree of Policy-supporting	How do you evaluate the current policy support for family farms? (In a low degree = 1, in a normal degree = 2, in a high degree = 3)
FCE	Satisfaction of Financial Support	Is your family farm a Demonstration Farm (DF)? (Group level of DF = 1, division level of DF = 2, provincial level of DF = 3, no = 4)
	Diversity of Financial Channels	How many farmers are driven by your family farm?
	Convenience of Financial Channels	Is the main difficulty of your family farm "financial difficulty"? (Yes = 1, no = 2)
ME	Registered Trademark	Does your Agri-product have a registered trademark? (Yes = 1, no = 2)
	The Difficulty of Sale	Do you think selling your Agri-products is difficult? (Yes = 1, no = 2)
	The Ratio of Direct Selling	The proportion of sales directly to total output.

3.3. Explanation of Variables

Explained variable: Family farm's operational performance (OP). OP is measured through factor analysis based on the evaluation indicator system of the family farms' operational performance. According to the performance scores, the samples are divided under the principle of three equal parts involving low-, medium-, and high- operational performance groups, with values of 1, 2, and 3, respectively. The higher the value, the better the operational performance of family farms.

Explanatory variable: Family farm's long-term cooperation with other entities in the industrial chain (IC). Through the results of the corresponding question "whether the family farm conducts long-term cooperation with other entities in the industrial chain?", a 0–1 binary dummy variable is set accordingly.

Moderating variable: Family farm external environment (EE). This is the score based on the factor analysis results of the family farm external environment evaluation indicator system.

Control variables: Scholars analyzed the factors that affect the operational performance of family farms from many aspects: first, the characteristics of farmers' endowment, such as farmers' characteristics and management capacity [35]; second, the characteristics of the farm's operation and management, such as multiple operation [36], e-commerce adoption [37], intergenerational succession [38], brand competitiveness [39], etc.; third, the external environment such as social environment [40], agricultural support policies [41], government subsidies [42], etc. However, family farms in the XPCC, with a unified arrangement by the XPCC, have a relatively single planting range and a low level of informatization and digitalization of production and operation. Given that the external environment variables have been reflected in the moderating variable in this paper, we choose endowment variables of family farm involving operating years (OY), farm size (FZ), square of farm size (FZ^2), number of employees (NE), and the endowment variables of family owner including gender (Gen), age (Age), and education background (EB) as the control variable group [43]. The definition of all variables is shown in Table 3.

Table 3. The Definition of Variables.

Name of Variable	Definition of Variable
Operational performance (OP)	Grouping of family farms based on the result of factor analysis (low operational performance = 1, medium operational performance = 2, high operational performance = 3)
Long-term Cooperation (LC)	Does the family farm have long-term cooperation with other entities of the industrial chain? (Yes = 1, no = 2)
External Environment (EE)	The score of the family farm's external environment based on the result of factor analysis.
Operation Year (OY)	Logarithmic of the family farm's operation year.
Farm Size (FZ)	Logarithmic of the family farm's size.
The Square of Farm Size (FZ^2)	Square of Logarithmic of the family farm's size.
Number of Employees (NE)	Logarithmic of the family farm's number of employees.
Gender (Gen)	Gender of the family farmer. (Male = 1, female = 2)
Age (Age)	The age range of the family farmer. (16~18 = 1, 18~24 = 2, 26~30 = 3, 30~40 = 4, 40~50 = 5, 50~60 = 6, >60 = 7)
Educational Background (EB)	Education background of the family owner. (Primary school and below = 1, junior high school = 2, senior high school = 3, technical secondary school = 5, college = 5, Bachelor and above = 6)
The Degree of Long-term Cooperation (DLC)	*ln*(Total number of long-term cooperative content + 1) plus (The amount of Agri-product sold by long-term cooperation/The total amount of Agri-product)
Location	Family farm location. (The 6th division = 1, the 8th division/Shihezi = 2, the 10th division = 3, the 12th division = 4)

3.4. The OPM

In general, the subsequent empirical research of the article may apply the OLS Model to establish a linear relationship between LC and OP. The probit model may also be utilized, as it simply demands a 0–1 dummy variable to determine whether a family farm has superior operational performance. Then, evaluate the coefficient of LC and undertake appropriate follow-up study. Nevertheless, according to our field survey, the majority of family farms have a medium operational performance, whereas a tiny number of family farms have either a very low or a very high operational performance. The operational performance distribution map of family farms is a typical one. In this case, it is essential to

categorize the operational performance of family farms and discuss the marginal effects of variables in different groups. Through the OPM, the effect of long-term cooperation between the family farm and other entities in the industrial chain on the operational performance of the family farm, as well as the marginal effects of variables in different groups can be accurately estimated, which can be viewed as explicit guidance for family farmers deciding whether to engage in long-term cooperation and subsequently making targeted decisions. Considering that the operational performance of family farms may be heterogeneous in different regions, the regional dummy variable is set as the fixed effect to adjust the possible fixed effect at the district and county levels. Finally, the regression model is established as follows:

$$Y_i = F(\beta_1 x_1 + \Gamma_1 \Pi_i + \delta_c + \varepsilon_i) \quad (1)$$

$$Y_i = F(\gamma_1 x_1 + \gamma_2 x_2 + \gamma_3 x_1 x_2 + \Gamma_2 \Pi_i + \delta_c + \varepsilon_i) \quad (2)$$

$F(\cdot)$ is a nonlinear function. i is the i_{th} family farm. β_1, γ_1, γ_2, γ_3 are the regression coefficients. Γ_1 and Γ_2 are the matrix of regression coefficient. Y_i refers to the operational performance group that the family farm belonged in. x_1 indicates whether the family farm has long-term cooperation with other entities in the IC. x_2 is the external environment of family farms (EE). Π_i is the matrix of control variables. δ_c represents regional fixed effect and ε_i is the residual error. This paper uses Equation (1) to test H1 and Equation (2) to test H3. In addition, the heterogeneous analysis based on the degree of family farms' long-term cooperation with other industrial entities of Equation (1) are conducted to test H2.

4. Experimental Analysis

4.1. Result of Factor Analysis

Using Stata17.0 software for factor analysis, the results are shown in Table 4. The KMO values of the family farm's operational performance and external environment indicator systems are 0.634 and 0.634, respectively, and the sig values of Bartlett's sphericity test are both 0.000. This means the two indicator systems are suitable for factor analysis.

Table 4. The Results of Factor Analysis.

Family Farm's Operational Performance					
Factor Analysis			**Factor Rotation and Loaded**		
Eigenvalue	**Proportion**	**Accumulation**	**Eigenvalue**	**Proportion**	**Accumulation**
2.45483	0.3507	0.3507	2.32670	0.3324	0.3324
1.59347	0.2276	0.5783	1.66887	0.2384	0.5708
1.34826	0.1926	0.7709	1.40099	0.2001	0.7709
0.84432	0.1206	0.8916			
0.37874	0.0541	0.9457			
0.20743	0.0296	0.9753			
0.17295	0.0247	1.0000			
Family Farm's External Environment					
Factor Analysis			**Factor Rotation and Loaded**		
Eigenvalue	**Proportion**	**Accumulation**	**Eigenvalue**	**Proportion**	**Accumulation**
2.43939	0.3025	0.3025	2.43939	0.2710	0.2710
1.90249	0.2036	0.5061	1.90249	0.2114	0.4824
1.73030	0.1686	0.6747	1.73030	0.1923	0.6747
0.94304	0.1048	0.7795			
0.71092	0.0790	0.8585			
0.60314	0.0670	0.9255			
0.42006	0.0467	0.9722			
0.19293	0.0214	0.9936			
0.05772	0.0064	1.0000			

(1) In terms of family farm operational performance, three common factors with matrix eigenvalues greater than 1 were extracted, and the cumulative variance contribution rate reached 77.09%. Therefore, the indicators were summarized into three public factors involving economic performance, ecological performance, and social performance after using the orthogonal rotation method. Finally, the economic performance weight was 45.49%, the ecological performance weight was 29.52%, and the social performance weight was 24.98%.

(2) In terms of the family farm's external environment, the same method was used to summarize the indicators into three common factors: policy support environment, financial credit environment, and marketing environment. The cumulative variance contribution rate reached 67.47%, including a policy-supporting environment weight of 40.17%, financial credit environment weight of 28.50%, and marketing environment weight of 31.33%.

Finally, in order to test the robustness of the results of factor analysis, we further use Amos software to conduct confirmatory factor analysis. The structural convergence and differentiation validity of the two indicator systems meet the requirements.

4.2. Descriptive Statistics

The results of the descriptive statistical analysis are shown in Table 5.

(1) In terms of family farm's endowment, 66.49% of family farms have been operating for more than 10 years, with an average of 8.02 years. The average operating scale is 15.22 hm^2. The ratio of family farms having completed commercial registration is 9.06%. The average number of employees is 3.12.

(2) In terms of the endowment of family owner, 76.45% of family owners are male, 82.61% of them are 41~60 years old, while only 7.25% of them have college or undergraduate degrees.

(3) According to the degree of long-term cooperation between family farms and the industrial chain, the inter-group mean difference test was conducted. The mean values of variables in different groups were listed, respectively (list 3 for high-degree of long-term cooperation groups, list 4 for low-degree of long-term cooperation groups). Compared with the low-degree group, family farms in the high-degree group have better performance in the average values of OP, LC, FZ, and EB. Besides Gen, other variables all have significant intergroup differences at 95% and 99% confidence levels, which preliminarily confirms the necessity of conducting heterogenous analysis based on the degree of long-term cooperation between family farms and other entities in the industrial chain.

Table 5. Descriptive Statistics.

Var	Number	Std.	Mean 1	Mean 2	Mean Difference of Group
OP	539	1.727	2.230	1.451	t = −0.779 ***
LC	551	0.750	0.970	0.623	t = −0.347 ***
OY	533	1.781	1.900	1.568	χ^2 = 60.917 ***
FZ	552	5.208	5.348	5.079	χ^2 = 22.174 ***
FZ^2	551	27.502	28.087	27.163	χ^2 = 42.165 ***
NE	344	1.868	1.473	2.085	t = 0.611 ***
Gen	552	0.764	0.748	0.774	t = 0.027
Age	552	5.103	5.178	5.060	χ^2 = 28.569 ***
EB	552	2.742	3.026	2.485	χ^2 = 14.413 **
EE	508	0.0001	– –	– –	– – – –
DLC	551	1.3648	– –	– –	– – – –

Notes: ** statistically significant at the 0.05 level; *** statistically significant at the 0.01 level.

4.3. Results and Discussion of the Basic Model

Through Stata17.0, we use the variance inflation factor (VIF) to test the multicollinearity between variables. The maximum value of VIF is 2.14, which is far less than 10. Therefore, no multicollinearity problem exists in the variables. Table 6 shows the results of the basic

model based on the whole samples. The regional dummy variable is statistically significant at the 99% confidence level, indicating that there is a regional fixed effect at the district and county levels. Since this paper focuses on the individual-level variables of family farms, no further discussion on regional fixed effects will be conducted.

Table 6. Results of the Basic Model.

	Model 1	
Var	**Coef.**	**Std.**
LC	1.813 ***	0.191
OY	0.178 **	0.074
FZ	4.031 ***	1.350
FZ^2	−0.397 ***	0.110
NE	−0.062 *	0.034
Gen	0.719 ***	0.144
Age	−0.310 ***	0.064
EB	0.120 **	0.059
fe	Control	
LR chi2	258.30	
Prob > chi2	0.0000	
Pseudo R2	0.2512	
N	498	

Notes: * Statistically significant at the 0.1 level; ** statistically significant at the 0.05 level; *** statistically significant at the 0.01 level.

4.3.1. Discussion of Results of the Basic Model

The long-term cooperation between family farms and other entities in the industrial chain has a positive and significant impact on the operational performance of family farms at the 99% confidence level (Table 1). Based on the symbiosis theory, the long-term cooperation transforms the symbiotic mode between the symbiotic units from the existing point or intermittent symbiosis to continuous symbiosis. In this way, family farms and other entities can promote mutual complementation and thereby improve the family farm's operating performance.

Here are discussions of the result of control variables:

(1) The operating years are positively significant at the 99% confidence level: the operating years correspond to the ability of family farms to cope with natural and economic risks. The higher the operating years of family farms, the more positive the impact on their operational performance.

(2) The farm's size and the square of the farm's size are significantly positive and negative at the 99% confidence level, respectively, meaning there is an inverted U relationship between the family farm's scale and its operational performance. That is, small scale is conducive to intensive farming, management, and supervision costs, while it is not conducive to the use of modern agricultural technology and agricultural machinery to enhance their efficiency. Otherwise, it may exceed the family farmer's management ability and improve costs of management and supervision, finally increasing the risk of production and operation [34].

(3) The number of employees is significantly negative at the 90% confidence level. The possible reason is that the XPCC has provided relatively complete social services for family farms in the region through continuous reform. Based on this, excessive labor input is not conducive to the improvement of family farms' own operational performance.

(4) The gender of the family owner is positively significant at the 99% confidence level. It is generally believed that men are better than women in physical strength, are more innovative and adventurous, and women are responsible for most of the housework. The differences in biology and human capital investment lead to different family farm operational performance expression [34].

(5) The confidence level of the age group at 99% is significantly negative. Older farmers may be more conservative in consciousness, which is not conducive to the adoption of new management methods and production technologies and hinders the improvement of family farm management performance.

(6) The educational background is positive and significant at the 95% confidence level. The higher the education level of the family owner is, the higher the level of production, operation, and management will be, which will help them to flexibly cope with the production environment, absorb and apply new knowledge and technology, and make decisions that are more conducive to optimizing resource configuration [44].

4.3.2. Endogeneity Test

Based on the following considerations, this paper selects the propensity score matching (PSM) method to test the potential endogenous problems. First, whether to carry out long-term cooperation with other entities is mainly voluntary and decided by the family farm owners. Therefore, there may exist the problem of self-selection. Second, family farms with high operating performance show a relatively superior performance in endowments of the family farm and family farmer, which may cause selective bias in the process of measurement and inspection. Third, the economic benefits brought by high operating performance may also reverse the long-term cooperation between family farms and other entities in the industrial chain, causing endogenous problems. The PSM method can simplify the multi-dimensional information of family farms to a factor by constructing counterfactual assumptions. Through the PSM method, we conduct multi-dimensional matching for family farms that have long-term cooperation and do not have long-term cooperation with other entities in the industrial chain, so as to effectively solve the endogenous problem.

Through Stata17.0, we select the neighbor matching, which is used in previous studies. First, we test the common support domain hypothesis. The common support domain kernel density map (Figure 2) shows that there is a significant difference in the probability density distribution of the propensity scores before matching. After matching, the probability distribution of the propensity scores has gradually become consistent. There is a considerable range of overlap between the tendency regions, i.e., the result of the common support domain hypothesis is satisfactory. Secondly, we test the balance hypothesis. The balance test results (Table 7) show that the standard deviation of the pre-processing variables before and after matching of variables are less than 10%, except for OY. Moreover, all variables are no longer significant after matching. In conclusion, the original assumption that there is no systematic difference between the treatment group and the control group is approved. Further, the sample data does not have significant endogenous problems.

Table 7. Results of the Balance Test.

Var	Matching	Bias (%)	*t*-Value	*p*-Value
OP	Before	73.5	9.06	0.000
LC	After	13.7	1.14	0.254
OY	Before	−2.4	−0.25	0.806
FZ	After	−8.8	−0.68	0.495
FZ^2	Before	24.8	10.25	0.000
NE	After	9.4	0.93	0.525
Gen	Before	−59.5	−5.80	0.000
Age	After	8.0	0.98	0.328
EB	Before	−19.2	−2.05	0.041

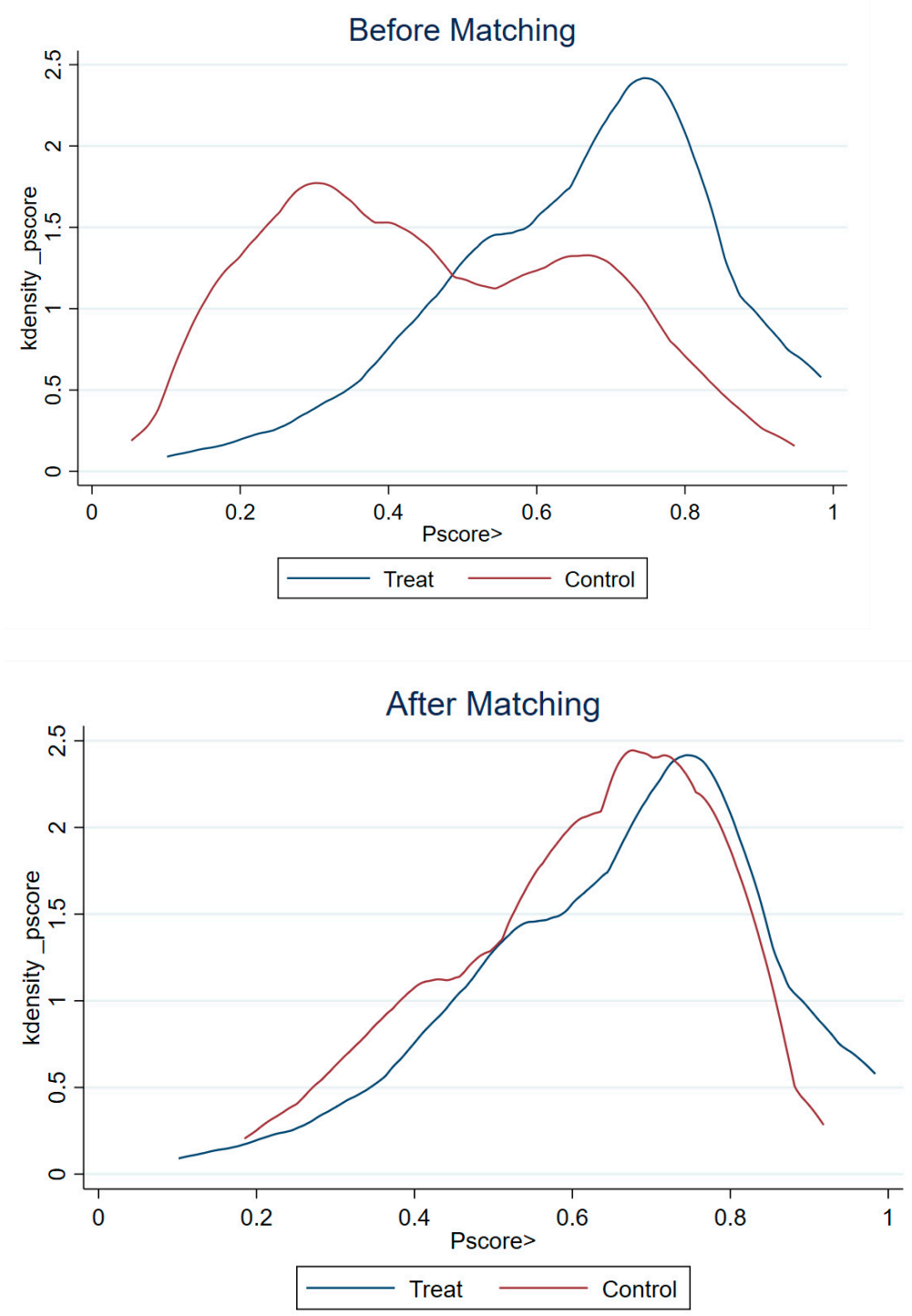

Figure 2. The Common Support Domain Kernel Density Map.

4.3.3. Test for Robustness

To investigate the robustness of the conclusion, this paper further uses Mahal matching, kernel matching, radius matching, and spline matching to analyze the average treated effect (ATT) of the long-term cooperation between family farms and other entities in the industrial chain on the operational performance of family farms. In order to enhance the accuracy of the analysis results, the self-service standard errors of more than 500 times of self-service sampling are used for the standard errors under each matching method. The results (Table 8) of different matching methods show similar results and trends. ATT is greater than 0 and at least significant at the 95% confidence level, i.e., the long-term

cooperation between family farms and other entities in the industrial chain has a significant positive impact on the family farms' operational performance, which is consistent with the previous results.

Table 8. Results of the PSM Method.

Method	Mean of Control Group	Mean of Treatment Group	ATT	SE.	*t*-Value
Neighbor Matching	1.890	1.225	0.665	0.103	7.14 ***
Mahal Matching	1.859	1.655	0.204	0.050	1.80 **
Kernel Matching	1.876	1.641	0.235	0.136	2.23 ***
Radius Matching	1.861	1.621	0.240	0.199	2.05 ***
Spline Matching	1.864	1.635	0.229	0.125	8.68 ***

Notes: ** statistically significant at the 0.05 level; *** statistically significant at the 0.01 level.

4.4. Results and Discussion of Heterogeneous Analysis

Compared with the low-degree group (Table 9, Model 2), in the high-degree group long-term cooperation has a stronger positive impact on family farms' operational performance (1.125 > 1.095). H2 has been proven. Based on the symbiosis theory, a high degree of long-term cooperation can enhance the joint dependence and correlation between symbiotic units, make the levels of symbiotic units' investment and profit to be symmetrical, and finally form an ideal continuous symmetrical mutualistic symbiotic model.

Table 9. Results of Heterogeneous Analysis and Moderating Analysis.

	Model 2		Model 3		Model 4	
	Coef.	SE	Coef.	SE	Coef.	SE
LC	1.095 **	0.263	1.125 ***	0.549	2.286 ***	0.252
EE					0.249 ***	0.181
LC × EE					1.510 ***	0.445
Controls	Control		Control		Control	
fe	Control		Control		Control	
LR chi2	170.10		71.51		107.16	
Prob > chi2	0.0000		0.0000		0.0000	
Pseudo R2	0.2970		0.2150		0.3657	
Number	327		171		454	

Notes: ** statistically significant at the 0.05 level; *** statistically significant at the 0.01 level.

Further marginal effect analysis of core variables is carried out. The results (Table 10) show that, compared with the low-level group, the positive marginal effects of long-term cooperation on family farms with different performance increases by 93.44%, 54.91%, and 86.87%, respectively. Although the ranges of increase are different, the positive marginal effect of long-term cooperation shows an increasing trend.

Table 10. Marginal Effect of LC.

	Low-Degree of Long-Term Cooperation Group			High-Degree of Long-Term Cooperation Group		
	Low OP	Medium OP	High OP	Low OP	Medium OP	High OP
LC	0.0717	0.1080	0.1637	0.1387	0.1673	0.3059

4.5. Results and Discussion of Moderating Analysis

Hypothesis 3 focuses on the moderating role of the external environment. Therefore, the core variable of Model 4 (Table 9) is the interactive term of LC and EE. This interactive term is positively significant at the 95% confidence level, i.e., the better the family farm's external environment, the higher the positive impact of the long-term cooperation. H3 has been proven. Based on the symbiosis theory, optimizing the operational environment

of a family farm can improve the symbiotic environment within its symbiotic system. Its positive external functions make the symbiotic medium exchange between symbiotic units more smooth and efficient. Thus, it finally stimulates the positive impact of long-term cooperation between symbiotic units on the operational performance of family farms.

5. Conclusions, Suggestions, and Future Research

5.1. Conclusions

Using the data of family farms in the XPCC, this paper discusses the impact of long-term cooperation between family farms and other entities in the industrial chain on the operational performance of family farms based on symbiosis theory. We further analyze the heterogeneous impact caused by the degree of long-term cooperation and the moderating role of the external environment. The following conclusions are drawn from the research.

(1) The long-term cooperation between family farms and other entities in the industrial chain has a significant positive impact on the operational performance of family farms.

(2) The degree of long-term cooperation can cause heterogeneous results of the positive effect of the family farm's long-term cooperation. The higher the degree of cooperation, the stronger the positive impact.

(3) The external environment plays a positive role in moderating the impact of the long-term cooperation of family farms and other entities in the industrial chain on the operational performance of family farms. A better operational environment can more effectively stimulate the positive impact of long-term cooperation.

5.2. Suggestions

(1) Promote the long-term cooperation between the symbiotic units of the family farm industrial chain and accelerate the formation of a continuous symbiotic model. Encourage the family farm to carry out long-term cooperation with other entities of the industrial chain. Meanwhile, deepen the participation of the family farm in the operation and management of the industrial chain, which can effectively resolve the crisis of the family farm being marginalized, and improve the stability and operating efficiency of the family farm industrial chain. Drive diversified operational entities to realize horizontal interaction and industrial chain expansion through cooperation, forming a benign interaction of both scope economy and scale economy.

(2) Improve the degree of long-term cooperation between symbiotic units of the family farm industrial chain, and drive the transformation of its symbiotic model into a symmetrical and mutually beneficial symbiosis. In response to the needs of the family farm, guide multiple entities to provide differentiated and complementary services in accordance with the principle of comparative advantage to build an efficient service system. Simultaneously, mining various resources such as agricultural machinery promotion departments, agricultural colleges, and universities to complement the short board of pre-production and post-production services. With land, capital, technology, and other elements as the link, establish a close interest connection mechanism of revenue sharing and risk sharing.

(3) Optimize the symbiotic environment of the family farm industrial chain: First, increase policy support and roll out unique programs to aid family farms. Carry out eco-friendly pest prevention and management and implement marketing of agricultural products that includes certification for geographical indication, organic, green, and pollution-free products. Support e-commerce development and brand promotion for agricultural products in the interim. Second, create non-profit platforms for internet sales marketing, legal assistance, agricultural insurance, and technical assistance in agriculture. Support family farms' fair demands for agricultural technologies and assistance. Third, enhance pertinent financial institutions, reduce interest rates and loan requirements, and offer family farms legitimate and fair financial support and subsidies to aid in their development.

5.3. Future Research

Given the special characteristics of the family farms in the XPCC, there are inevitable limitations to our research. Due to the relatively low level of digital economy development, family farms in developed countries may not be fully suitable for our operational farm evaluation indicator system. Additionally, it is quite consistent with the symbiosis idea due to their unified mode of production and operation.

According to the limitations above, future research can be concentrated in the following areas.

(1) The application of digital economy to the industrial chain of family farms is very important in the future. Some new indicators, such as e-commerce, can be incorporated in to the system for evaluating the operational performance of family farms, which can obtain more scientific and precise evaluation results.

(2) The diverse symbiotic systems of the family farm industrial chain in consideration of the production and operation features of family farms in various locations, can be further discussed.

(3) More targeted policies based on the regional economy, market, and the symbiotic system of the family farm industrial chain will be studied in the future.

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