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The Analysis of Family Farm Efficiency and Its Influencing Factors: Evidence from Rural China

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Abstract: Improving the efficiency of family farms is of great significance to rural revitalization and agricultural modernization in China. In order to find out the development status and shortcomings of family farms in China, and put forward targeted policy recommendations to improve the efficiency of various family farms, this paper applies the DEA model to measure the efficiency of family farms from a micro perspective by using the field survey data of the national family farm demonstration bases of Wuhan and Langxi, China. In addition, the Tobit model is further applied to explore the factors that affect the efficiency of full sample family farms, as well as to compare and analyze the differences in the efficiency in different regions and of different operation types. The results show that the efficiency of family farms is low, the efficiency of family farms in Wuhan is higher than that in Langxi, and the efficiency of breeding family farms is higher than that of planting family farms and mixed family farms. Capital input, farmers' education level, market channels, brand registration, fertilizer usage and financial credit have positively affected the efficiency of family farms, while government subsidies and natural disasters have had negative effects on it. Specially, the land operating area shows a U-shaped relationship with farm efficiency. The efficiency of planting family farms is positively affected by labor input, while that of breeding and mixed family farms rely more on capital input and financial credit instead.

Keywords: family farm; efficiency; DEA model; Tobit model; farm operation; influencing factors

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1. Introduction

The traditional production of small farmers in rural China has led to low agricultural production efficiency. In order to improve the efficiency of agricultural production, boost rural economy and achieve agricultural modernization in China, the Chinese government has been attaching great importance to encouraging the development of new agricultural operating entities, such as family farms. The Ministry of Agriculture issued the "Guiding Opinions on Promoting the Development of Family Farms" document in 2014, stating that the family farm mode is conducive to form moderate scale operations, which has played an important role in developing modern agriculture; therefore, it is of great importance to develop family farms in China. Subsequently, the No. 1 Central Documents, from 2015 to 2017, stipulated a series of measures to support the development of new agricultural operating entities, which created a nice social environment for the founding and developing of family farms. In 2019, the General Office of the State Council issued the "Opinions on Promoting the Organic Connection of Small Farmers and Modern Agriculture Development", which clearly proposed and clarified a family farm cultivation plan. The "High-Quality Development Plan for New Types of Agricultural Entities and Service Entities (2020–2022)", compiled by the Ministry of Agriculture and Rural Affairs in 2020, set the goal that the number of family farms in China will reach 1 million by 2022.

Under the guidance and support of government policies, the family farms in China have gained initial achievements, the number of which has been increasing every year.

According to data from the Ministry of Agriculture and Rural Affairs of China, the number of family farms in China over quadrupled from about 139,000 in 2014 to 600,000 in 2018. However, although the number of family farms increased by 461,000 households, the growth rate declined year by year after 2015. The chain growth rate of family farms was initially 146.8% in 2015, followed by 29.7% in 2016, further decreased to 23.4% in 2017, and eventually fell to 9.29% in 2018. Another characteristic that should not be ignored is that most family farms in China are in a single type of planting or breeding operation. Among all family farms existing in any year between 2014–2018, the planting family farms account for the largest proportion, followed by breeding family farms. For example, in 2018, the planting, breeding, fishery, planting and breeding, and other types of family farms accounted for 62.7%, 17.8%, 5.3%, 11.6% and 2.6%, respectively, and similar distributions can be observed in other years.

Although we have witnessed an initial development of family farms in China, we have to admit that the total number of family farms is still minor. According to the data of the third agricultural census for China, the number of family farms only accounts for 0.2% of China's agricultural total households. In comparison to the traditional Chinese small farms, family farms have the characteristics of family-based production unit and scale operation [1], and they have been proved to be the most efficient mode in current agricultural production [2,3]. Therefore, it is of great significance to figure out how to improve the efficiency of family farms so as to maximize their functions in driving agricultural economic development. In order to promote the development of family farms, we have to answer the following questions: what is the actual operating efficiency of family farms in China? What are the factors that affect the efficiency of family farms? What are the differences in the efficiency and the influencing factors of family farms in different regions and different operation types?

1.1. Literature Review and Research Hypothesis

1.1.1. Family Farm Efficiency

Scholars have conducted a great amount of research on the efficiency of family farms. Many scholars confirmed that, through empirical analysis, the efficiency of family farms in China is not high [4–7], and the conclusions drawn from the decomposition of pure technical efficiency and scale efficiency varies. Qian and Li [4] conducted a DEA measurement and analysis of the efficiency of different types of family farms in Songjiang, Shanghai; they found that the efficiency of family farms is not high at 0.3841, and planting-and-breeding family farms have the highest efficiency compared to pure-grain-planting family farms and machine-farming family farms. Han et al. [5] argued that there are many DEA ineffectiveness units in 62 households of fruit-and-vegetable family farms in Zhejiang Province, and the average pure technical efficiency is greater than their scale efficiency. Li et al. [6] calculated that the technical efficiency of 234 family farms in Shandong Province was only 0.170, and the low value was attributed to the relatively insufficient pure technical efficiency rather than scale efficiency. The planting-and-breeding family farms had the highest efficiency, while pure-planting family farms were the least efficient. The research of Gao et al. [8] proved that the technical efficiency of family farms depends more on scale efficiency, while the pure technical efficiency is low.

Hypothesis 1 (H1). *The efficiency of family farms in China is low.*

1.1.2. Factors Affecting the Efficiency of Family Farms

Regarding the factors that affect the efficiency of family farms, various scholars have asserted that agricultural factor inputs, farmers' characteristics, family farm operation characteristics and external factors may all affect the efficiency of family farms. Agricultural factor inputs refer to those basic elements that must be put into agriculture production to produce agricultural products, such as land, labor and capital. Farmers' characteristics are the farmers' personal characteristics, for example, the farmer's age, education level, training skills and farming experience. Family farm operation characteristics include family farm internal operating situations, for example, the regulations, market channels, technology adoption and brand registration. External factors refer to those environmental factors, such as the policy, credit support and disasters.

Zhang and Liu [9] believed that problems, such as over-scale, lack of labor, high production costs and single operating structure, lead to the lack of family farm efficiency. In Bangladesh, Peru and Thailand, farm scale and agricultural productivity are positively correlated [10]. However, some scholars concluded that the land operation area of family farms being overlarge can reduce their efficiencies [11,12], while others found that there seems to be an inverted U-shaped relationship between family farm efficiency and its land scale [4,13]. The inverted U-shaped relationship implies that the relationship between the land scale and the efficiency of family farms is not linearly correlated, either positively or negatively. With the expansion of land scale, the efficiency of family farms first increased because the full utilization of machines could create economics of scale, and then decreased after an optimal scale, forming an inverted U-shape. The education and skill level of the farmers [14–16], investment scale, agricultural machinery subsidies and agricultural insurance positively affect the operating efficiency of family farms, while the number of laborers, the cost of land transfer, agricultural machinery and credit funds show a negative correlation with it [8]. Kong and Zheng [17] asserted that agricultural subsidies can bring stable income expectations to farmers, thus positively affecting the efficiency of family farms, in contrast to researches by Zhu and Lansink [18] and Chen [19], which pointed out that agricultural subsidies would cause efficiency lost. It is also concluded that a fair external information environment and a perfect credit system [20] can promote the development of family farms, and the improvement of family farm efficiency requires external support from credit funds [21].

Hypothesis 2 (H2). *Factors that influence the efficiency of family farms vary by types and regions.*

In summary, most of the research objects in existing literatures are family farms in a certain area or of a certain type; comparative researches on family farms in different regions and of different operating types still need to be supplemented. Furthermore, most articles about the measurement and analysis of family farm efficiency focus on the comprehensive technical efficiency, which seldom decompose it and analyze its influencing factors. Based on the analysis of the literature reviews and their limitations, this paper uses the field survey data of two family farm demonstration bases in China as the research sample, and divides them into three categories, pure planting, pure breeding and mixed family farms, according to the type of operation, so that the family farms in different regions and of different operation types can be compared. In addition, this paper measures and decomposes the efficiency of family farms and analyzes its influencing factors. Through comparisons and analysis, this paper aims to find out the shortcomings of family farms in different regions and types, and put forward targeted policy recommendations to promote the efficiency of various family farms.

1.2. Contributions and Limitations

The contributions of this paper are as follows:

1. We conducted a field investigation of all family farms registered in Hubei Wuhan and Anhui Langxi family farm demonstration bases, and obtained full samples of those family farms in 2016 as our research samples, which not only reflects the actual operating situation of family farms in two areas, but also avoids information loss and bias that may exist in sampling surveys.
2. Unlike many papers that only use single dimensional economic indicators, such as the income or profit of family farms to evaluate the development situation of family farms, we measured the efficiency of family farms through a DEA model, the result of which reflects family farms' operating status more accurately and comprehensively,

for it covers as many input and output variables as possible that actually occurred in their agricultural production and operation in 2016.

3. In our paper, we not only analyze the possible influencing factors on full sample family farms' efficiency, but also compare the effect differences on family farms in different regions and of different operation types, which would be very helpful to promote the development of various family farms by applying targeted policies.

However, we admit that this paper has the following limitations:

1. We use a cross-sectional field survey data from 2016, which can only present the development status of family farms at that time, but cannot reflect the dynamic changes of family farms, especially after the COVID-19 pandemic, whereby the development situation of the local family farms may have changed.
2. There are a total of five family farm demonstration bases in China, namely, Shanghai Songjiang, Zhejiang Ningbo, Hubei Wuhan, Jilin Yanbian, and Anhui Langxi, but we only conduct a field investigation of two of them, which fails to compare all family farms in China more comprehensively.

2. Research Sample and Methods

2.1. Research Data

In order to guide the orderly development of local family farms, the Ministry of Agriculture summarized five development modes—Shanghai Songjiang, Zhejiang Ningbo, Hubei Wuhan, Jilin Yanbian, and Anhui Langxi—as typical modes for promotion, among which, the "Hubei Wuhan mode" is the typical example of suburban agriculture serving urban development under the background of the cities' industrialization and urbanization, and the "Anhui Langxi mode" is the representative of agricultural scale transformation in underdeveloped areas after the outflow of laborers, so that they have strong representation across China [22].

The emergence and development of family farms in Hubei Wuhan is closely related to the development of the agricultural product market. As a mega city, Wuhan has had a great and stable demand for agricultural products, resulting in the rise in suburban agriculture. Since the 1990s, under the context of Wuhan's accelerated industrialization and urbanization, some suburban farmers in Wuhan abandoned their farmland and intended to seek well-paid jobs in the urban city. Other farmers took the opportunity to rent contracted land from those farmers who had abandoned farmland, and engaged in vegetable planting and aquaculture; thus, a group of large professional planting and breeding households gradually formed, which is also the prototype of family farms. On the basis of the farms' self-development in the suburbs of Wuhan, the government became involved in time to promote the standardization of the land transfer market. In 2009, the Wuhan government launched a pilot project of developing family farms, and five municipal-level family farms were established. After that, a series of policies were introduced to support the development of family farms, contributing to the formation of the mature Hubei Wuhan family farm development mode. The biggest feature of the Hubei Wuhan mode is that the operating scope of family farms is in line with the needs of urban residents, including vegetables, aquatic products, melons and fruits, livestock and poultry, and other agricultural products, and there is a trend of diversification as people's consumption increases.

The generation of family farms in Anhui Langxi is closely related to industrialization and urbanization. In the early 1990s, with the accelerated development of some industrial cities in the Yangtze River Delta, a growing number of farmers in Langxi chose to work in these cities, leaving their farm land abandoned or for their relatives and friends for farming. In 2001, a farmer in Langxi took the opportunity to rent in more than 100 mu (Mu, a unit of area in China $\approx$ 0.1647 acre) of abandoned farmland, and established the first family farm in Langxi: "Lvfeng Family Farm". By engaging in the large-scale planting of rice and wheat, "Lvfeng Family Farm" obtained a higher income than traditional farmers, which played an exemplary role for other farmers, and many other farmers started to follow. The Langxi government also played an important role in the development of family farms; it not only actively guided farmers to transfer their farmland, but also arranged for the availability of special support funds worth CNY 10 million for the development of family farms in the annual budget, and evaluated 15–20 model family farms every year for awards or subsidies. The Family Farm Association is another important driving force for family farms in Langxi. In 2009, some family farms in Langxi with strong representation and obvious radiating effects established the "Langxi Family Farm Association", which is the first family farm association in China, and it has contributed to serving the local family farms as a nongovernmental organization, for example, to coordinate bank loans and organize farmer training. As Langxi is at a distance from big cities, limited by the market capacity and preservation ability, it is unlikely for family farms in Langxi to produce vegetables, aquatic products and other agricultural products with higher economic value on a large scale, so that the most significant feature of the family farms in Langxi is that they maintain the operating pattern dominated by crops.

From July to August 2017, we conducted an on-site investigation of the development situation of all the registered family farms in Wuhan City, Hubei Province, and Langxi County, Anhui Province by using the same set of questionnaires and obtained samples in 2016. The investigation method was face-to-face interviews, and every question was asked by the investigator and answered by the farmer. Then, every answer was recorded by the investigator and immediately confirmed by the farmer, which guaranteed the authenticity and accuracy of the data. The data covered the basic characteristics of the family farms and farmers, land circulation and utilization, fixed assets and investments, farm industry and scale, employment, production and sales, income and expenditure, agricultural technology application, farm operation and management, natural and market risks, agricultural cooperatives and financial support, and a total of 629 questionnaires were distributed. After deleting the questionable questionnaires, such as those that were missing or inconsistent, 584 final samples were obtained and divided by region: 273 in Wuhan and 311 in Langxi. In terms of the operating type, among the final samples, there were 294 for planting family farms, 127 for breeding family farms, and 163 for mixed family farms (the fishery family farms only account for a very small proportion of the total sample and are thus included in the category of breeding (as aquaculture) family farms in this paper). Planting family farms are the family farms that only operate and obtain income from the planting industry, for example, they grow grains, such as rice, wheat, vegetables and fruits. Breeding family farms refer to the family farms that only operate and obtain an income from the breeding industry, for example, they raise livestock, poultry and aquatic products. Mixed family farms are family farms that operate both planting and breeding industries and gain an income from them.

2.2. Empirical Model Setting

2.2.1. DEA Model

Efficiency usually refers to the relative value of the input and output in production activities. Therefore, the efficiency of family farms can be regarded as the maximum output ratio that can be achieved under certain input constraints [23]. The DEA (Data Envelopment Analysis) method is a common performance evaluation tool in the field of decision analysis. By comparing the distance between the decision-making unit and its production frontier, the production efficiency of the multi-input and multi-output decision-making unit is calculated [24]. If the observation value of the decision-making unit is on the production frontier, the efficiency value of the decision-making unit is the optimal value of 1. If the efficiency value is less than 1, it means that the decision-making unit is inefficient, and the gap between 1 and its efficiency value reflects the inefficiency degree of the decision unit. In this paper, A DEA model that considers multiple inputs and multiple outputs was applied to measure and decompose the operating efficiency of all family farms, as well as to compare the efficiency of family farms in different regions and of different types.

The traditional DEA mainly includes two models: the CCR model and BCC model. Among them, the CCR model was initially proposed by Charnes et al. [24] to obtain the technical efficiency value of the decision-making unit under the premise of constant return to scale by calculating multiple input and output variables, while the BCC model was put forward by Banker et al. [25]. Under the condition of variable returns to scale, it can not only obtain technical efficiency, but can also decompose the technical efficiency (TE) into pure technical efficiency (PTE) and scale efficiency (SE). Considering that family farms are only able to control and adjust the amount of input rather than the output during the production process, and they follow the premise of variable scale, this paper chose the input-oriented DEA-BCC model [26] as follows:

Suppose there are n decision-making units $DMU_j(j = 1, 2, 3 \cdots n)$, m input indicators, and s output indicators. Assume X_{ij} represents the i-th input of the j-th decision-making unit, Y_{rj} represents the r-th output of the j-th decision-making unit $(1 \leq i \leq m, 1 \leq r \leq s)$, S^- is the surplus variable, and S^+ is the insufficient variable. The CCR model is:

$$\begin{cases} \min\theta \\ s.t \sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta x_{i0} \\ \sum_{j=1}^{n} \lambda_j y_{rj} - s_i^+ = y_{i0} \\ \lambda_j \geq 0, (j = 1, 2, \cdots, n) \\ s_i^- \geq 0, s_i^+ \geq 0 \end{cases} \quad (\theta\ unconstrained) \tag{1}$$

The BCC model considers that the return to scale of the decision-making unit is variable, so it is modified on the basis of the CCR model and shown as follows:

$$\begin{cases} \min\theta \\ s.t \sum_{j=1}^{n} \lambda_j X_j + S^- = \theta X_0 \\ \sum_{j=1}^{n} \lambda_j Y_j - S^+ = Y_0 \\ \sum_{j=1}^{n} \lambda_i = 1 \\ \lambda_j \geq 0, (j = 1, 2, \cdots, n) \\ S^+ \geq 0, S^- \geq 0 \end{cases} \quad (\theta\ unconstrained) \tag{2}$$

2.2.2. Tobit Model

Considering that the family farm efficiency values that were calculated by the DEA model range from 0 to 1, which are censored data, the Tobit model with limited dependent variables should be applied for regression. Furthermore, in order to reduce the impact of heteroscedasticity, some agricultural factor input variables with large values are taken to logarithms [27], and a semi-logarithmic model is set as follows:

$$Y_i = \alpha + \sum \beta_1 \ln(X_i) + \sum \beta_2 Z_i + \varepsilon_i \tag{3}$$

In the formula (3), Y_i is the efficiency of the i-th family farm, X_i are the variables affecting the efficiency of the family farm that need to take logarithm, Z_i stands for other factors that affect the efficiency of the family farm, β is the coefficient to be estimated, ε_i is the random error term, and the subscript i represents every individual family farm.

2.3. Variables Selection

2.3.1. DEA Variables

Referring to the method of Qian and Li [4], and considering the actual situation of family farms in Wuhan and Langxi, from the perspective of considering the land, labor, and capital, this paper selected land input, labor input, and capital input as the input variables, and selected family farm operating income, which includes plantation income, livestock income, agricultural service income, and government subsidies, as the output indicators.

The land input refers to the actual land area operated by the family farm, including the area of self-owned land and circulation land. The question in the questionnaire is: "How much is the total area of the land operated by the family farm in 2016?", and the actual area filled in by the farmer is the land input indicator. The labor input refers to the total number of household laborers and hired laborers in the family farm's production activities, which is calculated according to the number of household laborers and the number of long-term employees of the family farms in 2016. The capital input refers to the operating expenditures of the family farm in 2016, including the expenditures on fertilizers, agricultural (livestock) medicines, seedlings, feeds, vaccines; expenditures on water, electricity, oil, gas, and coal; small mechanical tools, equipment and infrastructure maintenance expenses; specialized agricultural services expenditures; interest, housing rent, transportation and other productive expenses.

The family farm output indicator is measured by the operating income of the family farm, including the income from planting-and-breeding industries, agricultural service income and government subsidies. The descriptive statistics of the input and output indicators of the family farm are shown in Table 1.

Table 1. Descriptive statistics of the input and output indicators of family farms.

Variable Type	Variable Name	Unit	All Family Farm		Planting Family Farm		Breeding Family Farm		Mixed Family Farm	
			Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.
Land Input	Land operating area	Hectare	20.85	26.84	21.10	23.38	15.35	26.59	24.71	31.89
Labor Input	Household Laborer	Person	2.59	1.12	2.49	1.10	2.68	1.17	2.69	1.09
	Hired Laborer	Person	2.54	5.07	2.64	6.14	2.09	3.21	2.73	4.03
Capital Input	Expenditures on fertilizers, agricultural (livestock) medicines, seedlings, feeds, vaccines	CNY 10,000 (the average exchange rate of USD/CNY in 2016 was 1 USD = 6.6423 CNY)	43.63	157.15	17.17	33.46	77.18	108.71	65.19	273.93
	Expenditures on water, electricity, oil, gas, and coal	CNY 10,000	2.40	4.59	1.78	2.68	3.21	5.57	2.91	6.09
	Small mechanical tools, equipment and infrastructure maintenance expenses	CNY 10,000	1.38	4.86	0.88	2.62	2.09	8.47	1.72	3.97
	Specialized agricultural services expenditures	CNY 10,000	1.07	4.74	1.37	6.04	0.45	1.48	1.01	3.54
	Interest, housing rent, transportation and other productive expenses	CNY 10,000	3.15	9.02	2.55	7.20	3.98	10.02	3.57	10.93
Output	Planting industry income	CNY 10,000	55.78	136.93	74.85	111.24	-	-	64.85	204.73
	Breeding industry income	CNY 10,000	57.02	222.80	-	-	127.88	166.52	104.66	380.73
	Agricultural service income	CNY 10,000	0.35	1.90	0.32	1.45	0.33	2.46	0.43	2.12
	Government subsidies	CNY 10,000	1.89	6.18	1.33	4.03	1.12	5.55	3.50	8.98
	Total income	CNY 10,000	115.04	314.02	76.49	112.19	129.34	167.60	173.44	551.34

As shown in Table 1, the average land operating area of all family farms is 20.85 hectares, indicating that the scale operation among family farms has been initially achieved. The average land area operated by mixed-type family farms is 24.71 hectares, higher than that of all the family farms, while the average land area operated by breeding family farms is 15.35 hectares, lower than that of all the family farms. Meanwhile, the standard deviation of the land operating area for all types of family farms is relatively large, indicating that the land area operated by family farms varies. From the perspective of considering the labor input, the number of household laborers is similar to that of hired laborers, which is 2.59 and 2.54 people, respectively. The labor input of all types of family farms is similar, and the average of the household laborers and employed laborers for mixed family farms is slightly higher than that of the other types. From the perspective of considering the capital input, the average input of breeding and mixed family farms in most aspects is higher than that of all family farms, except in the expenditures for specialized agricultural services, in contrast to the input of planting family farms. As for the total income, the average income of all family farms is CNY 1.1504 million, and the income for the planting industry is similar to that for the breeding industry (CNY 557.8 thousand and CNY 570.2 thousand, respectively). Relatively speaking, mixed family farms have the highest income, followed by breeding family farms, and planting family farms receive the lowest income.

2.3.2. Tobit Variables

Table 2 shows the Tobit regression variables and their descriptive statistics. The variables include four aspects:

1. Agricultural input variables. Agricultural input variables include family farms' land input, labor input and capital input. Since the combination of different agricultural factors may lead to different efficiencies [28], the impact direction of agricultural factors is uncertain. Some scholars agree with the principle of optimal scale operation of land area, that is, as the scale of the family farms expands, the production materials, such as mechanized equipment, can be fully utilized, so that the production cost of the unit agricultural products can be reduced, and the scale benefits can be increased. However, when the scale of operation is too large, it leads to an increase in the management and production costs; when the marginal cost is greater than the marginal benefit, the benefit of scale diminishes. Therefore, there may be an inverted U relationship between the land operating area and the efficiency of the family farms [27,29]. However, there are also numerous studies showing that, in low-income developing countries, the agricultural productivity of farms has a U-curve relationship with the farm size, that is, productivity decreases as the farm size increases from its smallest unit, and then rises as the farm size increases after a threshold [30–32]. Therefore, the direction between the land input and the efficiency of family farms is uncertain. As China is a developing country, the present study assumes that they may present a U relationship. Generally speaking, if the family farm has a sufficient labor force and capital funds, it can have a better start-up condition and stronger operating ability. Therefore, it is expected that the labor input and capital input will positively affect the efficiency of the family farms.
2. Farmers' characteristic variables. The characteristic variables of farmers include gender, age, education level, and years of farming. Some scholars believe that the older the farmer is, the more experienced he or she is, which is helpful to improve the efficiency of family farms [33]. However, some scholars pointed out that older farmers usually have poorer health conditions, and are unlikely to accept new things, so they may not be able to undertake the task of family farms [34]. Therefore, the impact of family farmers' age on family farm efficiency is uncertain. From a gender perspective, men are usually physically more powerful than women, and they tend to be more aggressive and adventurous, while women may be better at detail management [35], so gender has an uncertain effect on the efficiency of family farms. The higher the education level of the farmer, the easier it is for him or her to master new knowledge, as well as apply new technology [15]. Therefore, the education level of the farmer is expected to have a positive impact on the efficiency of the family farm. Since the farmer who has longer farming years usually has a richer experience in agricultural production, it is inferred that the farmer's farming years are positively correlated with the efficiency of the family farm.
3. The family farm characteristic variables. Family farm characteristic variables mainly include the family farm's regulations, market channels, the brand trademark registration, the new technology adoption, and the use of fertilizer. Family farms that have good regulations have better internal management mechanisms, so it is expected that the family farms with perfect regulations have higher efficiency. Smooth market channels enable family farms to sell more products and obtain more profits, hence market channels are expected to have a positive impact on the efficiency of family farms. Registering a brand trademark helps to publicize the popularity and reputation of agricultural products to expand the market for family farms. Therefore, it is expected that the brand trademark registration is positively correlated with the efficiency of

family farms. Similarly, using new agricultural technologies can not only improve the productivity of family farms [36], but also increase the intellectual content of agricultural products and their derivatives, thus it is expected to positively influence family farm efficiency. Additionally, as the use of fertilizers is conducive to cultivating land fertility and increasing yields; it is projected to have a positive impact on the efficiency of family farms.

4. Environmental factors. The environmental factors mainly include government subsidies, financial credit, and natural disasters. Government subsidies may encourage family farms to invest in production, but they may also enable farmers to form the idea of "getting something for nothing" and reduce their production enthusiasm [13]. Therefore, the impact of government subsidies on family farm efficiency is uncertain. Financial credit is conducive to the production expansion of family farms, thus it is expected to be positively correlated with the performance of the family farm. Family farms that suffer from natural disasters face the plights of reduced or no harvest, so it is predicted that natural disasters negatively affect the performance of family farms.

Table 2. Tobit regression variables and descriptive statistics.

Variable Types	Variable Names	Variable Definitions	Total Samples		Wuhan		Langxi		Expected Direction
			Mean	Std.	Mean	Std.	Mean	Std.	
Agricultural Input Variables	Land input (land)	Land operating scale (hectares)	20.85	26.85	19.21	20.48	22.30	31.36	+/−
	Labor input (labor)	Number of laborers (people)	5.13	5.23	6.42	6.77	3.99	2.91	+
	Capital input (cap)	CNY 10,000	51.63	166.56	59.32	217.20	44.87	103.36	+
Farmers' Characteristic Variables	Gender (gender)	Female = 0, male = 1	0.89	0.31	0.85	0.35	0.93	0.26	+/−
	Age (age)	Years	46.48	7.51	46.38	8.03	46.57	7.03	+/−
	Education level (edu)	Never went to school = 1, primary school = 2, junior high school = 3, high school, secondary vocational and technical college = 4, junior college, higher vocational and technical college = 5, undergraduate and above = 6	3.45	0.96	3.86	0.81	3.08	0.93	+
	Years of farming (exp)	Years	20.70	11.69	20.17	11.32	21.16	11.99	+
Family Farm Characteristic Variables	Regulations (regu)	None = 1, yes but not standard = 2, yes = 3	1.95	0.88	1.97	0.87	1.93	0.89	+
	Market channels (market)	None = 0, yes = 1	0.64	0.48	0.64	0.48	0.65	0.48	+
	Brand (brand)	None = 1, registering = 2, yes = 3	1.38	0.74	1.32	0.69	1.43	0.78	+
	New technology (tec)	No = 0, Yes = 1	0.72	0.45	0.70	0.46	0.74	0.44	+
	Fertilizer (fer)	Never use = 1, use occasionally = 2, use often = 3	2.09	0.86	2.36	0.81	1.86	0.84	+
Environmental Factors	Government subsidies (aid)	No = 0, yes = 1	0.17	0.37	0.14	0.35	0.19	0.39	+/−
	Financial credit (credit)	Amount of credit funds obtained from financial institutions (CNY 10,000)	24.46	56.06	24.68	71.72	24.27	37.38	+
	Suffer from natural disasters (dis)	No = 0, yes = 1	0.89	0.31	0.89	0.31	0.89	0.31	−

Note: the total sample size is 584, 273 from the Wuhan area, and 311 from the Langxi area.

3. Results and Analysis

3.1. Efficiency Measurement of Family Farms: Based on the DEA Model

Table 3 presents the results of the variance inflation factor (VIF) of the input indicators and the results of the Pearson test on the input and output indicators. The results show that the VIF values of the input indicators are all less than 10, indicating no multicollinearity, and the Pearson correlation coefficients of the input and output indicators are significantly positive at the level of over 5%, indicating that the land input, labor input and capital input are all positively correlated with the output indicator, with the significant coefficients at 0.9078, 1.9938 and 1.6773, respectively. Therefore, the input and output indicators selected for this study satisfy the assumption of the same direction, so that the DEA model can be used for the analysis.

Table 3. Multicollinearity and Pearson test results.

Input Indicator	VIF	Pearson
Land input	1.10	0.9078 ***
Labor input	1.09	1.9938 **
Capital input	1.06	1.6773 ***

Note: ***, ** are their significance at the levels of 1% and 5%, respectively.

Table 4 shows the results of the efficiency value of the family farms. The average value of the technical efficiency (TE) of all the family farms is low (0.3058), verifying that H1 is true. From the decomposition of the technical efficiency (TE) into pure technical efficiency (PTE) and scale efficiency (SE), it is shown that the average value of the family farms either in SE or PTE is not high (0.5779 and 0.5213, respectively), contributing to the low TE. Although the PTE is slightly higher than the SE, both of them still have much room for improvement. Therefore, family farms should further improve their technical skills, while focusing on scale operations. A further analysis of the returns to scale shows that, among all the family farm samples, as many as 516 family farms are in a state of increasing their returns to scale, only 31 are in a state of decreasing their returns to scale, and the other 37 family farms are in a state of constant returns to scale.

Table 4. The efficiency of all the family farms of different types and in different regions.

Type	Households	Technical Efficiency (TE)	Pure Technical Efficiency (PTE)	Scale Efficiency (SE)	Increasing Returns to Scale	Diminishing Returns to Scale	Constant Returns to Scale
All family farms	584	0.3058	0.5779	0.5213	516	31	37
Planting family farms	294	0.2605	0.4997	0.5256	270	11	13
Breeding family farms	127	0.4104	0.7102	0.5547	96	17	14
Mixed family farms	163	0.3060	0.6160	0.4874	150	3	10
Wuhan district	273	0.3734	0.5994	0.5994	235	14	24
Langxi district	311	0.2464	0.5590	0.4527	281	17	13

Note: the efficiency values of the technical efficiency (TE), pure technical efficiency (PTE), and scale efficiency (SE) are the calculated average efficiencies; TE = PTE × SE.

Table 4 also presents the results of the efficiency values of the family farms of different types and in different regions. In terms of family farms of different types, the TE, PTE and SE of breeding family farms are the highest, with values reaching 0.4104, 0.7102, and 0.5547, respectively, while the efficiency values of the planting family farms and mixed family farms are relatively lower. The SE of the mixed family farms is the lowest (0.4874), and it is also confirmed by the fact that among the 163 mixed family farms, 150 households are in a state of increasing returns to scale. Hence, the mixed family farms need to pay more attention to adjusting the scale of operation to improve their TE. The PTE of the planting family farms is lower than their SE, indicating that the planting family farms should focus more on the improvement of technology and management skills.

From a regional perspective, the TE of the family farms in Wuhan is higher than that of Langxi (0.3734 and 0.2464, respectively). A similar pattern can be observed in the figure for the PTE and SE in Wuhan and Langxi, indicating that the family farms in Wuhan have more advantages in technology, management and scale operation, which contributes to a TE that is relatively higher.

3.2. Factors Affecting the Efficiency of the Family Farms: Based on the Tobit Model

This paper used stata11 to process and analyze the data. On the basis of estimating the total sample, regression estimations were also carried out by region and operation type, and the estimated value of each variable coefficient and its significance were obtained. The results are shown in Table 5.

Table 5. Tobit regression results of the variables affecting family farm efficiency.

Variable Types	Variable Names	Model 1-1 Total	Model 1-2 Total	Model 2 Planting	Model 3 Breeding	Model 4 Mixed	Model 5 Wuhan	Model 6 Langxi
Agricultural Input Variables	Ln(land)	−0.1601 *** (−5.77)	−0.1592 *** (−5.78)	−0.0766 * (−1.88)	−0.2049 *** (−4.06)	−0.2088 ** (−2.20)	−0.1182 * (−1.91)	−0.1665 *** (−5.78)
	$[\mathrm{Ln(land)}]^2$	0.0119 ** (2.10)	0.0127 ** (2.28)	0.0010 (0.11)	0.0264 ** (2.31)	0.0216 (1.35)	−0.0024 (−0.20)	0.0203 *** (3.55)
	Labor	0.0028 (1.26)		0.0049 ** (2.22)	−0.0050 (−0.49)	−0.0001 (−0.01)	0.0033 (1.08)	−0.0033 (−0.79)
	Ln(cap)	0.0333 *** (3.50)	0.0373 *** (3.99)	−0.0122 (−0.75)	0.0679 *** (2.72)	0.0459 ** (2.58)	0.0367 ** (2.35)	0.0198 * (1.65)
Farmers' Character-istic Variables	Gender	−0.0144 (−0.42)		−0.0425 (−1.02)	−0.0214 (−0.20)	0.0081 (0.14)	−0.0107 (−0.22)	0.0205 (0.46)
	Age	−0.0008 (−0.45)		−0.0024 (−1.07)	−0.0016 (−0.39)	0.0031 (1.15)	−0.0021 (−0.78)	0.0003 (0.14)
	Edu	0.0156 (1.34)	0.0235 ** (2.11)	0.0319 ** (2.24)	−0.0135 (−0.48)	−0.0279 (−1.21)	0.0055 (0.25)	−0.0150 (−1.16)
	Exp	−0.0007 (−0.61)		−0.0007 (−0.49)	−0.0001 (−0.04)	−0.0011 (−0.62)	0.0008 (0.44)	−0.0021 * (−1.75)
Family Farm Char-acteristic Variables	Regu	0.0154 (1.19)		0.0143 (0.89)	0.0394 (1.18)	0.0158 (0.72)	0.0033 (0.16)	0.0361 ** (2.48)
	Market	0.0644 *** (2.89)	0.0645 *** (2.91)	0.0340 (1.29)	0.0278 (0.43)	0.0992 ** (2.53)	0.0882 ** (2.39)	0.0467 * (1.93)
	Brand	0.0392 *** (2.57)	0.0453 *** (3.02)	0.0553 *** (2.74)	−0.0769 ** (−2.11)	0.0986 *** (3.84)	0.0223 (0.81)	0.0655 *** (3.97)
	Tec	0.0190 (0.81)		−0.0008 (−0.02)	0.2101 *** (3.73)	−0.0940 ** (−2.25)	0.0203 (0.53)	0.0400 (1.49)
	Fer	0.0371 *** (2.94)	0.0402 *** (3.20)	0.0400 ** (2.44)	0.0280 (0.91)	0.0303 (1.30)	−0.0092 (−0.43)	0.0449 *** (3.08)
Environmental Factors	Aid	−0.0675 ** (−2.35)	−0.0644 ** (−2.25)	−0.0490 (−1.37)	−0.1281 (−1.54)	−0.0578 (−1.21)	−0.0563 (−1.13)	−0.0502 (−1.61)
	Credit	0.0009 *** (3.34)	0.0009 *** (3.38)	0.0003 (0.54)	0.0013 * (1.81)	0.0015 *** (2.69)	0.0016 *** (3.26)	0.0001 (0.34)
	Dis	−0.0744 ** (−2.15)	−0.0720 ** (−2.09)	−0.1745 *** (−3.19)	−0.0272 (−0.40)	−0.0130 (−0.22)	0.0079 (0.14)	−0.1699 *** (−4.34)
Constant Term	c	0.3643 *** (3.50)	0.2939 *** (4.74)	0.4861 *** (3.38)	0.4460 * (1.82)	0.2797 (1.23)	0.5112 *** (2.77)	0.3863 *** (3.31)
Sample Size		584	584	294	127	163	273	311

Note: *t*-values are in brackets, ***, **, and * are their significance at the levels of 1%, 5%, and 10%, respectively.

Model 1-1 and 1-2 show the results of the efficiency influencing factors of all the family farm samples and those obtained after gradually eliminating the insignificant variables, respectively. From the perspective of considering the agricultural input variables, land input [ln(land)] is negatively correlated with the family farms' efficiency at the 1% level, while its square term shows an opposite trend, forming a U-shaped relationship between the farm efficiency and land operating area. In fact, there is an almost globally inverse relationship between the farm size and productivity within developing countries [37], including India, the Philippines, Latin America [38–41], China, Nigeria, Mexico, and Bangladesh [30]. In other words, in these developing countries, both small and large farmers are more productive than the intermediate-sized farmers, and this can be explained by the more efficient hiring labor utilization of small farmers and the machine scale economies of large farmers [30]. To be more specific, intermediate-sized farmers are most likely to employ part-time workers, which proves to be costly and less efficient than small farmers, while the full mechanization in large farms saves on labor-related costs [42], of which the increase in the scale capacity can explain for the upper tail of the U shape. The capital input (ln(cap)) of the family farm is significantly positive at the level of 1%, indicating that the efficiency of the family farms increases with the input of capital. To our knowledge, the more capital invested in the family farm, the easier it is for the family farms to purchase equipment, achieve mechanized production and economies of scale, which can promote the productivity of family farms. Among the farmers' characteristic variables, only the farmers' education level (Edu) has a significant impact on the efficiency of the family farm at a 5% level, proving that the farmers with a higher education degree have better skills relating to farming operations, which is beneficial in the making of smart decisions and enhancing the productivity of the farm. In terms of the family farm characteristic variables, the market channels (Market), brand trademark registration (Brand), and use of fertilizer (Fer) are all significantly positively correlated with the family farms' efficiency at a 1% level. Unblocked market channels contribute to the increase in product sales, registered brand trademarks enable the family farms to achieve a better publicity effect, and the use of fertilizer increases the fertility of the land and improves the unit output. Therefore, the three variables are conducive to the improvement of family farm efficiency. From the perspective of environmental factors, government subsidies (Aid) negatively affect the efficiency of the family farms at a 5% level; a possible explanation for this is that government subsidies may induce farmers to form the idea of "getting something for nothing", thereby reducing their enthusiasm for production. Financial credit (Credit) shows a positive correlation with family farm efficiency at the level of 1%. External credits can expand the budget constraint of the family farms and allow them to invest more funds for production, thus improving the efficiency of the family farms. When family farms suffer as a consequence of natural disasters (Dis), this significantly influences the efficiency of the family farm, because the natural disasters directly result in plights, such as a reduction in or no harvest, which poses a threat to the efficiency of the family farms.

Models 2, 3, and 4 present the results of the efficiency influencing factors of family farms of different operation types, while Models 5 and 6 show this for different regions. The heterogeneity of the results verify that H2 is true, and the analyses of each model are as follows:

Model 2 presents the result of regression on the factors affecting the efficiency of planting family farms. The land scale (ln(land)) shows a significantly negative correlation with the efficiency at a 10% level, with which the labor input (labor) is significantly positively correlated at the level of 5%, indicating that, for a planting type family farm, a smaller operating scale and a greater labor force can improve the production efficiency of the family farms. The education level (Edu) of the farmer positively affects the efficiency of the family farms at the level of 5%, proving that the higher the education level of the family farmer, the more possible it is for them to make decisions that are beneficial to the development of the planting family farm. The brand trademark registration (Brand) and use of fertilizer (Fer) both significantly and positively influence the efficiency of the family farm, indicating that brand promotion is conducive to the sale of planting products, and the use of fertilizer can boost the yield of agricultural products, thereby improving the efficiency of the family farms. As a consequence of suffering from natural disasters (Dis), the efficiency of family farms can lower, as the planting agricultural operations are weak and high risk, and therefore suffering from natural disasters may result in family farms having no income for the entire year.

Model 3 presents the result of regression on the factors affecting the efficiency of the breeding family farms. The land scale (ln(land)) and its square term show a U-shaped relationship with the efficiency of the family farm, where their coefficient values are significantly at -0.2049 and 0.0264, respectively, verifying that the smallest and largest breeding family farms are more efficient than the intermediated-sized farms. Capital input (ln(cap)) and new technology application (Tec) are both significantly positively correlated with efficiency at the 1% level; similarly, financial credit (Credit) presents a positive correlation with breeding family farms' efficiency at a 10% level, as the capital input and financial credit they obtain make it possible for breeding family farms to purchase advanced machinery and apply new technologies, such as cultivating new varieties and applying assembly lines, which contributes to the improvement of farm productivity. Brand trademark registration (Brand) is negatively related to the efficiency of the family farm at a 10% level. A possible explanation for this is that the breeding industry already has well-known brands, such as Hairy Crab of a famous Lake or Local Pork of a Mountain. Brands registered by single family farms find it difficult to compete with the more well-known trademarks in the market with a higher price, and, as a result, agricultural products with family farms' registered trademark brands may not be as popular as the original sales.

Model 4 shows the result of the factors that affect the efficiency of the mixed family farms. The land scale (ln(land)) negatively affects the family farm efficiency at the level of 5%, while the capital input (ln(cap)) presents an opposite influencing direction, indicating that the mixed family farms are not suitable for an excessively large scale of operation, and the capital input is proved to be helpful in building a good circular agricultural mixed model, such as the recycling of pig manure and urine, and rice–duck symbiosis, so as to improve the efficiency of the farm. In addition, the market channels (Market) and brand trademark registration (Brand) are significantly positively correlated with the farm efficiency at the levels of 5% and 1%, respectively, indicating that the smooth market channels and brand promotion can improve the efficiency of the mixed family farms by broadening the market. The adoption of new technology (Tec) shows a significantly negative correlation with farm efficiency at the 5% level, and it is probably because the new technologies are not yet mature in this field, which leads to a lower efficiency at this stage. Financial credit (Credit) positively influences the efficiency of the farm, since it can provide a sufficient source of external funds for the mixed family farms, which is conducive to their expansion in terms of production.

Models 5 and 6 are the regression results of the factors affecting the efficiency of the family farms in Wuhan and Langxi, respectively. From the perspective of the common points, firstly, among the agricultural input variables, the land operating area (ln(land)) in two regions is significantly negatively correlated with the family farm efficiency, while the capital input (ln(cap)) in the two regions is significantly positively correlated with this at a 5% level, showing that the family farms in both regions are more efficient at a smaller scale and with more capital investment. Capital investment contributes to the expansion of the production of the family farms, thereby increasing the productivity and efficiency of the family farms, and since family farms in Wuhan are located in the provincial capital city, the efficiency improvement affected by the capital input is better than that in Langxi. Secondly, among the other influencing factors, the market channels (Market) both in Wuhan and Langxi have positive impacts on the efficiency of the family farms. This is due to the fact that unblocked sales channels can increase the choice of markets at which family farms can sell more goods.

From the perspective of differences, in Langxi, the square term of the land operating area $[\ln(\text{land})]^2$ shows a positive relationship with the efficiency of the farm, thus the U-shaped relationship between the land area and farm efficiency is obvious in Langxi. The farmer's years of farming (Exp) shows a significantly negative relationship with the efficiency of the farm at the 10% level. Farmers who have spent more years in the practice of farming may have a richer farming experience, but they are also less likely to accept new technology and modernized methods, which is not conducive to improving the efficiency of the family farms. The regulation (Regu), the brand trademark registration (Brand), and the use of fertilizer (Fer) in the family farms in Langxi are all significantly positively correlated with the farms' efficiency, indicating that a complete internal regulation system, brand publicity, and fertilizer use will improve the farms' operating efficiency through an improvement of the management efficiency, the sale of more products, and the increase in yields, respectively. Among the environmental factors, financial credit (Credit) in Wuhan presents a significantly positive impact on farm efficiency, while that in Langxi is nonsignificant. This situation may be due to the relatively standardized development of the financial market in Wuhan, as Wuhan is a provincial capital city, so financial credit enables the family farms to expand their production and improve productivity through financing, while the development of the financial market in Langxi is relatively lagged. The efficiency of the family farms in the Langxi area is negatively affected at a 1% level, as a consequence of suffering from natural disasters (Dis). Since many family farms in the Langxi area suffered from natural disasters in 2016, they were affected by the disaster and their income was reduced. Therefore, this has a significantly negative impact on the efficiency of the local family farms.

4. Discussion

4.1. Discussion about the Efficiency of the Family Farms

In order to present family farm efficiency more specifically and elaborate on the discussion, this paper presents the decomposition of the DEA results of the family farms, according to the level of their ineffectiveness by types in Table 6.

Table 6. The decomposition of the efficiency of the family farms measured by the DEA.

Type		Mean	DEA Effectiveness (θ = 1)		Low Level of Ineffectiveness ($0.7 \leq \theta < 1$)		Medium Level of Ineffectiveness ($0.4 \leq \theta < 0.7$)		High Level of Ineffectiveness ($0 \leq \theta < 0.4$)	
			Mean	Percentage (%)	Mean	Percentage(%)	Mean	Percentage(%)	Mean	Percentage (%)
TE	All family farms	0.3058	1.0000	5.99	0.8374	5.14	0.5367	14.21	0.1695	74.66
	Planting family farms	0.2605	1.0000	4.76	0.8798	1.70	0.5368	11.22	0.1672	82.31
	Breeding family farms	0.4104	1.0000	8.66	0.8378	14.17	0.5286	22.83	0.1552	54.33
	Mixed family farms	0.3060	1.0000	6.13	0.8064	4.29	0.5478	12.88	0.1818	76.69
	Wuhan district	0.3734	1.0000	8.06	0.8348	5.86	0.5444	23.08	0.1877	63.00
	Langxi district	0.2464	1.0000	4.18	0.8406	4.50	0.5124	6.43	0.1577	84.89
PTE	All family farms	0.5779	1.0000	19.52	0.8232	11.99	0.5449	35.10	0.2778	33.39
	Planting family farms	0.4997	1.0000	12.59	0.8028	6.80	0.5411	37.07	0.2724	43.54
	Breeding family farms	0.7102	1.0000	31.50	0.8411	21.26	0.5539	30.71	0.2802	16.54
	Mixed family farms	0.6160	1.0000	22.70	0.8199	14.11	0.5458	34.97	0.2920	28.22
	Wuhan district	0.5994	1.0000	20.88	0.8276	15.02	0.5536	31.87	0.2790	32.23
	Langxi district	0.5590	1.0000	18.33	0.8171	9.32	0.5384	37.94	0.2769	34.41
SE	All family farms	0.5213	1.0000	6.68	0.8707	24.49	0.5451	28.25	0.2151	40.58
	Planting family farms	0.5256	1.0000	4.76	0.8756	24.83	0.5438	31.63	0.2284	38.78
	Breeding family farms	0.5547	1.0000	11.02	0.8835	30.71	0.5361	20.47	0.1677	37.80
	Mixed family farms	0.4874	1.0000	6.75	0.8428	19.02	0.5530	28.22	0.2252	46.01
	Wuhan district	0.5994	1.0000	9.52	0.8853	30.40	0.5549	31.14	0.2151	28.94
	Langxi district	0.4527	1.0000	4.18	0.8505	19.29	0.5348	25.72	0.2151	50.80

Note: the inefficiency of the DEA is divided into three levels: low, medium and high; θ is the efficiency value; TE = PTE $\times$ SE.

4.1.1. Full Sample Discussion

The results show that the TE (technical efficiency), PTE (pure technical efficiency) and SE (scale efficiency) of the family farms are low. The mean value of the TE of all the family farms is as low as 0.3058, and among all the family farms, only 5.99% have the status of DEA effectiveness, while up to 75.66% are at a high level of ineffectiveness. The TE reflects the distance between the actual output of each decision-making unit (family farm) and the optimal output (production frontier) under the premise that the inputs of the production factors, such as labor, capital, and land, remain unchanged. The higher the TE, the better the production capacity. The result implies that the TE of family farms is low, indicating that the resources have not been used reasonably and effectively by the family farms, so the family farms are still in the primary stage of development and have much room for improvement.

By decomposing the TE into PTE and SE, it can be observed that the PTE value of all family farms is similar to that of the SE (0.5779 and 0.5213, respectively). Although the PTE and SE values of all the family farms are both higher than the TE, only 19.52% and 6.68% of family farms are in an effective status in terms of the PTE and SE, respectively. According to the equation of "TE = PTE × SE", the values of the PTE and SE that are not high enough resulted in the low value of the TE. As the PTE refers to the management ability and technical level of the family farms when other conditions remain unchanged, and the SE reflects the effectiveness of farm specialization and moderate scale operation, in order to improve the TE of family farms, it is not only necessary for family farms to improve the PTE by improving their management ability and technical level, but also to improve the SE by forming a moderate operation scale.

4.1.2. Discussion of the Family Farm Efficiency in Different Regions and of Different Types

From the perspective that considers the different regions, the TE of family farms in Wuhan (0.3734) is slightly higher than that in Langxi (0.2464), and it is mainly attributed to the relatively higher SE in Wuhan (0.5994) than that in Langxi (0.4527), since the PTE values of Wuhan (0.5994) and Langxi (0.5590) are similar. Additionally, there are up to 50.8% of family farms in Langxi that are highly inefficient in terms of the SE, while the proportion for that in Wuhan is 28.94%, verifying that family farms in Wuhan are better at performing moderate scale operations to achieve higher efficiency.

From the perspective of different operation types, the TE of breeding family farms (0.4104) is higher than that of planting family farms (0.2605) and mixed family farms (0.3060). A possible explanation for this is that, given the similar SEs of the three types of family farms (0.5256, 0.5547 and 0.4874), breeding family farms have a higher PTE at 0.7102, while the PTE of planting and mixed family farms are 0.4997 and 0.6160, respectively. The values imply that the planting, breeding and mixed family farms all experience a similar condition of scale operation, whereas the breeding family farms benefit more from technical improvements rather than the expansion of scale, for breeding family farms do not require a scale as large as planting or mixed family farms, but rather require new technology to achieve intensive production.

4.2. Discussion about the U-Shaped Relationship between Farm Efficiency and Land Scale

The results of this paper show that the land scale has a U-shaped relationship with family farm efficiency. With the expansion of land scale, the efficiency of family farms first decreased then increased after a threshold, forming a U-shape.

However, many people are convinced that the land scale of family farms ought to have an inverted U relationship with their efficiency because of the achievement of optimal scale. In fact, the two views are not contradictory, because the U-shaped relationship between the land scale and farm efficiency is mostly observed in low-income developing countries, while the inverted U relationship is usually found in high-income developed countries.

Foster and Rosenzweig [30] explained the U-curve relationship very thoroughly. The U-curve relationship between land scale and farm efficiency is driven by two factors: the cost of hiring laborers and the scale economies of machine capacities. In low-income countries, such as India, Indonesia and China, family farms are, on average, much smaller than those in developed countries, such as the U.S. For very small family farms in low-income countries, limited by the land scale, it is unlikely to implement mechanized production, and only family members work the land and operate their own farms efficiently. As the farm size increases, the family members work harder until they are unable to afford operating larger farmland by themselves and begin to hire additional labor, which comes with additional transaction costs and thus lowers their net income. The family continues to work the land as the farm size increases until the point that the benefit of hiring additional laborers outweighs the cost, and productivity starts to increase—which is where we observed the bottom of the curve. After this point, productivity rises with the farm size, as larger farms can take advantage of machines that have a greater capacity at larger scales and lower labor use, mirroring the economies of scale that are well-observed in developed countries. The inverted U-shaped relationship that many other scholars observed appears after the optimal scale achieved by the larger family farms, as after this optimal size point, the overlarge scale of family farms may exceed the management ability of family farmers and lead to diminishing farm efficiency. Hence, small farms in developing countries are more productive than those that are slightly bigger, but far less productive than the larger farms observed in high-income countries, as shown in Figure 1.

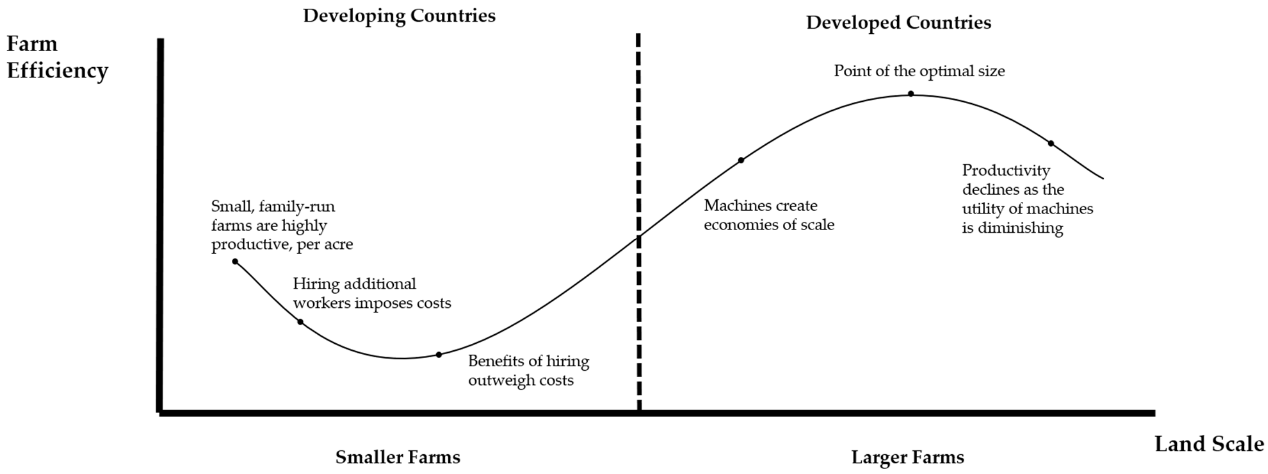

Figure 1. Relationship between farm efficiency and land scale.

The result of the U-shaped relationship between farm efficiency and land scale addressed in this paper indicates the left side of Figure 1, as the farm land scale is too small in China compared to that in developed countries, and family farms in China have to experience initial decreasing returns to increasing farm size to acquire a higher efficiency.

5. Research Conclusions and Suggestions

In recent years, in order to realize agriculture modernization and rural revitalization, the Chinese government has been focusing on the cultivation of new types of agricultural operating entities, among which family farms are promoted as typical representatives. Therefore, it is of great significance to study the efficiency of family farms and their influencing factors. This paper used the field survey data of 584 family farms in 2 national family farm demonstration bases in Wuhan City, Hubei Province and Langxi County, Anhui Province in 2016, and applied the DEA model to measure the efficiency of family farms. Then, the Tobit model was used to examine the key factors affecting the efficiency of family farms from four perspectives, agricultural factor input, characteristics of farmers, characteristics of family farms, and environmental factors, and further compared the family farms in different regions and of different types.

The research results show that the TE of all family farms is not high, and both the PTE and SE obtained by decomposing the efficiency can be improved. Breeding family farms have the highest efficiency, while planting family farms and mixed family farms have relatively lower efficiencies. The SE of mixed family farms is lower than their PTE, and it is the lowest among all types of family farms. The TE, PTE and SE of family farms in Wuhan are higher than that in Langxi.

Among the factors affecting the efficiency of family farms, capital input, farmer's education level, market channels, brand registration, the use of fertilizer and financial credit have positive impacts on the efficiency of family farms, while government subsidies and natural disasters negatively affect the efficiency of family farms. More specifically, the land operating area shows a U-shaped relationship with farm efficiency.

For planting family farms, labor input, farmer's education level, brand registration, and the use of fertilizer positively affect their efficiency, while land operating scale and natural disasters negatively affect it. For breeding family farms, capital input, new technology, and financial credit positively affect their efficiency, while brand registration negatively affects it. More specifically, the land operating area shows a U-shaped relationship with farm efficiency. As for the mixed family farms, capital input, market channels, brand registration, and financial credit positively affect their efficiency, while land operating scale and new technology negatively affect their efficiency.

From a regional perspective, the key factors affecting the efficiency of family farms in Wuhan mainly include the land operating scale, capital input, market channels and financial credit, and the key factors that affect the efficiency of family farms in Langxi include the land operating scale, capital input, farmer's years of farming, regulations, market channels, brand registration, fertilizer use, financial credit and natural disasters. More specifically, the land operating area negatively influences the farm efficiency in Wuhan, while it shows an obvious U-shaped relationship with farm efficiency in Langxi.

According to the research conclusions, it can be seen that although the family farms in the Wuhan and Langxi regions have been supported by the government for many years, the efficiencies of family farms in the two regions are still low, so it is of great significance to improve the family farms' efficiency. The factors affecting the efficiency of family farms in different types and regions vary. Therefore, family farms in each region and of different types needs to choose appropriate measures based on the actual situation and different types of local family farms, paying particular attention to the following points:

First, the local government should attach importance to the accumulation of agricultural input factors on family farms, especially encouraging the labor input of planting family farms and capital input of breeding and mixed family farms, to help improve the efficiency of family farms more precisely.

Second, the operating scale of family farms should be reasonably determined and family farms need to pay attention to moderate scale operations and not blindly expand their land scale. At the present stage, family farms in China should either stick to moderate scale operation, or transfer in a great amount of land under the support of the government to move beyond the bottom of the U-shape, to obtain a higher efficiency.

Third, family farms should be stimulated to optimize the internal operating environment, such as smooth their market channels, register brands and trademarks, and use fertilizer, so as to improve the productivity and market competitiveness of family farms.

Fourth, it is necessary for the government to create a favorable external environment for family farms, for example, build a standardized and multi-level rural financial market; increase support for financial credit; rationally plan government subsidies; and focus on the prevention and control of natural disasters.

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