

Article

A Configurational Analysis of Family Farm Management Efficiency: Evidence from China

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Abstract: Family farms are the “most-desirable”; new-style agricultural production and management entities in China at this stage, as well as their production behaviors, play an important role in achieving sustainability in agricultural development. The scientific evaluation of family farm management efficiency and the identification of an effective path to the high efficiency of family farms with different resource endowments are critical for family farms to transform from quantitative growth to qualitative improvement and develop in a sustainable and healthy way. Based on the data from a rural fixed observation point of the Chinese Ministry of Agriculture and Rural Affairs, this study randomly selected representatives from 532 family farms from 27 provinces, municipalities, and autonomous regions in China as research objects; calculated their total factor productivity based on the DEA model; and employed the Qualitative Comparative Analysis (QCA) method to identify the configuration models for a high total factor productivity, which combines the factors of land investment, capital investment, labor investment, education level of farm leaders, land transfer years, the introduction of new technology and new equipment, and financial support. It is found that the average efficiency of family farms in China is not high yet, and both the pure technical efficiency and scale efficiency have great room for improvement. The efficiency of family farms is not determined by one single condition, but by the combinations of multiple factors. The introduction of new technology and new equipment, long land transfer period, high input of production and labor, and financial support are the driving forces to improve the efficiency of family farms. This demonstrates that although the current family farms are still in the cultivation stage of capital and labor-intensive investment, they do not mainly rely on traditional agricultural productions such as labor to achieve high efficiency. The managerial implications are as follows. First, the strategy of intensive and efficient management instead of the blind expansion of land scale should be considered, the full play to the role of family labor while controlling the scale of employees is highly suggested. Second, attention should be paid to the accumulation of the human capital of family farm practitioners, which implies that more highly educated people for family farm management, as well as high-technical-skilled farm operators, should be employed. Third, it is necessary to create a good institutional environment for the development of family farms and to increase financial support such as credit loans for family farms.

Keywords: family farm; efficiency; agricultural inputs; QCA



Citation: Li, W.; Wang, L.; Wan, Q.; You, W.; Zhang, S. A Configurational Analysis of Family Farm Management Efficiency: Evidence from China. *Sustainability* **2022**, *14*, 6015. <https://doi.org/10.3390/su14106015>

Academic Editor: Lorenzo Ardito

Received: 2 April 2022

Accepted: 11 May 2022

Published: 16 May 2022

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1. Introduction

As the world’s largest developing country and a major carbon emitter, the Chinese government has proposed to strive for peak carbon dioxide emissions by 2030 and strive to achieve carbon neutrality by 2060. According to the third national communication submitted by the Secretariat of the United Nations Framework Convention on Climate Change, Chinese agricultural greenhouse gas emissions accounted for 7.9% of the country’s total greenhouse gas emissions in 2018. Agricultural and rural greenhouse gas emissions accounted for about 15% of the total national emissions, and they become an important

source of greenhouse gas emissions. In China, “Big country and small-scale peasant” is the basic national condition and agricultural condition [1]. For quite a long time, the small-scale peasant economy is the reality that agricultural development needs to face, which is determined by the highly tense relationship between people and land in China. By giving farmers the autonomy of agricultural production and management, family management effectively solves the problems of labor supervision and labor measurement in agricultural production and management. However, this ultra-small-scale farm household management has some defects, such as small land management scale, scattered and fragmented land, and a certain degree of a scale economy problem, which is not conducive to the application of modern large-scale and green low-carbon agricultural technology. This leads to excessive input of some production materials and low productivity per unit of resources, which results in the waste of resources and environmental pollution, and then prevents the sustainable development of agriculture [2]. At present, the Chinese government has been trying to innovate the form of agricultural management entities, promote the moderate scale of land management and save the input of production materials, so as to improve the efficiency of agricultural management and promote the development of agriculture in the direction of green, low-carbon, and sustainability. As the “most desirable” new agricultural management subject in China at this stage [3,4], family farms become important implementers of green low-carbon and sustainable development of agriculture in China. Family farms not only overcome the shortcomings of traditional small-scale management but also make up for the deficiencies in the application of green technology, which promote the high-quality and efficient development of agriculture [5]. Driven by policy support from both the central and local government, family farms have entered into the fast lane of sustained and rapid growth, exhibiting a booming trend. As Figure 1 shows, by the end of 2015, more than 343,000 family farms were registered in agricultural departments at or above the county level, an increase of more than two times compared to 139,000 in 2013. By the end of 2019, the number of family farms in China increased from 343,000 to 853,000, an increase of about 1.5 times compared to the figure in 2015.

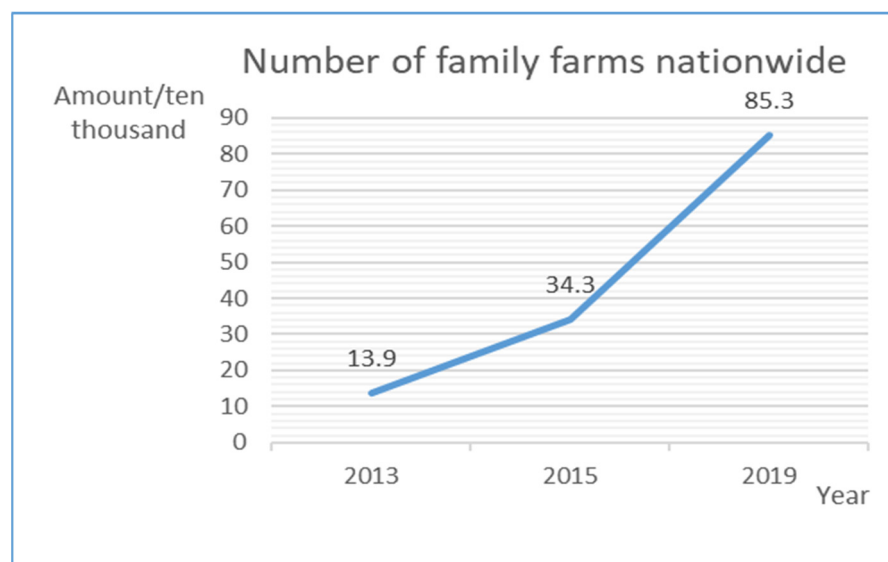


Figure 1. The development of family farms.

Despite the growth momentum of family farms in China, the development still needs to be improved. Firstly, the growth of family farms tends to slow down. As can be observed in Figure 1, from 2013 to 2019, although the number of family farms increased by 710,000, the growth rate declined after 2015. Secondly, the number of family farms is still insufficient. The “Bulletin on Major Data of the Third National Agricultural Census” demonstrates that by the end of 2016, there were 207.43 million agricultural operators in China, and

3.98 million-scale agricultural operators accounted for only 1.92% of agricultural operators, of which the number of family farms accounted for only 0.2% of China's agricultural operators. In general, there are still some problems with family farms, such as unbalanced and insufficient development, being relatively fragile, etc. Thus, family farms need to improve the efficiency of management and accelerate the development of cultivation in terms of quantity and quality; it is of particular importance to take measures to maximize the role and function of family farms as a new type of agricultural business, and thus to promote the healthy and sustainable development of family farms. Therefore, to effectively improve the management efficiency of family farms, it is necessary to accurately measure the efficiency of family farms and analyze their efficiency-related decisions and the paths to their improvement. Unlike previous measurements of family farm efficiency from regional data and "net effect" analysis of single factors, this paper employs the fuzzy set qualitative comparative analysis (QCA) method to analyze their combinations under different conditions and explore different approaches in order to improve the efficiency of family farms with different combinations of factors.

2. Literature Review

There are many studies devoted to the management efficiency of SMEs enterprises; Sangil et al. employed a propensity score matching method to examine whether R&D collaborations positively affect the business performances of SMEs that participate in joint R&D projects [6]. Firman et al., used a quantitative survey approach to analyze the effect of using sharia fintech on the financial performance and sustainability of SMEs and to strengthen human resource capacity, business diversification, business productivity, and product marketing to improve financial performance and business sustainability of SMEs [7]. In-depth research on the efficiency of family farms has been conducted in the theoretical community. For example, Imori et al., used stochastic production frontier and inefficiency effect models to compare and analyze the efficiency of family farms and commercial farms in Brazil and found that the efficiency of family farms was lower than that of commercial farms [8]. Madau compared the efficiencies measured by the SFA model and the DEA model, and the results demonstrated that the technical efficiency estimated by the SFA model was basically at the same level as that estimated by the DEA model; however, the scale efficiency measured by the SFA model was higher [9]. Jan Polcyn used the TOPSIS-CRITIC method to determine the relationship between eco-efficiency and human capital efficiency on small-and medium-sized family farms in selected European countries [10]. Marta G. et al. used the DEA model, the ANOVA method, and linear ordering methods to measure the technical efficiency and environmental sustainability of small-scale family farms under the conditions of agricultural policy support [11]. Asmiro et al., used the stochastic frontier translog production and Spatial Lagged Explanatory (SLX) models to examine the technical efficiency of Teff farms, controlling for neighborhood effects in Ethiopia using 858 Teff farmers [12]. Chen Zhigang et al. applied the DEA model to measure the efficiency of family farms by using the field survey data of the national family farm demonstration bases of Wuhan and Langxi, China, and used the Tobit model to explore the factors that affect the efficiency of full sample family farms [13]. At present, there are different research findings on the level of management efficiency of family farms in China. When some scholars used models to measure the efficiency of family farms, they found that family farms had higher management efficiency, such as Gao Xueping [14], Kong Lingcheng [15], Zeng Yurong [16], and so on. However, other scholars drew the opposite conclusion, believing that the current management efficiency of family farms was generally low, such as Qian Zhonghao [17], Wu Fang [18], and Zhang Chaohua [19].

Regarding the factors affecting the efficiency of family farms, researchers found that institutional environment, technical environment, factor inputs, individual characteristics and family farm characteristics, etc., may affect the efficiency of family farms. Based on the production function model of Cobb and Douglas, Cornia measured each factor affecting farm productivity and analyzed the relationships between them [20]. Utilizing

15 developing countries as research subjects, Kislev and Peterson analyzed that the ratio of labor-to-capital prices significantly influenced the size of family farms using data on US family farms from 1930–1970 [21]. By using data from Spanish family farms, Piedra et al. empirically analyzed the effects of the education and age of family farmers, the degree of specialization of family farms, and eco-innovative behavior on management efficiency [22]. In terms of the relationship between farm scale and farm efficiency, different scholars held different views. Sen demonstrated, through more detailed research, that the output per unit area decreases significantly as the farm size increases, known as the “IR relationship (inverse relationship)” in agricultural development [23]. Mishra [24], Holden and Fisher [25], Carletto et al. [26], Barrett et al. [27], and Larson et al. [28] confirm the inverse relationship between farm size and farm efficiency. Dethier and Effenberger [29], Fan and Chan-Kang [30], MacDonald et al. [31], and Bojnec and Latruffe [32] suggest that there is a positive relationship between farm size and farm efficiency. In contrast, Helfand and Levine [33], Adesina and Djato [34], Hansson [35], Townsend et al. [36], and Nkonde et al. [37] have demonstrated a non-linear relationship between the two. Wei Wei and Du Zhixiong also verified the accuracy of the IR relationship from different perspectives using differing metrological methods [38]. Kumbhakar et al. found a positive association between the education level of farmers and producers in a survey of 89 household dairy farms in Utah, USA [39]. Qian Zhonghao and Li Youyi found that there was an “inverted U-shaped” relationship between the area of land operated by family farms and its efficiency, with years of education of family farmers, whether family farmers have agricultural experience, the length of family farm management contract, the proportion of green manure cultivation to the area of land operated, and government subsidies having a positive effect on the efficiency of family farms. In addition, the efficiency of family farms was positively influenced by labor input and whether the family farms purchased farm machinery services [17]. Chen Junmin’s study found that unstable land ownership can make it difficult for family farm operators to form long-term stable expectations, which will lead to inefficiency in family farms [40]. The study by Gao Ming et al., found that the growth of operating efficiency mainly comes from technological progress and changes in factor allocation efficiency [41]. Mugeru and Langemeier studied the effects of operation size and farm type on the efficiency of family farms, and the results demonstrated that the efficiency of family farms varies according to their operation size, but the type of family farm has no significant effect on the efficiency [42]. Research by Latruffe et al., and Cao Wenjie demonstrated that the higher the education level of the operators was, the better the efficiency of the family farms [43,44]. The study by Larsén demonstrated that family farms that participated in machinery cooperation were more efficient than those that did not, and that the more extensive the form of cooperation was, the more efficient was the family farm management [45]. Zhu and Lansink’s study found that the effect of agricultural subsidies on the efficiency of family farms was uncertain because agricultural subsidies can, on the one hand, increase operators’ incentives to produce and on the other hand, may cause operators to reduce their efforts to improve efficiency levels because of the additional income they receive [46]. Jiang Lili et al., found that the efficiency of family farms could not be improved without the support of credit facilities and agricultural insurance [47].

Suggestions on how to improve the efficiency of family farms have been put forward by the theoretical community from several perspectives. Zeng Fusheng, Gao Ming, and Zhang Yue argue that attention should be paid to the rational allocation of land, labor, and capital inputs to avoid high land costs and redundant labor inputs and to promote the sustainable development of family farms [48,49]. Wang Lixia and Chang Wei argue that attention should be paid to the enhancement of human capital in family farms, and those appropriate ways should be adopted to strengthen training for family farm operators and to improve the ability of family farm owners to adopt new technologies and improve their business management [50]. McCloud and Kumbhakar, Liu Tongshan, and Xu Xuegao argue that institutional policies for family farms should be enhanced, the rural financial system

should be improved to consolidate the external environment for family farm operations, and family farms should be encouraged to participate in agricultural insurance [51,52].

Previous studies have mainly explored the relationship between family farm size, material input, and environmental characteristics, but most of them focus on the “net effect” of single factors such as education level, land ownership, and financing on family farms, ignoring the “combination effect” of multiple factors. To fill this gap, this paper attempts to employ the fuzzy set qualitative comparative analysis (QCA) method to identify the key factors affecting the efficiency of family farms and analyze their combinations under different conditions, to explore the approaches to improve the efficiency of family farms with different combinations of factors, and to provide theoretical basis and practical guidance for improving the sustainable development mechanism of family farms, thus enhancing the governance capacity of family farms.

3. Date and Methods

3.1. Data Sources

The data set in this study is obtained from the Rural Fixed Observation Point Survey System of the Ministry of Agriculture and Rural Affairs of China. Currently, the database of rural fixed observation points covers 31 provinces, municipalities, and autonomous regions (excluding Hong Kong, Macao and Taiwan), including 360 administrative villages and 23,000 farm households, making it the most comprehensive rural survey system in China. It should be noted that, unlike the database of fixed observation sites in a rural area, the data used in this paper are obtained from an additional survey of new agricultural business entities conducted in 2019 in all provinces, municipalities, and autonomous regions of China. The survey samples were from 31 provinces, cities, and autonomous regions across China, excluding Hong Kong, Macao, Taiwan and Tibet. The survey samples were selected randomly by the investigators in the fixed observation sites in a rural area. Two farms were randomly selected in each fixed observation sites. The survey covered eight aspects of the family farms’ operation, including the characteristics of the director, the characteristics of family farms, how to help other farmers to develop, the level of technological development, policy support, standardized production, and operational performance. In terms of sample collection, as the family farms in the three northeastern provinces and Inner Mongolia Autonomous Region differ greatly from those of family farms in other provinces and autonomous regions, 532 family farms registered in 2019 in 27 provinces (municipalities directly under the central Government and autonomous regions) across China were used as the research objects. Invalid samples were excluded, resulting in a total of 532 valid samples.

3.2. Methods

3.2.1. Data Envelopment Analysis

From the input–output perspective, efficiency can be observed as the extent to which a production unit achieves a input minimization or output maximization, and it is a comprehensive evaluation of various aspects of a production unit such as resource allocation, technology use, and cost control. In this study, Leibenstein’s definition of efficiency is adopted to assess the efficiency of family farms; i.e., the efficiency can be regarded as the ratio of the actual output of a production unit to the maximum output possible given a certain input constraint and the optimum allocation of factors [53].

There are many methods to calculate the efficiency of family farms, and the major methods used in the literature are the Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA). Stochastic Frontier Analysis (SFA) is a parametric method, which was used by Heshmati and Kumbhakar [54], Abdulai and Eberlin [55], Lawson et al. [56], Islam et al. [57], Yang Chenglin [58], and many others to estimate efficiency. Data Envelopment Analysis (DEA) is a non-parametric method, which does not require a production function. It can measure the relative efficiency of DMU without the requirement of a production function, as long as the data on input and output indicators are available, and it has been

widely used in practical studies, e.g., Helfand and Levine [33], Latruffe and Davidova [59], Balezentis et al. [60], Cao Wenjie [44], and so on. Considering that family farms in China are in their infancy stages of development, it is difficult to make correct assumptions about the specific form of the production frontier; therefore, it is more appropriate to use a DEA model to assess the management efficiency of family farms. The number of samples is far more than three times the sum of input and output indicators, meeting the requirements of the DEA model for sample data.

The theoretical approach of the DEA model, developed by Charnes et al. [61], uses input–output indicators to determine whether a Decision-Making Unit (DMU) is located on the “frontier” of the production possibility constraint set through a mathematical planning model, and measures its relative effectiveness by the degree of deviation from the production frontier. In terms of the choice of model, there are two main types of models: input-oriented and output-oriented. The former examines the extent to which each input indicator of technological effectiveness should be reduced without reducing output, while the latter examines the extent to which each output indicator of technological effectiveness should be increased without increasing the input. Concerning the CCR model constructed by Charnes et al. [61] and considering that family farms can only control and adjust the amount of material input in the production process, this paper chooses the input-oriented DEA model (Coelli et al.; Cooper et al.) [62,63]. The specific model is shown in Equation (1).

$$\begin{aligned}
 & \min \theta \\
 & s.t. \sum_{j=1}^n \lambda_j x_{ij} \leq \theta x_{ik} \\
 & \quad \sum_{j=1}^n \lambda_j y_j \geq y_k \\
 & \quad \lambda \geq 0 \\
 & \quad i = 1, 2, 3; j = 1, 2, \dots, n
 \end{aligned} \tag{1}$$

When calculating the efficiency of family farms, each family farm is considered as a Decision-Making Unit (DMU) of production, n family farms are denoted as DMU_j ($j = 1, 2, \dots, n$), and the evaluated family farms are denoted as DMU_k . x_i in Equation (1) ($i = 1, 2, 3$) denote three inputs of the family farm, i.e., x_1, x_2, x_3 represent the land input, labor input, and capital input, respectively; y represents the output of the family farm; λ_j is the linear combination coefficient of DMU_j ; x_{ik} and y_k denote the input and output vectors of DMU_k , respectively; the optimal solution of the model θ^* represents the efficiency value of DMU_k .

The CCR model assumes that all DMU for evaluation are at the optimal production scale. However, many family farms do not engage in production activities at the optimal scale. Therefore, the efficiency calculated using the CCR model contains both the difference between the actual production level and the production possibility curve, i.e., net technical efficiency, and the difference between the actual scale and the optimal scale, i.e., efficiency in scale. For this reason, this paper adopts the BCC model constructed by Banker et al., to decompose the efficiency of family farms into net technical efficiency and efficiency in scale [64]. The specific model is shown in Equation (2).

$$\begin{aligned}
 & \min \theta \\
 & s.t. \sum_{j=1}^n \lambda_j x_{ij} \leq \theta x_{ik} \\
 & \quad \sum_{j=1}^n \lambda_j y_j \geq y_k \\
 & \quad \sum_{j=1}^n \lambda_j = 1 \\
 & \quad \lambda \geq 0 \\
 & \quad i = 1, 2, 3; j = 1, 2, \dots, n
 \end{aligned} \tag{2}$$

Since the DEA model analyzes the relative effectiveness (DEA effectiveness) between DMU according to multiple input and output indicators, the correct selection of input and output indicators is the key to DEA evaluation of relative efficiency.

Based on existing research on the efficiency of family farms from Qian Zhonghao et al., Cai Yingping et al., Zhao Jinguo et al., and Gao Ming et al. [17,41,65,66], starting from the actual operation of family farms, the input indicators selected in this study include all the input in the process of agricultural production and management of 532 family farms in 2019, mainly involving land input, labor input, and capital input. Considering the availability of data and the difference of family farm operation types, the output measured by yield is not comparable. Output indicators mainly involve agricultural income and operating income from main products, and the unit is ten thousand RMB.

Land input refers to the actual land area of family farms. The land is the basis of family farm production activities, which is mostly realized through land transfer. Since the measurement indicators of land transfer costs are inconsistent across regions and the transfer prices in some regions are variable during the transfer period, this paper uses the total area of farmland to represent land input, with a unit of mu (0.165 acres). Labor input refers to the input of family farms in production, including family labor input and employment labor input. Employed labor inputs are converted into standard labor at the annual cost of family farms divided by the annual average wage level of local long-term employment. Capital input mainly refers to the expenditure on production materials, which refers to the amount spent on the purchase of crop seeds (livestock and poultry; aquatic seedlings), pesticides (veterinary medicine; fish medicine), fertilizers, feed and feed additives, agricultural machinery, and spare parts. The output index of family farms is measured by the agricultural income of family farms and the income from main products.

3.2.2. QCA

The QCA (Qualitative Comparative Analysis) method was first used in the field of natural sciences for the study of qualitative comparative procedures [67,68]. It was then creatively developed by sociologist Charles Larkin, who combined the strategic advantages of qualitative and quantitative research methods [69]. On the collection of case samples, the QCA method requires that the number of cases should match the number of antecedent conditions. This study contains seven antecedent conditions, which correspond to a sufficient number of 532 individual family farm cases to avoid a large number of logical residuals. Relative homogeneity and diversity of cases are the basic principles that should be followed for cases in the QCA method, and in practice, they are not contradictory. Homogeneity refers to the selection of cases that are comparable in a particular dimension, with the same or similar contextual characteristics, usually with common components across cases. The backgrounds of the cases in this study are homogeneous: (1) All 532 family farms are in normal operation, i.e., the production and operation of the case farms are relatively stable, all have been in operation for one year or more, and the scale of operation meets the scale standards determined by the local agricultural and rural departments at or above the county level. (2) The cases are all family farms and do not involve other new business entities such as agricultural companies and farmers' professional cooperatives. Diversity of cases, on the other hand, means that the cases should cover multiple types of research subjects rather than individual subjects, and covers cases in different directions rather than one-way cases [70]. This is mainly reflected in three aspects: (1) The selected family farms were all established from 2013 to 2019, spanning the entire process of family farms from inception to stable development, during which local governments attached increasing importance to the cultivation of new agricultural business entities and relevant policies and supporting measures were continuously improved. (2) Diversity of development models: Family farms cover a variety of development models such as government-led, market-led, market-led government-supported, and government-supported enterprise-led [71]. (3) Diversity of business types: Family farms cover a variety of types such as farming, planting, combined farming, and recreation.

This paper uses the fsQCA method to explore the configuration effects of production material input characteristics, environmental characteristics, farmer characteristics, and family farm characteristics on the management efficiency of family farms for the following reasons. First, total factor productivity on family farms is a complex phenomenon that arises under different combinations of multiple conditions. Compared to regression methods, Douglas et al. and Fiss argue that QCA methods are more suitable for exploring complex phenomenon [72,73]. Secondly, the QCA approach is effective in identifying interdependence, configuration equivalence, and causal asymmetry between different conditions [74]. The conditions for high and low efficiency in family farms are not necessarily symmetrical, and the QCA approach's assumption of causal asymmetry helps to explore the different paths to high and low efficiency in family farms. Thirdly, the QCA approach allows for both statistical analysis of the research subjects and also pays attention to the uniqueness and depth of individual cases, and further deepens the conclusions [75]. For example, in the analysis of each path for efficient management later in this paper, data from its typical cases are selected to illustrate the mechanisms at play in this pathway. Moreover, the sample size of 532 in this paper is medium, and the sample size matches the QCA method, which enhances external validity to a certain extent and also preserves the uniqueness and depth of the cases. Fourth, compared to the csQCA and mvQCA methods, the fsQCA method is more conducive to capturing the subtle effects of changes in antecedent conditions at different levels or degrees and does not exacerbate the problem of limited diversity [76].

Based on the literature of Ahmad et al., Cornia, Villano and Fleming, Bojnec and Latruffe, Khai and Yabe, Qian Zhonghao et al., Gao Ming et al., and Cai Yingping et al. on the influencing factors of family farm efficiency [17,20,41,65,77–80], there are about 10 variables affecting family farm efficiency. Based on the requirements of the QCA method, the most representative “land input”, “labor input”, “capital input”, “education level”, “introduction of new technology and new equipment”, “land transfer period”, and “loan” are selected as conditional variables, and they are divided into three categories.

- (1) Variables about production inputs characteristics: “land input”, “labor input”, and “capital input” are set as conditional variables. Land input is directly assigned according to the actual land area of family farms. Labor input is directly assigned according to the amount of family labor input and employment labor input. Capital input is directly assigned according to the expenditure on production materials.
- (2) Variables about family farms and the leaders' characteristics. Set the education level of farm leaders, the introduction of new technology and new equipment as conditional variables. The educational level of farm leaders is measured by the five-valued set assignment method, which are the primary school and below, junior high school, high school/secondary school, college, undergraduate, and above five categories of assignment. The introduction of new technology and new equipment equals one when new technology and new equipment are introduced, and 0 otherwise.
- (3) Variables about circumstance's characteristic. Set “land transfer period” and “loan” as conditional variables. “Land transfer period” is directly assigned. “Loan” is directly assigned based on the availability of loans from financial institutions.

Under the combination of antecedent conditions, the total factor productivity of family farms is set as the explained variable. At the same time, in order to realize the structured calibration of the results, clearly judge the membership degree of the outcome variables and improve the interpretation value of the outcome variable, the fsQCA3.0 software is used to set multiple qualitative anchor thresholds, and the total factor productivity of all family farm cases is calibrated according to the anchor threshold. The operational definition and assignment of variables are shown in Table 1.

Table 1. Operational definition and assignment of variables.

Type of Variables	Perspective	Variable Name	Variable Definition and Value Assignment
Conditional variables	Production materials input	Land input	Area of land in operation
		Labor input	Quantity of family labor force and employment labor force
		Capital input	Expenditure on production materials
	Characteristic of family farms and the leaders	Education level	Education level of farm leaders “1” = Primary school and below, “2” = junior high school, “3” = high school/technical secondary school, “4” = college, “5” = undergraduate and above,
			Introduction of new technology and new equipment
			whether new technology and new equipment are introduced or not. yes = “1”, no = “0”
Outcome variable	Family farm efficiency	Circumstance	Land Transfer Period Loan
		Total factor productivity	Length of land transfer period Whether to take a loan, yes = “1”, no = “0”
			measured by CCR Model, “1” = greater than median, otherwise = “0”

4. Results

4.1. DEA Input–Output Index System and Efficiency of Family Farms

To calculate the operating efficiency of family farms, it is necessary to construct a scientific input–output index system. Based on the integrity and availability of data, this study integrated the input–output index systems of relevant studies and constructs the index system under the Cobb–Douglas production function (as shown in Table 2).

Table 2. Input–output index system.

Input and Output	Index/Units	Medium Value	Standard Deviation
Output	Agricultural income/million yuan	154.28	335.26
	Operating income from main products/million RMB	144.49	320.03
	Total labor force	11.38	16.07
Input	Operating land/mu (0.165 acres)	433.44	740.96
	Total production expenditure/million RMB	82.66	266.71

In Table 2, the average land management area of family farms in 27 provinces and autonomous regions in 2018 was 433.44 mu, which just realized the scale management of land. From the perspective of family farm labor input, the average family labor input is 11.38 persons. From the perspective of production material input, the average production material input is 8266 million RMB. The average agricultural income of family farms in 27 provinces and autonomous regions is 15.428 million RMB, and the average income of main products is 1.4449 million RMB. The income of family farms mainly comes from the income of main products. The Ministry of Agriculture’s guidance on promoting the development of family farms requires that as a new type of agricultural management subject, family farms should take farmers’ family members as the main labor force, take agricultural operating income as the main source of income, and use household contracts or transfer land to engage in large-scale, intensive, and commercial agricultural production. As can be observed from Table 2, the development of family farms adheres to the essential characteristic of family business and meets the requirements mentioned above.

The results of family farms’ management efficiency are shown in Table 3. The average technical efficiency (TE) of all family farms measured by the CCR model is 0.191, which is small. Although the DEA model measures relative efficiency, which is the efficiency

of the evaluated production unit relative to the leading production unit, the calculation results demonstrated that the efficiency level of most family farms is far away from the relatively effective production frontier, and that the efficiency of family farms has great room for improvement. Using the BCC model, family farm efficiency is decomposed into pure technical efficiency (PTE) and scale efficiency (SE). The SE of all family farms is 0.568, which indicates that there is still room for improvement in the scale efficiency of family farms. The PTE of family farms is 0.341, which means that the low efficiency of family farms is mainly due to the low technical efficiency. Most family farms should further improve the management skill and technology application level.

Table 3. Efficiency of family farms.

Number of Family Farms	Technical Efficiency (TE)	Pure Technical Efficiency (PTE)	Scale Efficiency (SE)
532	0.191	0.341	0.568

4.2. QCA Analysis of Empirical Results

The necessity analysis of single variables is a prior step in conducting a qualitative comparative analysis and is a measure of the explanatory power of a single conditional variable. In general, the degree of consistency above 0.9 indicates that the single variable is necessary for the outcome variable to be generated. The degree of consistency showing the necessity of a single explanatory variable was obtained by running the calculations through the fsQCA 3.0 software and is shown in Table 4.

Table 4. Necessity analysis of single variables.

Conditional Variable	Consistency	Rate of Coverage
Education level	0.636	0.649
Land input	0.570	0.633
Capital input	0.672	0.729
Land transfer period	0.646	0.626
Labor input	0.656	0.673
Loan	0.594	0.495
Introduction of new technology and new equipment	0.808	0.474

The results of the calculation demonstrate that the consistency of all the antecedent variables does not reach 0.9, indicating that no single variable can constitute a necessary condition for the high efficiency of family farms, i.e., none of them have a significant impact on the operational efficiency of family farms independently. Therefore, the mechanism of the influence of each conditional variable on the efficiency of family farms is interdependent. This phenomenon demonstrates that the efficiency of a family farm is not determined by a single variable, but by a combination of factors. Therefore, it is necessary to further analyze different combinations of conditional variables to examine the impact of the combined effect on the operating efficiency of family farms.

By thinking holistically, the combination of multiple antecedent conditions is understood as a ‘subset’ of the outcome driven by combining the relevant antecedent variables to produce the outcome variable, and this combination of different condition variables acting on the outcome variable is referred to as a conditional configuration. In addition, as there is no single necessary condition for the outcome variable, the presence or absence of each antecedent condition may have an impact on the efficiency of the family farm operation, so instead of setting up an explicit counterfactual analysis in the configurational analysis, “presence or absence” is chosen for all conditions in the standardized analysis. Based on the three final solutions output by the logical operations of the Boolean algebra, the intermediate solution of moderate complexity and reasonableness was chosen as the result of the analysis (Table 5).

Table 5. Results of configuration analysis on family farm efficiency $n = 532$.

Conditional Variable	C1	C2	C3	C4	C5	C6	C7
Education level	—	▲	▲	★	★	▲	—
Land input	★	★	—	★	★	★	★
Capital input	▲	▲	▲	▲	▲	▲	▲
Land transfer period	▲	▲	—	★	▲	—	▲
Labor input	★	—	▲	★	▲	—	—
Loan	—	—	▲	▲	—	▲	▲
Introduction of new technology and new equipment	▲	▲	▲	—	★	▲	▲
Original coverage rate	0.275	0.277	0.222	0.175	0.060	0.217	0.228
Unique coverage rate	0.016	0.018	0.035	0.028	0.042	0.007	0.012
Accordance rate	0.890	0.873	0.819	0.870	0.866	0.849	0.866
Overall solution consistency rate				0.841			
Overall solution coverage rate				0.509			

Note: ▲ indicates the presence of variables in the conditional configuration. ★ represents non-existence or absence. — represents inessential.

From the arithmetic results, the configuration analysis for the high operational efficiency of the family farm includes seven different combinations of sufficient conditions, with an acceptable standard of consistency across all configuration. The overall solution consistency rate reached 0.841, meaning that approximately 84.1% of all cases were efficient; the overall solution coverage rate reached 0.509, indicating that the generated conditional configuration explained a total of approximately 50.9% of cases.

In terms of the distribution of each condition in the configuration, “capital input”, “loan”, “introduction of new technology & new equipment”, and “land transfer period” are the most widely covered of all the configuration. “land transfer period” is the combination with the highest coverage among all configuration. This indicates that the main approaches to achieve high operational efficiency for family farms at this stage are through the input of production materials, loan support from financial institutions, the introduction of new technologies and equipment, and stable land transfer.

(1) Configuration II (C2), configuration VI (C6), configuration VII (C7)

Three pathways of configuration II, configuration VI, and configuration VII are similar, and together they can explain about 72% of the cases, while 14.5% of the cases can only be explained by this pathway. Conditions II, VI, and VII show that the higher efficiency achieved by family farms in their operations is mainly attributed to the input of production materials, labor input, the higher education level of family farm leaders, access to loan support from financial institutions and the introduction of new technology and new equipment.

Through the observation of the corresponding case II, it can be found that the land management area is about 73 mu (around 12 acres), and the land transfer period is all above 15 years, with an average of about 23 years. The longer land transfer period helps to stabilize input expectations, and the stable management right arrangement can strengthen the confidence of operators in making investment and operation decisions with long-term consideration [81]. The average number of labor input is about 20, which is 10 times the average labor input per mu of all family farms. The average amount of capital input is about 2.31 million RMB, 17 times the average material input per mu of all of them. A total of 80% of family farms can successfully obtain financial support. The lowest educational level is high school or secondary school, while the highest level is university undergraduate and above. The higher the education level of family farmers is, the more it helps them to absorb and apply new knowledge and technology. The education level of family farmers has a positive effect on the efficiency of family farms, and all of them have introduced new technology and equipment.

Through the observation of the cases corresponding to configuration VI, it can be found that these cases have a land area of 74 mu (around 12.2 acres), an average land

transfer period of about 18 years, and stable land input expectations. A total of 95% have successful financial support, which helps to increase material input, material input of about 2.04 million RMB, 14 times the average value of all family farms' average input per mu (0.165 acres), and labor input of about 19 people on average. The average number of labor input is about 19, which is 9 times the average value of all family farms. In addition, the education level is high, with the lowest being high school or a secondary school education and most being college education or above. All of these family farms in these cases have introduced new technology and equipment.

Through the observation of the cases corresponding to configuration VII, we can see that these cases have a land area of 83 mu (around 13.67 acres). All have a land transfer period of more than 15 years and the average land transfer period is about 28 years. The land inputs are expected to be stable. All have successful financial borrowing support, which helps to increase agricultural factor inputs. The value of material inputs is about 2.23 million RMB, 14 times the average value of all family farms' inputs. The average number of labor input is about 15, which is 7 times the average value of all the inputs. The education level is high, and most of them have high school or secondary school education, which makes it easy to master new technologies, and nearly 80% of them have participated in the government vocational skills training, which is conducive to improving the level of new technologies and equipment use of the family farm leaders, as well as the operational capability of family farms. All of these family farms in these cases have introduced new technology and equipment.

(2) Conditional configuration III (C3)

This pathway explains about 22% of the cases and 3.5% can only be explained by this pathway. Conditional configuration III shows that the higher efficiency achieved in the course of their operations is mainly due to the inputs of production materials, labor inputs, the higher education level of those in charge of family farms, access to financial institutions for loan support and the introduction of new technologies and equipment. Looking at the cases corresponding to this configuration, we can see that these cases have a land area of about 962 mu, an average land transfer period of about 17 years, and stable land input expectations. All have successful financial support and can guarantee production material inputs under a large-scale operation, with production material inputs of about 3.58 million yuan, which is a larger average input per mu, at twice the average value of the average input per mu of all family farms. The average labor input is about 33 people, and the average labor input per mu is slightly higher than the average labor input of all family farms, and they are highly educated, and all obtain tertiary education or above, which makes it easier for them to master new technology and have stronger management skills. All of these family farms in these cases have introduced new technology and equipment.

(3) Conditional configuration I (C1)

This pathway explains about 18% of the cases and 2.8% of the cases can only be explained by this pathway. Achieving efficiency is mainly due to the input of production materials, the higher level of education of leaders of the family farm, and the introduction of new technologies and equipment. Looking at the cases corresponding to this configuration, it can be found that these have a land operation area of about 69 mu and an average land transfer period of about 23 years. Land input expectations are stable. Moreover, these cases have a production material input of about 880,000 yuan with larger average input per mu, at six times the average value of the average input per mu of all family farms. They obtain higher levels of education, with mostly high school or secondary school education. More than half of the personnel have participated in the training, which helps to master new technologies and improve their business management capabilities. All of these family farms in these cases have introduced new technology and equipment.

(4) Conditional configuration V (C5)

This pathway can explain about 6% of the cases and 4.2% of the cases can only be explained by this one. Compared to the above five pathways, it demonstrates through conditional configuration V that family farms achieving higher efficiency in their operations were mainly due to stable land transfer, production material inputs and labor inputs, and did not depend on the introduction of new technologies and equipment. Through the corresponding cases, it can be observed that the leaders of the family farms in these cases have low levels of education. All of them obtain junior high school education and thus have little knowledge and application of new technologies for their farms. The average land operation area is about 103 mu, and the land transfer period is above 15 years, with an average land transfer period of about 18 years. The long land transfer period helps to stabilize input expectations and increase agricultural factor input. With an average production material input of about 1.93 million yuan, the average input per mu is large and it is 10 times the average input per mu of all family farms. Twelve units of labor input are four times the average input per mu of all family farms.

(5) Conditional configuration IV (C4)

This pathway can explain about 17.5% of the cases, and 2.8% of the cases can only be explained by this one. The family farm owners in Configuration IV have limited educational attainment, with either junior high school or primary school background, and therefore obtain little knowledge and application of new technologies. These family farm owners do not rely on the introduction of new technologies and equipment to achieve high efficiency for their farms but access to financial support and production inputs. Looking at the cases corresponding to this configuration, we can see that these cases have an average land operation area of about 38 mu and an average land transfer period of about 9 years, all of which have successful financial support in terms of borrowing and help to increase the input of production materials. The average production input of family farms is about 450,000 yuan, and the average amount of input per mu is six times the average value of input per mu of all family farms.

5. Discussion

In this paper, 532 family farms in 27 Chinese provinces (municipalities and autonomous regions) are investigated. A DEA model is used to estimate the efficiency of family farms, and qualitative comparative analysis (QCA) is used to analyze the combination of factors for family farm's efficiency improvement. The results demonstrate that, first, the efficiency of all family farms in China now is not high, and both pure technical efficiency and scale efficiency of family farms have a large room for improvement, while the improvement room of technical efficiency is relatively larger than that of scale efficiency. Second, among the seven factors, no single factor can constitute a sufficient condition for the high efficiency of family farms, that is, it cannot have a significant indigenous impact on the high efficiency of family farms. Various factors collectively have an impact on the management efficiency of family farms. Third, there are mainly seven paths to achieve efficient management of family farms. The introduction of new technology and new equipment, long land transfer period, great input of production materials and labor force, and financial support are the core driving forces for the improvement of family farm operation efficiency at the present stage. Most of the family farmers with higher education levels achieve high efficiency by introducing new technology and new equipment. Family farmers with a low education level often achieve high efficiency through long land transfer period and high input of production materials and labor. Fourth, in the efficient configuration paths, land input is a mostly inessential factor and land scales of most high-efficiency family farms do not reach the average level, which is consistent with the uncertain results of the impact of land scale on efficiency in marginal "net effect" studies. For example, Sen [82], Heltberg [83], and Cornia [21], respectively, found a reverse relationship between farm-scale and land productivity based on farm studies on 15 developing countries such as India and

Pakistan. Deolalikar [84] and Helfand [26] found a positive relationship between farm size and land productivity based on the study of the relationship between family farm size and production efficiency in India and Brazil. Fifth, most of the family farms that realized the efficient management introduced new technology and new equipment. The high education level of farm leaders and technical ability of operators play an important role in realizing the efficient operation. This is also consistent with Li Shaoting's conclusion that the current low efficiency of family farms is mainly due to the low pure technical efficiency based on the study of 234 exemplary family farms in Shandong [85]. Moreover, for efficient family farms, the amount of capital investment and the amount of labor input are relatively large, which shows that family farms are still in the cultivation and development stage of capital investment and intensive labor investment. Lastly, some high-efficiency family farms have achieved high efficiency through capital investment and financial support under the condition of small labor input and no introduction of new technology or new equipment.

6. Conclusions

Therefore, how to effectively improve management efficiency is the key to the sustainable development of family farms. This demonstrates that although the current family farms are still in the cultivation stage of capital and labor-intensive investment, they do not mainly rely on traditional input factors such as labor to achieve high efficiency. To address the practical problems of the family farm's management, this paper explores the path to achieve efficient management and accordingly takes measures to effectively improve the management efficiency of family farms, with the goal of maximizing the role and function of this kind of new agricultural management subject. At this stage, we need to focus on the following aspects. First, based on the reality of family farms, we should take the strategy of intensive and efficient management. Given the fact that the land scale of high efficiency family farms does not reach the average value, it is recommended not to blindly expand the scale of land so that the operating risks can be avoided, to give full play to the role of family labor and to control the scale of employment. Second, it is recommended to pay attention to the accumulation of human capital of family farm practitioners, attract more highly educated people to return home for family farm management, strengthen the vocational training of family farm operators, and improve the skill of applying new technology and new equipment. Third, it is recommended to create a good institutional environment for the development of family farms, effectively protect the land management rights of family farms, and stabilize the expectations of family farm operators. It is also recommended to increase financial support such as credit funds for family farms, and alleviate the difficulty of loans application by using discounts and insurance subsidies. In addition, actively exploring new ways such as mortgage, pledge, and guarantee loans to reduce the difficulty of credit loans is advised.

Although this paper makes an in-depth analysis of the realization path of the efficient management of family farms by qualitative comparative analysis of fuzzy sets, there are still some limitations, which need follow-up studies. First, in terms of research methods, the fuzzy set qualitative comparative analysis method is helpful to explore the configuration path of the efficient management of family farms based on cross-case studies; however, it is limited to a comparison among a small number of variables, and the fine-grained measurement of various variables is still insufficient. Therefore, in the future, the micro-forces and mechanisms of various variables in the management efficiency of family farms can be investigated in depth through supplementary case studies. Second, this paper studies the family farms of the national sample and does not further explore the efficiency of family farms of different regions and different types. Further exploration from the angle of differences among regions or types is also the direction of future research.

Author Contributions: Conceptualization, W.L. and W.Y.; methodology, W.L.; software, W.L.; validation, W.L.; formal analysis, W.L. and W.Y.; investigation, W.L.; resources, W.L. and L.W.; data curation, W.L.; writing—original draft, W.L. and Q.W.; writing—review and editing, W.Y. and S.Z.; visualization, W.L.; supervision, W.Y. and S.Z.; project administration, W.Y.; funding acquisition, W.Y. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the Fundamental Research Funds for the Central Universities (2021SRY05) and the Major Project of National Forestry and Grassland Administration of China (2019132707).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data in this study are collected from questionnaires.

Conflicts of Interest: The authors declare no conflict of interest.

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