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Sustainable Development between Demonstration Farm and Agricultural Labor Productivity: Evidence from Family Farms in the Mountainous Area of Western China

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Abstract: Agricultural labor productivity is an important indicator that reflects the sustainable development of agriculture and rural areas. Demonstration farms provide an important link between small-scale farmers and modern agriculture in mountainous area of western China, which is playing an important role in improving labor productivity. This paper focuses on using the PSM-logit model and sensitivity analysis to empirically test the causal relationship between demonstration farms and labor productivity, and a micro-large sample of 1823 family farms was adopted. The highlighted findings are as follows: the average labor productivity of the demonstration farm is 2.8 times higher than that of the non-demonstration farm. There is a significant positive correlation between demonstration farms and labor productivity. Utilizing demonstration farms, when all control variables are added, can remarkably promote farm income by CNY301458 on average. In the matched sample, and under scenarios controlling for other covariates, we saw that demonstration farms can significantly enhance the farm income of CNY285108, CNY288509, and CNY291077 on average, respectively, after taking the radius matching, the kernel matching, and the nearest neighbor matching. The research inspired us to enhance the demonstrative establishment of family farms and accelerate the rate at which comprehensive development benefits are derived from demonstration farms. The results of this research could provide a policy reference for the promotion of high-quality development and the sustainable development of family farms in China and serve as an experience reference for promoting sustainable development of agriculture and rural areas globally.

Keywords: demonstration farm; labor productivity; sustainable development; sustainable agricultural economy; family farm

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1. Introduction

Improving agricultural labor productivity is an important symbol of realizing agricultural modernization [1,2]. First, it directly means increasing farm income, which is conducive to promoting the sustainable development of the agricultural economy. Secondly, it can drive farm employment, which is conducive to promoting the sustainable development of agricultural society. At the same time, the green development of agriculture also imposes new requirements on the improvement of labor productivity, which will also be conducive to indirectly promoting sustainable development of agricultural ecology. Family farms are the basis for the functioning of agricultural sectors in many regions of the world [3] and also serve as an important link between small-scale farmers and modern agriculture in China, especially in the western mountainous areas. The originally intent behind establishing demonstration family farms is to improve agricultural labor productivity, which has important and long-term significance in promoting agricultural and rural modernization and promoting the common prosperity of farmers and rural areas [4]. Family farms can effectively extend industrial chains, expand supply chains and improve value chains, which plays an important role in helping to eliminate poverty and assisting farmers to raise their income [5,6], and it has gradually developed into the important approach of promoting agricultural and rural modernization [7,8]. The Communist Party of China (CPC) have always insisted on solving the problems of agriculture, rural and farmers as the top priority of all developmental work [5]. The implementation of the family contract responsibility system promotes the development of the rural economy in China. However, with the development of the historical process, some problems have been exposed, such as small scale of agricultural management, scattered management, backward agricultural technology and low production efficiency [9–11], which make it difficult to elevate the improvement of agricultural labor productivity. Therefore, it is extremely important to find an effective business model that can not only effectively compensate for the shortcomings of traditional small-scale farmer management, but also promote the moderate-scale management of land.

In China, the No. 1 central document of the CPC Central Committee first saw the phrase "family farm" written in as the new type agricultural business entities in 2013 [12]. Since then, there has been an emphasis on strongly supporting family farm development [12–20], which has become an important topic of discussion in the political and academic circles. A series of family farms demonstration cases have been established and popularized [21]. This initiative is an important channel for the improvement of labor productivity and an important experience in promoting the revitalization of the rural industry. Mountainous areas in western China are the key support areas for the realization of agricultural modernization and sustainable development. In this paper, Tongren city, with the geographic structure characteristic of the western mountain region [4], is selected as the study area. An empirical test on the causal relationship between demonstration farms and agricultural labor productivity, with a micro-large sample of 1823 family farms and PSM-logit model, is adopted. Additionally, this article attempts to answer the following three questions: (1) What is the labor productivity level on family farms in the mountainous area of western China? (2) Can demonstration farms improve labor productivity? (3) How much room is there for demonstration farms to contribute to improving labor productivity?

The highlights several innovations of this paper are summarized as follows: Firstly, this paper researches the effects of demonstration farm on labor productivity, which has important and far-reaching theoretical value and practical significance for promoting the connection between small-scale farmers and modern agriculture. Secondly, we select Tongren city as the research area. This site has mountainous geographic characteristics and green ecological advantages [4]. Located in the mountainous area of western China, the area has special value and representational significance. Thirdly, we focus on matching two groups of samples, namely, demonstration farm and non-demonstration farm by propensity score matching (PSM) method, and then calculating the average treatment effect of the matched sample, further examines the sensitivity of PSM estimation results to "hidden bias". Based on the above innovations, the main academic contributions of this paper can be summarized as follows. The study is not only helpful in that it provides an effective development path for small-scale farmers in mountainous area to increase their income and become wealthy, but also helpfully provides an empirical basis and experiential reference for the development of modern agriculture in China. Finally, it is helpful as it provides a typical case in China for other countries or regions to use for the promotion of sustainable agricultural development.

The rest of the paper is structured as follows. Section 2 provides a literature review. Section 3 proposes a Theory and Method. Section 4 describes the Variables and Data. Section 5 details the Results and Discussions. Section 6 summarizes the Conclusions and Implications of this paper.

2. Literature Review

If a researcher looks extensively at the relevant theoretical research and academic exploration in policy and academic circles, they will find that the existing literature mainly comprises relatively rich research into the connotation and extension of family farm, the development of driving forces and factors, the development of efficiency and benefits, and the development of a path and policy proposal for improving labor productivity in family farm. This content lays a solid logical foundation for the research ideas and contents of this paper.

In the literature, there are numerous studies on the problems of connotation and extension of family farms. The development of family farms in Brazil [22,23], the Netherlands [24,25], France [26,27], Japan [28,29] and other countries has achieved good results, and the systems and mechanisms used are relatively perfect. The operation mode of first using a pilot and then promoting the system has been adopted in China, and a series of typical cases of family farm development have emerged [30–35]. Most studies fully indicate that family farms play outstanding roles and have obvious effect [5–7,35–37]. They also show the following remarkable characteristics centrally, such as family management, specialized division of labor, socialized cooperation, use of modern technology, enterprise operation, modern farming, market-oriented practice, agricultural commercialization, agricultural mechanization, green management, labor stability, and being agricultural income-oriented, etc. [38,39].

The subject of the development driving force and the influencing factors of labor productivity of family farms has attracted a great deal of attention and discussion from academic circles. In general, the development process of family farms is a process of continuously improving labor productivity to improve production power and grant the comparative advantages of low labor supervision cost, good scale benefit, high production efficiency, etc. [5–7,35–37]. Notwithstanding, the economic, social and ecological benefits of family farms can also be disturbed by various influencing factors [6,7,35–37,40,41]. For instance, mechanisms and tools of agricultural policy, agricultural mechanization, crop establishment, wage labor, quality capabilities of agricultural managers, level of internal management, rural financial credit system, satisfaction of social service demand, support for agricultural science and technology, and quality and safety of agricultural products, etc. [40–46]. As it should be, objectively speaking, the development of family farms in different countries and regions at different stages of development is affected by natural, social, economic, cultural, technical and other factors. Family farms also face many resource constraints.

There are many studies on the development efficiency and benefits of the labor productivity of family farms. Some scholars have reached relatively consistent conclusions. Some argue, for example, that welfare emerges as a legitimate element for the analysis of the family farm economy [47]; others assert that the larger the area of a small-scale family farm is, the greater its economic sustainability will be [46]. There is a positive correlation between the managing efficiency and economic benefits of family farms, and the management efficiency of family farms that adopt new technologies is relatively higher than that of family farms without new technologies [48]. The use of demonstration farms has a significant positive impact in terms of improving the develop benefits of family farms, increasing farm income, promoting the sustainable development of family farms, and enhancing the sense of the gain, happiness and security of farmers [6,7,35–37]. Of course, some scholars also found that the overall level of technical efficiency of Chinese family farms is relatively low and that the efficiency value is not high. There is a large room for improvement in both pure technical efficiency and scale-related efficiency [9,30].

There are also many scholars who have given constructive insights into the development path and policy recommendations for improving labor productivity in family farms. The development of family farms is a systematic, ecological, dynamic and sustainable process that needs to combine the internal force and external support of family farms organically [49]. Scholars should combine these policies with regional agricultural development, improve policy design for family farm development and popularize typical cases of demonstration farms [5,35,36]. We must establish and improve the efficiency improvement mechanisms and incentive and restraint system of demonstration farms [9]. We should cultivate new types of professional farmers [37], promote the integration of universities, enterprises and bases through “industry-university-research” cooperation [6], and cultivate demonstration farms with local characteristics [36]. At the same time, there is a need to improve farm infrastructure conditions, promote the rational allocation of resource elements, and strengthen agricultural green technology innovation and diffusion [50] in order to improve the labor productivity and economic sustainability of family farms [43], ensure the healthy and efficient development of family farms, and then accelerate the advancement of agricultural modernization [51].

In summary, the relevant research results at the domestic and foreign levels fully demonstrate the effectiveness and persistence of the demonstration farm, and various representative views provide rich theoretical support and empirical borrowing material for the research in this paper and lay the scientific research direction and idea framework. However, it is worth paying close attention to the fact that the following aspects of research are necessary to further deepen and expand our understanding in this area. This is also the unique feature of this paper.

Firstly, from a theoretical point of view, there is at present little to read literature when researching the causal effect of demonstration farm on labor productivity. This paper researches the effect of demonstration farms on labor productivity, a practice that has important and far-reaching theoretical value and practical significance for consolidating the family farm management system, promoting the connection between small-scale farmers and modern agriculture, increasing farm economic income, and advancing agriculture and rural sustainable development. This will also be the logical starting point of the strong argument presented in this paper.

Secondly, in the research into the existing literature on family farms, it can be observed that the eastern, northeastern and central parts of China are often selected as research areas. However, there is little literature on choosing western China as a representative area for research. This paper selects Tongren city as the research area. With mountainous geographic characteristics and green ecological advantages [4] in the mountainous area of western China, this area has special value and representational significance. It is beneficial to compare the heterogeneity of farm development in the western region with other regions, and also to provide typical cases of farm development for other countries or regions.

Thirdly, it can be seen from the research method used that the existing research on family farms mainly uses small sample analysis. For this reason, the micro-large sample data is adopted in this paper, that is, the empirical analysis based on the micro-large sample of 1823 family farms in the mountainous area of western China with relatively stronger reliability and validity is used. At the same time, this paper focuses on matching two groups of samples, namely, demonstration farms and non-demonstration farms via the PSM method, and then calculating the average treatment effect of the matched sample. In addition, this research further examines the sensitivity of PSM estimation results to “hidden bias”. This helps to avoid bias in the estimation results, which it is necessary to treat with the samples data before empirical research, due to the non-randomness of sample selection.

3. Theory and Method

3.1. Theoretical Mechanism

Reforming traditional agricultural theory [1] has played an important role as a theoretical basis supporting the process of promoting agricultural modernization in many countries. As an important component of the entire society, the agricultural industry not only provides development conditions for agricultural modernization, but also itself creates driving momentum for agricultural modernization [1], and its contributions, such as food, raw materials, markets, elements, and foreign exchange [2], have played indispensable and important roles in the process of agricultural modernization. Schultz [1] notes, however, that traditional agriculture in developing countries cannot contribute to economic growth, that only modern agriculture can make a significant contribution to economic growth, and that the key to the question is how to transform traditional agriculture into modern one. Furthermore, the question of how to transform weak traditional agriculture into a high-labor-productivity economic sector is also a central issue in transforming traditional agricultural theory. However, there are certain differences among different regions in China. For the mountainous area of western China, it is worth thinking about the kind of business entity that should be explored to improve agricultural labor productivity with adaptations to local conditions in the process of agricultural modernization. The theoretical mechanism for this paper is shown in Figure 1.

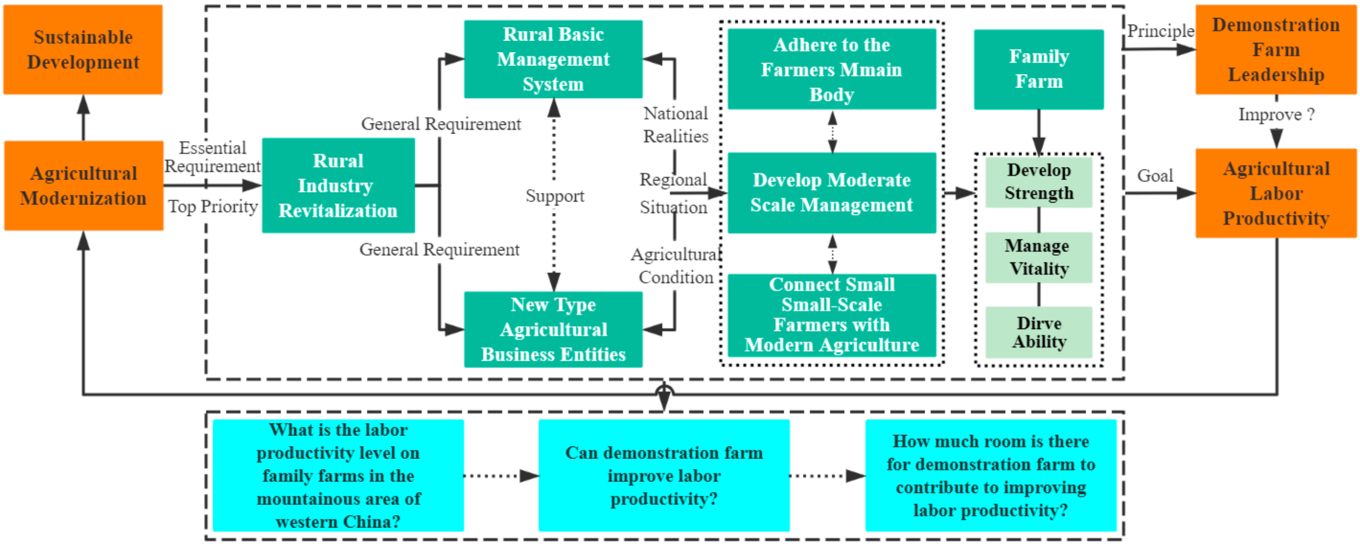

Figure 1. Theoretical mechanism for sustainable development between demonstration farm and agricultural labor productivity.

Firstly, transforming traditional agricultural industry implies the need to advance the revitalization of rural industry, which can neither be separated from the support force of the new type of agricultural business entities [5–7,35–37,51] nor from farmers, who occupy the primary position in this industry. Family farms in China mainly refer to the use of family members as the primary labor force and the family as the basic operational unit, and they are engaged in agriculturally scaled, standardized, and intensive production operations, which is the main business entity in modern agriculture [52]. Obviously, family farms are one of the best business entities to promote rural industry revitalization [5].

Secondly, family farms adhere to the rural basic management system and have played an important role as a booster in the process of agricultural modernization, and the issue of its scale is very noticeable in the theory of how to organize agricultural production. Schultz [1] suggests that we should not blindly establish large-scale farms, but rather create family farms that integrate ownership and management rights, adapt to market changes, and provide economic incentives and rewards for effective decision making. Clearly, Chinese family farms are an effective model for moderate-scale business.

Thirdly, there are still many small farmers in China, especially in western mountainous areas. Family farms are effective against the background of the realistic contradictions between and challenges of small-scale farming and modern agricultural development. Additionally, they serve to link these two issues. Comparatively speaking, the economic, social and ecological benefits of demonstration farms [6,7,9,35–37] are very significant.

Based on taking the above analyses together, we propose the following theoretical hypotheses.

Hypothesis 1. *The agricultural labor productivity level on family farms in the mountainous area of western China is uncertain.*

Hypothesis 2. *Demonstration farms have a positive effect on agricultural labor productivity.*

Hypothesis 3. *The room for demonstration farms to improve agricultural labor productivity is uncertain.*

3.2. Method

First of all, the paper draws on the experience of the Rubin causal model (RCM, also known as a counterfactual framework) [53,54], which can reflect whether there is a causal effect of demonstration farms on labor productivity.

Based on whether or not a family farm is a demonstration farm, the treatment group (the treated group) and the comparison group (the control group) are composed. That is, the treatment variable $DF_i = \{0, 1\}$. Among these values, "0" represents the demonstration farm, and "1" represents the non-demonstration farm. In this case, for a family farm sample i, there may be two states of the treatment variable DF on labor productivity (LP). These are as follows:

$$LP_i = \begin{cases} LP_{1i}, & if \;\; DF_i = 1 \\ LP_{0i}, & if \;\; DF_i = 0 \end{cases} \tag{1}$$

where LP_i is the labor productivity of sample i, LP_{1i} is the labor productivity of sample i of demonstration farm, and LP_{0i} is the labor productivity of sample i of non-demonstration farm. In order to ensure that the members in the sample can be matched, the matching assumption needs to be satisfied on each possible value of X_i and ensure that the propensity score of the treatment group and control group share common support. For any value of X_i, there exists $0 < P(X_i) < 1$. The common support of the propensity score is clearly depicted in Figure 2.

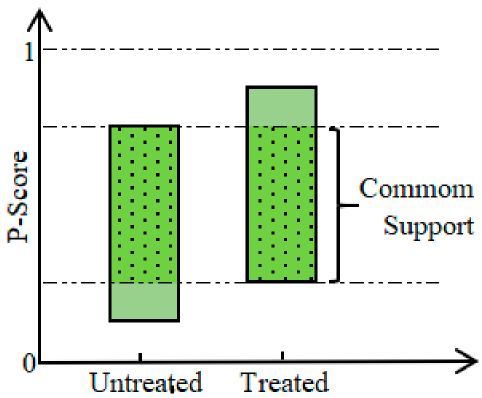

Figure 2. Common support of the propensity score.

Considering that the practice of establishing demonstration farms may be influenced by other factors, direct regression estimation may lead to biased empirical results. In view of this, firstly, the PSM method is used to search for control groups that are similar to those recognized as demonstration farms in order to eliminate the problem of sample selectivity so that the treated group and control group can have a common trend. Meanwhile, combining multiple logit models to estimate the true effects of the demonstration farm can ensure the accuracy and effectiveness of the empirical results to a large extent. The general steps [54,55] for calculating the average treatment effect using the PSM method are as follows.

Step 1: Select covariates. In order to ensure the quantity and quality of the selection of covariates and avoid bias, the relevant variables affecting (LP_{0i}, LP_{1i}) and DF_i should be taken into account as much as possible.

Step 2: Estimate propensity score. The purpose of estimating the propensity scores of the treatment group and the control group based on the logit regression model is to reduce the dimension of the multidimensional differences between the treatment group and the control group [35,54,55] so as to facilitate the subsequent matching of the propensity scores. This is shown in the Formula (2).

$$P(X_i) = P\ (DF_i = 1\ \mid\ X_i) = \frac{exp\ \left(\beta X_i'\right)}{1 + exp\ \left(\beta X_i'\right)} \tag{2}$$

where X_i is the covariates matrix, X_i' is the covariates vector, and $P(X_i)$ indicates the propensity score of the treatment group and the control group under the X_i.

Step 3: Propensity score matching. According to the suggestions of scholars [35,54,55], the three most commonly used and popular matching methods are adopted in this paper, namely, the nearest neighbor matching within caliper, radius matching, and kernel matching methods.

The absolute distance of propensity score for radius matching is as follows.

$$D\ (P_i) = \|P_{1i} - P_{0j}\| < \varepsilon \tag{3}$$

where P_{1i} and P_{0j} are the propensity score of the ith treatment group and the propensity score of the jth control group, respectively, and ε is the prior setting tolerance for matching. Generally speaking, caliper size uses a quarter of the standard deviation of the propensity score via sample estimates [35,54–56], that is, $\varepsilon \leq 0.25\sigma_{pscore}$, σ_{pscore} is the standard deviation of the propensity score by sample estimates.

The absolute distance of propensity score for nearest neighbor matching within caliper is as follows.

$$D\ (P_i) = \min_j\ \|P_{1i} - P_{0j}\| < \varepsilon \tag{4}$$

The purpose of nearest neighbor matching within the caliper is to find the nearest matching within the given caliper range. Under normal circumstances, $\varepsilon \leq 0.25\sigma_{pscore}$.

The weight expression of the propensity score for kernel matching is as follows.

$$W\ (i,\ j) = \frac{K\ [(X_j - X_i)/h]}{\sum_{k\ :\ D_k=0} K\ [(X_j - X_i)/h\ ]} \tag{5}$$

where $W\ (\ i,\ j)$ is means the weight suitable for the matched $(i,\ j)$, h is the bandwidth, and $K(\ \cdot\ )$ is the kernel function.

Step 4: Balance test. The purpose of using the balance test on the matched samples is to ensure that there are no significant statistical differences in the covariates between the matched samples of treatment group and control group. It is generally calculated with the "standardized bias" of each covariate. The calculation is performed as shown in Formula (6).

$$\frac{|\overline{X_1} - \overline{X_0}\ |}{\sqrt{(V_{1X}^2 + V_{0X}^2\ )/2}} \tag{6}$$

where V_{1X}^2 and V_{0X}^2 are the sample variance of the covariates of treatment group and control group, respectively. It is generally required that the standardization difference should not exceed 10%. If it exceeds this value, the second or first step should be repeated until there is no significant difference.

Step 5: Calculate average treatment effect on the treated. The average treatment effect on the treated (*ATT*) is mainly calculated according to the matched sample in this paper. *ATT* formula is as follows.

$$ATT \equiv E\ (LP_{1i} - LP_{0i}\ \mid\ DF_i\ = 1) \tag{7}$$

The formula of estimator for average treatment effect on the treated is as follows.

$$\widehat{ATT} = \frac{1}{N_1} \sum_{i:\ DF_i\ =1} \left(LP_{1i} - \widehat{LP_{0i}}\right) \tag{8}$$

where $N_1 = \sum_i DF_i$ is individual number of the treatment group, and $\sum_{i:\ DF_i=1}$ meant the total addition of individual number in the treatment group.

General steps of the propensity score matching is draw the outline of Figure 3.

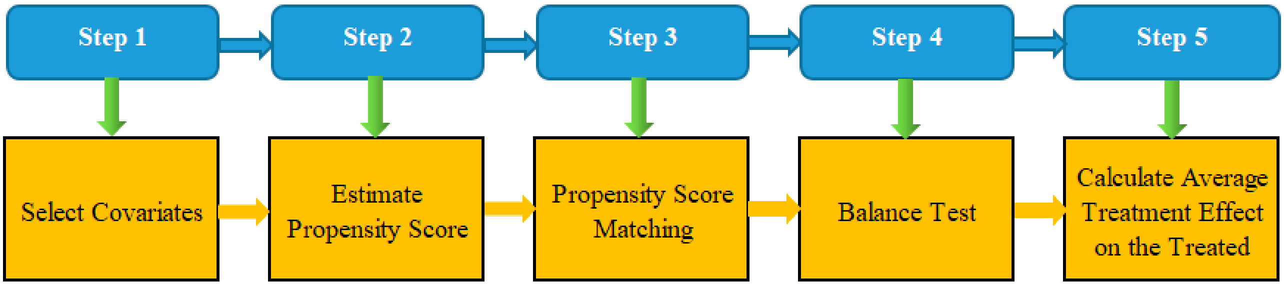

Figure 3. General steps of the propensity score matching.

4. Variables and Data

4.1. Variables Selection and Definition

Due to the difficulty of obtaining complete statistical data on variables, this paper draws on the research experience of other scholars for reference [6,7,35–37], considers the representativeness, availability and authority of the statistics, and follows the principles of consistency, integrity and scientificity of variables [4,57]. In view of these methods, which select the variables closely related to demonstration farms and the labor productivity of family farms, three classes of variable are included as follows. The settings and definitions of the variables are listed in Table 1.

Table 1. The settings and definitions of the variables.

Variables Classification	Variable Name	Variable Symbol	Variable Definitions	Variable Assignment
Dependent Variable	Labor Productivity	L.P.	The per capita production value of family farm	Calculate according to the annual output value of family farm and the family laborers
Core Independent Variable	Demonstration Farm	D.F.	Whether it is recognized as a demonstrative family farm	1 = Family farm is a demonstration farm; 0 = Otherwise
Control Variable	Head Farmer Gender	F.G.	The gender of the head farmer	1 = Head farmer is male; 0 = Otherwise
	Head Farmer Age	F.A.	The age of the head farmer	Statistics by actual age
	Head Farmer Education	F.E.	The educational level of the head farmer	1 = Illiteracy; 2 = Primary school level; 3 = Junior high level; 4 = Senior high level or secondary vocational school level; 5 = College degree or above
	Family Laborers	F.L_1	The number of family laborers engaging in agriculture	Statistics by the numerical value
	Farm Products	F.P.	The types of agricultural products operated by family farms	1 = Single planting industry; 2 = Single breeding industry; 3 = Combination of planting and breeding; 4 = Mixed planting industry; 5 = Mixed breeding industry
	Farm Land	F.L_2	The contiguous land area of family farm	Take logarithm according to the numerical value
	Managements Types	M.T.	The managements types or models of family farm	1 = Mountainous planting; 2 = Planting on dam land; 3 = Animal husbandry; 4 = Aquaculture; 5 = Integrated planting and breeding
	Management Experience	M.E.	Operating years after being recognized as a family farm	Statistics by the numerical value
	Farm Distance_County	D.C.	The distance from the head farmer location to the county	Statistics by actual distance
	Farm Distance_Town	D.T.	The distance from the head farmer location to the commercial market town	Statistics by actual distance

(1) Dependent variable. Improving labor productivity is the core indicator of agricultural modernization. In real-life applications, promoting the improvement of agricultural labor productivity will contribute to raising the income of agricultural family laborers. This, in turn, promotes the sustainable development of family farms. In view of this, this paper sets the labor productivity (L.P.) as the outcome variable, which is the per capita production value of family farms.

(2) Core independent variable. From a practical point of view, when a family farm is established like a demonstration farm, it means that the farm has complete infrastructure, moderate large-scale management, scientific management, production standards and specifications, obvious demonstrations driving roles, etc. These measures mean that the productivity of the farm is higher than a certain probability of the average level of the whole city, meaning that the per capita income of the farm is higher than a certain ratio of the per capita income of local farmers. Thus, in relative terms, the more obvious the role of demonstration as a driving force is, the more it can actively drive the surrounding farmers to increase their income. Therefore, the demonstration farm (D.F.) is taken as the treatment variable.

(3) Control variable. In this paper, the following covariates that have a close relationship with outcome variable and treatment variable are also selected as control variables to reflect the basic situation of individual characteristics, labor input, operating conditions, experience accumulation, and agricultural environment of the family farm. Examples include head farmer gender (F.G.), head farmer age (F.A.), head farmer education (F.E.), family laborers (F.L_1), farm products (F.P.), farmland (F.L_2), management type (M.T.), management experience (M.E.), farm distance_county (D.C.), farm distance_town (D.T.), etc.

4.2. Data Interpretation and Source

Before introducing the data sources, it is necessary to define the family farm of this paper. The family farm selected in this paper mainly refers to a new type of agricultural business entity identified by the Agriculture and Rural Bureau of Tongren city that takes family members as the main labor force, agricultural income as the main source, and engages in moderate-scale, intensive and commercialized production and management of agricultural land. According to the geographic characteristics of the mountainous area in Western China, this territory mainly includes the following business types, including mountain planting type, dam land planting type, animal husbandry type, aquaculture type, and comprehensive planting and breeding type. Demonstration farms are established on the basis of encouraging farmers to operate independently, cultivated by the township government, recommended by the county government, and approved by the municipal government in areas where meet the conditions of moderate business scale, standardized farm business management, good and safe product quality, significant economies of scale, strong demonstration and driven benefits. Some of the variables were derived from the family farm statistics data of the Agriculture and rural Bureau of Tongren city. Data collection, sorting out and statistical analyses were carried out on some variables by the authors of this study based on the basic statistical data of Agricultural and Rural Bureau of Tongren city. The empirical data used are mainly from the 1823 family farms in Tongren city from 2013 to 2020.

4.3. Descriptive Statistics Analysis

The results of the descriptive statistics analysis of the variables are shown in Table 2. The statistical results of the mean, standard deviation, skewness, kurtosis, and number of samples from the control group and treated group are displayed in detail in the table, respectively. On the whole, the distribution of most variables is relatively concentrated, and the degree of dispersion is small. However, it is also found that the standard deviation of farm land (F.L_2), labor productivity (L.P.), farm distance_county (D.C.), and farm Distance_Town (D.T.) are relatively high, which shows that there are some differences between farm land, labor productivity, farm distance_county, and farm Distance_Town in the sample data to some extent. Meanwhile, farmland (F.L_2), labor productivity (L.P.), and farm distance_town (D.T.) have higher positive skewness and positive kurtosis, as the results show that there are many extreme values in the data series of the above variables, there are outlier data values, and the distance between the data and the mean value is relatively large. In addition, it is worth mentioning that the average labor productivity of the treated group is 2.8 times higher than that of the control group.

Table 2. The descriptive statistics analysis of the variables.

Statistic	Control Group					Treated Group				
	Mean	**St. Dev.**	**Skewness**	**Kurtosis**	**N**	**Mean**	**St. Dev.**	**Skewness**	**Kurtosis**	**N**
L.P.	16.1355	38.4140	17.7482	404.3198	1411	45.4898	60.2822	4.5295	31.2134	412
F.G.	0.8590	0.3482	−2.0627	5.2546	1411	0.8204	0.3843	−1.6693	3.7865	412
F.A.	42.2481	8.5314	−0.4444	4.4944	1411	42.1359	8.6332	−0.4800	4.3414	412
F.E.	3.2069	0.7074	−0.1254	4.1774	1411	3.2403	0.7500	−0.1466	4.3000	412
F.L_1	3.5734	1.8029	2.5748	17.8143	1411	3.8835	2.7306	6.7468	80.3920	412
F.P.	2.3104	1.2677	0.7360	2.3187	1411	2.2791	1.1806	0.8323	2.6750	412
F.L_2	178.7068	167.9150	35.3037	1294.5500	1411	171.3880	505.9797	13.5441	228.8064	412
M.T.	2.4068	1.1468	0.4533	2.7110	1411	2.5534	1.1203	0.3289	2.8296	412
M.E.	4.1665	1.4046	−0.1176	3.4896	1411	4.4636	1.3166	0.5946	4.0862	412
D.C.	38.0789	25.3554	1.1631	4.0376	1411	31.0921	20.7681	1.5440	6.6040	412
D.T.	9.4897	10.1593	4.0041	25.5462	1411	8.0769	8.6788	3.9902	25.3037	412

5. Results and Discussions

5.1. Correlation Analysis

The detailed changes of the correlation analysis of the variables are arranged in Table 3. As a whole, from the data in the table, it can be seen that demonstration farms (D.F.) showed positive correlations with family laborers (F.L_1), management types (M.T.), management experience (M.E.), and labor productivity (L.P.). They passed the statistical significance level test at 1%, 5%, 1% and 1%, respectively. Demonstration farms (D.F.) were found to be negatively correlated with head farmer gender (F.G.), farm distance_county (D.C.), and farm distance_town (D.T.), and passed the statistical significance level test at 10%, 1% and 5%, respectively. At the same time, we also found that there was a significant positive correlation between labor productivity (L.P.) and head farmer education (F.E.), but there was a significant negative correlation between labor productivity (L.P.) and head farmer gender (F.G.), head farmer age (F.A.), family laborers (F.L_1), farm products (F.P.), respectively.

Table 3. The correlation analysis of variables.

	D.F.	**F.G.**	**F.A.**	**F.E.**	**F.L_1**	**F.P.**	**F.L_2**	**M.T.**	**M.E.**	**D.C.**	**D.T.**	**L.P.**
D.F.	1.0000											
F.G.	−0.0452 *	1.0000										
	(0.0536)											
F.A.	−0.0055	0.0332	1.0000									
	(0.8150)	(0.1562)										
F.E.	0.0195	0.0055	−0.1474 ***	1.0000								
	(0.4065)	(0.8153)	(0.0000)									
F.L_1	0.0632 ***	0.0222	−0.0140	0.0389 *	1.0000							
	(0.0069)	(0.3431)	(0.5490)	(0.0966)								
F.P.	−0.0105	−0.0335	−0.0176	−0.0255	−0.0002	1.0000						
	(0.6545)	(0.1529)	(0.4529)	(0.2764)	(0.9940)							
F.L_2	−0.0021	0.0144	−0.0234	0.0027	0.0221	−0.0280	1.0000					
	(0.9278)	(0.5380)	(0.3175)	(0.9098)	(0.3459)	(0.2327)						
M.T.	0.0537 **	0.0324	−0.0573 **	−0.0201	0.0115	0.2347 ***	−0.0503 **	1.0000				
	(0.0219)	(0.1661)	(0.0143)	(0.3908)	(0.6249)	(0.0000)	(0.0317)					
M.E.	0.0894 ***	−0.1186 ***	−0.0892 ***	−0.1345 ***	0.0277	0.0126	−0.0330	0.0037	1.0000			
	(0.0001)	(0.0000)	(0.0001)	(0.0000)	(0.2377)	(0.5915)	(0.1585)	(0.8759)				
D.C.	−0.1190 ***	0.0428 *	0.0383	0.0414 *	−0.0845 ***	−0.0181	0.0519 **	−0.0598 **	0.0328	1.0000		
	(0.0000)	(0.0675)	(0.1018)	(0.0769)	(0.0003)	(0.4402)	(0.0266)	(0.0107)	(0.1620)			
D.T.	−0.0599 **	0.0316	−0.0308	0.0445 *	−0.0183	−0.0067	−0.0140	−0.0207	−0.0151	0.1948 ***	1.0000	
	(0.0105)	(0.1773)	(0.1887)	(0.0573)	(0.4345)	(0.7734)	(0.5497)	(0.3767)	(0.5187)	(0.0000)		
L.P.	0.2672 ***	−0.0386 *	−0.0465 **	0.0826 ***	−0.1540 ***	−0.0405 *	−0.0028	0.0374	0.0026	−0.0083	0.0152	1.0000
	(0.0000)	(0.0999)	(0.0472)	(0.0004)	(0.0000)	(0.0842)	(0.9051)	(0.1106)	(0.9110)	(0.7221)	(0.5162)	

Note: Significance in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5.2. Benchmark Regression Analysis

For the sake of forming a reference for comparison with future research, in this paper, ordinary regression analysis of the results of the variables is carried out via ordinary least-squares (OLS) and linear regression methods. Table 4 clearly shows the benchmark regression analysis results of variables. In general, on the one hand, in both model (a) and model (b), the average treatment effect of demonstration farm is 29.3543 without controlling any covariates. This is equivalent to the results had been obtained from demonstration farms under the condition that other conditions remain unchanged, which can promote farm income by CNY293543 on average, and is significant at the level of 1‰. On the other hand, the average treatment effect of demonstration farm is 30.1458 in the case that covariates are added in both model (c) and model (d), and is also significant at the level of 1‰. Nevertheless, these results may not be reliable due to possible bias.

Table 4. Benchmark Regression Analysis of variables.

	Model (a)	**Model (b)**	**Model (c)**	**Model (d)**
D.F.	29.3543 *** (2.4810)	29.3543 *** (3.1392)	30.1458 *** (2.4666)	30.1458 *** (3.0579)
F.G.			−3.6700 (2.8766)	−3.6700 (3.1306)
F.A.			−0.1842 (0.1212)	−0.1842 * (0.0924)
F.E.			4.4703 ** (1.4589)	4.4703 * (1.9720)
F.L_1			−4.0348 *** (0.5005)	−4.0348 *** (0.7039)
F.P.			−1.8423 * (0.8397)	−1.8423 ** (0.5670)
F.L_2			1.7056 ** (0.5839)	1.7056 *** (0.4835)
M.T.			2.5096 * (0.9861)	2.5096 ** (0.9237)
M.E.			−0.7010 (0.7571)	−0.7010 (1.1305)
D.C.			−0.0059 (0.0432)	−0.0059 (0.0430)
D.T.			0.1071 (0.1052)	0.1071 (0.1286)
_cons	16.1355 *** (1.1794)	16.1355 *** (1.0228)	21.3053 * (9.8379)	21.33053 ** (7.8371)
F-test	139.99	87.44	21.82	14.13
N	1823	1823	1823	1823
R^2	0.0714	0.0714	0.1170	0.1170

Note: Standard errors in parentheses, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

5.3. Propensity Score Matching

Propensity score matching was performed and the results are shown in this section. The regression results of the PSM-logit are summarized in detail in Table 5. Overall, from the regression results of the PSM-logit model, the *p* value of the model result is 0.0000 for propensity score matching results, which is significant. In particular, family laborers (F.L_1), management types (M.T.), and management experience (M.E.) had positive effects on labor productivity that passed the statistical significance level test at 10%, 1%, and 1%, respectively. Farm distance_county (D.C.) had a negative effect on labor productivity that passed the statistical significance level test at 1%.

In addition, Figure 4 figuratively depicts the common support of the propensity patching score by nearest neighbor matching and kernel matching. As can be seen intuitively from Figure 4, most of the observed values are within the common support by the propensity score of the nearest neighbor matching. Similarly, most of the observed values are within the common support by the propensity score of the kernel matching. As a result, when propensity score matching is performed, the number of samples lost is particularly small.

Table 5. The regression results of the PSM-Logit.

Variable	Coefficient	Std. Err.	Z	P > ǀZǀ	[95% Conf. Interval]	
F.G.	−0.2011	0.1543	−1.3000	0.1930	−0.5035	0.1013
F.A.	0.0046	0.0069	0.6800	0.4990	−0.0088	0.0181
F.E.	0.1251	0.0804	1.5600	0.1200	−0.0324	0.2826
F.L_1	0.0484 *	0.0262	1.8500	0.0650	−0.0030	0.0997
F.P.	−0.0592	0.0485	−1.2200	0.2220	−0.1543	0.0359
F.L_2	0.0320	0.0322	0.9900	0.3200	−0.0311	0.0951
M.T.	0.1377 ***	0.0536	2.5700	0.0100	0.0327	0.2427
M.E.	0.1619 ***	0.0430	3.7600	0.0000	0.0775	0.2462
D.C.	−0.0126 ***	0.0027	−4.6300	0.0000	−0.0179	−0.0073
D.T.	-0.0111	0.0070	−1.5900	0.1120	−0.0247	0.0026
_cons	−2.3315 ***	0.5507	−4.2300	0.0000	−3.4109	−1.2522
Number of obs		1823				
LR chi2(10)		61.96				
Prob > chi2		0.0000				
Pseudo R2		0.0318				

Note: * $p < 0.10$, *** $p < 0.01$.

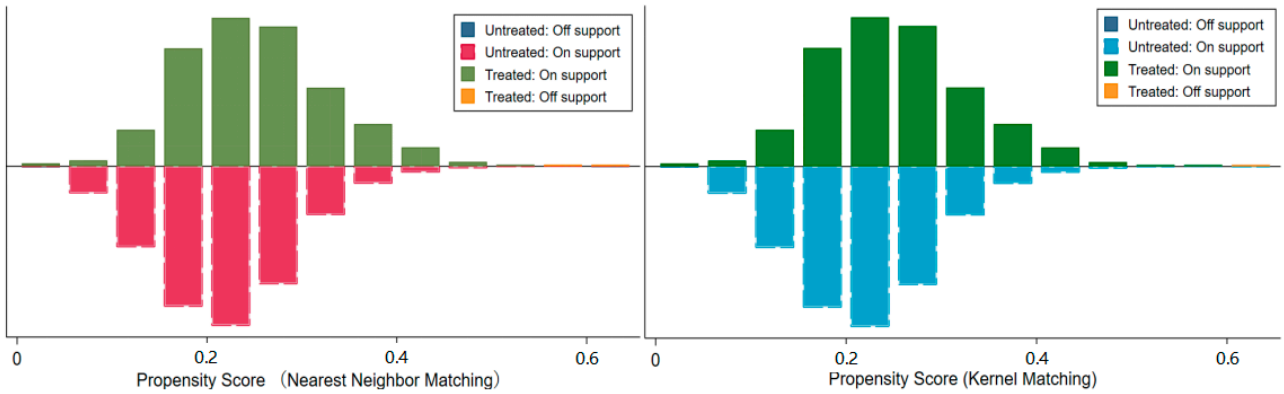

Figure 4. The common support of the Propensity Matching Score.

5.4. Balance Test

Next, we further examined whether the matching results for propensity scores balanced the data better. The balance test of the matching results, obtained by the three matching methods (including nearest neighbor matching, radius matching, and kernel matching), is put in order detail in Table 6. It can be clearly seen from Table 6 that there are still significant differences in the standardization bias (%Bias) of each variable before matching. However, it is obviously the case that the standardization bias of each variable is compared through different matching methods after matching, meaning that it can be found that the standardization bias of all variables after matching is much less than 10% and the standardization bias of each variable is significantly reduced. Hence, it can be considered that the matching results have passed the balance test. In addition, from the *t* test of the matching results, it was also found that the *t* statistic results of all variables after matching could not reject the original hypothesis that there was no systematic difference between the treatment group and the control group. To make a long story short, compared with the results before matching, the standardized bias of all variables after matching is reduced by a wide margin, which indicates that the matching results have well-balanced data and their estimation of propensity score is more accurate.

Table 6. The balance test of the matching results.

Variable	Matching Method	Treated	Control	%Bias	T-Stat.	Prob.
F.G.	Unmatched	0.8204	0.8590	−10.5000	−1.9300	0.0540 *
	Nearest Neighbor Matching	0.8220	0.8077	3.9000	0.5200	0.6000
	Radius Matching	0.8220	0.8180	1.1000	0.1500	0.8840
	Kernel Matching	0.8200	0.8256	−1.5000	−0.2100	0.8340
F.A.	Unmatched	42.1360	42.2480	−1.3000	−0.2300	0.8150
	Nearest Neighbor Matching	42.0930	42.3370	−2.9000	−0.4100	0.6800
	Radius Matching	42.0930	42.0950	0.0000	0.0000	0.9960
	Kernel Matching	42.0970	42.1230	−0.3000	−0.0400	0.9650
F.E.	Unmatched	3.2403	3.2069	4.6000	0.8300	0.4070
	Nearest Neighbor Matching	3.2439	3.2644	−2.8000	−0.4000	0.6920
	Radius Matching	3.2439	3.2401	0.5000	0.0700	0.9410
	Kernel Matching	3.2409	3.2345	0.9000	0.1200	0.9020
F.L_1	Unmatched	3.8835	3.5734	13.4000	2.7000	0.0070 ***
	Nearest Neighbor Matching	3.7610	3.8226	−2.7000	−0.4600	0.6470
	Radius Matching	3.7610	3.7641	−0.1000	−0.0200	0.9810
	Kernel Matching	3.7956	3.7746	0.9000	0.1500	0.8840
F.P.	Unmatched	2.2791	2.3104	−2.6000	−0.4500	0.6550
	Nearest Neighbor Matching	2.2805	2.2783	0.2000	0.0300	0.9790
	Radius Matching	2.2805	2.2804	0.0000	0.0000	1.0000
	Kernel Matching	2.2822	2.2915	−0.8000	−0.1100	0.9120
F.L_2	Unmatched	3.6543	3.6299	1.3000	0.2300	0.8210
	Nearest Neighbor Matching	3.6400	3.7003	−3.1000	−0.4500	0.6560
	Radius Matching	3.6400	3.6478	−0.4000	−0.0600	0.9540
	Kernel Matching	3.6486	3.6272	1.1000	0.1600	0.8750
M.T.	Unmatched	2.5534	2.4068	12.9000	2.2900	0.0220 **
	Nearest Neighbor Matching	2.5512	2.5512	0.0000	0.0000	1.0000
	Radius Matching	2.5512	2.5569	−0.5000	−0.0700	0.9440
	Kernel Matching	2.5572	2.5480	0.8000	0.1100	0.9100
M.E.	Unmatched	4.4636	4.1665	21.8000	3.8300	0.0000 ***
	Nearest Neighbor Matching	4.4585	4.4675	−0.7000	−0.0900	0.9260
	Radius Matching	4.4585	4.4700	−0.8000	−0.1200	0.9040
	Kernel Matching	4.4647	4.4382	1.9000	0.2800	0.7800
D.C.	Unmatched	31.0920	38.0790	−30.1000	−5.1100	0.0000 ***
	Nearest Neighbor Matching	31.1160	31.7510	−2.7000	−0.4300	0.6700
	Radius Matching	31.1160	31.1270	0.0000	−0.0100	0.9940
	Kernel Matching	31.1030	31.4910	−1.7000	−0.2700	0.7910
D.T.	Unmatched	8.0769	9.4897	−15.0000	−2.5600	0.0100 ***
	Nearest Neighbor Matching	8.0634	8.4799	−4.4000	−0.6600	0.5070
	Radius Matching	8.0634	8.4111	−3.7000	−0.5500	0.5840
	Kernel Matching	8.0834	8.1803	−1.0000	−0.1700	0.8670

Note: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Figure 5 more intuitively depicts the standardized bias graphs under different matching methods both before matching and after matching. In the first place, according to the change characteristics of the results obtained before matching and after matching, the standardized bias distribution of each variable is scattered, and the deviation is relatively large before matching. However, after matching, the standardized bias of each variable was significantly narrowed overall. In the second place, from the matching results of different matching methods, it can be quite clearly seen that, in contrast to one-to-one matching, the standard bias of each variable after nearest neighbor matching, radius matching, and kernel matching all decrease substantially. In particular, the distribution of the standard bias of each variable after kernel matching is relatively more concentrated.

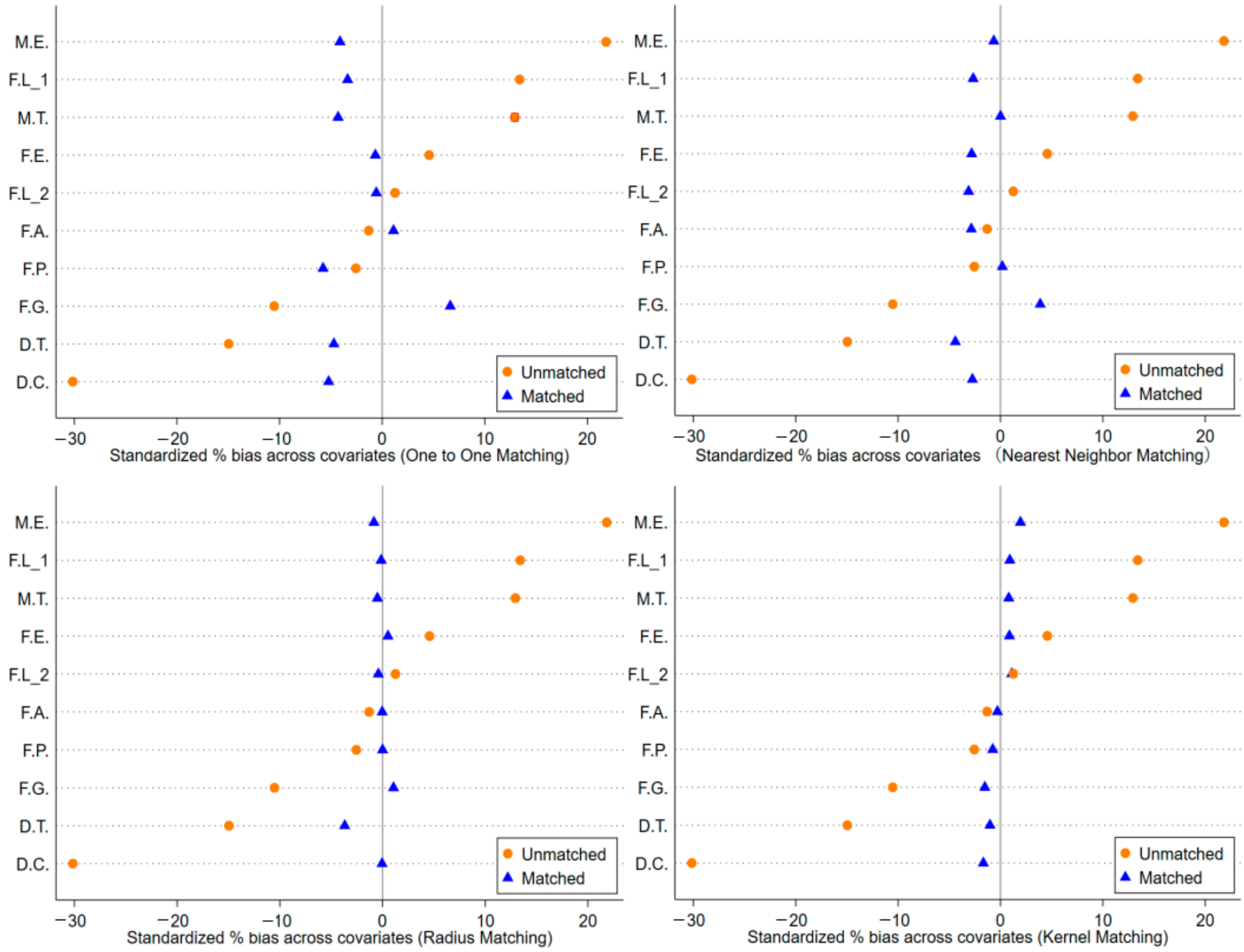

Figure 5. The standardized % bias across variables.

The kernel density estimate function distribution of the propensity matching score to before matching and after matching are depicted vividly in Figure 6. A comparison of the kernel density estimate function distribution for the four groups shows that, compared with the density estimate function distribution before matching, the treatment group after nearest neighbor matching, radius matching, and kernel matching has propensity scores relatively closer to the control group, which this means that one is able to find the matching sample to the treatment group from among the control group samples. In other words, we can distinguish between the matching samples for the family farms samples from an area with a demonstration farm and the family farms samples from an area that had not obtained a demonstration farm. At the same time, it also shows that the effect obtained from the sample data after matching can meet the common support hypothesis of PSM and that the matching effect of propensity score is better.

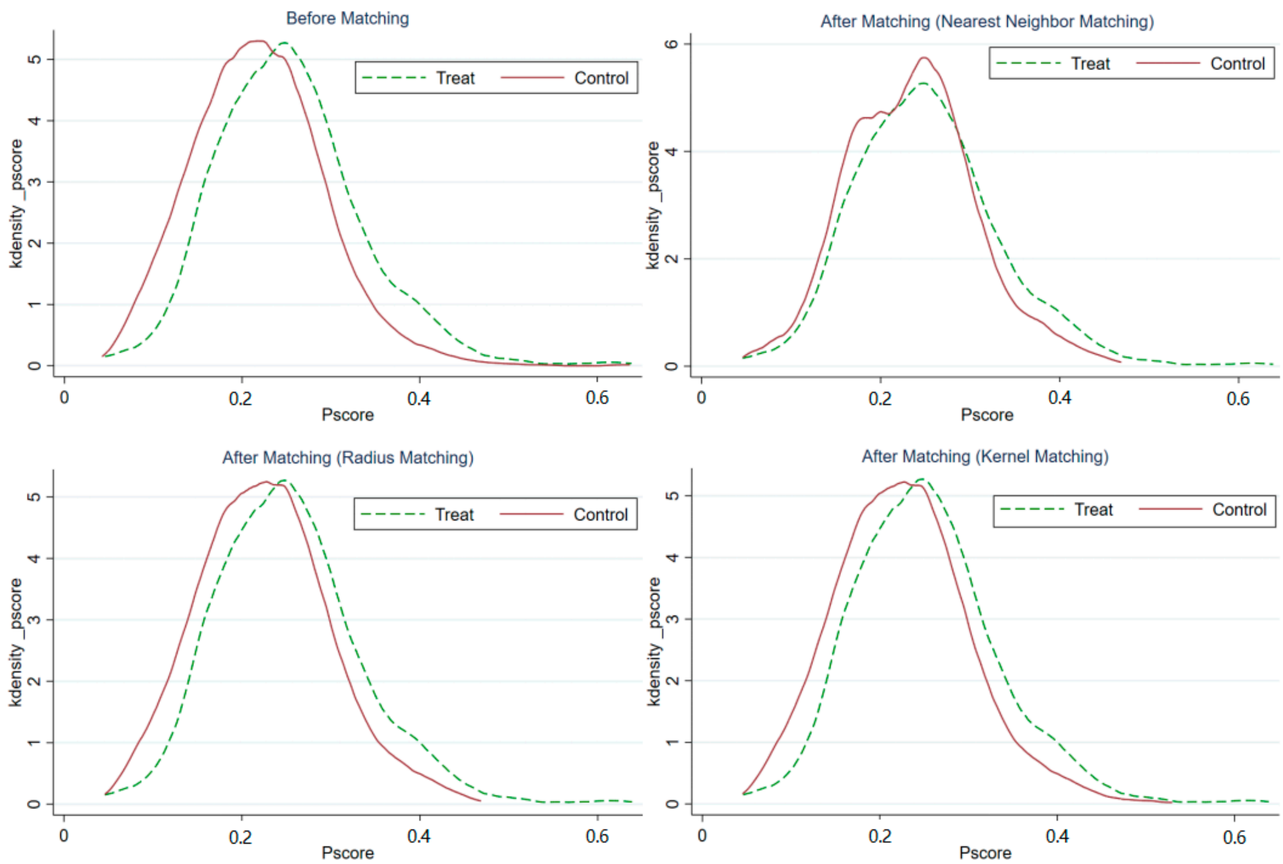

Figure 6. The kernel density function distribution of the propensity score to before matching and after matching.

5.5. Sensitivity Analysis

Given that basis of the PSM approach is to control the effects of the measurable variables, it still introduces a "hidden bias" if there is selection on unobservable variables [54]. In order to avoid the impact caused by "hidden bias", the level of bias should be estimated through sensitivity analysis [55,58], which aims to observe the sensitivity of PSM estimation results to "hidden bias". The fundamental task of sensitivity analysis is to derive a range of gamma attributable to "hidden bias". Gamma measures the departure degree from a study without "hidden bias" [59]. In view of this, this paper further examines the sensitivity of PSM estimation results to "hidden bias" based on the Rosenbaum bounds sensitivity analysis approach proposed by Rosenbaum et al. [55,58]. The sensitivity analysis of the Rosenbaum bounds is summarized neatly in Table 7. Among the terms used, "gamma" stands for the log odds of the differential assignment due to unobserved factors, "sig+" represents the upper-bound significance level, and "sig−" denotes lower-bound significance level. It should be illustrated, due to limited space, the Gamma values take values from 1 and increase by 0.2 increments until gamma = 3. The sensitivity analysis results fully reveal that the lower bound significance level of gamma at different value intervals was all less than 0.01, and that the upper bound significance level of gamma at different value intervals was also less than 0.01, as estimated by the three matching methods, including nearest neighbor matching, radius matching, and kernel matching. Therefore, in this paper, it is reasonable to believe that there is a close association between the demonstration farm and labor productivity, the estimation results obtained in this paper via the PSM method have good robustness, and the conclusions of the research are reliable and credible.

Table 7. The sensitivity analysis of the Rosenbaum bounds.

Gamma	Nearest Neighbor Matching sig+	Nearest Neighbor Matching sig−	Radius Matching sig+	Radius Matching sig−	Kernel Matching sig+	Kernel Matching sig−
1.0	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1.2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1.4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1.6	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
1.8	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2.0	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2.2	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2.4	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2.6	0.000000	0.000000	0.000006	0.000000	0.000001	0.000000
2.8	0.000005	0.000000	0.000054	0.000000	0.000011	0.000000
3.0	0.000037	0.000000	0.000334	0.000000	0.000078	0.000000

5.6. Discussions

Table 8 centrally reports the average treat effect on the treated of matched sample. Obtained by synthetically comparing the analysis data, the result of sample estimation before matching was determined to be 29.3543, which is completely consistent with the results of the single regression shown in Table 4, namely, the results of model (a) and model (b). After taking the nearest neighbor matching, the estimated value of ATT is 28.5108, and its corresponding t value is 8.4900, which is above the critical value of 2.58. This indicates that the estimated result of the matched sample passed the 1% significance level test, implying that, in the case of controlling for other covariates, the demonstration farm can significantly improve farm income by CNY285108 on average in the matched sample. After taking the radius matching method, the estimated value of ATT is 28.8509, and its corresponding t value is 9.0300, which indicates that the estimated result of the matched sample passes the 1% significance level test. This means that, when controlling for other covariates, the demonstration farm can significantly increase farm income by CNY288509 on average in the matched sample. After using the kernel matching, the estimated value of ATT is 29.1076, and its corresponding t value is 9.1700, indicating that the estimated result of the matched sample passes the 1% significance level test. This means that when controlling for other covariates, the demonstration farm can significantly raise farm income by CNY291077 on average in the matched sample.

Table 8. The average treat effect on the treated of matched sample.

Sample	Unmatched	ATT		
		Nearest Neighbor Matching	Radius Matching	Kernel Matching
Treated	45.4898	45.6668	45.6668	45.5895
Controls	16.1355	17.1560	16.8159	16.4818
Difference	29.3543	28.5108	28.8509	29.1077
Std. Err.	2.4809	3.3592	3.1966	3.1744
T-Statistic	11.8300	8.4900	9.0300	9.1700

6. Conclusions and Implications

In this paper, based on a sample of 1823 family farms in the mountainous areas of western China, the causal relationship of demonstration farm on labor productivity was empirically tested. Additionally, the PSM-logit model and sensitivity analysis wwere used. The conclusions of this paper are as follows.

Firstly, as the average agricultural labor productivity of the demonstration farm is CNY454898, which is 2.8 times higher than that of the non-demonstration farm, hypothesis 1 has been verified. Secondly, there is a significant positive correlation between demonstration family farm and agricultural labor productivity. Compared to family farms that did not obtain the demonstration farm, the use of demonstration farms in the case of adding all control variables, which can promote farm income by CNY301458 on average, gave significant values at the level of 1‰, verifying hypothesis 2. Thirdly, in the matched sample, and under scenarios controlling for other covariates, the use of demonstration farms, was shown to significantly enhance farm income of CNY285108, CNY288509, and CNY291077 on average, respectively. After taking the radius matching, the kernel matching, and the nearest neighbor matching, the average treat effect on the treated of matched sample passed the 1% significance level test. When propensity score matching is performed, most of the observed values are within the common support by the propensity score, indicating that the matching results have passed the balance test. Meanwhile, the sensitivity analysis results fully reveal that there is a close association between the demonstration farm and labor productivity, and the estimation results obtained in this paper by PSM method has good robustness, and the conclusions of the research are reliable and credible, meaning that hypothesis 3 has been verified. However, objectively speaking, the above research results may only be applicable to the mountainous area of western China and may not necessarily apply to the eastern or central regions of China, which may be greatly related to the varying degrees of differences in agricultural resource endowment, agricultural industry structure, agricultural industry resilience, and agricultural development potential in different regions of China.

Based on the above findings, the policy implications of this research are significant. First of all, farmers should actively develop family farms according to local conditions, and vigorously cultivate and develop demonstration farms [6,7,9,35–37], innovate experimental and demonstration models from the perspective of regional coordinated development [60], step up, publicize and promote unceasingly the typical cases and experience of demonstration farm, so as to encourage family farms to continuously improve labor productivity. Secondly, authorities should encourage family farms that have not been obtained demonstration farm to continue to give play to their comparative advantages, aggregate the optimized allocation and agglomeration effect of various resources, strengthen the professional skills education and management ability of farm owners, improve the quality and competitiveness of farm products, carry out continuous moderate scale management, summarize and promote the typical experience of the farm. Thirdly, on the basis of fully considering the factors of family farms, such as industrial foundation, development type, land continuity, convenient transportation, etc., authorities should innovate the management modes of mountainous planting or breeding and explore industrial models of mountain stereo agriculture, actions which in turn contribute to improving the labor productivity of family farms.

In addition, based on policy implications, this paper proposes the following future direction. The local government and its agricultural and rural departments should further improve the top-level design and supporting policies for high-quality development of family farms, optimizing and improving the developmental planning and construction system of family farms according to local conditions, strengthening the demonstrative establishment of family farms, accelerating the linkage and integration of family farms with other new type agricultural business entities, advancing high-quality development of agricultural modernization [61], and promoting sustainable development of agricultural and rural [62].

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