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Maintenance Skill Training Gives Agricultural Socialized Service Providers More Advantages

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Abstract: Agricultural machinery maintenance skill training is conducive to improving the fault diagnosis and maintenance levels of agricultural machinery for agricultural socialized service providers and plays an important role in providing stable and reliable agricultural machinery operation services. This paper aims to study whether maintenance skill training gives agricultural socialized service providers more advantages than untrained providers, exploring the relationship between maintenance skill training and agricultural machinery service area. Based on a survey of 4905 farmers from 10 provinces in China, an empirical analysis was carried out using a fixed effect model and a propensity score matching method. The results showed the following: First, maintenance skill training had a significant positive impact on agricultural machinery operation service area, including 10.426 ha of machinery tilling service area and 8.524 ha of machinery harvesting service area. Second, since maintenance skill training gave agricultural socialized service providers more advantages in agricultural machinery operation services and enabled them to obtain more orders, it had an indirect positive impact on the quantity of demand for large- and middle-sized agricultural machinery.

Keywords: maintenance skill training; agricultural machinery; agricultural socialized services; China

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1. Introduction

Agricultural machinery operation services are not only conducive to promoting large-scale operation and standardized production [1,2], but also to maintaining the connection between small farmers and agricultural modernization [3–5], as well as having an inhibitory effect on the abandonment of arable land [6–8]. According to the Statistics on China Agricultural Mechanization (2020), by the end of 2020, the number of people participating in agricultural mechanization operation services reached 2.12 million, and the number of agricultural machinery operators was about 47.52 million in China. In order to provide long-term and reliable services, agricultural machinery needs regular maintenance and repair [9,10]. As agricultural socialized service providers, agricultural machinery operators tend to use large- and middle-sized agricultural machinery [11]. Since large- and middle-sized agricultural machinery both have complex structures and high requirements for operation skill, operators mainly rely on agricultural machinery dealers for maintenance [9,12]. However, for agricultural machinery operators, on the one hand, the cost of maintenance is high [13]. On the other hand, especially in cross-regional operation, operation locations are generally in the countryside and far away from agricultural machinery maintenance points, which may result in missing the window for the best harvest time and a loss of operation service opportunities to operators. In harvest season, the failure rate of agricultural machinery increases rapidly [12] and has randomness [14]. With increase in the amount of agricultural machinery, the harvest window is continuously shortened. For example, in June 2022, the wheat harvest in Bozhou Prefecture, Anhui Province, China, was completed in only five days, creating a new record for wheat harvesting. However,

the time period for harvesting by manpower needs more than one month [15]. In this context, if a machine fails to be repaired in time during operation, it causes operators to miss the opportunity to provide operation services and causes great losses. However, the quality of agricultural machinery in China is not high, and the probability of failure is high [16]. In 2017, the average time between failures of tractors produced by Chinese companies was 330 h, which was 30–40 years behind that of tractors produced by Italian companies [17]. Training can increase farmers' knowledge [18]. Then, if operators participate in education and training for relevant agricultural machinery maintenance skills to master the maintenance skills, they may have more advantages in agricultural machinery operation services.

Based on survey data of 4905 sample farmers from 10 provinces in China in 2020, this study investigates whether agricultural machinery maintenance skill training gives trained operators more advantages than untrained operators in providing agricultural machinery operation services. Taking the areas of machinery tilling services and machinery harvesting service as an example, on the basis of controlling other variables, we study whether operators significantly increase the agricultural machinery operation service area because of their participation in maintenance skill training.

The main contributions of this study are as follows: First, it expands the research boundary of the impact of skills training on agricultural machinery operation services. Second, in terms of research methods, the cross-sectional data of farmers are processed into county panel data, and a fixed effect model is used to eliminate endogenous results caused by unobservable county environment characteristics. At the same time, the propensity score matching (PSM) method is used to eliminate the self-selection bias to strictly evaluate the causal relationship between maintenance skill training and agricultural machinery operation services, and on this basis, a robustness test is carried out.

2. Literature Background

2.1. Research on Agricultural Machinery Operation Services

The existing research on the influencing factors of agricultural machinery operation services focuses on two aspects: one is from the perspective of the demand side of agricultural machinery operation services. For example, some studies believe that, with the increase in correct farmland confirmation rate, farmers are more inclined to purchase agricultural machinery operation services [19]. Agricultural income promotes the demand for machinery operation services [20], while nonagricultural employment promotes farmers' incomes, which encourages farmers to purchase agricultural machinery services [21].

The other is from the perspective of the supply side of agricultural machinery operation services. Most studies believe that land scale affects the choice of agricultural machinery services, that is, when the scale reaches a large level, farmers change from the demanders to the suppliers of agricultural machinery operation services [22,23]. Wu et al. (2017) believed that weather had a great impact on agricultural machinery operation services [23]. Paman et al. (2014) considered that machinery type, land condition, and operation distance were important factors affecting the supply of agricultural machinery services [24]. Some scholars believe that operators specializing in agricultural machinery services tend to buy large- and middle-sized agricultural machinery for scale services, but large- and middle-sized agricultural machinery both have high purchase costs and maintenance costs [25,26]. Based on a survey of 1106 rice farmers in China that was jointly conducted by the China Agricultural University and the Research Center for Rural Economy (RCRE) of the Ministry of Agriculture and Rural Affairs of China in 2016, Qu et al. (2022) found that harvest outsourcing services had a negative impact on the working attitudes of agricultural socialized service providers [27]. Through an investigation in Xuzhou, China, Yang et al. (2013) found that agricultural machinery maintenance was one of the factors that needed to be considered in cross-regional operation services [28].

2.2. Research on Skills Training

Skills education and training is one of the effective ways to promote human capital accumulation and skill premium [29,30]. Existing studies have focused on testing the impact of agricultural skills training on farmers' production and management behaviors, including research on the use of chemical fertilizers and pesticides, straw utilization, water-saving irrigation, correct land management transfer, and planting technology adoption [31–36]. Agricultural skills training can not only improve agricultural technology and the knowledge of farmers [35] and promote sustainable development of rural areas [37], but also has a spillover effect, that is, it causes farmers who do not participate in training to implement scientific agricultural production behavior [34,38]. There are also studies that have indicated that agricultural skills training cannot make farmers fully understand agricultural knowledge, with no knowledge spillover [32,39]. In addition, agricultural skills training is also affected by training methods, training environment, and farmers' personal characteristics [18,40–42]. As a kind of agricultural skills training, agricultural machinery maintenance training is conducive to the maintenance of agricultural machinery equipment and normal operation. However, there is a possibility that operators cannot master the maintenance technology of agricultural machinery after participating in training [13]. In particular, short-term training courses are difficult for participants to fully adopt and utilize the skills and knowledge learned [10].

2.3. Literature Summary

To sum up, although there are abundant studies on agricultural machinery operation services and skills training, there is a lack in the literature on whether maintenance skill training has a positive impact on agricultural machinery operation services and how much of a positive impact it has. Over the background of the rapid reduction and aging in the agricultural labor force, agricultural machinery operation services have answered the question of who farms the land and have effectively guaranteed food security and major agricultural product supply security in China. Maintenance skill training may effectively improve the benefits and efficiency of the group of operators participating in agricultural machinery operation services. Therefore, this study focuses on the impact of maintenance skill training on agricultural machinery operation services, which has important practical significance and can also enrich research in the related fields of agricultural machinery operation services and skills training.

The research is organized as follows. First, based on the theoretical model, the hypothesis is carried out. Second, the empirical model is designed, and then the data source is reported, followed by a descriptive analysis. Finally, according to the research results, this study puts forward implications.

3. Theoretical Framework

3.1. Theoretical Model

As providers of agricultural machinery operation services, agricultural machinery operators pursue profit maximization. They strive to reduce costs in order to gain more market shares. Based on the perspective of service providers and assuming that the service price is given in a perfectly competitive market, we established a theoretical analysis framework for the relationship between the maintenance skill training and agricultural machinery operators' operation service supply behavior:

$$Q = f(C, P, O, D) \tag{1}$$

where the agricultural machinery operation service area Q is mainly affected by the failure of free work cost C, agricultural machinery performance P, agricultural machinery operation service opportunity O, and operation proficiency D. When other conditions remained

the same, the agricultural machinery services area decreased with the increase in the failure of free work cost, that is, $\partial P/\partial C \leq 0$.

$$C = f(M, R) \tag{2}$$

where the failure of free work cost C depends on the maintenance cost M and failure recovery time cost R. After training in agricultural machinery maintenance skills, operators had basic maintenance skills. When they had maintenance skills, the cost of repairing agricultural machinery by themselves was lower than that of socialized maintenance. This was because of the following: First, operators could buy parts in advance at a low price. Second, when the agricultural machinery broke down, operators could carry out basic maintenance work by themselves, and there was no need to consider labor cost, transportation cost, and other professional maintenance personnel service costs that only occurred in socialized maintenance. Third, operators did not need to wait for maintenance personnel, which reduced the failure recovery time cost. Therefore, when maintenance cost and failure recovery time cost were reduced, the failure of free work cost for agricultural machinery was also reduced. Then, because the cost of the failure of free work was the minus function of the agricultural machinery operation service area, it ultimately promoted an increase in the agricultural machinery operation service area.

$$P = f(Z, U, C) \tag{3}$$

where the agricultural machinery performance P is affected by operation quality Z and operation efficiency U. Theoretically, the agricultural machinery operation service area increased with the rise in agricultural machinery performance, that is, $\partial Q/\partial P \geq 0$.

$$O = f(S, E) \tag{4}$$

where the agricultural machinery operation service opportunity O is affected by social capital S and environment characteristics E. If an operator served as a village cadre or joined a co-operative or a college student village official, he had a wider network of contacts, that is, higher social capital, which was conducive to the operator understanding the operation needs of other farmers and obtaining more operation information. If the local environment was good, such as better terrain conditions and a larger planting area, there was more demand for agricultural machinery operation, so operators could obtain more operation opportunities.

$$D = f(A, L, W) \tag{5}$$

where the proficiency D of agricultural machinery operators depends on their age A, education L, and family wealth W. The older the operator, the weaker his physical strength to operate agricultural machinery and the lower his ability to accept new skills. The higher the education level of the operator, the stronger his learning ability. The greater the family wealth of the operator, showing that he was smart and good at business, the higher his proficiency in agricultural machinery operation.

3.2. Research Hypothesis

According to the analysis of previous theoretical model, when other conditions were unchanged, maintenance skill training had a positive impact on agricultural machinery operation service area. Therefore, we proposed the following assumption:

H1. Maintenance skill training gave agricultural machinery operators more advantages in agricultural machinery operation services. Under the same conditions, the service areas of agricultural machinery operators receiving maintenance training were larger.

In conclusion, the theoretical model is shown in Figure 1.

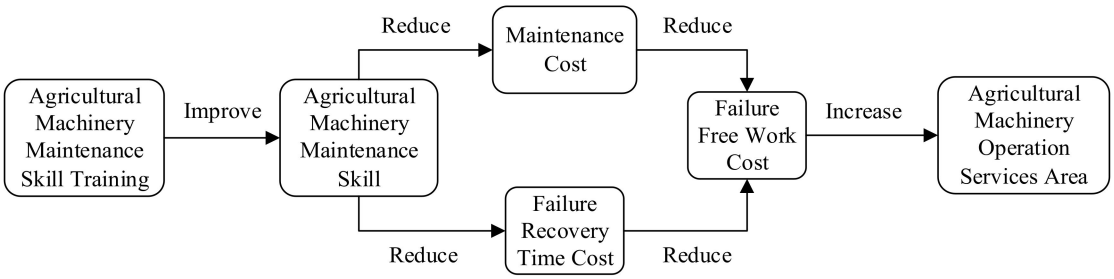


Figure 1. Theoretical model.

4. Methodology

4.1. Fixed Effect

Operators in the same county have similar common characteristics that cannot be observed. For example, there may be common agricultural mechanization support policies in the county, but we may fail to investigate and measure them in the questionnaire. If these variables are ignored, serious endogeneity may occur. In order to eliminate the endogeneity caused by region variables, we regarded a county as a sample and operators in the same county as different periods of the county sample. Then, we could process the cross-sectional data into panel data to eliminate the endogeneity of environment variables. Based on this, we built the following equation:

$$Y_{ji} = \alpha + \beta T_{ji} + \gamma C_{ji} + g_j(Z) + \varepsilon_{ji} \quad (6)$$

where Y_{ji} refers to the agricultural machinery operation service area, that is, the area of operator i services in county j; T_{ji} is maintenance skill training; C_{ji} is a vector of the control variables that affect the service area; the random disturbance term ε_{ji} follows a normal distribution; α, β, γ are the parameter vectors to be evaluated; the change in α in the fixed effect is related to the explanatory variable; and Z represents a series of county environment characteristics, that is, for different machinery operators in the same county, these county characteristics are unchanged and can be controlled by the fixed effect of the same county. If β was significantly positive, it indicated that operators who attended maintenance skill training had more agricultural machinery operation service area under the same conditions, and H1 could be verified.

4.2. Propensity Score Matching Method

Participation in maintenance skill training was mainly voluntary, and whether to participate was decided by the agricultural machinery operators themselves. Therefore, the operators who attended maintenance skill training and those who did not attend maintenance skill training in the sample were not random, which could produce the problem of sample self-selection bias. Based on this, we used a PSM method to analyze the impact of maintenance skill training on operation service area. We selected covariates and use a Logit model to calculate the propensity score, that is, to estimate the probability of an operator i participating in training for agricultural machinery maintenance skills, and the expression was as follows:

$$P(T_i = 1|X = X_i) = P(X_i) \quad (7)$$

where $P(X_i)$ is the propensity score of an operator i, T_i indicates whether an operator participates in maintenance skill training (T_i = 1 means participation in maintenance skill training, otherwise T_i = 0), and X_i represents the covariates of operator i, such as personal characteristics, family characteristics, operation characteristics, policy characteristics, and agricultural machinery equipment characteristics.

Then, we matched the control samples with those who participated in the training. In order to ensure the reliability of the results, we chose four matching methods and then

calculated the average value with the following: k-nearest neighbor matching (finding k untrained operators with the closest propensity scores with k = 4); k-nearest neighbor matching within a caliper (finding k-nearest neighbor matching within an absolute distance with k = 4 and a caliper radius of 0.05); radius matching (finding the absolute distance to limit the propensity score and a caliper radius of 0.05); and kernel matching (using the kernel function to calculate weight, default kernel function, and bandwidth). At the same time, a balancing test was carried out for both the treatment group and the control group to ensure the balanced distribution of the samples. Finally, we calculated the average treatment effect on the treated (*ATT*) according to the matched samples, and the expression was as follows:

$$ATT = \frac{1}{N}\sum_{i:T_i=1}(y_i\text{-}y_{0i}) \quad (8)$$

where N is the number of operators in the treatment group, and $\sum_{i:T_i=1}$ is the aggregation of individuals in the treatment group. If *ATT* was significantly positive, it indicated that, under the condition of basically equal covariates, the agricultural machinery operation service areas of the treatment group samples participating in maintenance skill training were significantly higher than those of the control group that did not participate in maintenance skill training for agricultural machinery, and H1 could be repeatedly verified.

4.3. Robustness Test Method

To verify the robustness of the hypothesis testing, we included the samples retained after k-nearest neighbor matching (k = 4) in the fixed effect model of formula (6) to verify the impact of agricultural machinery maintenance skill training on agricultural machinery service area. The steps were as follows: After using the Logit model to calculate the propensity score, we used k-nearest neighbor matching (k = 4) in the PSM method, that is, matching the treatment group and the control group according to the 1:4 matching method. Selecting the 1:4 matching could minimize the mean square error [43]. Finally, only the samples participating in the matching were included in the fixed effect model (6). If the regression result was still consistent with the results of formula (6), it was proved that the verification of H1 was robust.

5. Data Source and Descriptive Analysis

5.1. Data Source

The data used in this study came from a questionnaire survey conducted by the Department of Agricultural Mechanization of the Ministry of Agriculture and Rural Affairs of the People's Republic of China from May to July 2020 on farmers in 10 provinces (Yunnan, Guizhou, Sichuan, Chongqing, Hunan, Hubei, Guangxi, Fujian, Shaanxi, and Shanxi). Before the survey, the questionnaire was pre-investigated and revised, and statisticians in county-level agricultural departments were trained. During the formal survey, statisticians helped farmers answer questions through specially designed mobile applications. The questionnaire was initially reviewed by the statisticians and finally reviewed by the project team members of the Department of Agricultural Mechanization of the Ministry of Agriculture and Rural Affairs, including refilling if there were problems, 10% telephone sampling return visits, and deletion of unqualified samples. A total of 5030 questionnaires were collected, of which 4905 were valid, and the effective rate was 97.51%.

5.2. Descriptive Analysis

In this study, the explained variable was agricultural machinery operation service area, including the machinery tilling service area and the machinery harvesting service area. The key explanatory variable of this study was maintenance skill training, which was recorded as "1" if an operator participated or, otherwise, as "0". In addition, referring to the previous theoretical model analysis, the control variables of this study included characteristics of the individuals (gender, age, education, social identity, risk appetite), characteristics of families (distance from residence to town, number of family farm laborers, family wealth),

characteristics of agricultural operation (cultivated land area, land fragmentation, land transfer, land transfer channel, land transfer terrain, land leveling, proportion of cash crops, proportion of forest fruit tea crops), characteristics of policy (agricultural machinery purchase subsidy policy, satisfaction with agricultural machinery purchase subsidy policy), and characteristics of agricultural machinery equipment (number of tractors under 60 hp (horsepower, a unit of power equal to 746 watts), number of tractors above 60 hp, number of rice and wheat combine harvesters under 4 kg/s, number of rice and wheat combine harvesters above 4 kg/s). See Table 1 for specific variables.

Table 1. Summary of variables.

Type of Variable	Name of Variable	Description of Variable	Mean	Standard Deviation
Explained variable	Machinery tilling service area	Agricultural machinery tilling service area operated by operator (ha)	21.737	93.869
	Machinery harvesting service area	Agricultural machinery harvesting service area operated by operator (ha)	12.319	60.843
Key explanatory variable	Maintenance skill training	Agricultural machinery maintenance skill training: no = 0, yes = 1	0.270	0.444
Characteristics of individuals	Gender	Gender of head: female = 0, male = 1	0.893	0.308
	Age	Age of head	45.881	9.450
	Education	Education level of head: illiterate = 0, primary school = 1, junior high school = 2, senior high school = 3, college and above = 4	3.408	0.892
	Social identity	Used to be a rural cadre = 1, other = 0	0.134	0.341
	Risk appetite	Conservative = 1, robust = 2, balanced = 3, active = 4, radical = 5	2.779	0.987
Characteristics of families	Distance from residence to town	(km): D (Distance) $\leq$ 5 = 1, 5 < D $\leq$ 10 = 2, D > 10 = 3	1.794	0.798
	Number of family farm laborers	Total number of family members mainly engaged in agriculture	2.190	0.994
	Family wealth	W (Wealth)$\leq$ 10 = 1, 10 < W $\leq$ 30 = 2, 30 < W $\leq$ 50 = 3, 50 < W $\leq$ 80 = 4, 80 < W $\leq$ 120 = 5, W > 120 = 6	2.617	1.476
Characteristics of agricultural operation	Cultivated land area	Land area cultivated by farmers themselves (ha)	15.822	38.003
	Land fragmentation	Cultivated land area/amount of cultivated land	1.269	6.560
	land transfer	Land transfer behavior: no = 0, yes = 1	0.726	0.445
	Land transfer channel	Transfer from acquaintances: no = 0, yes = 1	0.575	0.494
	Land transfer terrain	Highly fragmented land: no = 0, yes = 1	0.265	0.441
	Land leveling	Land-leveling behavior: no = 0, yes = 1	0.391	0.488
	Proportion of cash crops	Sowing area of cash crops/ sowing area of all crops	0.279	0.377
	Proportion of forest fruit tea crops	Sowing area of forest fruit tea crops/ sowing area of all crops	0.192	0.371

Table 1. *Cont.*

Type of Variable	Name of Variable	Description of Variable	Mean	Standard Deviation
Characteristics of policy	Agricultural machinery purchase subsidy policy	Farmer received agricultural machinery purchase subsidy: no = 0, yes = 1	0.755	0.429
	Satisfaction with agricultural machinery purchase subsidy policy	Excellent = 1, good = 2, medium = 3, poor = 4, very poor = 5	1.684	0.852
Characteristics of agricultural machinery equipment	Number of tractors under 60 hp	Number of tractors under 60 hp actually purchased by operators	0.499	1.391
	Number of tractors above 60 hp	Number of tractors above 60 hp actually purchased by operators	0.627	1.424
	Number of rice and wheat combine harvesters under 4 kg/s	Number of rice and wheat combine harvesters under 4 kg/s actually purchased by operators	0.203	1.131
	Number of rice and wheat combine harvesters above 4 kg/s	Number of rice and wheat combine harvesters above 4 kg/s actually purchased by operators	0.207	0.737

6. Results

6.1. Results of Fixed Effect Analysis

A multicollinearity diagnosis showed that the tolerance of all the variables was less than 5, so the possibility of multicollinearity between variables was small. As shown in Table 2, model (1) and model (2) gave the fixed effect results of maintenance skill training on agricultural machinery operation service area. We found that the training variable had a significant positive impact on agricultural machinery operation service area at the level of 1%. This indicates that agricultural machinery maintenance skill training could improve the maintenance abilities of operators, reduce maintenance cost and waiting time, decrease the failure of free work cost, and increase service area. Therefore, based on the results of machinery tilling service and machinery harvesting service, we tended to accept H1.

Table 2. Results of fixed effect model (agricultural machinery operation service area).

Type of Variable	Name of Variable	Machinery Tilling Service Area	Machinery Harvesting Service Area
		(1)	(2)
Key explanatory variable	Maintenance skill training	12.109 *** (2.957)	8.212 *** (1.867)
Characteristics of individuals	Gender	4.868 (4.086)	−2.864 (2.586)
	Age	−0.186 (0.137)	−0.087 (0.086)
	Education	1.613 (1.603)	0.533 (1.015)
	Social identity	0.548 (3.720)	1.297 (2.355)
	Risk appetite	1.804 (1.291)	0.306 (0.817)
Characteristics of families	Distance from residence to town	−1.447 (1.597)	−1.805 * (1.010)
	Number of family farm laborers	−1.534 (1.286)	−0.741 (0.813)
	Family wealth	2.358 ** (0.967)	1.523 ** (0.611)

Table 2. *Cont.*

Type of Variable	Name of Variable	Machinery Tilling Service Area	Machinery Harvesting Service Area
		(1)	(2)
Characteristics of agricultural operation	Cultivated land area	−0.003 (0.038)	0.085 *** (0.024)
	Land fragmentation	0.454 (1.071)	−0.706 (0.677)
	Land transfer	−9.382 ** (4.701)	−0.637 (2.975)
	Land transfer channel	0.945 (3.801)	−0.970 (2.405)
	Land transfer terrain	2.113 (3.133)	4.049 ** (1.982)
	Land leveling	1.414 (2.708)	−0.746 (1.712)
	Proportion of cash crops	−4.649 (4.232)	−1.615 (2.695)
	Proportion of forest fruit tea crops	−1.681 (4.616)	−4.772 (2.922)
Characteristics of policy	Agricultural machinery purchase subsidy policy	9.442 *** (3.204)	1.970 (2.018)
	Satisfaction with agricultural machinery purchase subsidy policy	−0.083 (1.516)	−0.070 (0.959)
Characteristics of agricultural machinery equipment	Number of tractors under 60 horsepower	1.514 * (0.901)	–
	Number of tractors above 60 horsepower	21.497 *** (1.002)	–
	Number of rice wheat combine harvesters under 4 kg/s	–	7.465 *** (0.685)
	Number of rice wheat combine harvesters above 4 kg/s	–	31.281 *** (1.194)
	Constant	−4.583 (11.576)	6.800 (7.335)
	Environment Fixed Effect	Yes	Yes
	Number of observations	4567	4567
	F	31.25	46.72
	Prob > F	0.000	0.000

Note: * indicates statistical significance at the 10% level, ** at the 5% level, and *** at the 1% level. Prob > F = 0.000 refers to accept the fixed effect model.

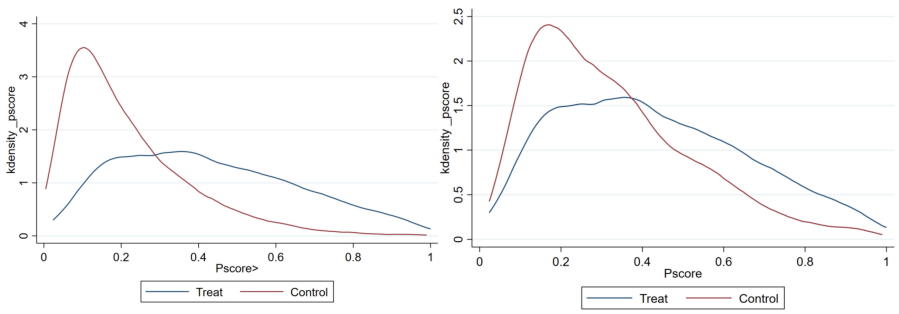
6.2. Results of PSM Analysis

However, the fixed effect analysis did not eliminate the problem of self-selection bias. The following is a further analysis using the PSM method.

6.2.1. Common Support Area and Balancing Test

In order to solve the problem of sample self-selection bias, we used the PSM method. At the same time, we introduced the county variable, where the operator was located in the model as a classification variable. Based on the results of the equation for participation in maintenance skill training, we calculated the fitting value of the conditional probability Pi of an agricultural machinery operator i attending maintenance skill training, that is, the propensity score. In order to test the validity of the matching results and the sample data, a kernel density estimation was drawn to test the common support area after sample matching (Figure 2). It can be seen that the propensity scores of the matched treatment

group and the control group overlapped in a large range, and most of the observed values were within the common value range.



(**a**) Before matching (**b**) After matching

Figure 2. Kernel density before and after matching.

In order to ensure the reliability of the matching results, it was necessary to test the balance of the covariates. As shown in Table 3, after matching, the explanatory variable of pseudo R^2 participating in maintenance skill training decreased from 0.182 to 0.012, LR chi^2 decreased from 976.32 to 42.97, the mean bias decreased from 8.3% to 1.8%, and the median bias decreased from 6.7% to 1.6%.

Table 3. Results of balancing test before and after matching.

	Pseudo R^2	LR Chi^2	Mean Bias	Median Bias
Unmatched	0.182	976.32	8.3	6.7
Matched	0.012	42.97	1.8	1.6

The results in Figure 3 show that the absolute value of the standardized bias of each variable basically dropped below 10% after matching, which indicates that propensity score matching could reduce the differences between those who participated in maintenance skill training and those who did not participate in maintenance skill training. From the results of the *t*-test, all the covariates were not significantly different between the treatment group and the control group after matching. This shows that, after using the PSM, the individual differences between the treatment group and the control group were basically eliminated within a reasonable range. Therefore, the above test results indicate that the matched samples basically passed the balancing test, that is, the sample selection was reasonable, and it was meaningful to use this method.

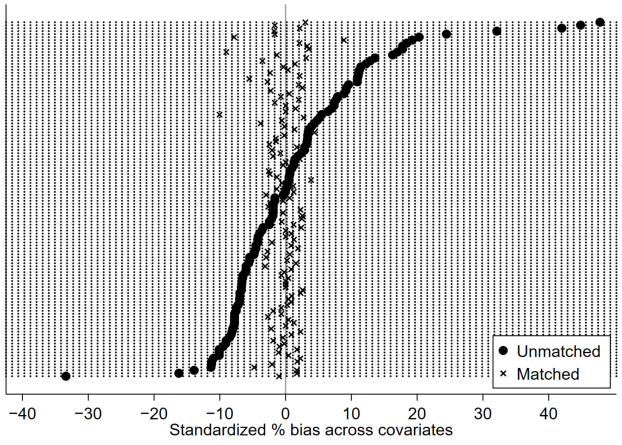


Figure 3. Distribution of standardized percentage bias across covariates between groups before and after matching. Note: due to the large number of county variables, the ordinate does not list all the variable names.

6.2.2. ATT of Maintenance Skill Training

We used four different matching methods to measure impact. Table 4 shows the ATT of maintenance skill training on agricultural machinery operation service area. It can be found that training in agricultural machinery maintenance skill had a significant impact on the machinery tilling service area, and the net effect range was 12.481–14.672 ha, with an average of 13.584 ha. This shows that, after considering the bias of agricultural machinery operator participation in training, maintenance skill training significantly increased the area of 13.584 ha of machinery tilling service. In machinery harvesting service area, the estimated range of ATT was 9.409–9.480 ha, with an average of 9.457 ha. After controlling the self-selection bias between the treatment group and the control group, the difference level in machinery harvesting service area caused by the maintenance skill training was 9.457 ha, that is, when the operators attended training, the machinery harvesting service area increased by 9.457 ha. All the ATT results rejected the original hypothesis equal to 0 at the 1% significance level, and H1 was confirmed again.

Table 4. Results of PSM (agricultural machinery operation service area).

	Machinery Tilling Service Area		Machinery Harvesting Service Area	
Matching Methods	**ATT**	**Standard Error**	**ATT**	**Standard Error**
K-nearest neighbor matching	14.672 ***	4.626	9.480 ***	2.871
K-nearest neighbor matching within a caliper	14.672 ***	4.626	9.480 ***	2.871
Radius matching	12.481 ***	4.352	9.409 ***	2.733
Kernel matching	12.512 ***	4.354	9.460 ***	2.734
Average value	13.584	–	9.457	–

Note: *** indicates statistical significance at the 1% level.

6.3. Robustness Test

To further verify the robustness of H1, we performed regression on the fixed effect model again with the samples retained in the k-nearest neighbor matching method (k = 4). First, we conducted a common support and balancing test. The results were good, which is not shown here. As shown in Table 5, the robustness test results were basically consistent with the previous results, indicating that the regression results had high reliability. The conclusions of H1 were robust for the fixed effect model, the PSM method, and a combination of the two.

Table 5. Robustness test results of fixed effect model.

	(1) Machinery Tilling Service Area	**(2)** Machinery Harvesting Service Area
Maintenance skill training	10.426 ***	8.524 ***
	(3.556)	(2.097)
Control variables	Introduced	Introduced

Note: *** indicates statistical significance at the 1% level.

Maintenance skill training significantly increased the machinery tilling service area and the machinery harvesting service area. On the basis of controlling individual characteristics, family characteristics, agricultural operation characteristics, policy characteristics, and agricultural machinery equipment characteristics, due to participation in agricultural machinery maintenance skill training, the machinery tilling service area was increased by 10.426 ha, and the machinery harvesting service area was increased by 8.524 ha.

6.4. Further Discussion

In the previous empirical literature, there are some studies on the influencing factors of agricultural machinery purchase, such as the amount of agricultural labor force, agri-

cultural machinery subsidy policies, land characteristics, operation scale, and farmland leasing [25,44–46]. However, most of these studies are based on farmers who purchase and use agricultural machinery for their own use and ignore agricultural machinery operators who provide agricultural machinery operation services. Therefore, we took the services providers, that is, the agricultural machinery operators, as the object, and first analyzed the direct impact of maintenance skill training on the quantity of demand for large- and middle-sized agricultural machinery and then tested the transmission mechanism of agricultural machinery operation service area under the impact of maintenance skill training for the quantity of demand for large- and middle-sized agricultural machinery purchased by operators.

6.4.1. Maintenance Skill Training and the Amount of Large- and Middle-Sized Agricultural Machinery

First, we took maintenance skill training as the independent variable and the amount of large- and middle-sized agricultural machinery as the dependent variable in the fixed effect model. The results are shown in Table 6. We found that maintenance training had a significant positive impact on the quantity of demand for operators purchasing two types of agricultural machinery at the level of 1%. Then, the PSM method was used to measure the impact on the purchase of large- and middle-sized agricultural machinery. The results of the common support and balancing test were good and are not shown here. The impact results of large- and middle-sized agricultural machinery purchases of operators are shown in Table 7. For the purchase of tractors above 60 hp, the average ATT was 0.326, that is, after controlling the self-selection bias between the treatment group and the control group, the difference in the purchase of tractors above 60 hp caused by maintenance skill training was about 0.326. For the number of rice and wheat combine harvesters above 4 kg/s, the average ATT was 0.191, that is, after controlling the self-selection bias between the treatment group and control group, the difference in the number of rice and wheat combine harvesters above 4 kg/s caused by maintenance skill training was about 0.191. The results were significantly higher than the critical value of the 95% confidence level of 1.96, indicating that the test results were significant and robust. Based on the results for quantity of two types of large- and middle-sized agricultural machinery, we believe that maintenance skill training had a significant positive impact on the quantity of demand for large- and middle-sized agricultural machinery.

Table 6. Results of fixed effect model (amount of large- and middle-sized agricultural machinery).

	(1)	**(2)**
	Number of Tractors Above 60 Hp	**Number of Rice and Wheat Combine Harvesters above 4 kg/s**
Maintenance skill training	0.245 ***	0.168 ***
	(0.041)	(0.022)
Control variables	Introduced	Introduced
Number of observations	4567	4567

Note: *** indicates statistical significance at the 1% level.

Table 7. Results of PSM (amount of large- and middle-sized agricultural machinery).

	Number of Tractors Above 60 Hp		**Number of Rice and Wheat Combine Harvesters above 4 kg/s**	
Matching methods	ATT	**Standard Deviation**	ATT	**Standard Deviation**
K-nearest neighbor matching	0.327 ***	0.068	0.188 ***	0.037
K-nearest neighbor matching within a caliper	0.327 ***	0.068	0.190 ***	0.037
Radius matching	0.327 ***	0.062	0.191 ***	0.034
Kernel matching	0.323 ***	0.062	0.195 ***	0.034
Average value	0.326	–	0.191	–

Note: *** indicates statistical significance at the 1% level.

6.4.2. Mediating Effect of Agricultural Machinery Operation Service Area

Agricultural machinery is a kind of durable good serving multiple agricultural production cycles [25]. According to the human capital theory, effective training can give full play to people's subjective initiative and promote the realization of goals [47]. When agricultural machinery operators attend maintenance skill training, they can master basic fault diagnosis methods for large- and middle-sized agricultural machinery, which not only improves the human capital of the agricultural labor force [48], but also enhances their confidence in the use of large- and middle-sized agricultural machinery and operation efficiency. On the one hand, if operators master basic maintenance skills, their consumption of large- and middle-sized agricultural machinery maintenance services is reduced, which decreases the operation and maintenance costs of large- and middle-sized agricultural machinery. On the other hand, when the operation service area increases, operators increase their purchases of large- and middle-sized agricultural machinery to meet their demand for agricultural machinery operation services.

Therefore, we further used a mediating effect model to test the transmission mechanism of agricultural machinery operation service area in the impact of agricultural machinery maintenance skill training on the quantity of demand for large- and middle-sized agricultural machinery. With reference to both Baron and Kenny (1986) [49] and Wen (2014) [50], the stepwise method and the Bootstrap method were used to conduct the mediating effect test. Specifically, the stepwise regression still adopted the fixed effect model, while the Bootstrap method set the county model variables to be included to control the county environment characteristics. As shown in Table 8, models (1), (2), and (3) are the results of the mediating effect test for machinery tilling service area, and models (4), (5), and (6) are the mediating effect test results for machinery harvesting service area. Taking machinery tilling service area as an example, the first step of the stepwise regression (model (1)) took the number of tractors above 60 hp as the dependent variable and maintenance skill training as the independent variable, and the second step (model (2)) took the machinery tilling service area as the dependent variable and maintenance skill training as the independent variable, while the third step (model (3)) took the number of tractors above 60 hp as the dependent variable and simultaneously took maintenance skill training and machinery tilling service area as the independent variables. The regression coefficients in the three models were significant, indicating that the mediating effect was significant, that is, in addition to directly increasing the number of tractors above 60 hp due to maintenance skill training, operators participating in maintenance skill training also indirectly increased the number of tractors above 60 hp by increasing the service area and, thus, promoting large-scale production. Similarly, the regression coefficients in models (4), (5), and (6) were significantly positive at 1%. The results of the mediating effect test with the Bootstrap method are shown in Table 9. Both the direct effect and the indirect effect passed the significance test at the level of 1%. However, the indirect effect was lower than the direct effect, no matter the number of tractors above 60 hp or the number of rice and wheat combine harvesters above 4 kg/s. That is, the purchase of large- and middle-sized tractors and harvesters was more directly affected by maintenance skill training. At the same time, some of the purchase behaviors were due to the training, which made them superior in agricultural machinery operation services, and they obtained more service orders, resulting in more demand for agricultural machinery operation services.

Table 8. Results of mediating effect test with stepwise method.

	(1)	(2)	(3)	(4)	(5)	(6)
	Number of Tractors above 60 Hp	**Machinery Tilling Service Area**	**Number of Tractors above 60 Hp**	**Number of Rice and Wheat Combine Harvesters above 4 kg/s**	**Machinery Harvesting Service Area**	**Number of Rice and Wheat Combine Harvesters above 4 kg/s**
Maintenance skill training	0.245 *** (0.041)	15.215 *** (3.068)	0.189 *** (0.039)	0.168 *** (0.022)	10.615 *** (1.941)	0.129 *** (0.021)
Machinery tilling service area	–	–	0.003 *** (0.0001)	–	–	–
Machinery harvesting service area	–	–	–	–	–	0.003 *** (0.0001)
Control variables	Introduced	Introduced	Introduced	Introduced	Introduced	Introduced

Note: *** indicates statistical significance at the 1% level.

Table 9. Results of mediating effect test with Bootstrap method.

		Observed Coefficient	Bootstrap Standard Error	Normal-Based (95% Confidence Interval)	
Maintenance skill training and number of tractors above 60 hp	Indirect effect	0.055 ***	0.021	0.012	0.098
	Direct effect	0.189 ***	0.044	0.102	0.276
Maintenance skill training and number of rice and wheat combine harvesters above 4 kg/s	Indirect effect	0.039 ***	0.009	0.020	0.058
	Direct effect	0.129 ***	0.025	0.079	0.178

Note: *** indicates statistical significance at the 1% level.

7. Conclusions

This study raised the question of whether agricultural socialized service providers could increase their agricultural machinery operation service area because of participation in agricultural machinery maintenance skill training. Based on the survey data of 4905 sample farmers in 100 counties of 10 provinces in China, we found that maintenance skill training significantly increased the agricultural machinery service area after controlling and eliminating the endogenous effects caused by unobservable variables, such as the nature, economy, and policy of a county, through the fixed effect model. Moreover, after eliminating the self-selection bias based on the PSM method, it was further verified that, after agricultural machinery operators participated in maintenance skill training, the machinery tilling service area increased by 10.426 ha, and the machinery harvesting service area increased by 8.524 ha. In addition, maintenance skill training not only had a positive impact on agricultural machinery operation service area, but also had an indirect impact on the quantity of demand for large- and middle-sized agricultural machinery through the mediating effect of agricultural machinery operation service area. Obviously, maintenance skill training could enhance the maintenance skill and human capital level of operators, which directly reduced the maintenance cost and failure recovery time cost, which reduced the failure of free work cost and, finally, increased the agricultural machinery operation service area, that is to say, operators participating in maintenance skill training had an advantage in operation services. At the same time, since training in agricultural machinery maintenance skill made the operators better at agricultural machinery service and obtaining more orders, it had an indirect positive impact on the number of large- and middle-sized agricultural machinery purchased.

The implications of this study were as follows:

(1) Since maintenance skill training could reduce maintenance costs and shorten the failure recovery time costs of agricultural machinery in operation services, it could enable operators to gain an advantage in cross-regional operation under the background of the gradual saturation of agricultural machinery, the rapid shortening of agricultural

machinery operation time windows, and the overall low quality of agricultural machinery. Therefore, from the perspective of improving operators efficiency or from the perspective of improving regional agricultural machinery efficiency and ensuring agricultural production, it is necessary for agricultural departments to organize special training courses on simple maintenance skills for large- and middle-sized tractors, harvesters, rice transplanters, straw balers, and other major machines involved in cross-regional operations for operators participating in agricultural machinery operation services during their slack season. Relevant departments related to agriculture should strengthen coordination. For example, when designing training projects, agricultural economy departments, agricultural science and education departments, and agricultural machinery departments should coordinate training projects and training funds and take maintenance skills as important training content to create synergy.

(2) One reason why maintenance skills are important is that the quality of agricultural machinery is unreliable at present. In order to improve the efficiency of agricultural machinery operation and ensure agricultural production in the best agricultural time, agricultural machinery manufacturing enterprises should make more efforts to improve the reliability of agricultural machinery in terms of technology, materials, and structure. At the same time, a competent department of agricultural machinery should also give appropriate policy preference to agricultural machinery with high-quality reliability in purchase subsidies to guide agricultural machinery enterprises to improve production quality.

(3) Agricultural machinery maintenance skill training not only gives operators more advantages in agricultural machinery operation services, but also makes them able to purchase more large- and middle-sized agricultural machinery through direct and indirect paths, which is conducive to further strengthening the individual competitiveness and advantages of the agricultural machinery operation service market. Therefore, it is also possible to find potential education objects, that is, to give priority to the training of large- and middle-sized agricultural machinery operators to enhance the effect of skills education.

We enriched the research on skills training and agricultural machinery operation services by analyzing the impact of maintenance skill training on agricultural machinery operation service area. However, this study also had the following limitations: First, the sample data were from 10 provinces in China, and there was uncertainty about whether there were similar conclusions in other regions. Therefore, the universality of the conclusions and recommendations needs further exploration. Second, there are many methods of agricultural training, such as lectures, visits, and on-site guidance. Understanding the effectiveness of different training methods is of great significance to the scientific design of training plans and the promotion of the skills of agricultural machinery operators. In the future, researchers should consider the impact of different agricultural machinery maintenance skill training methods on the service supply behavior of operators.

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