Book Chapter

What are the Effects of Participation in Production Outsourcing? Evidence from Chinese Apple Farmers

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Abstract

This study used a multiple linear regression and a propensity score matching model to estimate the different effects of participation in production outsourcing on farmers' apple production efficiency and apple income based on field survey data from 960 apple farmers in the Shandong, Shaanxi, and Gansu Provinces. The results showed that, on average, the outsourcing of apple production increased farmers' apple production technology efficiency by 5.60%, their labor productivity by 2,121.48 kg/person, land productivity by 334.50 kg/mu, capital productivity by 0.05 kg/Yuan, and their apple sales revenue by 13,300 Yuan. However, farmers' net income from apples decreased by an average of 5,000 Yuan. The outsourcing of apple production, which is labor-intensive, is constrained by the increase in labor costs, which in turn, affect the transformation of the apple industry into a service scale operation driven by the economy of division. Therefore, it is necessary to actively promote socialization services, such as apple production outsourcing, and develop labor-saving production outsourcing to reduce the service costs of apple production.

Keywords
Production Outsourcing; Production Efficiency; Propensity Score Matching; Apple Farmers; China

Introduction

There is a broad understanding that agriculture is a fundamental industry and that it is playing an increasingly important role in the national economy and in people's livelihoods. The modernization of agriculture and rural areas is also the key to the realization of national modernization. In particular, scale management, as the foundation of agricultural modernization, has received extensive attention in political and academic circles. In 2017, the report of the 19th National Congress of the Communist Party emphasized, from a policy perspective, the development of various forms of moderate scale management to realize the organic connection between small farmers and modern agricultural development. On the other hand, from an academic research perspective, scholars have focused on the development path and the mode of agricultural scale management; some scholars believe that the trend of "part-time" and "off-farm" labor, caused by the transfer of agricultural labor, promotes the concentration of rural land and the processes of industrialization and urbanization and that this is conducive to the realization of agricultural scale operations [1-4], but the decentralized operation of small farmers is still the basic organizational form of agricultural production and management at this stage in China. There are nearly 260 million farmers in China whose scale of land management was below 50mu at the end of 2016, which accounts for 97% of the total number of farmers, and the average area of cultivated land is approximately 5 acres. Although land transfer has alleviated the problem of scale management to a certain extent, the overall promotion is slow, and the development path of land scale management based on land logic is limited [5-6]. Therefore, exploring other paths to realize scaled operations is particularly important for agricultural modernization.

Based on the principle of division of labor, some researchers have suggested that on the basis of family management, the

transformation from a land scale operation to a service scale operation through socialized services, such as agricultural production outsourcing, is an important in innovation in agricultural management methods in China [7-8]. In essence, the separability of agricultural activities and the outsourcing of services have increased the possibility of family businesses being involved in the social division of labor. Family management and service organizations share the cooperative surplus together by increasing their efficiency through specialization and the division of labor. In this context, the scale of agriculture is ultimately expressed as the division of labor [9-10].

There have been numerous studies from researchers across different disciplines investigating outsourcing mechanisms, welfare effects and the determining factors that affect the farmers' adaptative behaviors toward outsourcing in agriculture. With regard to outsourcing mechanisms, most studies have been designed to explain the economic implications of agricultural production outsourcing based on resource-based theory and transaction cost theory. Family resource endowment constraints and lower transaction costs are both important factors that promote the outsourcing of agricultural production [11-15]. Studies on the welfare effects of outsourcing have confirmed that the outsourcing of agricultural production can reduce production costs and improve production efficiency [16-18], deepen a specialized division of labor and promote agricultural scale operations [19], and improve the degree of organization of agricultural production [20]. Existing research on the decision-making behavior of farmers has theoretically analyzed and empirically tested decision-making behavior with regard to agricultural production outsourcing using behavior choice theory, the production function model and property rights theory from the perspectives of the differentiation of the farmers' role [21], the difference in cultivated scale [22], the differences in the attributes of production links [23], transaction characteristics and the capacity for subjective behavior [19,24] as well as other perspectives.

In summary, the results of multi-perspective research have laid a rich foundation for this study, but the existing research has the

following shortcomings: First, the research objects is mainly rice, wheat and other grain growers; studies of perennial economic crops are lacking. As a perennial and high-value economic crop, apple has clear differences in its outsourcing from other crops; the apple industry is a labor-intensive industry, and its outsourcing is still dependent on employees because of the lower degree of mechanization compared with grain production. Thus, the study of outsourcing in apple production is of great significance for the construction of a productive service system in the apple industry. Second, the research methods have generally utilized traditional regression models, such as logistic and probit models, which do not address the endogeneity that may be caused by heterogeneity resulting from the causal relationship between outsourcing and farmer welfare. Therefore, this study uses the propensity score matching (PSM) model to reduce the impact of endogenous problems based on the framework of counterfactual analysis and expands the empirical methods of the existing researches. Third, although these studies have the advantages of partially explaining the farmers' decision-making mechanisms for outsourcing behaviors, the effects of outsourcing on farmers have to date been largely neglected, particularly the effects on agricultural production efficiency and income. A few researchers have expressed concern about the influence of outsourcing on the farmers' production efficiency, but these studies did not consider the impact on the farmers' agricultural income. In fact, increasing the farmers' income is the ultimate goal of agricultural production. Outsourcing, as a productive service, aims to improve agricultural production efficiency through specialization and the division of labor and increasing farmers' income. Therefore, this study attempts to contribute to the literature by investigating how outsourcing influences the farmers' agricultural production efficiency and agricultural income.

This study focuses on the relationship between apple production outsourcing and apple production efficiency (e.g., technology efficiency, labor productivity, land productivity and capital productivity) and apple's income (e.g., apple sales revenue and apple net profit). Based on micro-survey data from 960 apple farmers in Shandong, Shaanxi and Gansu Provinces, the multiple

linear regression (MLR) and PSM models were used to comprehensively examine the influence of outsourcing on the farmers' apple production efficiency and income and to explore the actual effect of outsourcing of apple production. On the micro level, apple production usually entails more labor-related investment, implying that outsourcing might be more complex and active. Clarifying the perennial role of outsourcing activities in apple production will contribute towards an understanding of the mechanisms, functions and efficiency of a general socialized service system in China.

This study is structured as follows. Section 1 is the introduction. Section 2 outlines the analysis framework and the corresponding model design. Section 3 presents the data sources and provides descriptive statistics for the characteristic differences between participants and non-participants within specialized apple production sites. Section 4 discusses the empirical results by estimating the determinants of outsourcing participation and assessing the economic effects of outsourcing behavior on apple farmers. Section 5 concludes with policy implications.

Conceptual Framework and Estimation Strategies

Conceptual Framework

Since the publication of the *Wealth of Nations* written by Adam Smith in 1776, the division and specialization of labor have gradually attracted the attention of economists. Academia generally believes that the division and specialization of labor are the key to increasing marginal returns [25], which is the source of economic growth, and can improve production efficiency [26]. The outsourcing of agricultural production has emerged in the context of the deepening of a specialized division of labor, the continuous advancement of technological innovation, and the increasing shortage of agricultural labor. It take the form of the separation of different production links or functions among different farmers in the process of agricultural production. The new transition of scale operation from land logic to division logic is the embodiment of the specialization and division of labor, the purpose of which is to increase agricultural

income by improving agricultural production efficiency. This study defines the outsourcing of apple production links as a management behavior that apple farmers with land management rights pay service fees to an individual or organization to complete one or more production tasks in order to increase apple productivity and income or reduce the opportunity cost of farming.

Specifically, according to resource-based theory and comparative advantage theory, resource endowment that is influenced by the scarcity and heterogeneity of agricultural production resources promotes the outsourcing of agricultural production links among farmers, and depending on the family comparative advantage of the family, apple farmers who are rational economic agents comprehensively consider and determine whether to participate in the outsourcing of apple production links based on household's resource endowment and external environmental conditions. Based on these considerations, apple farmers reconfigure domestic resources and external resources, and change the combination of production inputs, such as labor, capital, land and technology, to directly affect productivity. Some studies have shown that the outsourcing of agricultural production can significantly improve agricultural production efficiency [16-17]. The outsourcing of apple production can effectively compensate for a shortage in the quantity and skills of apple farmers' agricultural labor, and the effects of reorganization and technology spillovers can increase the apple farmers' productivity. Therefore, participating in the outsourcing of apple production links can improve apple production efficiency.

As the degree of specialization of apple production continues to increase, the division of labor will promote a more rational combination of production factors and increase apple production efficiency and the marginal production of production factors. The increase in apple production directly promotes an increase in the farmers' income when the market price of apples is fixed. Therefore, participating in the outsourcing of apple production links can increase the households' apple income. Based on the

above analysis, the conceptual framework of this study can be expressed as shown in Figure 1.

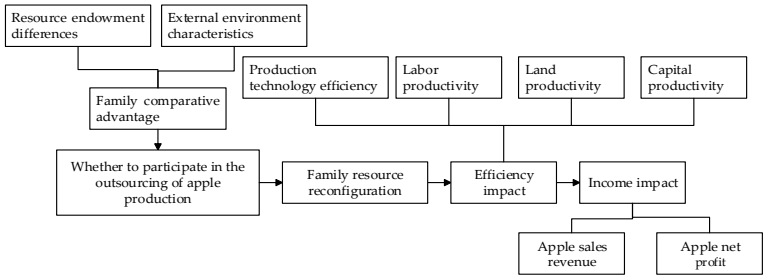

Figure 1: Conceptual framework for the outsourcing behavior of apple farmers.

Estimation Strategies

Based on the approach of Xu et al. [27], this study uses both the multiple linear regression (MLR) and propensity score matching (PSM) models and compares the similarities and differences of the results from these two models.

(1) MLR model: assumes that there is no heterogeneity among farmers.

To evaluate the effect of the apple farmers' participation in the outsourcing of apple production, this study first assumes that there is no heterogeneity between participants and non-participants in the outsourcing of apple production. Specifically, the impact of outsourcing on the farmers' apple production efficiency and income is estimated using a MLR model. The specified model is:

$$Y_i = \beta_0 + \alpha \times Outsourcing_i + \beta \times X_i + e_i \qquad (1)$$

where Y_i is the dependent variable that represents the apple production efficiency or income, $Outsourcing_i$ is the observed binary variable that takes the value 1 for outsourcing participants and 0 for non-participants, X_i is a vector of other explanatory

variables that affect apple production efficiency and income, β_0 is the intercept term, e_i is an error term, and α and β are the vectors of the parameters to be estimated.

(2) PSM model: assumes that there is heterogeneity among farmers.

In the case of heterogeneity between participants and non-participants in the outsourcing of apple production, the PSM model is used to compare apple production efficiency and income differences between participants and non-participants. The decision of farmers to participate in the outsourcing of apple production is the result of self-selection; the apple farmers who have more labor engaged in apple production and a high degree of concurrent business do not need to outsource, but most of the farmers involved in the outsourcing of apple production usually have a high level of education, many years of apple planting and a large scale of apple planting [28]. It is clear that outsourcing participants and non-participants are systematically different, mainly because the farmers themselves decide whether to participate in outsourcing (self-selection). When outsourcing participation is not randomly distributed, the farmers' outsourcing participation decisions are most likely influenced by observable factors (e.g., education, growing experience, and planting scale) that may be correlated with the outcome (apple production efficiency and income, in this case). This correlation influences the sample selection and potentially results in endogeneity, which must be addressed to obtain an unbiased and consistent estimation of the treatment effect of outsourcing participation on apple production efficiency and income. The econometric technique used to deal with selection bias in the case of a continuous outcome variable (here, the apple production efficiency and the income status of apple farmers) is the propensity score matching (PSM) model.

It is worth noting that based on the counterfactual framework of Rubin, the PSM model can address the problem of selection bias and biased estimation caused by self-selection in the process of outsourcing decision-making. Furthermore, the PSM model enables the correction of the implicit problem of endogeneity in

the sample by using the matching method, and it relaxes the assumptions of function form, parameter constraints and error term distribution [29]. For these reasons, the PSM model is used to estimate the effect of outsourcing participation on apple production efficiency and income in this study.

In the PSM model, the decision to participate in outsourcing and its impact on apple production efficiency and income can be modeled in a three-stage treatment framework. In the first stage, the decision of farmers to participate in outsourcing is modeled and estimated using a logit model. Following a random profit maximization framework, apple farmers choose to participate in outsourcing if the profits gained from the participation are greater than the profits gained from non-participation. Thus, an apple farmer's decision to participate in outsourcing can be expressed in a discrete choice model. The logit model is used to estimate the conditional probability fitted value (namely the propensity score) of each farmer's participation in outsourcing under the given pretreatment characteristics. The specified model is:

$$p(X_i) = P_r\left[D = 1 \middle| X_i\right] = \frac{\exp(\beta X_i)}{1 + \exp(\beta X_i)} \quad (2)$$

where D is the treatment variable (i.e., the observed binary variable that takes the value 1 for outsourcing participants and 0 for non-participants), X_i is a multidimensional vector of covariates (e.g., education, growing experience, and planting scale) that may influence apple farmers' participation in the outsourcing of apple production, and p is a vector of the propensity scores to be estimated, which represents the conditional probability of the apple farmer to participate in outsourcing.

In the second stage, the participants and non-participants are matched according to their propensity scores. Because the matching values and weights applied by different matching methods are different, the matching results are different. This study uses four matching methods (including k-nearest neighbor matching, caliper matching, k-nearest neighbor matching in

calipers, and kernel matching) and compares these results (similar to a sensitivity analysis). If the results of the different matching methods are similar, the matching result is robust and does not depend on the specific method.

In the third stage, the average treatment effect on the treated (ATT) can be estimated to obtain the effect of participating in outsourcing on apple production efficiency and income. The ATT refers to the expected effect of the treatment on individuals with the observed characteristics X who participate in outsourcing. After correcting for the selection bias arising from both the observed and unobserved factors as previously discussed, the ATT estimates are unbiased:

$$ATT = E\left[Y_1^i - Y_0^i\right] = E\left[Y_1^i - Y_0^i \middle| D=1\right] = E\left[Y_1^i \middle| D=1\right] - E\left[Y_0^i \middle| D=0\right] \quad (3)$$

where the outer expectation is over the distribution of $p(X_i \mid D=1)$, Y_1^i and Y_0^i are the potential outcomes in the two counterfactual situations of (respectively) participation and no participation, $E\left[Y_1^i \middle| D=1\right]$ is the expectation of apple production efficiency and income of the participants in an observed context, and $E\left[Y_0^i \middle| D=1\right]$ is the expectation of apple production efficiency and income of the participants in a counterfactual context. By using the PSM model, we can identify a group of non-participating farmers who have characteristics similar to the participating farmers, and observe their apple production efficiency and income to estimate $E\left[Y_0^i \middle| D=1\right]$. The difference between $E\left[Y_1^i \middle| D=1\right]$ and $E\left[Y_0^i \middle| D=1\right]$ is the effect of participation in outsourcing on the farmers' apple productivity and income.

Data and Descriptive Statistics

Data Source and Sampling Methods

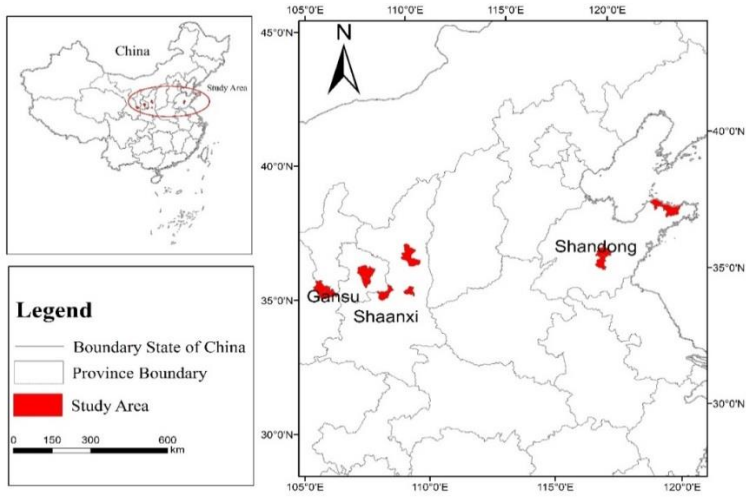

Figure 2: Geographic locations of sample sites.

The data used in the present study was collected by the China Agriculture Research System (CARS) through a field survey of apple farmers between July and August 2016 in Shaanxi and Gansu Provinces in the Loess Plateau region and in Shandong Province in the Bohai Gulf region (see Figure 2). The investigators were first trained, and they then conducted preliminary research to ensure that they accurately understood the questionnaires; finally, formal interviews were conducted with the farmers. The field survey collected detailed information on the respondents' apple production and operation details as well as organizational participation.

A multi-stage sampling procedure was used to select counties and their sub-divisions and farm households. In the first stage, we used the probability proportional to size (PPS) sampling method to select 4 apple-producing counties in Shandong, four counties in Gansu, and three counties in Shaanxi based on the size of apple production in 2015. In the second stage, 8 villages

in each selected county were randomly selected. In the third stage, random sampling techniques were used to identify the sample of apple farmers, and approximately 8–12 households in each village were randomly selected. A sample frame acquired from the local apple sector in each selected county was used to sample the required number of farmers from each village. Overall, 11 counties were randomly selected in the three Provinces, and 967 sample households were selected for interview. The survey collected a range of information including household and farm-level characteristics, apple production and operation details, cooperative membership, and outsourcing participation for 2015.

A structured face-to-face questionnaire was conducted to household heads or their spouses who were willing to participate. The collected information was based as much as possible on written records; for farmers who did not keep records, information was based on recall data. Some of the interviewed farmers had not sold the apples harvested in 2015, but kept these apples in cold storage. We excluded these farmers from our analysis.Data from 960 farmers, including 686 outsourcing participants (185 in Shaanxi, 236 in Shandong and 265 in Gansu) and 274 non-participants (67 in Shaanxi, 131 in Shandong and 76 in Gansu) were used in the analysis.

Basic Characterization

Based on the conclusions of these former studies and the characteristics of apple growing, the technology efficiency, labor productivity, land productivity, capital productivity, apple revenue and apple profit are used as outcome variables, the binary variable of outsourcing (whether to participate in the outsourcing of apple production) is used as a treatment variable, and the individual characteristics of apple production decision makers, household characteristics, apple production characteristics, and external environmental characteristics are used as the covariates in this study.

Table 1 presents the definitions of and the mean differences in the demographic and socioeconomic characteristics between

outsourcing participants and non-participants for the variables used in the present study. There are statistically significant differences at least 10% level in the mean value of 13 variables between the two groups. The heterogeneity of outsourcing participants and non-participants is also revealed to some extent. Furthermore, it can be observed that participating in the outsourcing of apple production has a significant positive impact on apple productivity and income. Outsourcing participants are more efficient than non-participants. On average, the per capita apple production and the apple revenue for outsourcing participants is 3,748.36 kg/person and 32,420.17 Yuan, respectively, which is higher than their counterparts. The technology efficiency for outsourcing participants is 4.51% higher than those who do not outsource. Table 1 also demonstrates that relative to non-participants, outsourcing participants are generally older and have lower education levels. Outsourcing participants have, on average, fewer apple laborers, and smaller acreage (5.02 mu compared with 7.94 mu for non-participants). However, it is worth noting that this difference does not account for the effect of other farmer characteristics and thus cannot be taken as an ultimate outcome. Therefore, the MLR and PSM models are needed to further analyze and confirm the promotion effect of outsourcing on production efficiency and income.

Table 1: Group differences between outsourcing participants and non-participants.

Variables	Definition	Participants	Non-participants	Mean difference
Outcome variable				
Technology efficiency	Calculated by Stochastic Frontier Approach	0.60	0.64	0.045***
Labor productivity	Apple production per capita in 2015 (kg/person)	4,556.59	8,304.94	3,748.357***
Land productivity	Apple productions per mu in 2015 (kg/mu)	2,327.89	2,348.58	20.695
Capital productivity	Apple productions per capital in 2015 (kg/Yuan)	0.72	0.73	0.013
Apple revenue	Apple sales gross income in 2015 (Yuan)	37,379.17	69,799.34	32,420.174***
Apple profit	Household apple net income in 2015 (Yuan)	20,399.41	26,651.40	6,251.996*
Covariate				
Personal characteristics of apple production decision makers				
Sex	Gender: 1=male; 0=female	0.93	0.92	-0.010
Age	Actual age in 2015 (years)	52.31	50.37	-1.945***
Education	0= illiteracy; 1=primary school; 2=middle school; 3=high school; 4= college or above	1.73	1.89	0.161***
Organization member	Party members or village cadres: 1=yes; 0=no	0.23	0.23	0.006
Cooperative member	1=yes; 0=no	0.37	0.37	-0.005
Household characteristics				
Grower number	Total number of apple laborers (number)	2.08	2.00	-0.078*
Growing experience	Years of apple planting (years)	20.57	20.78	0.206
Concurrent business	Proportion of agricultural income in 2015 (%)	0.77	0.79	0.022
Apple production characteristics				
Planting scale	Apple acreage in 2015 (mu)	5.02	7.94	2.924***
Fragmentation degree	Average orchard area per block (mu)	1.28	0.78	-0.503**
External environment characteristics				
Township distance	Distance from home to the nearest township (km)	13.35	17.86	4.517**
Hired labor price	Arithmetic mean of the price in each production link (Yuan/workday)	130.24	125.60	-4.637**
Shandong	1=yes; 0=no	0.48	0.34	-0.134***
Shaanxi	1=yes; 0=no	0.24	0.27	0.025
Gansu	1=yes ;0=no	0.28	0.39	0.109***

Note: Technology efficiency is the measure of the ability of production units to achieve maximum output under the maximum use of existing technology. It is measuredas the ratio between the actual output and the maximum potential output of the unit. This study uses the stochastic frontier approach (SFA) of the Frontier 4.1 software package and the translog production function to measure the farmers' apple production technology efficiency. In particular, the input of the production factors includes labor (the total amount of labor used in apple production by the household in 2015, i.e., the sum of self-employed and employed labor; a standard labor day is the normal amount of work by one middle-aged laborer in 8 hours), land (the household's apple acreage) and capital (the cost of fertilizer, pesticides, fruit bags, and reflective film for apple production of the household in 2015). The output is the total apple output of the household in 2015; 1 mu = 0.06667 hectare, Yuan is the Chinese currency, and 1 Yuan = 0.1442 US dollars in 2018. *, **, *** indicates significance at the 10, 5, and 1 percent levels, respectively.

Empirical Results

Regression Analysis of Outsourcing Participation Effect in Apple Production

To demonstrate the effect of participation in outsourcing on apple production efficiency and income, a MLR model calculated using the ordinary least square (OLS) approach can be used to estimate Eq. (1) without considering the influence of heterogeneity. The results are shown in Table 2. In terms of production efficiency, participating in the outsourcing of apple production can improve the technology efficiency of apple production by 5.31%, labor productivity by 2,079.99 kg/person, land productivity by 312.81 kg/mu, and capital productivity by 0.03 kg/Yuan, but the effect on capital productivity is not statistically significant. In terms of apple income, participating in the outsourcing of apple production can significantly increase the farmers' apple revenue by 14,320.75 Yuan, but reduce the farmers' apple net profit by 3,840.01 Yuan, although the impact is not statistically significant.

Table 2: Estimation results of multiple linear regression models.

Variables	Technology efficiency	Labor productivity	Land productivity	Capital productivity	Apple revenue	Apple profit
core variable						
outsourcing	0.0531***	2,079.9895***	312.8094***	0.0261	14,320.7500***	-3,840.0110
control variables						
Personal characteristics of apple production decision makers						
Sex	0.0075	-209.6380	-116.8471	0.0677*	3,789.1120	10,079.1400**
Age	-0.0013**	-5.1766	-7.8067*	-0.0010	200.9413	15.2144
Education	0.0038	743.2185***	28.0121	-0.0136	8,609.4760**	5,473.2510**
Organization member	0.0012	-1,433.3385***	-202.8282**	0.0008	-2,594.2660	4,086.1890
Cooperative member	-0.0036	305.7484	60.7651	0.0134	-3,198.0390	-7,104.6250
Household characteristics						
Grower number	0.0007	-2,776.1155***	139.5331**	0.0086	-5,299.2920	-5,510.4040
Growing experience	0.0028***	-35.5300	11.8895**	0.0040***	-1,299.4790***	-715.4605*
Concurrent business	-0.0438	-1,525.7250	-446.1875**	-0.0636	-30,896.4000**	-23,538.3300**
Apple production characteristics						
Planting scale	-0.0005	750.5785***	-41.2456***	-0.0018	8,007.4220***	3,608.4450***
Fragmentation degree	-0.0091*	-148.5191	149.0635***	-0.0178	180.1038	-14.5041
External environment characteristics						
Township distance	0.0000	2.9390	0.8344	-0.0000	32.6379	28.5808
Hired labor price	-0.0002	-8.6255	-4.4715***	-0.0009**	47.0112	54.1362
Shandong	0.1189***	5,028.2500***	1,475.4555***	0.1312***	34,804.7600***	12,063.5900**
Shaanxi	-0.0111	-930.7320*	55.3985	-0.0801***	-19,184.8300***	-12,687.4100**
Constant	0.5859***	4,875.8895***	2,339.4215***	0.7429***	-18,468.7000	-318.9363

Note: *, **, *** indicate significance at the 10, 5, and 1 percent levels, respectively. The reference region is Gansu.

Determinants of Outsourcing Participation in Apple Production

As indicated previously, the logit model is used to evaluate the participation in outsourcing. There were 686 outsourcing participants and 274 non-participants. The estimates of the determinants of outsourcing participation are presented in Table 3. It can be seen that the explanatory variables selected in this study have a significant impact on the decision-making behavior of outsourcing participation. In particular, age appears to be an important factor that affects outsourcing participation; the likelihood of participating in outsourcing decreases as age increases. This result is consistent with the findings of Ji et al. [21] for China. The significant and positive impact of education suggests that better-educated apple production decision makers have a significantly higher probability of engaging in outsourcing. This result is consistent with Wang et al. [30], who found that education played an essential role in accessing machine services.

The number of laborers engaged in apple production in a household and the level of concurrent business are negatively correlated with outsourcing participation and statistically significant, suggesting that the likelihood of outsourcing participation decreases as the number of apple growers and the level of concurrent business in a household increases. The available evidence from China is presented in Ji et al. [21]. An increase in apple growing experience increases the probability of outsourcing participation. This finding is consistent with the results of Chen and Huang [31], who investigated the relationship between farmers' skills and the willingness to outsource, and found that the likelihood of participation in outsourcing was higher in experienced farmers than in inexperienced farmers in China. The significant and positive impact of apple orchard area suggests that larger scale apple households have a significantly higher probability of engaging in outsourcing, which is consistent with the findings of Ji et al. [21] for China.

The significance of location variables suggests that, in comparison with apple farmers in Gansu, apple farmers in Shandong and Shaanxi are less likely to participate in outsourcing. This may be explained by the fact that Gansu is a less economically developed Province compered to Shandong and Shaanxi Provinces, and its price for agricultural labor is also lower than the other two Provinces (115.65 Yuan/workday in Gansu, 124.64 Yuan/workday in Shaanxi and 138.96 Yuan/workday in Shandong in the survey). It is worth emphasizing here that the primary objective of the outsourcing equation estimation at the first stage of the PSM model is to control for unobserved heterogeneities that may bias the effect of outsourcing participation on apple production efficiency and income.

Table 3: Determinants of outsourcing participation.

Explanatory variable	Estimates	S.E.
Personal characteristics of apple production decision makers		
Sex	-0.1780	0.2853
Age	-0.0197**	0.0090
Education	0.2193**	0.0955
Organization member	-0.0461	0.1833
Cooperative member	0.0282	0.1747
Household characteristics		
Grower number	-0.4391***	0.1341
Growing experience	0.0220**	0.0102
Concurrent business	-0.5033*	0.2737
Apple production characteristics		
Planting scale	0.0478***	0.0155
Fragmentation degree	-0.1071	0.0726
External environment characteristics		
Township distance	0.0020	0.0016
Hired labor price	-0.0038	0.0026
Shandong	-0.6439***	0.2206
Shaanxi	-0.5411**	0.2087
Constant	2.8138***	0.7179

Note: *, **, *** indicate significance at the 10, 5, and 1 percent levels, respectively.

Matching Quality Inspection

To ensure the quality of the matching, it is necessary to further examine the common support domain of the propensity scores. These results are shown in Figure 3 and Figure 4. Most of the observations are within the common range (on support), and only a small number of samples are lost when matching from Figure 3. The results from Figure 4 clearly demonstrate that most of the propensity score intervals of the outsourcing participant group and the non-participant group have substantial overlap, i.e., most of the propensity scores are in the common support domain, indicating that this sample meets the requirements of matching.

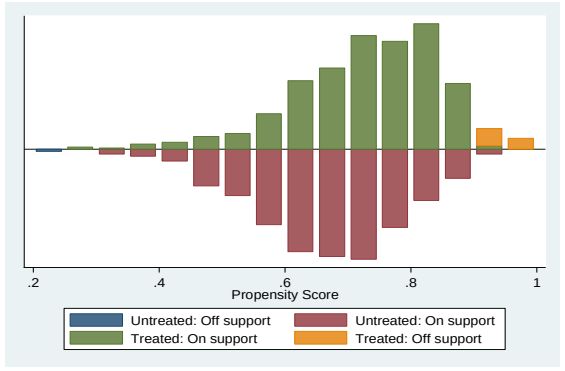

Figure 3: Common range of propensity scores.

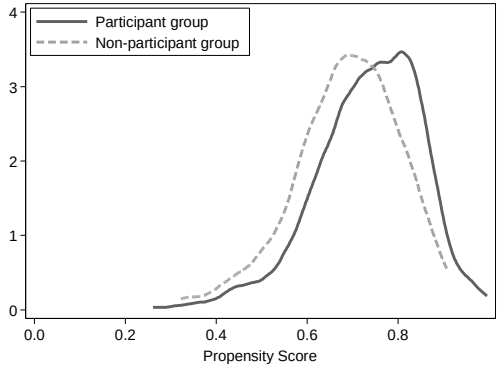

Figure 4: Density function of propensity scores.

A balance test is also used to measure the quality of matching; this test evaluates whether the PSM model satisfies the overlap hypothesis, i.e., there is no systematic difference between the participant group and the non-participant group in each covariate. If the sample matching effect is good, the Pseudo-R^2 value calculated after matching will be very small, and the likelihood ratio test before matching will be rejected, but after matching accepted, the difference of the standardized mean (B) will be less than 25%. Table 4 shows the results of the balance test of matching quality. After matching, the Pseudo-R^2 value is nearly reduced to zero, the likelihood ratio test accepts the null hypothesis that the coefficients of the covariates are simultaneously zero, the mean deviation and the median deviation are sharply reduced, and the B value drops significantly to less than 25%. Generally, these findings justify the use of the PSM model to identify the factors that influence apple farmers' decisions to participate in outsourcing, as well as to estimate the unbiased treatment effects of outsourcing.

Table 4: Balance test of matching quality.

Matching method	Pseudo-R^2	LR chi2	Mean deviation	Median deviation	B (%)
Before matching	0.063	72.28***	14.4	14.2	61.6+
K-nearest neighbor matching	0.006	10.14	2.8	1.8	17.6
Caliper matching	0.004	6.53	2	1.6	14.2
K-nearest matching in caliper	0.006	11.01	2.7	1.6	18.4
kernel matching	0.004	7.21	2.3	1.8	14.9

Note: ***Significant at the 1 percent levels. + indicates that B is greater than 25%.

Table 5: Average treatment effect of outsourcing of apple production.

Matching method	Technology efficiency	Labor productivity	Land productivity	Capital productivity	Apple revenue	Apple profit
Before matching	0.0576***	2,123.8743***	326.5244***	0.0495	13,237.1130***	-4,958.4703*
K-nearest neighbor matching	0.0550***	2,127.6255***	349.2802***	0.0436	13,460.1154***	-4,982.5345*
Caliper matching	0.0582***	2,131.3836***	323.3120***	0.0512	13,315.8987***	-4,832.1668*
K-nearest matching in caliper	0.0530***	2,103.0209***	338.8790***	0.0381	13,188.4661***	-5,219.5079*
Mean	0.0560	2,121.4761	334.4989	0.0456	13,300.3983	-4,998.1699

Note: K-nearest matching is performed for one-to-four matching.

Matching Analysis of Outsourcing Participation Effect in Apple Production

The ATT is estimated by the four matching methods to measure the effect of participation in outsourcing on apple production efficiency and income. The empirical results show that although a variety of matching methods were used, the direction and degree of the influence of outsourcing on apple production efficiency and income are largely consistent. These findings demonstrate that the estimation results are fairly robust. When the estimation results of the PSM and MLR are compared, the two models are consistent in the sign of the estimated value. With regard to the magnitude of the estimation values, in addition to the apple sales income, the PSM estimates of technology efficiency, labor productivity, land productivity, capital productivity, and apple net income are all larger than the MLR estimates. Because the PSM model is based on the counterfactual analysis framework, which assumes that the missing variables are only controlled by the observable covariates, and the outsourcing of apple production is separated from other factors affecting the apple production efficiency and income through the hierarchical matching of covariates, so the estimation results of the PSM are more accurate and reliable.

The caliper range is 0.02 for the caliper matching. As discussed by Abadie et al. [32], a one-to-four match can generally minimize the mean square error (MSE), thus the k-nearest neighbor matching in the caliper is one-to-four matching with a caliper range of 0.02. The core matching uses a default bandwidth of 0.06. The average value is the mean value of ATT obtained from the above four matching methods.

We used the coefficient estimates from the PSM selection and the outcome equations in combination with Eqs. (2) and (3) (see Section 2.2) to calculate the treatment effects of outsourcing. The ATT is shown in Table 5. It is worth noting that the ATT is the actual effect that participants experience through outsourcing participation. Specifically, participation in the outsourcing of apple production has a positive effect on the apple farmers' technology efficiency, labor productivity, land productivity, and

capital productivity. This finding suggests that other factors aside, outsourcing participation, on average, significantly increases the apple production of technology efficiency by 5.60 percentage points, labor productivity by 2,121.48 kg/person, land productivity by 334.50 kg/mu, and capital productivity by 0.05 kg/Yuan. A possible explanation for this result is that participation in the outsourcing of apple production can compensate for the shortage of domestic laborers caused by transfer and the shortcomings caused by insufficient human capital. Outsourcing can also significantly promote the improvement of apple production technology efficiency [17], labor productivity [33], and land productivity [7]. However, capital investment is a hard constraint in the process of apple production; i.e., no matter how the output of apples changes, the input of capital elements (such as fertilizer and pesticide) is rigid. Based on the statistical analysis of the survey data, the average capital input of apple farmers accounts for 67.20% of the total apple input. As the input of capital elements increases, the marginal output of capital elements diminishes. Thus, the coefficient between outsourcing and capital productivity is positive but not statistically significant. In addition, we can see that participation in the outsourcing of apple production has the greatest effect on the promotion of labor productivity. At present, the employment of laborers plays a dominant role in the outsourcing of apple production, and labor-intensive industries (such as the apple industry) have become the main production types absorbing rural labor. This, to a certain extent, highlights the importance of the rural labor market in the agricultural factor market.

The results presented in Table 5 also show that participation in the outsourcing of apple production has a significant positive effect on farmers' apple sales income but has a significant inhibitory effect on apple net income. A possible explanation for this result is that the outsourcing of apple production increased the apple production efficiency through a division of labor, which then increased apple output and apple sales income. The average apple sales income of the apple farmers who participated in outsourcing increased by 13,300.40 Yuan. However, participation in the outsourcing of apple production has reduced

the apple net income by 4,998.17 Yuan on average. The reason for this result is that apple industry is a labor-intensive industry, and apple farmers are constrained by family agricultural labor resources. Due to the need for employees and the low degree of mechanization, the opportunity for roundabout production through the purchase of machinery from the industry is relatively limited. Therefore, apple farmers are inclined to become involved in the outsourcing of apple production through employment during the busiest seasons. In addition, the development of the rural outsourcing market is underdeveloped and unregulated, and the relaxed regulation of rural laborer mobility and the seasonal shortage of supply are still prominent at this stage in China. This suggests that the employment cost of rural labor stays at a high level. On the other hand, the difficulty of supervising employees increases the transaction costs of outsourcing and reduces the farmers' apples net income. Therefore, participation in the outsourcing of apple production has a negative impact on the apple net income of farmers.

In summary, this observation confirms that the outsourcing of apple production is one of the most important factors explaining the improvement in apple production productivity and the decline of apple net income. Our results also lend support to the finding that productivity effect and income effect are associated with outsourcing participation.

Conclusions and Policy Implications

Studies that investigate the effect of farmers' participation in outsourcing are relatively scarce. This study aimed to fill this gap by examining the effect of outsourcing participation on apple production productivity and income by drawing on cross-sectional data from 960 rural households in Shandong, Shaanxi and Gansu Provinces. A MLR model was used to estimate the effect of participation in outsourcing without considering the influence of heterogeneity. A PSM model was employed to address the potential selectivity bias from both observed factors. The results show that outsourcing participation has a positive and significant impact on technology efficiency, labor productivity, land productivity, and apple sales income, but has a

significant negative impact on apple net income. In particular, the ATT estimates show that outsourcing participation, on average, increases the technology efficiency by 5.60%, labor productivity by 2,121.48 kg/person, land productivity by 334.50 kg/mu, capital productivity by 0.05 kg/Yuan, apple sales income by 13,300.40 Yuan, and decreases the apple net income by 4,998.17 Yuan. Although outsourcing participation has increased the farmers' apple income by increasing the apple productivity, the increase in the labor input costs and the transaction costs reduces the apple net income.

With respect to the factors that influence the farmers' decisions to outsource, the empirical results indicated that the decision to outsource by rural household decision makers in China is associated with age, education, and the number of apple laborers, growing experience, the proportion of income derived from agriculture, and the scale of planting in the household. Overall, our results support the conclusion that outsourcing can increase apple sales income by raising productivity.

The outsourcing of apple production is an important way to realize the transformation of apple production from a land scale operation to a service scale operation. We concluded that outsourcing participation can actually increase household income and enhance rural development. Thus, to introduce smallholder farmer production into the development track of modern apple industry, relevant policies encouraging more specialized market-oriented services, particularly labor-substituting services, can facilitate the adoption of outsourcing and reduce the cost of participation in outsourcing.

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