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How Productive Services Affect Apple Production Technical Efficiency: Promote or Inhibit?

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Abstract: Agricultural productive services provide a new entry point to solve the "labor dilemma" and contributes to the sustainable development of the apple industry. In this study, we establish a random frontier model with the Translog production function to analyze the influence of productive services on the technical efficiency of apple production based on a microscopic survey data of 661 apple farmers. The results indicate that the purchasing proportions of productive services are obviously different among the different links of apple production, while those among different regions are not obvious. Overall, productive services have a positive effect on improving the technical efficiency of apple production, but productive services in different links have a different effect; specifically, productive services in the bagging link have a positive effect on the technical efficiency of apple production, productive services in the pest controlling link have a negative effect, and productive services in other links have no significant effect. We suggest that policymakers should promote the orderly development of agricultural productive services, focus on improving the popularity of productive services in bagging links, and improve the quality of productive services in the pest control link.

Keywords: Productive services; Taylor's quadratic expansion; stochastic production frontier; apple farmers; China

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1. Introduction

The decision of Central Committee of the Communist Party of China (CPC) on Several Major Issues in Promoting Rural Reform and Development adopted at the Third Plenary Session of the Seventeenth Central Committee of the CPC pointed out that "building a socialized service system that covers the whole process, comprehensively supporting, conveniently and efficiently is an inevitable requirement for the development of modern agriculture." In 2014, the "No. 1 Document" of the Central Committee once again emphasized that the socialized service system of agricultural production should be improved and a new mode of agricultural operation should be constructed. Driven by policies, agricultural socialization services—especially productive services—have developed rapidly and have become an important factor in transforming traditional agricultural modes [1,2], improving agricultural production technology efficiency [3–6], and increasing farmers' income [7].

As a typical labor-intensive product, apple production needs a lot of labor in different parts of its life cycle. However, with the rural labor continually transferring to non-agricultural sectors, the aging and feminization of agriculture labor seriously restrict the sustainable development of the modern apple industry. The development of agricultural productive services provides a new entry point to solve the "human predicament" of the apple industry development. Relevant statistics show that the expenditure of fruit farmers on purchasing productive services increased from 119 yuan per mu in 2004 to 1106 yuan per mu in 2014, and the proportion of service expenditure in production cost increased from 9.56% in 2004 to 21.8% in 2014. In this context, researching whether agricultural production services have an impact on the technical efficiency of apple production has important practical significance to ensure the sustainable development of the apple industry.

The rest of this paper is arranged as follows: Section 2 provides a literature review, Section 3 develops a number of hypotheses on a brief theoretical discussion, Section 4 analyzes the sample data, Section 5 describes the empirical method, Section 6 provides the empirical results, and Section 7 provides the conclusion and policy implications.

2. Literature Review

2.1. The Qualitative and Quantitative Analysis of Agricultural Productive Services

Productive services, also known as producer services, can be traced back to the concept of producer services proposed by Machlup in the field of manufacturing [8]. Hansen condensed the concept of a productive service industry, which is a service industry that plays an intermediate role in the production of products or other input services [9]. Concerning the concept of agricultural productive services, political circles and academic circles have extensively discussed and basically reached the consensus that agricultural productive services are services and their combination which includes pre-natal, mid-natal and post-natal links.

At present, research on agricultural productive services has mainly been divided into qualitative and quantitative analyses. Some scholars have qualitatively analyzed the evolution process, current situation and mode of agricultural productive service development [2,7,10,11]. For example, Ji [12] believed that, in order to accelerate its development, the agricultural productive service industry needs to focus on solving constraints and to take practical measures from the perspectives of talents, technology, capital, arable land and industry management. Some scholars have quantitatively analyzed the demand, willingness, influencing factors and pricing mechanism of agricultural productive services [13–17]. For example, Chen et al. analyzed factors affecting farmers' decisions to outsource any or some production tasks using data from rice farmers in the Zhejiang province [18].

2.2. Impact of Agricultural Productive Services on Agricultural Production

The impact of agricultural productive services on agricultural production mainly affects three aspects: The first is about the impact of agricultural productive services on the scale of land management. At present, there is no consensus on the impact of agricultural productive services on the scale of farmers' land management. Some scholars believe that agricultural productive services can help to improve farmers' land management area [19,20], while some scholars believe that there is an inverted U-shaped relationship between the two [21]. The second is about the impact of agricultural productive services on farmers' factor productivity and income [22]. For example, a study by Wang and Li [23] found that irrigation and drainage, mechanized tillage services and planting planning had significant promoting effects on rice yield per unit area, while the rule of integrated pest control and the purchase of the means of production had no significant impact; irrigation and drainage, mechanized tillage services and integrated pest control had significant promoting effects on farmers' income, while the use of the means of production and planting planning did not show a significant impact.

The third is about the impact of agricultural productive services on the technical efficiency of agricultural production. Agricultural production technical efficiency is an important support beam of the transformation from traditional agriculture to modern agriculture and plays an important role in promoting the development of modern agriculture. Therefore, academic circles have carried out rich studies on the factors which affect the technical efficiency of agricultural production, involving the characteristics of farmers, geographical location, agricultural infrastructure, land fragmentation, land property rights, labor transfer, technology adoption, the scale of production, agricultural policies, and other aspects [24–31]. With the background of the rapid development of agricultural productive services, some scholars began to pay attention to the impact of productive services on the technical efficiency of agricultural production and the differences in different links, especially for rice [3–6].

2.3. Comment and Discussion

From the above literature review, we can find that the existing literature still has two shortcomings: Firstly, the existing literature has focused on researching food crops, ignoring the consideration of cash crops, especially labor-intensive agricultural products, which is not in line with the actual demand of "promoting the development of a characteristically superior agricultural products industry." Therefore, this paper takes the apple as a case study, as it is a supplement to the main body of the study. Secondly, compared with food crops, on the one hand, the chain of production of cash crops is more complex; on the other hand, cash crops, especially apples and other perennial crops, are limited by factors such as growth environment, and the degree of mechanical substitution for the labor force is relatively weak. Productive services' influence on the mechanism of apple production may be different from that of food crops. Thus, it is necessary to carry out special research on high-value agricultural products under the dual constraints of labor transfer and aging.

Considering the above limitations, we took apple farmers in Shaanxi Province as an example to analyze the impact of production services on the technical efficiency of the different stages of apple production and their differences. This article focuses on answering the following questions: Firstly, how the purchasing proportion of productive services among the main apple producing areas? Secondly, how do productive services promote or inhibit the technical efficiency of apple production in Shaanxi? Thirdly, is there any difference in the impact of productive services on the technical efficiency of apple production in different production links? Fourthly, how should the construction of Shaanxi apple production service system be guided?

3. Theoretical Analysis and Research Hypothesis

Under the dual constraints of rural labor transfer and the aging of fruit farmers, the development of productive services has become an inevitable choice for the development of the modern fruit industry. Apple is a labor-intensive agricultural product which requires a large amount of labor and more strict physical strength during the growth cycle, requirements which are inconsistent with the actual situation of apple cultivation. The average family labor force of apple growers in Shaanxi Province is 2.13, and the average age of the head of the farmers is 50.9. The quantity and physical strength needs of modern fruit industry development are difficult to meet. Productive services are urgently needed to alleviate the shortage of family labor force and improve the technical efficiency of agricultural production [4,24]. Compared with food crops, apple production has strict seasonal requirements. Once the management time is missed, the technical efficiency of apple production may significantly decrease, affecting current apple production and farmers' income. Therefore, the timely purchase of productive services can ease the quantitative and physical constraints of the labor force and reduce the loss of efficiency. On this basis, we put forward the first hypothesis:

Hypothesis 1 (H1). *Productive services can significantly improve the technological efficiency of apple production.*

Unlike other industrial sectors, agricultural production has a long cycle, the relationship between input factors and output is not clear, and the labor supervision cost in the production process is huge, all of which may reduce the technical efficiency of agricultural production. It can be seen that the impact of agricultural productive services on the technical efficiency of production is a comprehensive reflection of their average positive and negative effects. Moreover, the adoption of technology and the degree of standardization in different production links are not consistent, the cost of labor supervision is different, and production services in different links may have different impacts on the technical efficiency of agricultural production. The growth cycle of the apple is long, and the production process is complex. Thus, the difference of effect of productive services in the different stages of apple production on the technical efficiency may be more obvious. For example, fertilization is typically a labor-intensive link, with low supervision cost and high service quality, and productive services in this link may improve the technical efficiency of agricultural production; flower thinning and fruit thinning is a typically technology-intensive link, with high labor supervision cost and low quality services, and productive services in this link may reduce the technical efficiency of agricultural production. Therefore, this paper argues that productive services have different effects on the technical efficiency of apple production in different production links, and the sum of the effects of each link determines its final impact on the technical efficiency of apple production. On this basis, we put forward the second hypothesis:

Hypothesis 2 (H2). *There are differences in the impact of productive services on technological efficiency in the different stages of apple production.*

The mechanism of the effect of productive services on the technological efficiency of apple production is shown in Figure 1 Because this paper focuses on the input of factors, there is no discussion on the link between "building and clearing gardens" in the growth cycle.

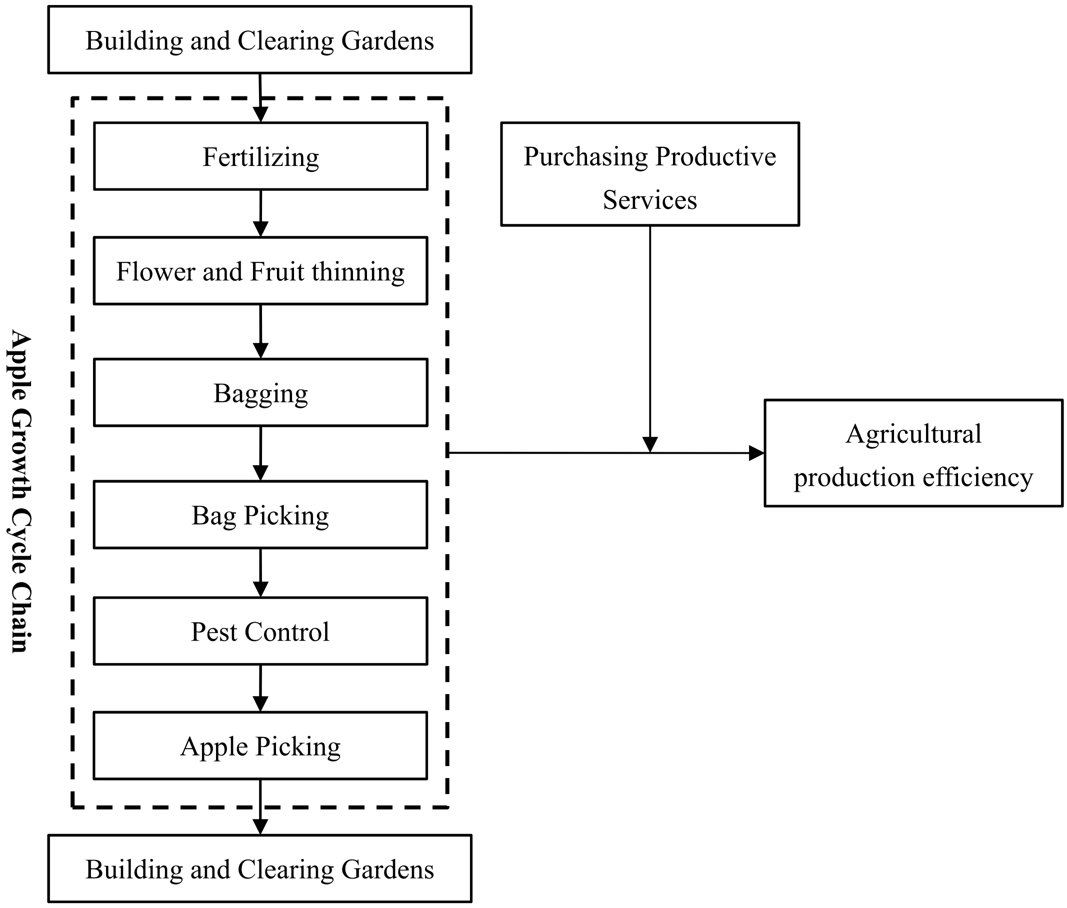

Figure 1. The mechanism of the impact of productive services on the technical efficiency of apple production.

4. Data Collection and Descriptive Analysis

4.1. Data Collection

The data used in this paper were from the field survey of apple growers in Shaanxi Province conducted by the National Modern Apple Industry System Research Group from June to August in

2015. The sample areas included Xianyang City, Yan'an City, and Weinan City, Changwu County, Binxian County, Xunyi County, Baota District, Yichuan County, Fuxian County, Luochuan County and Baishui County. It is widely representative and can truly reflect the development of the apple industry in Shaanxi Province. The limitation of research scope was beneficial to control the factors affecting apple planting, such as natural conditions, the regional characteristics of agriculture, and the regional economic development level. This survey used face-to-face interviews to collect 663 samples of farmers (see Table 1 for the regional distribution of the samples). Excluding the missing important variables and inconsistent answers, a total of 661 samples, the questionnaire efficiency was 99.7%.

Table 1. The regional distribution of the samples.

Region	**Xianyang City**			**Yan'an City**				**Weinan City**
County	Changwu	Binxian	Xunyi	Baota	Yichuan	Fuxian	Luochuan	Baishui
Samples	80	82	83	78	85	87	82	84
Proportion (%)	12.1	12.4	12.6	11.8	12.9	13.2	12.4	12.7

4.2. Descriptive Statistical Analysis of Samples

Table 2 compares and analyzes the regional differences in the proportion of purchasing productive services, the expenditure on productive services per mu, and the proportion of expenditure on services per mu to total production costs in eight base counties of Shaanxi Province. Overall, the proportion of apple growers purchasing productive services in Shaanxi Province is relatively high, accounting for 74.9%. This shows that in the apple production process, labor shortages caused by labor transfer and aging has become a common phenomenon, and purchasing productive services has become an important choice to alleviate the shortage of household labor forces. The average expenditure on productive services per mu is 1203 yuan, which is only 13.8% of the total production cost per mu. This shows that farmers in the main apple-producing areas in Shaanxi still have a low degree of purchasing productive services, mainly relying on family labor to guide production and management, and there is a large space for the development of productive services. From the perspective of regional differences, there is no obvious difference in the proportion of purchasing productive services among the eight counties in Shaanxi Province, which fluctuates between 71.8% and 78.9%. However, the purchasing degree of productive services is quite different. The purchasing degree of farmers in Changwu, Baota and Fuxian counties is higher than the average level of Shaanxi Province, among which Changwu County is the highest, with 1975 yuan per mu. Binxian County, Xunyi County, Fuxian County, Yichuan County, Luochuan County, and Baishui County are lower than the average level of Shaanxi Province, among which Xunyi County is the lowest, with 910 yuan per mu. Though there are obvious differences in farmers' expenditure on productive services in different regions, the proportion of farmers' expenditure on productive services in production costs is not significantly different, fluctuating from 12.2% to 16.6%. This indicates that the difference of farmers' total cost of apple production in different regions is obvious.

Table 3 compares and analyzes the difference between the purchasing ratio of productive services and the expenditure of productive services in different apple production links. Generally speaking, there are obvious differences in the proportion of purchasing productive services in the main links of apple production, which just shows that different links have different technical requirements and labor supervision costs, and it is very necessary to separately discuss each production link. The proportion of purchasing productive services in pest control is 7.11%, and the average service expenditure per mu is 151 yuan, which is the lowest among all links. This shows that on the one hand, pest control is a technology-intensive link and requires a high quality of service which results in higher labor supervision costs and low enthusiasm for farmers to purchase services. The results are similar to those of Zhang and Yi [6] and Sun et al. [4]. On the other hand, pest control belongs to the labor-sparse sector because it requires less labor force, a demand which the family-owned labor force can basically meet; this is also the reason for the low purchase ratio and productive service expenditure. The proportion of service purchasing in the fertilization link is 26.6%, and the average service expenditure per mu is 260. Overall, the proportion and degree of service purchasing are not high. The main reason for this is that the implementation period of the fertilization link is longer, and farmers have enough buffer time to complete it through their own labor force. However, under the restriction of aging, the physical strength of fruit growers gradually declines, and the proportion and degree of purchasing productive services should be increased in the future.

Table 2. Analysis of regional differences in productive services expenditure ratio and service expenditure in apple production.

Region	Productive Services Purchase Ratio (%)	Productive Services Expenditure per Mu (RMB)	The Percentage of Production Costs (%)
Changwu	78.8	1975	13.4
Binxian	73.2	956	12.2
Xunyi	77.1	910	12.6
Baota	75.6	1282	14.8
Yichuan	71.8	1171	15.4
Fuxian	73.6	1229	14.0
Luochuan	72.0	1151	16.6
Baishui	77.4	953	12.6
Shaanxi	74.9	1203	13.8

Note: The average production cost per mu in the table is the calculated cost including the cost of household workers and own lands.

Table 3. Contrastive analysis of purchasing ratio of productive services and service expenditure in the main links of apple production.

Major Production Links	Productive Services Purchase Ratio (%)	Productive Services Expenditure (¥/mu)
Fertilization	26.6	260
Flower thinning and fruit thinning	34.8	288
Bagging	62.9	570
Pest control	7.11	151
Bag picking	50.2	264
Apple picking	40.4	393

There are obvious time constraints in the flower thinning and fruit thinning, bagging, bag picking and apple picking links in the apple production process. Completing related links within time constraints is a basic necessity to ensure apple yield. Therefore, the labor shortage in the apple production process is mainly reflected in these four links, which is also the reason for the overall high proportion of purchasing productive services in these four links, especially the bagging, bag picking and apple picking links. Flower thinning and fruit thinning, bagging, bag picking and apple picking are technology-intensive links with high costs of labor supervision. At the same time, they are labor-intensive links, and family labor has difficulty meeting production needs. Under this double restriction, focusing on the development of productive services for these four links has become a choice to solve the dilemma of modern fruit industry development.

5. Research Method

5.1. Model

The method of stochastic frontier production function was first proposed to estimate production technology efficiency [32,33], which can estimate the loss of stochastic production frontier and production technology efficiency at the same time. It can avoid biases and inconsistencies caused by traditional two-stage estimation methods [34] so as to ensure that the factors affecting the loss of production technology efficiency are unbiasedly and effectively analyzed. Therefore, on the basis of previous research, this paper used the SFA (stochastic frontier approach) model to analyze the technological efficiency of apple production and its influencing factors. Supposing that the average apple yield per mu of farmers is Y_i, its expression is as follows:

$$Y_i = f(K_i, L_i, \beta)\exp(\nu_i - \mu_i) \tag{1}$$

In Equation (1), Y_i denotes the average apple yield per mu (kg/mu); K_i and L_i denote the average capital and labor input per mu, respectively; β denotes the parameters to be estimated; $f(\cdot)$ denotes the agricultural production function; the error term ν_i is the uncontrollable factor in production, which is used to distinguish the measurement error and the random interference effect, according to $\nu_i \sim N\left(0, \sigma_\nu{}^2\right)$; and the error term μ_i represents the non-technology of farmers, which is the distance between output and production possibility boundary, according to a truncated normal distribution. Therefore, production technology efficiency can be expressed by $TE_i = \exp(-\mu_i)$.

In order to simplify the model, a relatively flexible form of the Translog production function was obtained by taking logarithms on both sides of Equation (1) and Taylor's quadratic expansion.

$$\ln Y_i = \alpha_0 + \alpha_1 \ln K + \alpha_2 \ln L + 1/2\alpha_3(\ln K)^2 + 1/2\alpha_4(\ln L)^2 + \alpha_5 \ln K \ln L + \nu_i - \mu_i \tag{2}$$

In order to explain the impact of productive services on technological efficiency, this paper established a loss model of technological efficiency as follows:

$$m_i = \lambda_0 + \lambda_1 Service_i + \sum \gamma_k X_{ik} + \varepsilon_i \tag{3}$$

In Equation (3), m_i is the technical inefficiency item for the farmer i, $Service_i$ is the total expenditure on apple production services for farmer i, X_{ik} represents the other control variables that may affect the technical efficiency, and λ and γ are the parameters to be estimated.

In order to further investigate the impact of productive services on apple technological efficiency in different production links, this paper established a loss model of technological efficiency by different production links as follows:

$$m_i = \theta_0 + \sum_{j=1}^{6} \theta_j Service_{ij} + \sum \delta_k X_{ik} + \varepsilon_i \tag{4}$$

In Equation (4), $Service_{ij}$ is the expenditure on productive services for the farmer i in the apple production process including fertilization, flower thinning and fruit thinning, bagging, pest control, bag picking, and apple picking. Other variables are consistent with Equation (3).

5.2. Variable Settings

On the basis of measuring the technological efficiency of apple production, this paper focused on analyzing the impact of productive services and other control variables on the loss of apple technological efficiency. The productive services variable is measured by the expenditure of production services fee per mu, and if productive services can effectively replace the shortage of family labor force and improve production efficiency, the coefficient of the variable is negative; if the cost of labor supervision is higher and the quality of service is lower than that of family labor force in the process of purchasing productive services, the coefficient of this variable is positive, which indicates that production services has brought about the loss of apple production technology efficiency.

Controlling variables other than productive services may also have an impact on the loss of apple production technology efficiency, so control variables must be added in the process of model estimation. Referring to the existing research results [3,4,35–38], this paper divided the control variables into family endowment variables, land characteristics variables, apple attribute variables, and village virtual variables. Among them, family endowment variables include: The average age of family farming labor, the average education years of family farming labor, female proportion in family labors, the square term of land management area and land management area. Land characteristic variables include plot numbers and irrigation conditions. Apple attribute characteristic variables include varieties, age and the cultivation methods of apples.

The definitions, descriptions and descriptive statistics of relevant variables are shown in Table 4.

Table 4. Definition, description and descriptive statistics of relevant variables.

Variables	Variable Definition and Description	Mean	SD
Stochastic Frontier Production Function			
Outcome	Yield of apple per mu (unit: kg/mu)	3606	2485
Capital input	Capital input per mu, including material capital such as chemical fertilizer, organic fertilizer, pesticides, fruit bags, and service costs such as irrigation and mechanical maintenance (unit: Yuan/mu)	4519	2729
Labor input	Total labor input per mu, including employees and self-employed workers (unit: Working day/mu)	39.4	53.8
Efficiency Loss Model			
Key variables			
Productive services expenditure in total	Expenditure of productive services in the whole link (unit: Yuan/mu)	6617	8882
Productive services expenditure of the fertilization link	Expenditure of productive services in the fertilization link (unit: Yuan/mu)	526	1492
Productive services expenditure of the flower and fruit thinning link	Expenditure of productive services in the flower and fruit thinning link (unit: Yuan/mu)	734	1517
Productive services expenditure of the bagging link	Expenditure of productive services in the bagging link (unit: Yuan/mu)	2615	3894
Productive services expenditure of the pest control link	Expenditure of productive services in the pest control link (unit: Yuan/mu)	44.4	193
Productive services expenditure of the bag picking link	Expenditure of productive services in the bag picking link (unit: Yuan/mu)	1003	1654
Productive services expenditure of the apple picking link	Expenditure of productive services in the apple picking link (unit: Yuan/mu)	1694	2757
Control variables			
Age	Average age of family farming labor (unit: Year)	48.8	9.15
Years of education	Average education years of family farming labor (unit: Year)	7.96	2.62
Labor structure	female proportion in family labors (unit: People)	45.1	16.2
land management area	land management area (unit: Mu)	3.47	2.47
land management area^2	square of land management area (unit: Mu)	18.1	32.8
Land fragmentation	number of plots (unit: Block)	2.75	1.63
Land Irrigation Conditions	Irrigation Ability; 1 = Yes, 0 = No	0.14	0.35
Apple cultivars	1 = multi-cultivar mixed planting; 0 = single cultivar	0.07	0.25
Age of tree	Years of the planting tree (unit: Year)	16.9	6.25
Apple cultivation methods	1 = arborization cultivation; 0 = dwarfing cultivation	0.95	0.21

6. Results

6.1. Impact of Productive Services through All Links on the Technical Efficiency

In this paper, the "one-step method" by Coeli and Battese [34] was used to estimate the stochastic frontier production function and the efficiency loss model. The results are detailed in Table 5 and show that the coefficients of the square term and the interaction term of the factor input were significantly less than 0, so the estimation using the Translog production function was better than Cobb-Douglas (C-D) production function. The Gamma coefficient was 0.86, which was significantly different from 0 at the 1% level, indicating the existence of an inefficiency term of apple production technology, and the stochastic frontier production function model had a higher applicability.

The estimated results of efficiency loss model showed that the total expenditure of productive services had a negative impact on the loss of apple production technology efficiency, and it was significant at the level of 1%, which indicates that the higher the expenditure of agricultural productive services, the higher the technical efficiency of apple production. Thus, Hypothesis 1 is supported, which is consistent with the results of Zhou et al. [24] and Sun et al. [4]. It can be seen that under the background of labor force transfer and population aging, productive services can alleviate the shortage of the quantity and quality of family labor force and improve the technological efficiency of apple production. Total expenditure on productive services reflects the positive and negative effects of productive services on the technical efficiency of apple production. This does not mean that productive services can improve the technical efficiency of apple production in all production links.

Among the variables of family endowment characteristics, age, years of education, labor force structure and land management area all have negative effects on the loss of production technology efficiency. Age is a pronoun of rich experience. The more experience, the higher the technical efficiency of apple production. The educational level reflects the human capital endowment of farmers, and the higher endowment, the stronger ability of using advanced production technology and management mode, and the higher the technical efficiency of apple production. Apple production belongs to a typical intensive and intensive farming agriculture. Though the female labor force has disadvantages in physical strength, it has obvious advantages in technology-intensive links. The larger the proportion of female household labor force is, the more refined the apple production and management is. Expanding the scale of operation can optimize the allocation of factors and improve the efficiency of production technology. In land characteristic variables, land fragmentation and irrigation conditions have significant effects on improving the technical efficiency of apple production. Irrigation can improve the utilization efficiency of production factors and promote the technical efficiency of apple production. Theoretically, the more land plots the farmer manages, the more difficult it is to reasonably allocate the input of factors and the lower the efficiency of production technology, which is contrary to the empirical results in this paper. A possible reason is that on the one hand, the distance between different plots is short, which weakens the difficulty of factor distribution. On the other hand, it is easier to realize fine operation and management in block production with a limited endowment structure of farmers. Among the characteristic variables of apple attributes, the effect of tree age on the loss of production technology efficiency is negative, and it is significant at the 1% level, which indicates that the production technology efficiency of fruit trees in the "fruitful period" is higher; the selection of cultivars and cultivation methods has a negative impact on the loss of technical efficiency of apple production, but there is no significant difference.

Table 5. "One-step" estimates of the impact of total expenditure on the technical efficiency of apple production.

Estimation of Stochastic Frontier Analysis Model (Interpreted Variable: Ln Value of Apple Yield)					
Variable	**Estimation Coefficient**	**T-Value**	**Variable**	**Estimation Coefficient**	**T-Value**
lnK	−0.86 *	−1.78	lnC*lnC	−0.09 ***	−2.95
lnC	2.31 ***	3.87	lnC*lnK	−0.14 *	−1.75
lnK*lnK	0.10 **	2.44	Constant	5.82 ***	3.56
Estimation of Efficiency Loss Model (Interpreted Variable: Technical Efficiency Loss)					
Key independent variable					
Total expenditure on productive services	−0.11 ***	−4.07			
Control variables					
Age	−0.04	−0.41	Land Irrigation Conditions	−1.78 ***	−3.56
Years of education	−0.01	−0.79	Apple cultivars	−0.19	−0.25
Labor structure	−0.00	−0.20	Age of tree	−0.11 ***	−4.86
land management area	−0.03	−0.85	Apple cultivation methods	−0.20	−0.54
land management area^2	−0.94	−1.64	Constant	2.94 ***	3.56
Land fragmentation	−0.40 ***	−4.26	Regional Virtual Variables	Controlled	
Sigma-square	0.86 *** (0.14)				
Gamma coefficient	0.86 *** (0.27)				
Log function	−421				

Note: ***, **, * denote statistical significance at the 1%, 5%, 10% levels, respectively.

6.2. Impact of Productive Services in Different Links on the Technical Efficiency

The effect of the total expenditure of productive services on the technical efficiency of apple production is a comprehensive reflection of its average positive and negative effects. Each link of production has different attributes, and there are obvious differences in labor supervision cost. As a result, the impact of productive services in different links on the technical efficiency of apple production may be different. Therefore, this paper decomposed the total service expenditure according to the production links, and it analyzed the impact of productive services expenditure in different links on apple farmers' production technology efficiency. The results are detailed in Table 6. The results of stochastic frontier analysis model showed that the coefficients of square and cross terms of input factors were significantly less than 0, indicating that the use of Translog production function was better than the C-D function; the Gamma coefficient was 0.890, which was significant at the 1% level, indicating that the loss of technological efficiency of apple production was significantly less than 0 and the use of stochastic frontier analysis had better applicability.

Table 6. The "one-step" estimation results of the impact of productive service expenditure on the technical efficiency of apple production in different links.

Estimation of Stochastic Frontier Analysis Model (Interpreted Variable: Ln Value of Apple Yield)					
Variable	**Estimation Coefficient**	**T-Value**	**Variable**	**Estimation Coefficient**	**T-Value**
lnK	−1.38 ***	−2.64	lnC*lnC	−0.08 ***	−2.64
lnC	2.73 ***	4.80	lnC*lnK	−0.21 ***	−2.81
lnK*lnK	0.15 ***	3.50	Constant	7.18 ***	3.94
Estimation of Efficiency Loss Model (Interpreted Variable: Technical Efficiency Loss)					
Key independent variable					
Productive services expenditure of the fertilization link	0.04	1.48			
Productive services expenditure of the flower and fruit thinning link	0.02	0.40			
Productive services expenditure of the bagging link	−0.17 ***	−4.99			
Productive services expenditure of the pest control link	0.08 ***	2.67			
Productive services expenditure of the bag picking link	0.02	0.77			
Productive services expenditure of the apple picking link	−0.03	−1.08			
Control variables					
Age	−0.02	−0.19	Land Irrigation Conditions	−2.12 ***	−4.04
Years of education	−0.01	−1.19	Apple cultivars	−0.32	−0.48
Labor structure	−0.00	−0.44	Age of tree	−0.12 ***	−5.25
land management area	−0.03	−0.98	Apple cultivation methods	−0.13	−0.34
land management area^2	−1.13	−1.58	Constant	2.85 ***	3.51
Land fragmentation	−0.44 ***	−4.49	Regional Virtual Variables	Controlled	
Sigma-square	0.99 *** (0.16)				
Gamma coefficient	0.89 *** (0.24)				
Log function	−419				

Note: ***, * represent 1% significant levels.

The results of efficiency loss model estimation showed that there are obvious differences in the impact of production service expenditure in different links on apple production technology efficiency, and Hypothesis 2 of this paper is supported. Among them, the expenditure of productive services in bagging has a positive impact on the improvement of apple production technology efficiency, and it is significant at the level of 1%. Apple bagging usually occurs in June when the weather changes frequently, and the operation and management process has strong time constraints, which aggravates the negative impact of family labor shortage. The purchase of productive services in this link can effectively alleviate the efficiency loss caused by family labor shortages and improve the efficiency of production technology. At the same time, apple bagging is also a technology-intensive link, the cost of labor supervision is very high, and the level of service quality has a significant difference on the technical efficiency of apple production. It can be seen that the effect of productive service expenditure in bagging on technology efficiency is the result of the game between the quantity and quality of labor force. The expenditure on productive services in pest control has a positive effect on the loss of the technical efficiency of apple production, and it is significant at the 1% level, which indicates that the higher the expenditure of productive services are, the lower the technical efficiency of apple production is. This result is consistent with the research results of Sun et al. [4]. In the field survey, there are two main forms of purchasing productive services in the link of pest control: Hiring workers and purchasing services directly. On the whole, the mechanical level in the pest control link is higher than other links, but the main body of implementation is still manual. With the lack of accurate service evaluation criteria, there are higher labor supervision costs for employees or direct purchasing services in this link, and the technology efficiency of apple production is lower than that only with self-employed workers. Pests and diseases have the characteristics of "fast spread" and "big impact," and imperfect prevention and control may lead to a serious decline in production. Therefore, in order to reduce planting risk, farmers still choose to purchase productive services in this link under the constraints of an insufficient labor force.

Fertilization, flower thinning and fruit thinning, and bag picking have positive but insignificant effects on the loss of technological efficiency of apple production, indicating that the quality of purchasing service is still lower than the level of family labor force, but the difference is not obvious. Under the double constraints of labor transfer and ageing, the shortage of labor force in apple production may be further aggravated, and the proportion of purchasing productive services in all links may be further increased, especially in labor-intensive links with strict physical requirements. Therefore, attention should be paid to identifying and selecting service subjects to prevent the further deterioration of inefficiency caused by moral hazards. The effect of productive service expenditure in apple picking on the loss of apple production technology efficiency is negative and not significant, which is similar to the results of Sun et al. [4]. Apple picking is a labor-intensive process, so purchasing productive services in this link can alleviate the shortage of domestic labor force and improve the efficiency of production technology. The reason it is not significant may be that apple picking belongs to the end of apple production, so the moral hazards of employees are more likely to affect apple's earnings than its output.

7. Conclusions and Policy Implications

In this study, we established a stochastic frontier model with the Translog production function to discuss the effects of productive services on the technical efficiency of apple production, and we analyzed the effects of productive services in different production links on the technical efficiency of apple farmers and their differences contrastively based on the micro-survey data of farmers in eight apple-base counties in Shaanxi Province. According to the results, we found that there is no obvious regional difference in the proportion of purchasing productive services in Shaanxi Province, which fluctuates from 71.8% to 78.8%. However, the proportion of sample farmers purchasing productive services in different apple production links is quite different. Specifically, the proportion of purchasing productive services in bagging links is the highest, accounting for 62.9%, while that in pest control links is the lowest, accounting for 7.11%. Overall, productive services have a significant promoting effect on the technical efficiency of apple farmers, but the impact of productive services on different links on the technical efficiency of apple farmers is obviously different. Specifically, productive services in bagging links have a significant promoting effect on improving the technical efficiency of apple production, and productive services in the pest control links have a significant inhibitory effect on the improvement of technical efficiency in apple production, while productive services in the fertilization, flower thinning and fruit thinning, bag picking and picking links have no significant impact on the technical efficiency of apple production.

The empirical analysis suggested the following policy implications:

(1) Aim at meeting differentiated service needs, promoting the orderly development of agricultural productive services, focusing on improving the popularity of productive services in bagging links, and strengthening the role of productive services in bagging links in promoting the technical efficiency of apple production.

(2) Improve the effectiveness of the productive service market, reduce the transaction cost of apple farmers participating in the service market, focus on improving the quality of productive services in the pest control link, and weaken the inhibitory effect of productive services on the technical efficiency of apple production.

(3) In view of the fact that labor is the main body of the implementation of productive services, relevant departments should accelerate the construction of apple production technology training and information service systems, improve the human capital of service implementers, and improve the service level of agricultural productive services.

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References

1. Pan, J.Y.; Wang, S.Z.; Li, Y.S. Theoretical and empirical research on the transformation of traditional agriculture by modern service industry from the perspective of industrial coupling. *Economist* **2011**, *12*, 40–47.
2. Dong, H.; Guo, X.M. Productive Services and Traditional Agriculture: Reform or Continuation: An Empirical Analysis Based on 501 Family Questionnaires of Farmers in Sichuan Province. *Economist* **2014**, *6*, 84–90.
3. Yang, W.J.; Li, Q. Study on the effect of new business Entities' productive services on the technical efficiency of rice production based on the survey data of 1926 households in 12 provinces. *J. Huazhong Agric. Univ. (Soc. Sci. Ed.)* **2017**, *5*, 12–19.
4. Sun, D.Q.; Lu, Y.T.; Tian, X. The impact of productive services on the technical efficiency of rice production in China: Empirical analysis based on micro-survey data of Jilin, Zhejiang, Hunan and Sichuan provinces. *Rural Econ. China* **2016**, *8*, 70–81.
5. Hao, A.M. The impact of agricultural productive services on the contribution of agricultural technology progress. *J. South China Agric. Univ. (Soc. Sci. Ed.)* **2015**, *14*, 8–15.
6. Zhang, Z.J.; Yi, Z.Y. Study on the Impact of Outsourcing of Agricultural Productive Services on Rice Productivity Based on the Empirical Analysis of 358 Farmers. *Agric. Econ. Issues* **2015**, *36*, 69–76.
7. Jiang, C.Y. Models, Enlightenments and Policy Suggestions for Developing Agricultural Productive Services: Investigation and Consideration on Developing High-end Brand Agriculture in Pingdu City, Shandong Province. *Macroecon. Res.* **2011**, *3*, 14–20.
8. Machlup, F. *The Production and Distribution of Knowledge in the United States*; Princeton University Press: Princeton, NJ, USA, 1962.
9. Hansen, N. The strategic role of producer service in regional development. *Int. Reg. Sci. Rev.* **1994**, *23*, 13–20. [CrossRef]
10. Kong, X.Z.; Xu, Z.Y. Research on the supply and demand of agricultural socialization services based on the analysis of farmer household data considering supplier and demand intensity. *Guangxi Soc. Sci.* **2010**, *3*, 120–125.
11. Lu, Q.W.; Jiang, C.Y. Development course and experience enlightenment of agricultural productive service industry in China. *J. Nanjing Agric. Univ. (Soc. Sci. Ed.)* **2016**, *16*, 104–115.
12. Ji, M.F. Agricultural Productive Services: The Third Kinetic Energy in the History of Agricultural Modernization in China. *Agric. Econ. Issues* **2018**, *3*, 9–15.
13. Zhuang, L.J.; He, M.Y.; Zhang, J. Analysis of the desire and influencing factors of demand for agricultural productive services: A survey of 450 litchi producers in Guangdong Province. *Rural Econ. China* **2011**, *3*, 70–78.
14. Huang, W. Farmers' desire for paid technical services and its influencing factors: A case study of planting industry in Jiangsu. *China Rural Obs.* **2010**, *2*, 54–62.
15. Ji, Y.Q.; Wang, Y.A.; Zhong, F.N. Study on the Demand and Structure of Farmer's Agricultural Machinery in China: Based on the Data of Provincial Level. *Agric. Technol. Econ.* **2013**, *7*, 19–26.

16. Zhang, X.M.; Jiang, C.Y. Supply evaluation and Demand Willingness of agricultural productive services for different types of farmers. *Econ. Manag. Res.* **2015**, *36*, 70–76.
17. Cai, R.; Cai, S.K. Empirical Study on Outsourcing of Agricultural Production Links Based on the Survey of Main Rice-producing Areas in Anhui Province. *Agric. Technol. Econ.* **2014**, *4*, 34–42.
18. Ji, C.; Guo, H.; Jin, S.; Yang, J. Outsourcing Agricultural Production: Evidence from Rice Farmers in Zhejiang Province. *PLoS ONE* **2017**, *12*, e0170861. [CrossRef]
19. Jiang, S.; Cao, Z.L.; Liu, H. The Impact of Agricultural Socialized Services on Land Moderate Scale Management and the Comparative Study: Empirical Study Based on CHIP Micro-data. *Agric. Technol. Econ.* **2016**, *11*, 4–13.
20. Yang, W.J.; Li, Q. Farmers' Part-time Business, Productive Services and Rice Planting Area Decision-making: An Empirical Study Based on 1646 Farmers in 11 Provinces. *J. China Agric. Univ. (Soc. Sci. Ed.)* **2018**, *35*, 100–109.
21. Chen, Z.J.; Hu, W. Matching factors of agricultural scale operation: Employment operation or service outsourcing: An empirical analysis based on the questionnaire of farmers in Jiangxi and Guangdong provinces. *Acad. Res.* **2016**, *8*, 93–100.
22. Zhang, Q.; Yan, B.; Huo, X. What Are the Effects of Participation in Production Outsourcing? Evidence from Chinese Apple Farmers. *Sustainability* **2018**, *10*, 4525. [CrossRef]
23. Wang, Y.B.; Li, Q. Agricultural Productive Services, Grain Yield Increase and Farmer Income Increase: Empirical Analysis Based on CHIP Data. *Financ. Sci.* **2019**, *3*, 92–104.
24. Zhou, H.; Wang, Q.Z.; Zhang, Q. Aging of rural labor force and lack of rice production efficiency from the perspective of social services. *Popul. Sci. China* **2014**, *3*, 53–65.
25. Qiao, S.J. Empirical Study on Technical Efficiency of China's Grain Production: Application of Stochastic Frontier Production Function. *Math. Stat. Manag.* **2004**, *3*, 11–16.
26. Zheng, X.G. Technical efficiency of agricultural production and its influencing factors in China. *Stat. Decis. Mak.* **2009**, *23*, 102–104.
27. Xu, Q.; Tian, S.C.; Xu, Z.G.; Shao, T. Agricultural land system, land fragmentation and farmers' income inequality. *Econ. Res.* **2008**, *2*, 83–92.
28. Liu, T.; Qu, F.T.; Jin, J.; Shi, X.P. Impact of land fragmentation and land transfer on land use efficiency of farmers. *Resour. Sci.* **2008**, *10*, 1511–1516.
29. Chen, S.Q.; Zhang, G.S. The effect of rural labor transfer on the technical efficiency of rice production: Whether intergenerational differences exist or not? Based on the survey of Liaoning Province. *Agric. Technol. Econ.* **2012**, *12*, 31–38.
30. Ge, J.H.; Zhou, S.D. The effect of environment-friendly technology on the technical efficiency of rice cultivation: Taking soil testing and formula fertilization technology as an example. *J. Nanjing Agric. Univ. (Soc. Sci. Ed.)* **2012**, *12*, 52–57.
31. Wang, X.B.; Xu, D.; Zhang, Y.J.; Yang, J. Study on farm scale, labor input and technical efficiency and their correlation. *Resour. Sci.* **2016**, *38*, 476–484.
32. Aigner, D.; Lovell, C.A.K.; Schmidt, P. Formulation and Estimation of Stochastic Frontier Production Function Models. *J. Econ.* **1977**, *6*, 21–37. [CrossRef]
33. Meeusen, W.; van den Broeck, J. Technical Efficiency and Dimension of the Firm: Some Results on the Use of Frontier Production Functions. *Empir. Econ.* **1977**, *2*, 109–122. [CrossRef]
34. Coeli, T.J.; Battese, G.E. Identification of Factors Which Influence the Technical Inefficiency of Indian Farmers. *Aust. J. Agric. Econ.* **1996**, *40*, 103–128. [CrossRef]
35. Wang, X.Q.; Su, X.X. The Impact of Agricultural Land Fragmentation on Agricultural Production: A Case Study of Laixi City, Shandong Province. *Agric. Technol. Econ.* **2002**, *2*, 2–7.
36. Guo, X.M.; Zuo, Z.Y. Analysis of farmers' production technology selection and technical efficiency in traditional rural areas from the perspective of aging: Micro-data of farmers from Fushun, Anyue and Zhongjiang counties in Sichuan Province. *Agric. Technol. Econ.* **2015**, *1*, 42–53.

37. Huo, X.X.; Hou, J.Y. An analysis of technological efficiency and factors output elasticity of apple production in China: Taking apple growers in 10 key Apple counties of Shaanxi, Shanxi and Gansu as examples. *J. Northwest Univ. Agric. For. Sci. Technol. (Soc. Sci. Ed.)* **2012**, *12*, 75–80.
38. Liu, T.J.; Pan, M.Y.; Zhu, Y.C.; Huo, X.X. Characteristics and convergence of technological efficiency change of apple production in dominant areas: Data from 573 fruit growers in 5 provinces of the Loess Plateau. *J. Shanxi Univ. Financ. Econ.* **2012**, *34*, 58–66.