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RESEARCH ARTICLE

Does Informatization Cause the Relative Substitution Bias of Agricultural Machinery Inputs for Labor Inputs? Evidence from Apple Farmers in China

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Abstract: The change of information scenario may change the market transaction cost of different factors, thus changing the relative price of factors and inducing the substitution of production factors, but there is no research to prove this. Therefore, this study takes labor-saving technology (mechanical substitution of labor) as an example, evaluates informatization from three aspects of information technology access, information technology application and information literacy comprehensively, and uses the probit model and CMP method to analyze whether informatization causes the substitution of agricultural machinery inputs for labor inputs and its heterogeneity. The results show that informatization has a significant negative impact on farmers' choice of labor-saving technology, and the result is robust at the regional level, but the negative impact of informatization on farmers' choice of labor-saving technology in the eastern region is smaller than that in the western region. The level of information literacy has the largest negative impact on farmers' choice of labor-saving technology, followed by the level of access to information technology, and the level of application of information technology has the smallest impact. The study concludes that informatization has not led to the significant substitution of labor by machinery in apple production. Thus, the results are important for enriching the theory of induced change in agricultural technology in the context of informatization.

Keywords: Information technology access; Information technology application; Information literacy; Labor-saving technology; Agricultural factor substitution

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1. Introduction

The theory of induced technological change has been widely used to analyze agricultural technological change and adaption [1-3]. Its main view is that the change in the relative price of factors caused by the change in resource scarcity will induce agricultural factor substitution. In production, micro-enterprises will seek relatively abundant factors to replace relatively scarce elements through the market mechanism, and apply technologies to save relatively scarce elements in order to maximize the marginal revenue of total factor input. Since the 1990s, the development of informatization based on ICT (Information Communication Technology) has broken the barrier of information asymmetry [4], which effectively promoted the innovation of agricultural market operation mechanism [5,6], the reform of the agricultural factor market and the improvement of agricultural public service capacity, and provided a good market environment for the realization of optimal resource allocation in a wide range. Theoretically, under the dual constraints of factor endowments and production conditions, the information asymmetry between the production and management units and different factor retailers is different. As a result, farmers participate in different factor markets and their transaction costs are different. In this case, the relative price changes of factors may be caused by informatization, which has a different impact on the price changes of different factors. Will informatization then lead to the substitution bias of agricultural machinery inputs for labor inputs? The answer to this question is important for the formulation or adjustment of factor marketization policies under the background of informatization and the promotion of "Internet+" agricultural upgrading.

Agriculturally induced technology includes labor-saving technologies and land-saving technologies from the perspective of the relative scarcity of factors. In literature, empirical studies on agricultural induced technology mainly focus on the importance of factor endowment. However, the existing studies show obvious regional characteristics due to the differences in factor endowment structure in different regions and different historical stages. For example, Hayami and Ruttan [7] took the example of agriculture in Japan and the United States as an example, and found that due to the difference in factor endowment between America and Japan, American agriculture was based on labor-saving technologies, while Japanese agriculture was based on land-saving technologies. On this basis, some scholars have also studied the relationship between factor endowment structure and agricultural technology change in China [3,8,9]. For example, Zheng et al. [10] found that differences in farmers' technology choice preferences are due to asymmetries in different types of farmers' endowment constraints and characteristics of different agricultural technologies. However, some scholars have found that the impact of farmers' endowments on the choice of agricultural technology had general similarities and differences at the same time [11]. With the application of new institutional economics and information economics in the agricultural field, some scholars have started to pay attention to the impact of transaction costs on the choice of agricultural production technology [12]. For example, Zhang et al. [13] found that the transaction cost is an important factor limiting the extensiveness of technology adoption by farmers. Some scholars also analyzed the influence of information acquisition on the choice of production technology [14,15]. For example, Luh et al. [16] investigated the influence of information acquisition on farmers' choice of transgenic seed technology in Taiwan. They found that information acquisition significantly increased farmers' likelihood of choosing transgenic technology. In addition, some scholars focused on the influence of information acquisition ability on new technology choices [17].

Based on the above analysis, we can see that the research on the relationship between informatization and production technology choice is still worth paying attention to, so as to overcome the shortcoming that the existing research focuses on taking a certain technology as an example and lacks in-depth analysis of the impact of informatization on farmers' technology selection behavior induced by factor scarcity from the perspective of production factor structure. In addition, the existing research only focuses on the influence of one aspect of information acquisition mode or information acquisition ability on technology selection, and lacks a comprehensive consideration of the informatization level from multiple perspectives and a comparative analysis of informatization in different dimensions. Theoretically, both information acquisition mode and information acquisition ability are important factors in determining farmers' information abundance for production decision-making. Based on this, this paper takes labor-saving technology as an example, comprehensively evaluates the informatization level from three dimensions of information technology access, information technology application and information literacy, and analyzes whether informatization causes the substitution bias of agricultural machinery inputs for labor inputs. The reason for choosing labor-saving technology is that apple is a labor-intensive crop, under the dual constraints of the continuous transfer of agricultural labor to non-agricultural industries and the ageing of agricultural labor, the labor cost is in a continuous upward trend, and the labor may be in a state of relative scarcity for a long time.

2. Theoretical Analysis and Research Hypothesis

2.1 Conceptual Definition and Measurement of Informatization

In 1963, the Japanese sociologist Tadao Umesao first put forward the idea of informatization in his article entitled "Information Industry". He thought that informatization was the general term for the modernization of communication, computerization and rationalization of behavior. Since then, domestic scholars have done a lot of research on the definition of informatization. The First National Informatization Work Conference held in 1997 defined informatization as "the historical process of cultivating and developing new productivity represented by intelligent tools and making it benefit the society". In 2006, the General Office of the CPC Central Committee and the General Office of the State Council issued the National Informatization Development Strategy for 2006-2020, which defined informatization as "the historical process of fully utilizing ICT to develop and utilize information resources, promote information exchange and knowledge sharing, improve the quality of economic growth, and promote the transformation of economic and social development". The Informatization Statistical Evaluation Research Group of the Institute of statistics of the National Bureau of Statistics (2011) defined informatization as "the process of transforming, reorganizing or reorienting the socio-economic structure and industrial structure by using high-tech information technology to improve the information and knowledge content of products and economic activities, and then promoting the whole society to achieve a higher level, more organized and more efficient economic development". Overall, the current discussion on the connotation of informatization focuses only on the access to and application of information technology, which has been verified in the literature on assessing the level of informatization.

In the process of the integrated development of informatization and agricultural modernization, the exploration of informatization has gradually extended to the level of agriculture, rural areas and farmers, and the concepts of agricultural informatization [18,19], rural informatization [20,21] and farmer informatization [22] have been put forward. Due to the obvious differences in the connotation and research methods of informatization among different research topics, it is necessary to clarify the research scope and boundary of informatization before the research. From the perspective of the research topic and research object, this paper mainly focuses on the analysis of farmers' informatization level. In the process of developing a digital society, inequality in the distribution of information infrastructure, the development and application of digital technology, and the ability to acquire and process digital information leads to the unequal enjoyment of the dividends brought by ICT among different social groups, resulting in the phenomenon of "information poverty" and "information differentiation" [23]. The key to eliminating information poverty and differentiation is to improve the information literacy of the whole population and to enhance the ability of social members to seek, assimilate and use information [24]. Therefore, in addition to considering information technology access and application, information literacy should be an important part of assessing farmers' informatization levels.

Based on the research idea of Busindeli [25] on the media preference for agricultural information acquisition and dissemination, this paper designs the informatization measurement system in terms of information availability and information accessibility, where information availability reflects the level of farmers' access to information, and information accessibility reflects the level of farmers' utilization of information. In terms of the information diffusion process, efficient farm information in the information environment needs to cross two thresholds for final use in farmers' production decisions (as shown in Figure 1). The first threshold determines whether farmers can obtain the information and the amount of information, i.e. information availability, and the second threshold determines whether farmers can effectively absorb and use the information and the amount of information absorbed and used, i.e. information accessibility. Thus, it is clear that the level of information ultimately used in farmers' production decisions is a comprehensive consideration of information availability and information accessibility.

Based on the above analysis, the informatization studied in this paper includes information technology access, information technology application and information literacy. Among them, information technology access mainly refers to farmers' access to smartphones, computers, mobile internet and fixed broadband internet [4]; information technology application mainly refers to the extent to which farmers use ICT to obtain information on agricultural operations; information literacy mainly refers to farmers' information awareness and the ability to search, judge, select, absorb and use the required information and apply it to agricultural production by ICT tools [26].

2.2 Research Hypothesis

According to the theory of induced technological

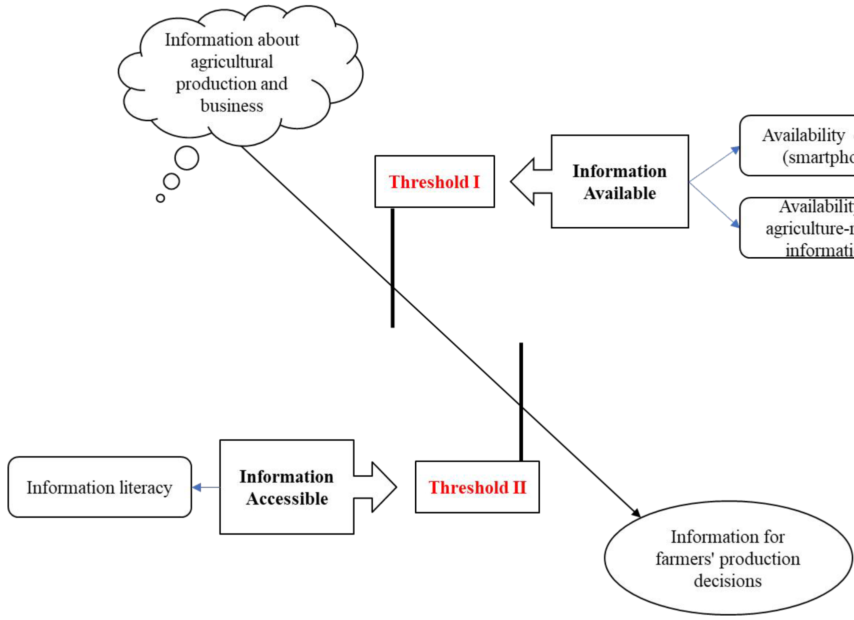

Figure 1. Theoretical framework of the informatization measurement system.

change, the change in the relative price of factors caused by the change in resource scarcity will induce technological change [7]. Under the assumption that the factor market is effective, the change in the relative price of production factors can fully reflect the scarcity degree of scarcity of production factors, and micro-production units will use the market mechanism to realize the substitution of cheap and relatively abundant factors for expensive scarce elements, and choose the technology of saving the use of relatively scarce elements [27], so as to eliminate or partially eliminate the restriction of relatively scarce production factors on the development of agriculture. According to Hicks' definition of technology type, the induced technology of factor scarcity can be divided into two categories, including labor-saving technology and land-saving technology. The former aims to expand the cultivated area per unit of labor force or reduce the labor input per unit of land area, while the latter aims to increase the output per unit of the land area [28,29].

From the perspective of the production chain, apple is a typical labor-intensive crop, and labor is more scarce than land or capital elements, especially in the context of urbanization and the rising price of agricultural labor. This problem is more prominent. Therefore, micro production units tend to use capital to substitute labor, and this kind of substitution is first realized through mechanization [30]. Specifically, if the labor factor input per unit area is relatively less than the mechanical factor input per unit area, the technology type is defined as a labor-saving technology, and if not, it is a labor-intensive technology.

Based on the above analysis, we suppose that farmer i has fixed land endowment A_0 and labor endowment L_0, and only input land, labor and machinery in the apple production process. Further assuming that the input cost of land factor is constant, then the output and production cost of apple depend on the factor input ratio of labor and machinery, i.e. the total income R_i and total cost C_i of apple production are the functions of relative factor bias. Assuming that the relative factor bias of farmer i is Tb_i, then the optimal decision function of farmers based on the maximization of the net income effect is as follows:

$$MaxU_{Tb_i} = U_i\left[R_i(Tb_i) - C_i(Tb_i)\right] \tag{1}$$

Referring to the existing research results, we further assume that farmers have a fixed risk aversion preference and that apple planting income follows a normal distribution, and farmers' expected utility function can be expressed as an increasing mean variance standard concave function [31]. Then, under the condition of maximizing the net income effect, the optimal decision function of farmers can be extended as follows:

$$\underset{Tb_i}{Max}\, U_i(R_i, Tb_i) = E(R_i) - \frac{1}{2}\varsigma_i \operatorname{var}(R_i) - C_i(Tb_i) \tag{2}$$

In formula (2), $E(\cdot)$ is the mean function, $\operatorname{var}(\cdot)$ is the variance function and ς_i is the risk preference of farmer i.

On this basis, the total revenue of apple production is defined as:

$$R_i(Tb_i) = p_i q_i A_i + p_i A_i (Z_i + Tb_i)\mu_i \tag{3}$$

In formula (3), p_i is the apple selling price of farmer i; q_i is the apple yield per unit area of farmer i; A_i is the apple planting area of farmer i; Z_i is the characteristics of households and head of households; Tb_i is the technology selection bias of farmer i; μ_i is the random variable to measure environmental impact, which meets $\mu_i \sim N(1, \sigma^2)$; $A_i p_i (Z_i + Tb_i) \mu_i$ refers to the relative income change of agricultural production caused by the relative change of factor output rate measured by market price.

Sadoulet and de Janvry [32] found that it was not necessary to estimate the input demand and output supply system under transaction costs. Thus, our assumption is that farmers are only constrained by transaction costs when participating in factor markets. According to the research method of Key et al. [33], transaction cost is further divided into fixed transaction cost and variable transaction cost. Fixed transaction cost does not change with the change of transaction volume, including information search cost, negotiation cost, monitoring and execution cost, while variable transaction cost increases with the increase of transaction volume, including transportation cost and other costs related to incomplete information [31]. Assuming that the fixed transaction cost and unit variable transaction cost faced by farmer i due to technology selection bias are FTC_i and VTC_i respectively, then the total apple production cost of farmer i can be defined as:

$$C_i(Tb_i) = C_i^0 + A_i Tb_i (P_i^{lm} + VTC_i) + FTC_i \quad (4)$$

In formula (4), C_i^0 represents the land input cost of farmer i, and P_i^{lm} represents the input price ratio of labor and machinery when farmer i prefer technology selection bias.

By substituting formula (3) and formula (4) into formula (2), the optimal decision-making function of maximizing net income utility considering the transaction cost of farmers' participation in the factor market is obtained as follows:

$$\begin{aligned} \underset{Tb_i}{Max}\, U_i(R_i, Tb_i) = {} & A_i p_i q_i + A_i p_i (Z_i + Tb_i) - \frac{\varsigma_i}{2} A_i^2 p_i^2 (Z_i + Tb_i)^2 \sigma_i^2 \\ & - C_i^0 - A_i Tb_i (p_i^{lm} + VTC_i) - FTC_i \end{aligned} \quad (5)$$

Based on the above analysis, we attempt to introduce the informatization level into the formula (5). On the one hand, informatization can effectively alleviate the information asymmetry between farmers and factor retailers, make up for the lack of market information, and contribute to reducing the cost of farmers' search for factor market information, the cost of negotiation with factor retailers and the cost of supervision [34]. On the other hand, informatization can reduce farmers' sensitivity to variable transaction costs and increase market transaction efficiency [35]. Thus, assuming that the informatization level of a farmer i is I_i, the fixed transaction cost and variable transaction cost of biased input can be further defined as follows:

$$FTC_i = \psi(I_i; Z_\mu, Z_i), \text{ s.t. } \partial FTC_i / \partial I_i < 0 \quad (6)$$

$$VTC_i = \gamma(I_i) d_i^2, \text{ s.t. } \partial \gamma(I_i) / \partial I_i < 0 \quad (7)$$

In formula (6) and formula (7), Z_μ are the variables that affect farmers' fixed transaction costs of biased inputting; $\gamma(\cdot)$ is the sensitivity function of farmer i to variable transaction costs of biased inputting; and d_i is the distance between farmers and the factor market.

Furthermore, by substituting formula (6) and formula (7) into formula (5), the optimal decision-making function of farmers' biased inputting is obtained as follows:

$$\begin{aligned} \underset{Tb_i}{Max}\, U_i(R_i, Tb_i) = {} & A_i p_i q_i + A_i p_i (Z_i + Tb_i) - \frac{\varsigma_i}{2} A_i^2 p_i^2 \\ & (Z_i + Tb_i)^2 \sigma_i^2 - C_i^0 - A_i Tb_i (p_i^{lm} \\ & + \gamma(I_i) d_i^2) - \psi(I_i; Z_\mu, Z_i) \end{aligned} \quad (8)$$

The first derivative of technology selection bias can be obtained as follows:

$$\frac{\partial U_i}{\partial Tb_i} = A_i p_i - \varsigma_i A_i^2 p_i^2 (Z_i + Tb_i) \sigma_i^2 - A_i (p_i^{lm} + \gamma(I_i) d_i^2) = 0 \quad (9)$$

Then, the optimal technology selection bias Tb_i^* can be calculated as follows:

$$Tb_i^* = \frac{p_i - (p_i^{lm} + \gamma(I_i) d_i^2)}{\varsigma_i A_i p_i^2 \sigma_i^2} - Z_i \quad (10)$$

According to formula (10), we can see that apple growers' technology selection bias depends on apple's sale price p_i, the price ratio of labor and machinery input p_i^{lm}, informatization level I_i, distance between farmers and factor market d_i, farmer's risk preference ς_i, apple planting area A_i, the variance of environmental impact σ_i^2, family characteristics and individual characteristics of the household head Z_i.

Overall, informatization changes the relative prices of labor and machinery elements by affecting the transaction costs of farmers participating in the factor market, leading farmers to choose relatively abundant factors to replace the relatively scarce ones, thus forming a technology selection bias (Figure 2). Based on the above analysis, the research hypothesis is proposed as follows:

Hypothesis: Because of the uncertainty about the relative size of the impact of the development of informatization on the prices of machinery and labor factors, informatization may induce farmers to choose labor-saving technology or labor-intensive technology.

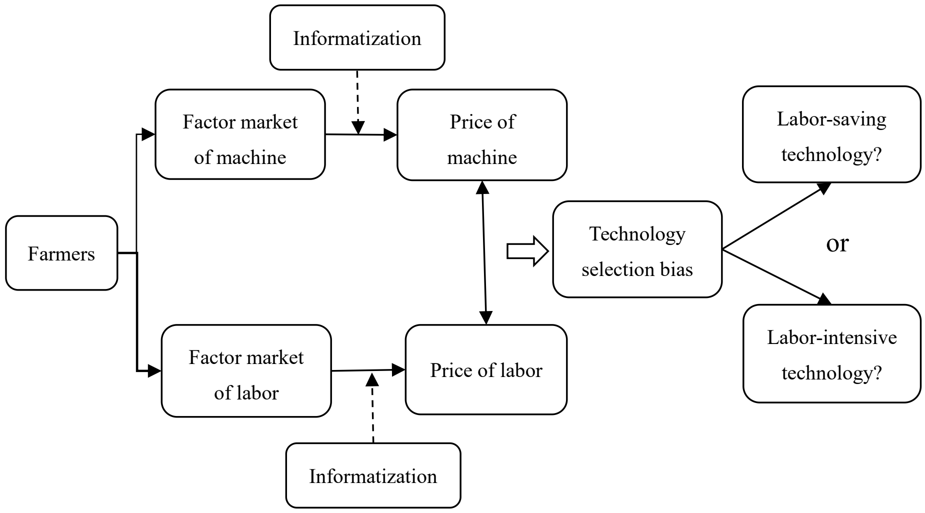

Figure 2. Theoretical framework of how informatization causes the substitution of factors inputs.

3. Methodology

3.1 Data

The data used in this paper are from the field survey of apple growers in Shandong, Shaanxi and Gansu by the research team of the National Apple Industrial Economy Research Office in July and August 2018. The multi-stage sampling method was adopted in this survey. In the first stage, Shandong, Shaanxi and Gansu were selected as the sample provinces according to the difference in regional informatization level by using typical sampling and stratified sampling methods. In the second stage, six counties are selected according to the concentration level of the apple industry by using a typical sampling method. In the third stage, three towns were selected from each sample county by using a simple random sampling method. In the fourth stage, two villages were selected from each sample town by using a simple random sampling method. In the fifth stage, 20-21 farmers were selected from each sample village by using a simple random sampling method. In this survey, 744 questionnaires were collected through face-to-face interviews. After excluding the samples with inconsistent answers or important missing variables, 727 questionnaires were collected through face-to-face interviews. After excluding the samples with inconsistent answers or important missing variables, 727 questionnaires were valid and the effective rate was 97.72%. The sample distribution area is shown in Figure 3.

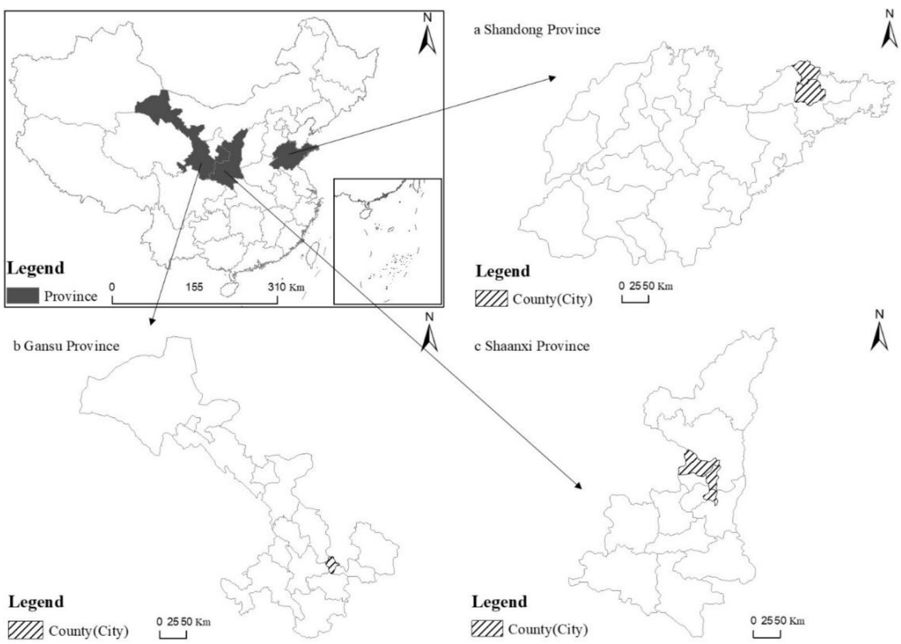

Figure 3. Sample distribution.

3.2 Model

In the theoretical analysis, the induced technology of factor scarcity can be divided into labor-saving technology and land-saving technology. Considering the labor-intensive characteristics of apple production, this paper takes labor-saving technology as an example for empirical analysis. In particular, the relative bias of factor inputs is used to define the technology choice behavior of farmers, i.e. the type of technology in which the labor factor input per unit area is relatively larger than the mechanical factor input per unit area is defined as labor-intensive technology. The type of technology with labor factor input per unit area greater than mechanical factor input per unit area is defined as labor-intensive technology, while the opposite is defined as labor-saving technology [36,37]. Referring to the existing research methods [38], the calculation formula of the bias of labor-saving technology is as follows:

$$Tb_i = (m_i / M)/(l_i / L) \tag{11}$$

In formula (11), m_i refers to the mechanical input per unit area of farmer i; M represents the average mechanical element input per unit area of the whole sample farmers; l_i represents the labor factor input per unit area of farmer i; L represents the average labor factor input of the whole sample farmers. If $Tb_i > 1$, it indicates that farmers prefer labor-saving technology; if $0 < Tb_i < 1$, it indicates that farmers prefer labor-intensive technology; if $Tb_i = 1$, it indicates that farmers prefer neutral technology.

According to formula (11), we found that the technical selection bias index of sample farmers is not equal to 1. Therefore, the factor scarcity induced technology selection behavior was defined as a binary variable T_i. If the technology selection bias index T_i of farmer i was greater than 1, the value T_i was 1, indicating that farmers choose labor-saving technology; if farmers' technology selection bias index T_i of farmer i was between 0 and 1, the value T_i was 0, indicating that farmers chose labor-intensive technology. Based on this, the Probit model was used to analyze the impact of informatization level on farmers' factor scarcity induced technology selection behavior. The benchmark model is set as follows:

$$\begin{aligned} Prob(T_i = 1) = \beta_0 + \beta_1 I_i + \beta_2 p_i + \beta_3 p_i^{lm} + \beta_4 d_i + \beta_5 A_i \\ + \beta_6 \varsigma_i + \beta_7 Z_i + \beta_8 \sigma_i^2 + v \end{aligned} \tag{12}$$

In formula (12), I_i refers to the informatization level of farmer i; p_i represents the apple sales price of farmer i; p_i^{lm} represents the input price ratio of labor and machinery elements of farmer i; d_i represents the distance between farmer i and the factor market; ς_i represents the risk preference of farmer i; A_i represents the apple planting area of farmer i; and represents the apple business area of farmer i; σ_i^2 represents the variance of environmental impact; Z_i represents the characteristics of the family and the head of household. $\beta_1 \sim \beta_8$ are the parameters to be estimated; v is the random error term, and satisfies $v \sim (1, \sigma_v^2)$. In the process of model estimation, the significance and direction of β_1 to judge the influence of informatization level on farmers' factor scarcity induced technology selection behavior.

3.3 Variables Setting and Description

Based on the conclusions of the theoretical analysis above, whether farmers choose the labor-saving technology or labor-intensive technology depends on the level of informatization, the apple selling price, the price ratio of labor and machinery factor input, the distance between farmers and the factor market, the size of apple plantation, the risk preference, the characteristics of the family and the head of the household, the characteristics of the production environment. However, the causality remains to be tested. On the basis of previous studies, the specific variables are defined and explained in Table 1.

(1) Dependent variable: In this paper, whether or not the farmer chooses labor-saving technology is used to assess labor and machinery substitution bias. Combined with the technology selection bias index, it is defined as a binary variable. Specifically, if the farmer chooses labor-saving technology, the value is 1; if the farmer chooses labor-intensive technology, the value is 0.

(2) The key independent variable: the level of Informatization. Most of the existing studies use the ICT penetration rate as a proxy variable for informatization [4], which focuses on the means of information acquisition, but does not fully consider the degree of farmers' information utilization. Therefore, in this paper, we measure farmers' informatization level from three aspects: information technology access level, information technology application level and information literacy level. The specific steps are as follows: First, we select "whether to access smartphones", "whether to access mobile Internet", "whether to access computers" and "whether to access fixed broadband Internet", and use the "entropy weight method" to measure the information technology access level; select "the degree of agricultural information obtained by mobile network" and "the degree of agricultural information obtained by using fixed broadband Internet", and use the "entropy weight method" to measure the information technology application level. Second, the principal component analysis method is used to measure the information literacy level from five aspects: information awareness, information acquisition ability, information evaluation ability, information application ability and information sharing ability. Third, to comprehensively evaluate the informatization level, the entropy weight method is used to calculate the weight of information access level, information technology application level and information literacy level.

(3) Other controlled variables. 1) Price factors, including apple selling price and the input price ratio of the labor-machinery factor. Since it is known that apple selling price is endogenous, in order to eliminate the influence of endogeneity on the estimation results, this paper uses the average apple selling price of the village as a proxy variable for individual apple prices. 2) Distance between farmers and factor market. In this paper, we focus mainly on the labor and machinery markets. Since the distance between the two-factor markets cannot be accurately measured, this paper chooses the distance between farmers and the nearest farm factor market as a proxy variable. 3) Apple farm size and farmers' risk preferences. Apple is a perennial crop, and farmers' production factor input is mainly concentrated on fruit trees during the fruit-bearing season. Therefore, in this paper, apple orchard area in the fruiting season is used to represent the farm size of apple farmers. In the questionnaire, the question was designed as follows: "If there was a new apple planting technology, how would you adopt it? (1 = not to adopt; 2 = to adopt according to the situation of others; 3 = to decide after a trial on a small area; 4 = to adopt actively)". 4) Characteristics of the family and the household head. The individual characteristic variables of the head of the household include age, years of education and experience in cultivation; the characteristic variables of the family include the proportion of agricultural labor and total household income. 5) Production characteristics and environmental conditions. In combination with apple production characteristics, the proportion of irrigated area, age of apple trees, planting density and site conditions were selected to measure apple production characteristics and environmental conditions. In particular, due to the differences in planting time and structural layout in different plots, the measurement of apple tree age and planting density is at the mean level. Site conditions are represented by regional virtual features, and Gansu Province is taken as the reference group.

Table 1. Variable selection, definition and description.

Variables	Definition and description	Min	Max	Mean
Dependent variable				
Technology selection bias (Substitution of mechanical and labor factors)	Binary variable; 1 = labor-saving technology, 0 = labor-intensive technology	0	1	0.44
Independent variables				
The level of informatization	Informatization index based on "entropy weight method"	0.11	3.79	1.39
Price				
Apple selling price	The average price of apples sold in villages (yuan/kg)	1.13	4.43	2.21
Input price ratio of the labor-machinery factor	Labor factor input average price/mechanical factor input average price	0	259.55	8.94
Distance between farmers and factor market	Distance from factor market to nearest agricultural material sales market (km)	0.01	100	5.01
Apple farm size	Apple planting area in the fruit bearing period (mu)	1	60	7.38
Farmers' risk preference	1 = not to adopt; 2 = to adopt according to the situation of others; 3 = to decide after trial in small area; 4 = to adopt actively	1	4	2.83
Characteristics of the family and household head				
Age	The actual age of the surveyed farmer (year)	21	76	51.76
Years of education	Education years of the surveyed farmers (year)	0	16	8.36
Years of experience in cultivation	Apple planting years of the surveyed farmers (years)	1	47	23.02
The proportion of agricultural labor	Number of agricultural labors in the family divided by the total number of households	0.2	1	0.74
Total household income	Total household income in 2017 (Ln)	8.91	13.84	10.98
Production characteristics and environmental conditions				
The proportion of irrigated area	The irrigated fruit bearing area divided by the total fruit bearing area of apple	0	1	0.52
Age of apple trees	Average age of apple trees (year)	3.6	37	18.56
Planting density	Number of apple trees cultivated per mu (trees/mu)	20	218.78	47.25
Shaanxi	Dummy variable; 1 = Yes, 0 = No	0	1	0.52
Shandong	Dummy variable; 1 = Yes, 0 = No	0	1	0.32

3.4 Endogenous Discussion

According to the existing literature, the level of informatization in this paper may be endogenous, leading to estimation errors in the empirical analysis. Therefore, to avoid endogenous effects, we use the conditional mixed process (CMP) method proposed by Rodman [39] to estimate the econometric model to avoid endogenous effects. Compared with the traditional 2SLS, the CMP estimation method can better resolve the discontinuity of endogenous variables. The CMP method is also a two-stage estimation process. In the first stage, the instrumental variable of the potential endogenous variable is found and the correlation between the instrumental variable and the endogenous variable is tested; in the second stage, the instrumental variable is substituted into the regression model, and then the value of the parameter atanhrho_12 is used to test the endogeneity of the endogenous variable. If the value of the parameter atanhrho_12 value is significantly different from 0, the model is endogenous and the CMP is effective for estimating the econometric model.

4. Results and Discussion

4.1 The Benchmark Regression

In this paper, "the proportion of 10 households near your home that use the Internet through smartphones" is selected as the instrumental variable of informatization, and the probit model, CMP estimation method are used to estimate model (12), which analyzes whether informatization causes the substitution bias of agricultural machinery inputs for labor inputs in Table 2. The reason why we chose the instrumental variable is that this variable can better reflect the regional informatization level. As the existing literature shows, the degree of information technology diffusion and use in a region has an important impact on the individual informatization level [40]. However, "the proportion of 10 households near your home that use the Internet through smartphones" is relatively exogenous to farmers' choice of labor-saving technology or labor-intensive technology, indicating that the instrumental variable is valid. As for the endogeneity test results, the instrumental variable has a significant positive impact on the informatization at the level of 1% in the first stage, and at the same time, the value of atanhrho_12 is significantly different from 0. This indicates that the variable of informatization level is endogenous, and the instrumental variable and the CMP method are effective. The results and discussion for Table 2 are as follows.

According to the estimation results in Table 3, the level of informatization has a negative significant effect on farmers' choice of labor-saving technology at the 1% level. This result indicates that the level of informatization improves the possibility of selecting labor-intensive technology, and Hypothesis is verified. In terms of the marginal effect, for every 1 unit increase in the level of informatization, the likelihood of selecting labor-intensive technologies increases by 0.224. The possible explanation is that, in apple production, it is much more difficult to find suitable agricultural machinery than labor due to the topographical constraints of the main apple-producing areas. Under this constraint, the level of informatization plays a greater role in reducing the transaction costs of farmers' participation in the labor market than in the machinery market, causing the price ratio of labor and machinery to fall, which induces farmers to choose labor-intensive technologies. It is worth noting that although informatization encourages farmers to choose labor-intensive technology, the reverse induced effect of the level of informatization on labor-saving technology may be short-lived against the background that the labor cost of agricultural production is still rising and the ageing of production units continues to intensify. Therefore, it is very necessary to induce farmers to choose labor-saving technology based on the regulatory role of informatization in the labor and machinery factor markets.

In terms of the impact of price factors on labor-saving technology selection, the apple selling price has a positive and significant impact on farmers' choice of labor-saving technology at the 5% level, which indicates that the increase in apple price will encourage farmers to choose labor-saving technology, contrary to the findings of existing studies. The possible explanation is that the agricultural product market and production factor market are dynamic markets, and the change in agricultural product price will change the input structure of farmers' production factors, which will cause farmers to change the technology selection bias. That is, the effect of agricultural product market price on farmers' choice of labor-saving technology is not stable. The input price ratio of labor and machinery has a positive and significant impact on farmers' choice of labor-saving technology at the 10% level. This result indicates that the higher the price ratio of labor and machinery, the more the farmers tend to choose labor-saving technology. The increasing price ratio of labor and machinery means that the marginal cost of labor input is higher than the marginal cost of machinery input, i.e. labor is more scarce than machinery factor. In this case, farmers tend to increase mechanical inputs to replace labor.

Farmers' risk preference positively affects farmers' choice of labor-saving technology at the 1% level, indicating that farmers with risk preferences prefer labor-saving technology, which is contrary to the existing studies.

The possible explanation is that with the increasing labor costs, farmers with risk preference are more likely to seek alternative labor factors in the factor market and reduce the unit cost of apple production. The distance between the factor market and farmers, and the area of apple production does not have a significant influence on farmers' choice of labor-saving technology.

In terms of household head characteristics, age has a significant negative effect on farmers' choice of labor-saving technology at the 1% level, indicating that older farmers prefer to choose labor-intensive technology. The possible reason for this is that with increasing age, farmers' ideology is easily consolidated and the recognition of labor-saving technology or production mode is low. In comparison, they still stick to the traditional labor mode. In addition, the influence of years of education and farming experience on farmers' choice of labor-saving technology does not pass the significance test. In terms of family characteristics, the proportion of agricultural labor has a significant negative impact on farmers' choice of labor-saving technology at the 1% level, indicating that the households with abundant agricultural labor endowment tend to choose labor-intensive technology. The possible explanation is that the proportion of agricultural labor reflects to some extent the abundance of family labor factors. The more agricultural labor there is in the family, the more farmers tend to increase the input of labor, substituting other relatively scarce factors. Total household income has a positive impact on farmers' choice of labor-saving technology at the 10% level, indicating that the higher the family income, the more likely farmers are to choose labor-saving technology. The possible explanation is that total household income reflects to some extent the degree of capital accumulation of farmers. The higher the total income, the lower the financial constraints on investment in agricultural production, and the more conducive it is to encourage farmers to increase mechanical inputs to replace the relatively scarce factor of labor. In terms of production characteristics, the share of irrigated area, age of apple trees and planting density do not pass the significance test for farmers' choice of labor-saving technology.

In terms of location and environmental conditions, apple farmers in Shaanxi prefer labor-saving technology compared to apple farmers in Gansu province, which may be related to regional differences in apple production mode and labor endowment. Compared with Shaanxi and Shandong, due to the backward economic development in Gansu, the price of agricultural labor is relatively low and labor is more abundant. In addition, the dwarf apple cultivation mode, which is good at "labor saving", is popularized in Shaanxi and Gansu, especially in Shaanxi, which improves the substitution efficiency of mechanical factors for labor factors. It is worth noting that there is no significant difference in technology selection bias between Shandong apple farmers and Gansu apple farmers. The possible explanation is that higher labor prices in Shandong have a pull effect on farmers' choice of labor-saving technology. However, due to the restrictive climatic conditions, it is difficult to popularize the labor-saving production mode in Shandong. The nature of the practical constraints has a push effect on farmers' choice of labor-saving technology, so the two effects may cancel each other out.

4.2 Robustness Test Analysis

In order to further test the robustness of the above research results, this paper takes the technology selection bias index as a proxy variable, and selects "the proportion of 10 households near your home that use the Internet through smartphones" as an instrumental variable. Tobit model and CMP method are used to test the robustness of the impact of informatization level on farmers' choice of labor-saving technology in Table 4. According to the estimation results of the first stage equation, the instrumental variable is correlated with the informatization at the 1% level, and the endogenous test parameter value atanhrho_12 is different from 0 at the 10% level, indicating that the CMP method and instrumental variable selection are effective. The results of the second stage show that the level of informatization has a significant negative impact on the technology selection bias index at the 10% level, which indicates that the increase in informatization will induce farmers to choose labor-intensive technology, which is consistent with the result of the benchmark model. Therefore, the conclusion that the level of informatization negatively affects farmers' choice of labor-saving technology is robust.

4.3 Heterogeneity Analysis

Analysis of Regional Heterogeneity

The above analysis shows that the level of informatization has a significant negative impact on farmers' choice of labor-saving technologies. However, there are obvious regional differences in the level of informatization and the degree of factor market development in different regions, which may lead to the differences in the influence of informatization on farmers' choice of labor-saving technology. Therefore, this paper divides the total sample into two sub-samples according to the geographical region division standard, including the eastern region and the western region. The probit model and CMP method are used to estimate the econometric model in order to test the robustness of the information level affecting farmers' labor-saving technology selection.

Table 2. Results of the benchmark regression.

Variable	Independent variable: labor-saving technology = 1; labor-intensive technology = 0 (CMP-Probit)		
	Stage I Independent variable: Informatization	Stage II	
		Coefficient	Marginal effect
The level of informatization	—	–0.710*** (–2.89)	–0.224*** (–3.26)
Apple selling price	—	0.173** (1.97)	0.055* (1.94)
Input price ratio of the labor-machinery factor	—	0.030* (1.71)	0.009* (1.71)
Distance between factor market and farmers	—	0.001 (0.17)	0.000 (0.17)
Apple farm size	0.011 (1.40)	–0.015 (–0.97)	–0.005 (–0.95)
Farmers' risk preference	0.171*** (5.93)	0.186*** (3.04)	0.059*** (3.28)
Age	–0.035*** (–9.11)	–0.039*** (–3.85)	–0.012*** (–4.37)
Years of education	0.054*** (5.09)	0.026 (1.16)	0.008 (1.19)
Years of experience in cultivation	0.001 (0.29)	–0.008 (–1.05)	–0.003 (–1.04)
The proportion of agricultural labor	–0.110 (–0.92)	–0.531*** (–2.67)	–0.168*** (–2.64)
Total household income	0.159*** (3.54)	0.215* (1.69)	0.068* (1.74)
The proportion of irrigated area	—	0.029 (0.25)	0.009 (0.25)
Age of apple trees	—	0.006 (0.68)	0.002 (0.68)
Planting density	—	–0.000 (–0.04)	–0.000 (–0.04)
Shaanxi	—	0.597*** (3.80)	0.188*** (3.51)
Shandong	—	–0.058 (–0.33)	–0.018 (–0.33)
Constant	0.103 (0.19)	–0.562 (–0.36)	—
IV_1	0.006*** (4.90)	—	—
Atanhrho_12	0.622** (2.19)		
Wald test	654.76***		
Samples	727	727	727

*** p < 0.01, ** p < 0.05, * p < 0.1; Z-value under robust standard error is shown in parentheses; IV_1 is defined as the proportion of 10 households near your home that use the Internet through smartphones.

Table 3. Results of robustness test.

Variable	Independent variable: Technology selection bias index (CMP-Tobit)		
	Stage I Independent variable: Informatization	Stage II	
		Coefficient	Marginal effect
The level of informatization	—	–0.552* (–1.68)	–0.460* (–1.75)
Controlled variables	Controlled	Controlled	Controlled
IV_1	0.006*** (4.90)	—	—
Constant	0.103 (0.19)	1.226 (1.24)	—
Atanhrho_12	0.414* (1.65)		
Wald test	624.44***		
Samples	727	727	727

*** p < 0.01, * p < 0.1; Z-value under robust standard error is shown in parentheses; IV_1 is defined as the proportion of 10 households near your home that use the Internet through smartphones.

According to the results of the subsample fitting in Table 4, in Stage I, the instrumental variables "the proportion of 10 households near your home that use the Internet through smartphones" and "whether the village broadcasts market information or not" are significantly correlated with the level of informatization, and the values of the endogenous test parameter atanhrho_12 are significantly different from 0 at the 1% level, respectively, indicating that the CMP method and instrumental variables are effective. In Stage II, the level of informatization negatively affects the farmers' choice of labor-saving technology in the eastern and western regions, which is consistent with the benchmark regression results, indicating that the negative influence of informatization level on farmers' choice of labor-saving technology is robust at the regional level. However, the impact of the level of informatization level on the choice of labor-saving technology in the eastern region (marginal effect: –0.198) is smaller than that in the western region (marginal effect: –0.303). On the one hand, compared with the eastern region, the informatization process in the western region is lagging behind, and the problem of imperfect and asymmetric information is more serious in the western region, so the marginal effect of the informatization level on the factor market in the western region may be larger. On the other hand, compared with the eastern region, the labor price in the western region is lower, which provides a better environment for inducing farmers to choose labor-intensive technology based on the informatization level.

Table 4. Results of regional heterogeneity analysis.

Variables	**Independent variable: labor-saving technology = 1; labor-intensive technology = 0 (CMP-Probit)**			
	Eastern region		Western region	
	Stage I	Stage II	Stage I	Stage II
Informatization level	—	–0.686*** (–3.38)	—	–0.999*** (–4.95)
Controlled variables	Controlled	Controlled	Controlled	Controlled
IV_1	—	—	0.005*** (3.09)	—
IV_2	–0.473*** (–2.80)	—	—	—
Constant	–0.005 (–0.00)	—	0.255 (0.41)	0.369 (0.27)
Atanhrho_12	0.727*** (2.61)		1.038*** (2.67)	
Wald test	209.53***		634.98***	
Samples	233	233	494	494

*** $p < 0.01$; Z-value under robust standard error is shown in parentheses; IV_1 is defined as the proportion of 10 households near your home that use the Internet through smartphones; IV-2 is defined as whether the village broadcasts market information or not.

Analysis of Different Dimensions of Informatization

There may be differences in the impact of information technology access level, information technology application level and information literacy level on farmers' information processing efficiency in the three dimensions of informatization, which leads to farmers' heterogeneous transaction cost of participating in the labor and machinery factor market, and further causes the relative price changes of labor and machinery factors, thus causing them to choose heterogeneous labor-saving technology. Based on this, this paper uses the probit model and CMP method to estimate the benchmark model, and discusses the influence of information technology access level, information technology application level and information literacy level on farmers' labor-saving technology choice, so as to further verify the robustness of the above research results.

According to the estimation results in Table 5, the instrumental variable "the proportion of 10 households near your home that use the Internet through smartphones" is significantly correlated with the information technology access level, information technology application level and information literacy level, respectively, and the endogenous test parameter values of anhrho_12 are significantly different from 0 at the 5%, 1% and 5% levels, indicating that the CMP method and instrumental variable are effective. In terms of the results in Stage II, the level of access to information technology, the level of application of information technology and the level of information literacy has a negative effect on farmers' choice of labor-saving technology at the level of 10%, 1% and 1%, respectively, which is consistent with the benchmark estimation results. However, in terms of the marginal effect, the information literacy level has the largest impact on farmers' choice of labor-saving technology (marginal effect: –0.391), followed by the information technology access level (marginal effect: –0.369), and the information technology application level has the smallest effect (marginal effect: –0.078). The level of information literacy reflects the ability of farmers to obtain and process information, which is supposed to eliminate the internal constraints of information asymmetry and directly affects the farmers' decision to participate in the factor market. In contrast, the access to and use of information technology are external constraints that determine the size of the information set available to farmers. Theoretically, the final information for decision making is more dependent on internal constraints, so the marginal effect of information literacy level is larger. In addition, the reason why the marginal effect of information literacy level is smaller than that of information technology access level may be related to the low level of information technology application among farmers, although information technology application is more focused on obtaining factor market information. According to the statistics of the survey data, although 64.79% of the farmers use information technology to obtain information related to agriculture, only 6.46% of the farmers obtain two or more types of information related to agriculture.

Table 5. Analysis results of different dimensions of informatization.

Variables	Independent variable: labor-saving technology = 1; labor-intensive technology = 0 (CMP-Probit)					
	Stage I	Stage II	Stage I	Stage II	Stage I	Stage II
Information technology access	—	-1.108^{*} (–1.87)	—	—	—	—
Information technology application	—	—	—	-0.241^{***} (–3.15)	—	—
Information literacy	—	—	—	—	—	-1.225^{***} (–2.60)
Controlled variables	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
IV_1	0.003^{***} (5.33)	—	0.018^{***} (4.85)	—	0.003^{***} (4.76)	—
Constant	0.006 (0.03)	–0.647 (–0.37)	–1.715 (–1.01)	–0.865 (–0.51)	2.080^{***} (7.88)	1.899 (0.95)
Atanhrho_12	0.386^{**} (2.02)		0.436^{***} (2.71)		0.586^{**} (2.22)	
Wald test	460.92^{***}		436.48^{***}		417.45^{***}	
Samples	727	727	727	727	727	727

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; Z-value under robust standard error is shown in parentheses; IV_1 is defined as the proportion of 10 households near your home that use the Internet through smartphones.

5. Conclusions and Implications

In the context of informatization, the transaction costs of farmers' participation in the factor market may change, leading to a change in the relative prices of factors and inducing farmers to choose the scarce factor-saving technology. However, there is no research to confirm this conclusion. Therefore, this study comprehensively evaluates the informatization level from three aspects of information technology access, information technology application and information literacy, and analyzes the impact of informatization on farmers' choice of labor-saving technology with 727 apple farmers randomly selected. To address endogeneity issues, this paper uses the probit model and CMP method, which can better resolve the discontinuity of endogenous variables compared with the traditional 2SLS.

The empirical results of CMP revealed a negative and significant relationship between informatization and farmers' choice of labor-saving technology, and the conclusion is robust at the regional level, but the negative impact of the level of informatization on farmers' choice of labor-saving technology is smaller in the eastern region than that in the western region. The effects of three different dimensions of informatization on farmers' choice of labor-saving technology are varied. In particular, the level of information literacy has the largest impact on farmers' choice of labor-saving technology, followed by the level of access to information technology, and the level of information technology application is the least. Furthermore, some factors were identified as important drivers of farmers' choice of labor-saving technology. Especially, the apple selling price, farmers' risk preference, total household income, labor-machinery factor input price ratio had a positive and significant impact on farmers' choice of labor-saving technology, while age, the proportion of agricultural labor had a significant negative effect on farmers' choice of labor-saving technology. However, Several factors did not impact significantly farmers' choice of labor-saving technology, including the distance between factor market and farmers, apple farm size, years of education, years of experience in cultivation, the proportion of irrigated area, age of apple trees and planting density.

Based on the above conclusions, this paper has two implications:

(1) The government should seize the opportunity of rural revitalization and development to coordinate the popularization of information technology and the improvement of information literacy, formulate differentiated regional informatization development strategies, orderly promote agricultural and rural informatization, comprehensively improve the informatization level of farmers, invigorate the factor market and effectively reduce the transaction cost of farmers' participation in the factor market. First, we should join hands with network operators to lower the tariff standards of mobile Internet and fixed broadband Internet to improve the information access level in rural areas. Second, we should promote factor market innovation based on big data or cloud computing, and guide farmers to use information technology to obtain market informa-

tion and production factors. Third, we should promote information training in various ways (e.g. adult education and on-site guidance training) to gradually improve farmers' information literacy.

(2) The government should strengthen the innovation of mechanical technology suitable for the current apple cultivation mode, and pay attention to the construction of an information disclosure mechanism for the agricultural machinery market or mechanized service market based on information technology, so as to reduce the transaction cost of farmers' participation in agricultural machinery market and mechanized service market, and guide farmers to choose labor-saving technology, so as to avoid farmers to fall into the trap of technological progress.

Overall, this paper examines the impact of informatization on the relative input bias of machinery and labor factors by taking apple farmers as an example, providing a Chinese case for the application of induced technological change theory in the context of informatization. However, due to the relatively slow technological progress of machinery and the upgrading of agricultural machinery in the apple production process, it may lead to relatively high fixed transaction costs for farmers to participate in the machinery factor market. However, this issue is not well addressed in the analysis of this paper due to measurement difficulties, which may affect the input costs of machinery factors for farmers and thus lead to changes in the relative input bias of mechanical labor. This is a research deficiency of this paper and we hope to be able to identify this problem more precisely in further research.

Author Contributions

Congying Zhang collected all field data, analyzed, interpreted the result, and wrote the manuscript. Jingru Xiang analyzed, interpreted the result, and wrote the manuscript. Qian Chang interpreted the result and reviewed the paper.

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Data Availability

Data used for this study are extracted from the Rural Micro Survey and can be accessed from the corresponding author upon request.

Conflict of Interest

All authors disclosed no conflict of interest.

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