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The Impact of Aging and Mechanization on Total Factor Productivity in Agriculture

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Abstract

With the rapid development of urbanization in China, a large number of young and able-bodied rural laborers choose to seek development in cities, leading to a increasingly serious problem of rural population aging. Against the backdrop of rural revitalization, population aging is a key factor restricting the development of agriculture in China. Based on the China Family Panel Studies (CFPS) data and using the least squares method, this paper studies the impact of aging and mechanization on total factor productivity in agriculture by treating age and agricultural machinery input as cross terms. This study provides some relevant methods and suggestions for solving the problems of insufficient labor supply and improving the input of total factor productivity in agriculture in the process of rural construction.

Keywords

Aging; Mechanization; Least Squares Method; Total Factor Productivity in Agriculture.

1. Introduction

Improving total factor productivity in agriculture and achieving high-quality and efficient agricultural development are the necessary requirements for rural revitalization. With the rapid development of urbanization, young and able-bodied people gradually leave their land and hometowns, highlighting the problem of aging population in rural areas. "Old man's agriculture" has become one of the key factors restricting the improvement of agricultural productivity and agricultural development. Mechanization, as an important symbol of agricultural modernization, can reduce labor intensity in agricultural production and significantly improve agricultural production efficiency, thus becoming one of the ways to promote the growth of total factor productivity in agriculture. In-depth exploration of the impact of rural population aging and mechanization on total factor productivity in agriculture is of great significance for achieving high-quality agricultural development.

This paper, based on field surveys and using data from the China Family Panel Studies (CFPS), theoretically analyzes the impact mechanism of population aging and mechanization on total factor productivity in agriculture through relevant literature research. Then a multiple linear regression model is constructed. By taking the age of the agricultural population and the input of agricultural machinery and their interaction terms as analysis variables, this paper empirically analyzes the impact of rural population aging and mechanization on total factor productivity in agriculture respectively, as well as the moderating role of machinery input in the process of population aging affecting total factor productivity in agriculture. Finally, according to the analysis results and research conclusions, this paper explores feasible paths to solve the dilemma of "old man's agriculture", puts forward targeted policy recommendations for improving total factor productivity in agriculture and achieving high-quality development of agriculture and rural areas, and provides meaningful reference for promoting rural revitalization.

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2. Literature Review

There is currently widespread and profound discussion in the academic community regarding the impact of population aging and mechanization on total factor productivity in agriculture, but a relatively consistent conclusion has not yet been reached on this issue.

One viewpoint holds that population aging will have a negative impact on total factor productivity in agriculture. The increasing age of the labor force in rural areas, as well as the large number of young and able-bodied rural laborers seeking development in cities, have had a very adverse effect on agricultural production in rural areas (Wang Jiaoxi and Li Chaozhu, 2020) [1]65; Wang Shuhong and Yang Zhihai [2] indicated in their study that as the degree of aging of the agricultural labor force continues to deepen, the green total factor productivity of grain will first decrease and then increase.

Another viewpoint is that population aging does not have a significant negative impact on total factor productivity in agriculture. According to Zhang Hongsheng[3], with a large number of rural young and able-bodied workers moving to urban areas for development, the problem of aging population in rural areas has become increasingly serious. However, relevant studies have shown that population aging in rural areas has not led to a decrease in grain production, but rather an increase. The reason is that, to compensate for the shortage of labor in agricultural production due to rural population aging, it has triggered an improvement in agricultural mechanization levels. Peng Weizhuojia[4] believes that as the age of rural labor force continues to increase, the loss of agricultural production technology efficiency will first continue to increase, but after a certain period of time, there will be a trend of continuous decline. Gao Sheng and Deng Feng[5] confirmed through empirical analysis that population aging in rural areas has promoted the improvement of wheat production efficiency to a certain extent, but the degree varies among eastern, central and western regions.

From the above literature, we can see that there are two opposing views on the impact of population aging on total factor productivity in agriculture: positive and negative effects. Existing literature ignores the impact of factors such as age growth, capital investment, and the efficiency of machinery input on total factor productivity in agriculture, whic provides research space for this paper.

3. Theoretical Analysis

3.1. The Labor Supply Effect of Rural Population Aging on Agriculture.

With the continuous increase in the age of rural labor force, their physical strength and ability will gradually decrease. Agricultural production is a very physically and mentally demanding activity. Therefore, the labor force with declining physical fitness will correspondingly reduce their participation in agricultural production activities, resulting in a decline in the overall supply of agricultural labor force [6]. In addition, the continuous increase in the age of the original rural labor force leads to an increasing number of middle-aged and elderly workers on the basis of the original village population base. Coupled with the rapid development of urbanization in China, more and more young and able-bodied rural labor force choose to leave rural areas for urban residence, resulting in fewer young labor forces in rural areas. If this situation continues to develop, the supply of rural labor force will continue to decrease, that is, the middle-aged and elderly labor force in the village will continue to increase while the young and able-bodied labor force will decrease, leading to a continuous decrease in the effective labor force supply for agricultural labor. Therefore, this paper proposes research hypothesis 1:

Hypothesis 1: Rural population aging will have a negative impact on total factor productivity in agriculture.

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3.2. The Transformation Effect of the Mechanical Factor of Rural Population Aging

With the increasing trend of rural population aging, the current rural labor force in China is increasingly unable to meet the demand for production and labor, while the price of labor has been on the rise in recent years. At the same time, with the continuous progress and development of modern science and technology in recent years, China's agricultural development is also developing at an unprecedented speed. The scale of agricultural mechanization in China has already been considerable. In addition to farmers purchasing and holding their own agricultural machinery and equipment, the development of agricultural machinery socialization services has also brought about tremendous changes in the realization form of agricultural mechanization. Practice has shown that agricultural machinery services for production and operation activities in rural areas are no longer limited to a single village or region. Therefore, when facing a shortage of labor supply, farmers may choose to increase capital investment and agricultural machinery input to increase crop yields per unit area of land. Therefore, this paper proposes research hypothesis 2:

Hypothesis 2: Rural population aging may have a beneficial impact on agricultural production through the transformation of capital and machinery factors.

4. Data and Methods

4.1. Data Sources

The data for this paper come from the China Family Panel Studies (CFPS) database at Peking University. In the process of data analysis, we mainly used the data from 2012, 2014, 2016 and 2018 based on experimental needs. The following treatments were made to the required data in the study: Firstly, on the basis of the relevant adult database, variables such as age, standard labor force quantity, labor force age quantity, child age, and years of education were synthesized according to the personal information that remained unchanged. Sample variables such as capital input and agricultural machinery input were generated in the household economic database. Secondly, since family land scale is relatively important for this study, but there is no statistical data on it in the household economic databases of 2014, 2016 and 2018, we used the variable of land area allocated in 2012's household economic database for substitution. Thirdly, samples with missing key information such as individuals and ages were deleted. Fourthly, horizontal and vertical mergers of data were carried out.

4.2. Research Methods

This study mainly explores the impact of aging and mechanization on total factor productivity in agriculture. Firstly, we evaluate the impact of aging on total factor productivity. The benchmark model and empirical model selected for this study are:

$$\mathrm{TFP} = X_1 Age + X_2 Mac + X_3 Cap + X_4 Lab + X_5 Chi + X_6 Edu + X_7 NLab + X_0 + \partial \quad (1)$$

In the above formula, TFP represents total factor productivity in agriculture, AgeIn the above formula, TFP represents total factor productivity in agriculture, Age represents aging, Mac represents agricultural machinery input, Cap represents capital input, Lab represents the total number of household labor, Chi represents the number of children, Edu represents the years of education of the labor force, NLab represents the number of non-agricultural labor force, X0 represents a constant term, and ∂ represents the residual term.

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At the same time, in order to analyze the moderating effect of mechanization on the impact of population aging on total factor productivity in agriculture, this study constructed the following empirical model:

$$TFP = X_1 Age \times Mac + X_2 Mac + X_3 Cap + X_4 Lab + X_5 Chi + X_6 Edu + X_7 NLab + X_0 + \partial \quad (2)$$

In the above formula, Age × Mac represents the interaction term of age and agricultural machinery input. The rest of the code remains consistent with Formula (1). Based on the above empirical model, a least squares model is established and empirically tested using multivariate linear regression analysis.

4.3. Variable Selection and Descriptive Statistics

4.3.1. Dependent Variable

According to the C-D production function, the total factor productivity of agriculture can be expressed as:

$$y = AK^{\alpha}L^{\beta}e^{\varepsilon} \quad (3)$$

Then take the logarithm of both sides to get:

$$lny = lnA + \alpha lnK + \beta lnL + \varepsilon \quad (4)$$

Finally, the result is obtained as:

$$lnA = lny - \alpha lnK - \beta lnL \quad (5)$$

Therefore, we can calculate the total facto-r productivity.

4.3.2. Core Explanatory Variables

In response to rural population aging, this paper draws on the research of Tang Xiaoping and other scholars [7], using the average age of labor force engaged in agricultural work in families as a consideration. For agricultural machinery input, the cost index of agricultural machinery input is calculated by adding the cost of machine rental and irrigation expenses incurred in agricultural production activities.

4.3.3. Control Variables

Regarding the agricultural labor supply [1]64, the first is the number of effective laborers engaged in agricultural production activities. The second is the amount of agricultural labor time spent on agricultural production. Following Li Lu's [8] approach, considering that the CFPS data used in this paper does not have a relatively complete statistical variable for the amount of labor time spent on agricultural production, this paper uses the measure of effective labor quantity engaged in agricultural production activities. According to China's labor law, the standard labor age in this paper is 18-60 years old. The variable of standard labor force quantity used in this paper can effectively reflect the heterogeneity of labor quality in families engaged in agricultural production activities.

In terms of capital investment, it includes expenses such as fish seedlings, livestock, and feed costs required for agricultural breeding, or seed and fertilizer pesticide costs required for agricultural production, as well as hiring labor costs and some other expenses. However, it does

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not include the rental cost of agricultural machinery and irrigation cost in the process of agricultural production.

For family labor force total, it is represented by the number of people aged 16-59 in the family members. This group of people are those with higher labor capacity in the family to engage in agricultural production activities. The more family labor age numbers there are, the more positive impact it will have on improving the total factor productivity of agriculture.

For child quantity, it refers to children under the age of 16. In some rural areas, children can also help families engage in some simple agricultural production activities, so children may alleviate the problem of labor supply in families to some extent.

For education level, it uses the average time during which labor members receive cultural education while they are still in school. The longer the years of education of labor members, the stronger their ability to accept new things, and their ability to learn and accept agricultural machinery is strong, so it is conducive to improving the level of investment in agricultural mechanization during agricultural production activities, thereby further improving the total factor productivity of agriculture.

For non-agricultural labor quantity, it refers to the number of family members who do not engage in agricultural labor. The larger the non-agricultural labor quantity, the smaller the agricultural labor quantity, which may have a negative impact on the total factor productivity of agriculture.

Table 1. Variable Selection and Descriptive Statistics

Variable name	Code	Variable definition	Mean value	standard deviation
Explained variable				
Total factor productivity	TFP	Total factor productivity	2.80	0.90
Core explanatory variable				
Aging	Age	Average age of household labor force (years)	46.42	12.26
Agricultural machinery input	Mac	Mechanical rental and irrigation expenses (yuan)	413.00	3203.26
Control variable				
Capital input	Cap	Seed fertilizer and pesticide expenses, fry expenses, etc. (yuan)	5346.82	24096.47
Education level	Edu	Average time of receiving cultural education (year)	7.43	3.73
Non-agricultural labor force	NLab	Number of people who are not engaged in agricultural labor (person)	0.61	0.81
Family labor force	Lab	Number of people aged 16-59 (person)	2.30	1.42
Total number of children	Chi	Less than 16 years old (person)	0.09	0.34

5. Analysis of Empirical Results

5.1. Analysis of Benchmark Regression Results

In this paper, the data obtained by processing are analyzed by multiple linear regression, and the following regression results are obtained (see Table 2).

In Table 2, in order to understand the influence of aging and mechanization on agricultural total factor productivity, model (1) firstly selects two core variables, namely age and input of

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agricultural machinery, and it can be seen that the negative influence of age on total factor productivity is very significant, that is, the total factor productivity will decrease by 0.07% for every 1% increase of age. The input of agricultural machinery has a significant positive impact on total factor productivity, that is, every 1% increase in agricultural machinery input will increase agricultural total factor productivity by 0.05%. Overall, the result of model (1) is relatively simple. In order to analyze the influence of aging and mechanization on agricultural total factor productivity more systematically, control variables are further added to model (2), and it can be seen that the influence of age on total factor productivity is significantly reduced, which shows that the influence of aging on total factor productivity is influenced by other variables.

Model (2) analyzes the influence of the core explanatory variables aging and the input of agricultural machinery on the agricultural total factor productivity, and at the same time adds the control variables such as capital input, education level, family standardized labor force and the number of children as the analysis benchmark. According to Table 2, we have passed the joint significance test of 1% in this model, so the model fits well.

Judging from the regression coefficient of the core explanatory variables, aging has a significant negative impact on agricultural total factor productivity, and it has passed the 1% significance test. That is, the higher the age of family labor force, the lower the agricultural total factor productivity. In family agricultural labor activities, every 1% increase in the age of family labor force will reduce the agricultural total factor productivity by 0.03%, which proves hypothesis 1; The input of agricultural machinery has a significant positive impact on agricultural total factor productivity, and it has passed the significance test of 1%. That is, the higher the input ofagricultural machinery, the higher the agricultural total factor productivity. With the increase of agricultural machinery input by 1%, the agricultural total factor productivity will increase by 0.05%. This result is highly similar to the above-mentioned research conclusions of Wang Jianxu and other scholars [1]65, which largely explain the significant negative impact of aging on total factor productivity, but its influence degree is greatly influenced by other control variables.

From the regression coefficient of controlled variables, firstly, capital investment has a significant positive impact on agricultural total factor productivity, and it has passed the significance test of 1%. That is, the greater the capital investment, the higher the agricultural total factor productivity. The possible reason is that the capital investment mentioned above includes the cost of seeds, chemical fertilizers and pesticides needed in agricultural production, or the cost of fry, breeding animals and feed needed in agricultural breeding, and also includes the cost of hiring labor and some other expenses. Therefore, with the increase of the age of the labor force, farmers can choose to increase the cost of chemical fertilizers and pesticides and increase the agricultural output per unit area, thus improving the agricultural total factor productivity, or they can choose to increase the cost of employees and improve the total factor productivity by increasing the labor force. At the same time, it also shows that in agricultural production and operation activities, the increase of capital investment can weaken the influence of aging on agricultural production and operation activities to some extent. Secondly, the education level of family labor force, the number of standardized family labor force and the number of children have a very significant positive impact on agricultural total factor productivity, and they all passed the 1% significance test. That is, with the increase of the education level of family labor force, the number of standardized family labor force and the number of children, the agricultural total factor productivity has shown an increasing trend.

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Table 2. Benchmark Regression Results

	(1)	(2)
	TFP	TFP
ln age	-0.070***	-0.027***
	(61.47)	(24.37)
ln agricultural machinery investment	0.052***	0.051***
	(746.28)	(811.03)
ln capital investment		0.001***
		(3.52)
Education level		0.003***
		(19.59)
Family standardized labor force		0.043***
		(125.94)
Number of children		0.005***
		(4.05)
_cons	1.126***	0.819***
	(262.72)	(147.31)

Note: ***p<0.01,**p<0.05,*p<0.1, t value is in brackets.

5.2. Adjustment Effect of Mechanization in the Influence of Aging on TFP

Table 3. Adjustment Function of Agricultural Machinery Input

	(1)	(2)
ln age*ln input of agricultural machinery	0.005***	0.004***
	(29.94)	(32.15)
ln age	-0.078***	-0.034***
	(66.99)	(30.74)
ln agricultural machinery investment	0.035***	0.035***
	(60.45)	(68.42)
ln capital investment		0.001***
		(3.41)
Education level		0.003***
		(20.48)
Family standardized labor force		0.043***
		(126.48)
Number of children		0.004***
		(3.29)
_cons	1.155***	0.847***
	(264.50)	(151.65)

Note: ***p<0.01,**p<0.05,*p<0.1, t value is in brackets.

Table 3, Model (1) In order to show the substitution of agricultural machinery for labor input more intuitively, the cross term of age and agricultural machinery input is used, and the core explanatory variables of age and agricultural machinery input are added. The regression results show that the cross-term coefficient between age and agricultural machinery input is positive, and it has passed the significance level test of 1%. In the model, we can see that age has a significant negative effect on agricultural total factor productivity. This shows that with the increase of mechanization, the negative impact of age on agricultural total factor productivity

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gradually weakens. That is to say, the input of agricultural machinery can weaken the negative impact of age on agricultural total factor productivity. Because with the increase of the age of the labor force, the total factor productivity of agriculture decreases, and the use of mechanization can make up for the shortage of labor supply caused by the increase of age.

In model (2), control variables such as capital investment, education level of labor force, number of family standardized labor force and number of children are added. The regression results show that the control variables such as capital investment, education level of labor force, number of family standardized labor force and number of children have significant positive effects on agricultural total factor productivity, and all of them have passed the 1% significance level test. The cross-term coefficient between age and agricultural machinery input is still positive, but compared with the coefficient of model (1), it shows that even if other control variables are added, agricultural machinery input can weaken the negative impact of age on agricultural total factor productivity, which is unchanged, but its weakening degree is affected by other factors, which proves hypothesis 2.

6. Conclusion and Policy Suggestions

6.1. Research Conclusion

Based on the data of China household follow-up survey (CFPS) from 2012 to 2018, this paper empirically analyzes the influence of rural population aging and mechanization on agricultural total factor productivity and the moderating effect of agricultural machinery input as a moderating variable on the negative influence of aging and total factor productivity, and draws the following conclusions:

The aging of rural population has a significant negative impact on agricultural total factor productivity. Mainly in two aspects, the increasing age of rural effective labor force has significantly reduced the quality of labor force engaged in agricultural labor. At the same time, the acceleration of urbanization in China makes the rural young and middle-aged labor force transfer to cities, resulting in a significant decrease in the number of effective labor force engaged in agricultural labor.

Agricultural mechanization has a significant positive impact on agricultural total factor productivity. With the continuous improvement of China's scientific and technological level and the continuous development of agricultural machinery technology, the scale and degree of agricultural mechanization in China are increasing, which can effectively promote the improvement of China's agricultural total factor productivity.

As a regulating variable, the input of agricultural machinery can effectively weaken the negative influence of age on total factor productivity. That is to say, the input of agricultural machinery, which can be expressed as a variable, has a significant weakening or inhibiting effect on the negative relationship between aging and total factor productivity. According to the continuous improvement of the development level of agricultural production technology in China, farmers may choose to increase the use of agricultural machinery in the face of the fact that the effective work of family engaged in agricultural labor can not meet the requirements of agricultural production and the current rising labor price in China, thus partially making up for the shortage of rural labor supply.

In addition to the above-mentioned aging and the input of agricultural machinery, the influencing factors of agricultural total factor productivity also include the capital input in agricultural production, the education level of family labor force, the number of standardized labor force in the family and the number of children in the family. The data show that the variables such as capital investment, education level, family standardized labor force and the number of children have significant positive effects on agricultural total factor productivity, and all of them have passed the 1% significance test.

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6.2. Policy Enlightenment

Based on the above research results, we can draw the following policy enlightenment.

To inject vitality into the countryside, to ensure the effective supply of rural labor. Under the background of rural revitalization strategy, we should fully grasp this opportunity, not only to retain the existing young and middle-aged laborers in rural areas, but also to actively cultivate diversified agricultural business entities and attract young and middle-aged laborers outside rural areas to develop in rural areas. Support and develop graduates to take rural areas as the starting point for employment and entrepreneurship, and broaden the employment channels for graduates, so that more and more young people can understand and like agriculture and participate in the agricultural production process. For example, by recruiting university student village officials to strengthen the basic service projects in rural areas, and recruiting graduates to bring goods live, it will create employment opportunities and bring higher agricultural income to farmers [9].

Continuously improve the level of agricultural mechanization in rural areas. Promote the use of mechanization, strengthen agricultural production technology training. Increase capital investment and improve the education level of the labor force. In the process of agricultural production, the existing family production factors can be adjusted according to the actual situation, and the substitution of agricultural capital factors for the negative impact between age and total factor productivity can be promoted according to local conditions; Strengthen the construction of education, medical care and other infrastructure in rural areas, so as to create better education conditions for rural areas and make agricultural production develop in the direction of knowledge and information.

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References

[1] Y.X. Wang, C.Z. Li: The effect mechanism of rural population aging and agricultural production, Journal of South China Agricultural University (Social Science Edition), Vol. 19 (2020) No.2, p.60-73.

[2] S.H. Wang, Z.H.Yang: Study on the influence of the aging of agricultural labor force on the change of grain green total factor productivity, Study on agricultural modernization, Vol. 41 (2020) No.3, p.396-406.

ISSN: 2692-7608 DOI: 10.6981/FEM.202312_4(12).0026

[3] H.S. Zhang: The path of farmers' sustainable income increase under the background of rural revitalization strategy-taking Guizhou Province as an example, Agricultural mechanization in Guangxi, Vol.(2019) No.4, p.67-70.

[4] W.Z.J. Peng: The influence of rural labor aging on farmers' technical choice and technical efficiency, Economic geography, Vol. 41 (2021) No.7, p.155-163.

[5] S. Gao,F. Deng: Rural population aging, agricultural mechanization and two-stage production efficiency of wheat, Technical economy and management research, Vol. (2019) No. 10, p.117-121.

[6] S.G. Wang, X. Tian: Study on the influence of rural labor aging on agricultural production-an empirical analysis based on cultivated land topography, Agricultural technical economy, Vol. (2018) No. 4, p.15-26.

[7] X.P. Tang, J. Jiang, S.S. Li: The influence of agricultural mechanization on the total factor productivity of planting industry in China-based on the panel threshold model of rural population aging, China Journal of Agricultural Machinery Chemistry, Vol. 42 (2021) No.12, p.204-213+236.

[8] L. Lu, W.X. Xu: Changes of agricultural ecological efficiency under the aging effect of rural population, Journal of South China Agricultural University (Social Science Edition), Vol. 20 (2021) No.2, p.14-29.

[9] C.K. Liu: Rural population aging and regional heterogeneity of agricultural total factor productivity, Journal of South China Agricultural University (Social Science Edition), Vol. 20 (2021) No.6, p.46-55.