

## Research Article

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# An Empirical Examination of Aging's Ramifications on Large-scale Agriculture: China's Perspective

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**Abstract:** Population aging has become a significant issue faced by major global economies. The rapid urbanisation process in China has led to a higher rate of aging in rural areas compared to urban areas. Existing studies have predominantly focused on the impact of aging on agricultural economics and production, with limited exploration into its effects on large-scale agriculture. Given the importance of large-scale agriculture as a crucial initiative for expanding agricultural investment and increasing land capital accumulation, it is pertinent to further investigate the implications of aging in this sector. The empirical examination of the impact of population aging on large-scale agriculture holds significant relevance for developing countries globally. These nations face dual challenges: an aging population and the need for agricultural modernisation. Research can aid in formulating targeted policies to address labour shortages, agricultural technological innovation, and market dynamics, thereby promoting sustainable development and food security. This study utilises data from China's Third National Agricultural Census and employs measurements of aging at both the rural household and county-city dimensions. The analysis includes an examination of the moderating effects of per capita arable land area and the level of mechanisation on the impact of aging on large-scale agriculture. The findings of the study are as follows: (1) From the perspective of rural households, aging leads to an increase in the age of the rural labour force, resulting in a significant decrease in the probability of rural households participating in large-scale

agriculture. (2) At the county-city level, aging contributes to a decline in the proportion of the population participating in large-scale agriculture, which is detrimental to the development of this sector. (3) In certain circumstances, the negative impact of aging on large-scale agriculture is exacerbated in areas with higher levels of agricultural mechanisation.

**Keywords:** aging, large-scale agriculture, agricultural mechanisation

## 1 Introduction

Aging is one of the most important social trends of the 21st century, affecting several areas of economy and society. According to the United Nations World Population Prospects (2019 Revision), one in six people worldwide will be over 65 years old (16%) by 2050, whereas this number will be only 11 (9%) by 2019. As one of the most populous countries worldwide, the age structure of China's population has changed dramatically over the past decade. According to the World Health Organization classification criteria, China's elderly population will exceed 400 million in 2037, and China will gradually become an older society (Fang et al., 2015; Peng & Hu, 2011; Wang & Ai, 2015). In the last two decades, China's urbanization has accelerated, and the trend of a large number of agricultural labourers moving to cities in search of non-farm jobs has accelerated significantly (Cai & Wang, 2007; Cai, 2018), leading to more rapid aging in rural areas of China than in cities. The average age of the population engaged in agricultural labour is also significantly higher than in other sectors (Chen, 2013; Hu & Zhong, 2012; Yang et al., 2016).

The impact of the rapid aging of the agricultural population on agricultural production has become an area of increasing academic interest, with attention focused on the effects of aging on production factor inputs (Guo et al., 2015; Qin et al., 2011) and agricultural output (Li & Li, 2009; Li & Sicular, 2013). Some literature argues that there

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is an imbalance in the supply of effective agricultural labour due to the gradual decline in the physical functioning of the rural agricultural workforce and the decreasing number of effective labourers for agricultural production inputs (Wang *et al.*, 2024; Yi *et al.*, 2023). In addition, studying the effects of aging on land use efficiency (Lin & Deng, 2012; Sui *et al.*, 2022) and the impact of aging on agricultural production behaviour decisions (Hu & Zhong, 2012; Li & Zhao, 2009; Zhong & Hu, 2008) has also been the focus of research. Through the study, it was found that population aging has profoundly affected the land transfer behaviour of the elderly left behind in rural areas (He & Yi, 2024; Wang & Liu, 2023). However, few studies have examined the effects of aging on large-scale agriculture. As an important initiative to expand agricultural investment and increase land capital accumulation, the Chinese government has been committed to promoting the development of large-scale agriculture and has introduced various supportive policies to encourage farmers to join cooperatives and professional associations or build platforms to facilitate cooperation between rural households, companies, and land trusts (Clegg, 2006). The development of new agricultural enterprises has been affected by the outflow of labour (Deng *et al.*, 2024). It can be argued that large-scale agriculture is extremely important for enhancing agricultural productivity and modernizing agricultural development (Teng *et al.*, 2021). There is no doubt that aging will also have far-reaching effects on large-scale agriculture, and the conclusions drawn from existing studies are divergent. Some scholars believe that aging can positively affect large-scale agriculture by enabling farming households to rent out their land that is difficult to operate (Liu *et al.*, 2021). However, some argue that labour outflows can significantly increase the labour costs of large-scale agriculture (Lu *et al.*, 2017). Other scholars have questioned the negative effects of aging, arguing that the existing agricultural mechanization can fully compensate for the impact of aging on large-scale agriculture (Lu *et al.*, 2022; Yang *et al.*, 2016).

Previous studies provide the necessary reference for us to address the impact of aging on large-scale agriculture, but they have room for further refinement. First, previous studies have a single statistical calibre of aging, failing to break down to different age groups or analyse different dimensions such as households and cities. Aging is a long-term process in which quantitative changes cause qualitative changes. It is also a process in which microscopic households accumulate effects until they change the age structure of the macroscopic county city population. Using only one type of variable for analysis will

inaccurately describe the impact, which is one of the reasons for the divergent conclusions of previous studies. Second, research on large-scale agriculture at the rural household level is limited. Unlike large-scale operations conducted by agricultural capital, large-scale agriculture involving local rural households reflects the true level of rural economic development. Previous studies have failed to use census data effectively. Although the research subjects remain in the category of large-scale agriculture, the conclusions drawn come from efficient agricultural capital and ignore the outflow of agricultural production returns. This would overestimate the actual returns of rural households and disguise the negative effects of aging in rural areas. Finally, there have been recent changes in the rural economy, such as the revalidation of land ownership and use rights and the upgrading of rural infrastructure. These changes, along with aging, have affected large-scale agriculture. Therefore, further research on per capita arable land area and farm machinery is necessary. Therefore, this study uses multiple dimensions to describe aging, and regressions using a logistic model to verify the effects of aging on large-scale agriculture and further analyse other related effects. First, from the farm household perspective, aging leads to an increase in the age of the rural household labour force and a decrease in the probability of farm household participation in large-scale agriculture. Second, in the county-city dimension, aging leads to a decrease in the proportion of the participating population in large-scale agriculture, which is not conducive to the development of large-scale agriculture. Third, increasing arable land per capita does not weaken the negative effects of aging on large-scale agriculture. In some cases, the negative effects of aging on large-scale agriculture are reinforced in areas with high levels of agricultural mechanization.

Our study contributes in three ways. First, it uses data from the Third National Agricultural Census 2016. Census data are the most intuitive and comprehensive, reflecting the changing trends in China's rural large-scale agriculture in the face of aging. Second, we measure aging in two dimensions, rural households and county cities, and divide them into different age groups. Third, we analysed the moderating effects of per capita acreage and mechanization level on the impact of aging on large-scale agriculture, providing a reference for formulating targeted policies.

The remainder of the paper is structured as follows: Section 2 presents the theoretical analysis and research assumptions. Section 3 presents the data and estimation strategy used in this study. Section 4 presents the empirical results. Section 5 provides further analyses and discusses the findings and shortcomings of the study. Finally, Section 6 presents the conclusions of this study.

## 2 Theoretical Analysis and Research Hypothesis

Aging has different transmission paths based on the dimensions of farmers and cities, and the impact on large-scale agriculture has different transmission paths that eventually converge into a complete impact. As rural households age, the health and strength of their labour force gradually decline, and they are no longer able to perform overly strenuous physical labour (Wang et al., 2021). Farmers are more inclined to rent out their land than to operate their own land alone and are more reluctant to participate in various types of cooperative farming (Gao, 2022). In addition, participation in large-scale agriculture requires not only physical strength but also the necessary learning ability and ability to apply agricultural technology. For individual farmers, although increasing age increases their farming experience to a certain extent, their experience forms a fixed mindset that is not conducive to the adoption of new technologies, which creates further barriers for older farmers to engage in cooperative farming (Gao, 2022; Hu & Zhong, 2012). Therefore, we propose hypothesis 1:

**Hypothesis 1.** *In the rural household dimension, the probability of farmers' participation in large-scale agriculture decreases as the degree of aging increases.*

In the county-city dimension, we further subdivided the rural population into youth, middle-aged, and elderly groups according to age, and the degree of aging was intuitively represented by fluctuations in the proportion of the population in different age groups. County cities with a lower degree of aging have higher proportions of middle-aged and younger populations. As local aging increases, the share of the local middle-aged and young population continues to decrease, whereas the share of the older population increases (Chang et al., 2021; Čiutienė & Railaitė, 2015). Attitudes toward large-scale agriculture differ significantly among people of different age groups; the main participants in large-scale agriculture are middle-aged rural populations. They generally have some urban work experience. As they enter middle age, the benefits of remaining in urban, high-intensity non-farm employment may already be lower than the benefits they would receive if they returned to rural areas to participate in large-scale agriculture (Nie & Li, 2015; Xiao & Luo, 2019). In addition, the relatively stable earnings and low cost of living from agricultural production are among the reasons why the middle-aged cohort chose to return to the countryside (Zhang et al., 2023). They tend to have experience in technology applications and management,

which motivates them to expand their business areas and participate in large-scale agriculture (Xu & Zhao, 2022). Young people can also participate in large-scale agriculture. However, compared with the middle-aged population, their physical condition is more suitable for high-intensity urban non-farm industry positions. The rural youth cohort is constrained by a weaker level of education and is therefore employed in urban areas, mainly in labour-intensive industries. These industries have lower skill thresholds, and income returns are directly proportional to the labour input (Liu & Lei, 2020). Currently, the rising cost of human resources in China has led to rural youth earning higher wages for farming in cities than in rural areas. In the context of the scissor difference between urban and rural wage returns, they are more inclined to work (Song & Gao, 2022; Wang & Luo, 2022). As their income is focused on non-agricultural jobs in urban areas, they pay less attention to rural land, and more than half of rural youth have indifferent attitudes toward land (Yang & Zuo, 2015). However, the elderly population is constrained by their health status and learning ability to meet the general requirements for participation in large-scale agriculture (Ma et al., 2023). Therefore, an increase in aging in the county-city dimension will lead to a decrease in the share of middle-aged and young people as the main participants in large-scale agriculture, which, in turn, will have a negative impact on the level of large-scale agriculture in their cities. Therefore, we propose hypothesis 2:

**Hypothesis 2.** *The deepening of aging in the county city dimension leads to a decrease in the size of the population of subjects involved in large-scale agriculture and a decrease in the probability of farmers' participation in large-scale agriculture.*

## 3 Data, Variables, and Models

### 3.1 Data Sources

The data used in this study were mainly derived from the Census of Rural Households, the Census of Large-Scale Agricultural Business Households, and the Census of Agricultural Business Units of the Third National Agricultural Census 2016. The Third National Agricultural Census is registered for households, agricultural business units, and households living in rural areas that own land. The data can fully reflect the level of development of China's rural economy in areas such as large-scale agriculture and are representative data for studying agricultural issues in China. Compared with

sampling data, the Third National Agricultural Census has obvious advantages in terms of data depth and breadth. This agricultural census will conduct a comprehensive survey of all agricultural business units, agricultural business households, administrative villages and townships across the country, involving more than 30,000 townships, more than 600,000 village committees, more than 200 million agricultural households, and more than 3 million agricultural production and business units, with a large number of census targets, dispersed residences, and frequent mobility, and taking into account the fact that a large number of farmers work outside the home, and that citizens and enterprises are more concerned about the protection of privacy and commercial secrets, the census is an extremely difficult and complex task.

The period information for this census is for the year 2016, and a total of 230 million farm households, 600,000 village-level units, 40,000 township-level units, and more than 2 million agricultural business units have been registered. In accordance with internationally accepted practices, the Agricultural Census Office of the State Council organised a data quality sample check to assess the quality of the census data. The results of the comprehensive sample check showed that the omission rate of registered households in the agricultural census was 0.19%, and the data discrepancy rate of census indicators was 0.40%, with the data quality meeting the design standards. The census results released by the National Bureau of Statistics showed that the number of agricultural business households in China in 2016 was 207.43 million, of which the number of ordinary business households was 203.45 million, and the number of large-scale business households was 3.98 million, with the proportion of ordinary business households accounting for up to 98%. It can be seen that ordinary farmers are still the main force engaged in agricultural production in China.

## 3.2 Variable Selection

### 3.2.1 Predicted Variable

In this study, the probability of rural households participating in large-scale agriculture was selected to reflect large-scale agriculture in the agricultural sector. During the agricultural census, respondents were asked whether they participated in large-scale agriculture and were coded as 1 if they participated and 0 if they did not. For rural households that participate in large-scale agriculture, the following five main forms of large-scale agriculture are

used: company + rural household, farmers' cooperatives, professional associations, and land trusts. A total of 10.33% of rural households participated in cooperative farming, whereas the remaining 89.67% did not participate in cooperative farming. Specifically, among the rural households participating in large-scale agriculture, 49.11% chose the organisational form of farmers' cooperatives, 13.38% chose companies + rural households, 6.87% chose the organizational form of land trusts, 3.38% chose the organizational form of professional associations, and the remaining 27.16% chose other organizational forms. This shows that rural households mostly participate in large-scale agriculture by joining farmers' cooperatives, which has been related to the introduction of various policies to encourage the development of farmers' cooperatives in China in recent years.

### 3.2.2 Key Explanatory Variables

The key explanatory variable was the level of aging, which was measured using two dimensions: rural households and county cities. Among them, the age ( $age_i$ ) of the rural household dimension was directly measured using the average age of adult males in rural households, while the age structure of the county-city dimension included the following.

- (1) Age structure of the household population: the proportion of the population of each age group in county cities where rural areas are located ( $city\_age_j$ ). The decreasing share of the youth and middle-aged populations indicates a deepening of local aging.
- (2) Age structure of migrant workers: the proportion of each age group who had been out for more than six months among county cities ( $city\_out_j$ ). The larger proportion of the outflow of people under 60 years of age indicates a decrease in young and middle-aged people who stay in local agricultural production and a deepening of aging.

### 3.2.3 Control Variables

This study also refers to existing literature (Ren *et al.*, 2023; Xia *et al.*, 2017), and controls for other variables that affect farm households' large-scale agriculture. These included the number of household members, marital status, number of properties and cars, arable land area, time spent on agricultural production, and management in 2016, whether they were engaged in agriculture outside their household for 30 days or more in 2016, whether they were engaged in non-farm businesses, and whether they had farm machinery. The number of family members has an impact on large-scale

agriculture, as the larger the family size and the more labour available, the more conducive it is to large-scale agriculture; the same is true of marital status. In traditional rural China, marriage increases the size of family members, extends blood ties, and enhances the human and material resources that can be mobilised; and things like the number of automobiles, the amount of agricultural machinery, and the area of arable land are indicative of the basic level of wealth of the rural family, which is an important condition for large-scale agriculture. As can be seen from Table 1, 98% of rural households

**Table 1:** Descriptive statistics of variables

Abbreviations	Variables	Definition	Mean (SD)	<i>n</i>
	<b>Predicted variable</b>			
$y_i$	Whether to participate in large-scale agriculture	Yes = 1; No = 0	0.17(0.38)	23,948
	<b>Key explanatory variables</b>			
age <sub>0</sub>	Age	Average age of adult males in farm households	56.12(12.42)	23,948
age <sub>1</sub>	Proportion of population aged 20–30	Proportion of household registration population by age group in the county city	0.22(0.04)	23,948
age <sub>2</sub>	Proportion of population aged 30–40		0.19(0.04)	23,948
age <sub>3</sub>	Proportion of population aged 40–50		0.24(0.04)	23,948
age <sub>4</sub>	Proportion of population aged 50–60		0.2(0.04)	23,948
age <sub>5</sub>	Proportion of population aged 60–70		0.15(0.04)	23,948
out <sub>0</sub>	Whether to go out	Whether to leave the countryside for more than six months Yes = 1; No = 0	0.07(0.25)	23,948
out <sub>1</sub>	Proportion of migrant workers aged 20–30	Proportion of population of each age group who have left their countryside for more than six months to the population of their county cities	0.33(0.18)	23,948
out <sub>2</sub>	Proportion of migrant workers aged 30–40		0.26(0.17)	23,948
out <sub>3</sub>	Proportion of migrant workers aged 40–50		0.15(0.12)	23,948
out <sub>4</sub>	Proportion of migrant workers aged 50–60		0.09(0.08)	23,948
out <sub>5</sub>	Proportion of migrant workers aged 60–70		0.05(0.05)	23,948
	<b>Control variables</b>			
edu <sub>1</sub>	Did not attend school	Education level	0.03(0.16)	23,948
edu <sub>2</sub>	Elementary School	Did not attend school = 1; elementary school = 2; junior high school = 3; high school or junior college = 4; college and above = 5	0.3(0.46)	23,948
edu <sub>3</sub>	Junior high school		0.56(0.5)	23,948
edu <sub>4</sub>	High School or Junior College		0.09(0.29)	23,948
edu <sub>5</sub>	College and above		0.02(0.12)	23,948
ms <sub>1</sub>	Unmarried	Marital Status	0.08(0.27)	23,948
ms <sub>2</sub>	Spouse		0.87(0.34)	23,948
ms <sub>3</sub>	Divorced	Unmarried = 1; Spouse = 2; Divorced = 3; Widowed = 4	0.02(0.15)	23,948
ms <sub>4</sub>	Widowed		0.03(0.16)	23,948
nf <sub>1</sub>	Not working in non-farm industry	Whether working in non-farm industry	0.55(0.5)	23,948
nf <sub>2</sub>	Employer		0.01(0.08)	23,948
nf <sub>3</sub>	Self-employed		0.07(0.25)	23,948
nf <sub>4</sub>	Employee	No = 1; Employer = 2; Self-employed = 3; Employee = 4; Civil servant = 5; Other = 6	0.33(0.47)	23,948
nf <sub>5</sub>	Civil servant		0.01(0.09)	23,948
nf <sub>6</sub>	Other		0.04(0.2)	23,948
atm	Agricultural production and management time	No = 1; 1–14 days = 2; 15–29 days = 3; 30 days and over = 4	3.66(0.69)	23,948
at	Whether the household is engaged in agriculture for 30 days or more outside the household	Yes = 1; No = 0	0.05(0.22)	23,948
regi	Whether the household registration in the township	Yes = 1; No = 0	0.99(0.11)	23,948
Numh	Number of household members	Number of members in the farm household	4.11(1.67)	23,948
Nump	Number of properties	Number of properties in farming households	1.15(0.4)	23,948
Numc	Number of cars	Number of cars in farm households	0.29(0.5)	23,948
Land	Area of confirmed (contracted) arable land	Area of farmland in the household with contractual rights	9.96(31.06)	23,948
Ama	Whether there is agricultural machinery	Yes = 1; No = 0	0.36(0.48)	23,948

are registered in the township, 86% have a spouse with an average of 3.63 household members, have an average of 10.87 acres of arable land, 15–29 days of agricultural households are management in 2016, 5% have a spouse with an average of 30 days and more, 29% have agricultural machinery, and 43% are engaged in employment, self-employment, labour, public employment, and other forms of non-farm industries.

### 3.3 Estimation Model

Because our explanatory variable  $y_i$  is a dummy variable, we use a logistic model for the regression as follows:

$$\ln\left(\frac{p_i}{1-p_i}\right) = \alpha_0 + \alpha_1 \text{age}_i + \alpha_2 \text{city\_age}_j + \alpha_3 \text{city\_out}_j + X_i + \mu, \quad (1)$$

where  $i$  denotes farm households,  $y_i$  is the explanatory variable of interest, and  $p_i$  is the probability of  $y_i = 1$ . This represents the probability of a farmer participating in large-scale agriculture.  $\text{age}_i$  denotes the age of adult males in rural households,  $\text{city\_age}_j$  is the age structure of the household population in cities, and  $\text{city\_out}_j$  is the age structure of migrant workers in cities.  $\alpha_1$ ,  $\alpha_2$ , and  $\alpha_3$  are the coefficients of interest in this paper, indicating whether aging has a significant effect on large-scale agriculture in rural households.  $X_i$  represents a series of control variables, including marital status, number of household members, number of properties and cars, time spent on agricultural production and management in 2016, whether they are engaged in non-farm industries, and whether they have farm machinery. In addition, rural households working outside the home can directly affect large-scale agriculture, which is constrained by education levels and arable land area. Therefore, we also controlled for rural households' educational attainment, whether they had been engaged in agriculture outside their own households for 30 days or more in 2016, and the area of cultivated land in their households.  $\mu$  was a disturbance term.

## 4 Empirical Results

Table 2 presents the regression results with stepwise inclusion of key explanatory and control variables. Column (5) shows the results of adding all explanatory and control variables, indicating that as the age of the rural household

head increases, the probability of the household's participation in cooperative farming decreases significantly. This indicates that in terms of the household dimension, the probability of rural households participating in large-scale agriculture decreases with increasing age, verifying Hypothesis 1. In terms of the population share indicator, which measures the degree of aging in county cities, when the remaining control variables are not included, the probability of participating in large-scale agriculture increases as the proportion of rural youths and middle-aged people aged 20–60 years increases. When the remaining control variables were included, the positive effect of an increase in the proportion of rural youth population on the probability of participation in large-scale agriculture was not significant, while the positive effect of rural middle-aged people between the ages of 40 and 60 remained highly significant. Both youth and middle-aged people from rural areas are the main participants in cooperative farming, but youth tend to work more in urban areas, while middle-aged people have a higher tendency to return to their hometowns to expand their production scales compared to youth. In terms of another measure of the impact of aging, the proportion of migrant workers in different age groups and the probability of participating in large-scale agriculture decrease as the proportion of rural people aged 30–60 years who go out increases, which is consistent with the previous analysis. This is because young and middle-aged populations are the main groups involved in large-scale agriculture. The higher the proportion of migrant workers among the 60–70 year old population, the higher the probability of participating in large-scale agriculture. An increase in the proportion of the 20–30-year-old population going out of the country also increases the probability of participating in large-scale agriculture. The youngest population lacks experience in agricultural production and their choice of urban employment can facilitate the rental of unused land for large-scale agriculture. Thus, deepening aging (decreasing the share of the young and middle-aged population and increasing the share of the older population) decreases the probability of participation in large-scale agriculture by affecting the proportion of the participating subject population, as proved by Hypothesis 2.

In addition, other control variables have different effects on large-scale agriculture: Education has a positive effect on the probability of participation in large-scale agriculture. As the level of education increased, farmers became more likely to participate in cooperative farming. Additionally, large-scale agriculture benefits harmonious and intact families, whereas family situations such as divorce and widowhood reduce the probability of rural households participating in large-scale agriculture. Most of China's agricultural population has experience working outside the home in non-farm

Table 2: Impact of aging on large-scale agriculture

Explanatory variables		Predicted variable				
		(1)	(2)	(3)	(4)	(5)
age <sub>0</sub>	Age	-0.0249*** (0.00661)			-0.0214*** (0.00702)	-0.027*** (0.010)
	<b>Proportion of population aged 60–70 (Reference group)</b>					
age <sub>1</sub>	Proportion of population aged 20–30		0.533* (0.556)		0.681* (0.579)	0.301 (0.616)
age <sub>2</sub>	Proportion of population aged 30–40		1.709** (0.601)		1.258** (0.620)	0.949 (0.672)
age <sub>3</sub>	Proportion of population aged 40–50		20.27*** (0.490)		17.65*** (0.494)	7.596*** (0.707)
age <sub>4</sub>	Proportion of population aged 50–60		15.00*** (0.441)		11.67*** (0.467)	7.666*** (0.814)
out <sub>0</sub>	Whether to go out			-0.757*** (0.0501)	-0.778*** (0.0511)	-0.639*** (0.121)
out <sub>1</sub>	Proportion of migrant workers aged 20–30			1.973*** (0.146)	0.991*** (0.154)	0.924*** (0.218)
out <sub>2</sub>	Proportion of migrant workers aged 30–40			-1.640*** (0.162)	-1.587*** (0.166)	-1.491*** (0.227)
out <sub>3</sub>	Proportion of migrant workers aged 40–50			-4.849*** (0.268)	-2.408*** (0.284)	-1.931*** (0.393)
out <sub>4</sub>	Proportion of migrant workers aged 50–60			-2.626*** (0.333)	-2.754*** (0.342)	-1.878*** (0.465)
out <sub>5</sub>	Proportion of migrant workers aged 60–70			0.792** (0.385)	0.344 (0.402)	1.623*** (0.507)
edu <sub>1</sub>	<b>Did not attend school (Reference group)</b>					
edu <sub>2</sub>	Elementary School					0.749*** (0.194)
edu <sub>3</sub>	Junior high school					1.165*** (0.192)
edu <sub>4</sub>	High School or Junior College					1.389*** (0.201)
edu <sub>5</sub>	College and above					1.749*** (0.245)
ms <sub>1</sub>	<b>Unmarried (Reference group)</b>					
ms <sub>2</sub>	Spouse					0.075 (0.087)
ms <sub>3</sub>	Divorced					-0.362** (0.178)
ms <sub>4</sub>	Widowed					-0.291* (0.169)
atm	Agricultural production and management time					0.462*** (0.044)
at	Whether the household is engaged in agriculture for 30 days or more outside the household					0.051 (0.094)
nf <sub>1</sub>	<b>Not working in non-farm industry (Reference group)</b>					
nf <sub>2</sub>	Employer					0.839*** (0.208)
nf <sub>3</sub>	Self-employed					0.103 (0.081)
nf <sub>4</sub>	Employee					-0.890*** (0.055)
nf <sub>5</sub>	Civil servant					-0.361 (0.251)
nf <sub>6</sub>	Other					-0.081

(Continued)

Table 2: *Continued*

Explanatory variables	Predicted variable				
	(1)	(2)	(3)	(4)	(5)
regi					(0.110)
					−1.973***
Numh					(0.143)
					−0.008
Nump					(0.015)
					0.168***
Numc					(0.050)
					0.672***
Land					(0.040)
					0.031***
Ama					(0.002)
					1.296***
					(0.043)
Constant term	−1.545***	−10.87***	−1.062***	−8.605***	−5.905***
	(0.216)	(0.245)	(0.0291)	(0.338)	(0.661)
Observations	23,948	23,948	23,948	23,948	23,948

Notes: The numbers in parentheses are robust standard errors; \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

employment, and those with employer work experience have an increased probability of participating in large-scale agriculture. More household assets will also increase the probability of participation in large-scale agriculture, and their investment and management strategies will be more active.

## 5 Discussion

Based on the findings of the baseline regression, we discuss whether arable land area and agricultural mechanization produce moderating effects, summarise the strengths and limitations of this study, and propose targeted policy recommendations based on these findings.

### 5.1 Further Analysis

The larger the area of arable land, the larger the total size of land that rural households can manage, which can generate economies of scale and result in a significant increase in the maximum returns that can be obtained from engaging in agricultural production (Zhang *et al.*, 2023). This will help farmers stay in rural areas to engage in agricultural production and will also have an impact on large-scale agriculture. Additionally, the higher the level of agricultural mechanization, the lower the threshold for operating large tracts of land, which also affects local large-scale agriculture

(Li *et al.*, 2021). Therefore, we measured the size of arable land by the local per capita arable area, and the local level of agricultural mechanization by the percentage of households owning agricultural machinery. In addition, arable land size and mechanization level confound rural labour outflow; thus, we constructed their interaction terms with the share of migrant workers in different age groups. The model is as follows, where  $M_j$  represents the arable land area or mechanization level per capita in the region. The results are summarised in Table 3.

$$\ln\left(\frac{p_i}{1-p_i}\right) = \alpha_0 + \alpha_1 \text{city\_out}_j + \alpha_2 M_j + \alpha_3 \text{city\_out}_j \times M_j + X_i + \mu. \quad (2)$$

The results clearly show that the area of arable land per capita does not reduce the negative impact of aging on large-scale agriculture, because the coefficient of the interaction term is not significant. Since the interaction term was not significant, the mechanization level did not weaken or strengthen the effect of the youth labour exodus on large-scale agriculture. The interaction term between the share of migrant workers in the middle-aged group and the level of mechanization is significantly negative, indicating that the negative impact of aging on large-scale agriculture is strengthened in areas with higher levels of mechanization. This may be due to the fact that under the conditions of higher mechanization levels, it is less difficult for farm households to operate large tracts of land independently.

**Table 3:** Moderating effects of arable land area and farm mechanization level

Explanatory variables	Predicted variable	
	(1)	(2)
Percentage of local migrant workers aged 20–40	−1.343*** (0.300)	−0.332*** (0.054)
Local arable land per capita	0.023*** (0.003)	
Percentage of local migrant workers aged 20–40 × Local arable land per capita	0.044 (0.028)	
Percentage of local migrant workers aged 40–60	−2.477*** (0.545)	−1.470*** (0.041)
Percentage of local migrant workers aged 40–60 × Local arable land per capita	−0.069 (0.067)	
Percentage of local households with farm machinery		1.030*** (0.177)
Percentage of local migrant workers aged 20–40 × Local arable land per capita × Percentage of local households with farm machinery		−2.743 (1.695)
Percentage of local migrant workers aged 40–60 × Percentage of local households with farm machinery		−6.450** (3.224)
Other control variables	Yes	Yes
Constant	−3.793*** (0.683)	−5.367*** (0.670)
Observations	23,896	23,896

Notes: The numbers in parentheses are robust standard errors; \* $p < 0.10$ , \*\* $p < 0.05$ , \*\*\* $p < 0.01$ .

By contrast, rural households participate in cooperative farming mostly because it is more difficult to manage large tracts of land independently.

## 5.2 Strengths and Limitations

Previous studies have mostly focused on the impact of aging on macro-level areas, such as agricultural production and technology applications, and few studies have been conducted on the impact of large-scale agriculture. Moreover, studies on the effect of aging on large-scale agriculture have not reached consistent conclusions. There were differences in the way aging was measured, and the conclusions were drawn. We measured aging in two dimensions – microscopic rural households and macroscopic county-level cities – to explore the impact of aging on large-scale agriculture, which is an enrichment and addition to the existing literature and can provide a more comprehensive and clear understanding of the impact of aging on agricultural development and a reference for the formulation of cooperative agricultural policies. In addition, the Government of China

has been committed to promoting large-scale agriculture and has introduced various support policies to encourage farmers to join cooperatives and professional associations or to establish platforms to promote cooperation among rural households, companies, and land trusts. This has been mentioned in previous literature, but mostly directed at how to establish appropriate organizational structures and promote large-scale agriculture at the institutional level. It can be argued that the research attention on labour allocation and population aging shocks is insufficient. In addition to this, most of the studies from the labour perspective have analysed from the point of view of restricting farm households from engaging in non-farm industries. The principle of flexible labour allocation of part-time farming refers to the law of labour rationing in which the labour force in different industries within a household moves back and forth between agriculture and non-agricultural industries according to seasonal changes and the principle of maximizing marginal output. It is these principles that drive the current prevalence of part-time farming in China. However, from the conclusion of this paper, the effect produced by different age groups is not the same and blindly hindering the spontaneous labour rationing law may be counterproductive. This makes it advisable for the relevant authorities to be more prudent in formulating industrial policies. Nevertheless, this study has some limitations. Although we used agricultural census data, the data were cross-sectional rather than panel. This prevented us from identifying the impact of the dynamics of aging on farmers' large-scale agriculture, and unobservable characteristics at the individual level were not controlled for, which could be further investigated using panel data.

## 6 Conclusion

In this study, based on microdata from the Third National Agricultural Census of 2016, a logistic model was used for regression to verify the impact of aging on large-scale agriculture. It was found that, first, from the microscopic rural household dimension, aging led to an increase in the age of the rural household labour force and a significant decrease in the probability of farmers' participation in large-scale agriculture. Second, in the county-city dimension, aging at the macro level reduces the share of young and middle-aged populations, which are the main group of rural participants in large-scale agriculture, and the probability of participating in large-scale agriculture decreases as a result. Third, the use of agricultural machinery can exacerbate the negative effects of aging on large-scale agriculture.

Meanwhile, owing to the limitations of cross-sectional data, we could not further analyse the impact of aging dynamics on large-scale agriculture, which provides a direction for our future research. Based on the above conclusions of the study, we put forward the following policy recommendations. First, we should pay attention to the important role played by young and middle-aged people between 30 and 40 years in the field of large-scale rural agriculture and give them more precise policy support. They are the most active participants in land transfer and have certain business and management knowledge, which is the most likely fresh blood to inject vitality into the rural economy; secondly, we should improve the publicity of land transfer-related policies among the youth. Secondly, we should improve the publicity of land transfer policies among young people. They pay little attention to land transfer and do not realise the importance of revitalizing their own property. In order to solve the problem of land abandonment and improve agricultural production capacity, the publicity of land transfer among young people should be strengthened and the convenience of participating in land transfer should be improved; third, the regulation of the land transfer market should be emphasised. Aging will lead to an oversupply in the land transfer market, which will jeopardise the interests of farmers who rent out their land. The government should actively cultivate large-scale agricultural entities and give them tax incentives to increase the demand for land transfer; fourth, the government should improve the comprehensive quality of the aging rural population. Through analysis, we find that for the same elderly population, the more educated they are, the more inclined they are to participate in large-scale agriculture. Therefore, re-education and adult training for the rural population can offset some of the negative impacts of aging; Fifth, continue to provide subsidies for farmers to purchase agricultural machinery. Investments in agricultural machinery can increase the level of large-scale rural operations and mitigate the impact of ageing on agricultural production.

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Methodology; Statistical analysis, revised the manuscript. XS: Situation analysis; revised the manuscript. YT: Led and supervised this study: Fund support; Revise the final manuscript.

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## References

- Cai, F. (2018). The great exodus: How agricultural surplus laborers have been transferred and reallocated in China's reform period? *Agricultural Economic Review*, 10(1), 3–15. doi: 10.1108/CAER-10-2017-0178.
- Cai, F., & Wang, M. Y. (2007). A re-examination of rural labor surplus and its related facts—an application of the counterfactual approach. *China Rural Economy*, 10, 4–12 (in Chinese).
- Chang, Z. Z., Jiang, K., & Feng, Y. (2021). Study on the impact and contribution of population aging on human capital investment. *Contemporary Economic Science*, 43(5), 29–43 (in Chinese).
- Chen, X. (2013). Several major issues facing China's rural reform and development. *Agricultural Economic Issues*, 34(1), 4–6 + 110. doi: 10.13246/j.cnki.iae.2013.01.004.
- Čiutienė, R., & Railaitė, R. (2015). A development of human capital in the context of an aging population. *Procedia – Social and Behavioral Sciences*, 213, 753–757. doi: 10.1016/j.sbspro.2015.11.463.
- Clegg, J. (2006). Rural cooperatives in China: Policy and practice. *Journal of Small Business and Enterprise Development*, 13(2), 219–234. doi: 10.1108/14626000610665926.
- Deng, Y., Xiao, Y., & Xu, H. (2024). The effect of new agricultural management subjects on labor mobility. *Journal of Huazhong Agricultural University (Social Science Edition)*, 1–15. <http://kns.cnki.net/kcms/detail/42.1558.C.20240118.0856.002.html>.
- Fang, E. F., Scheibye-Knudsen, M., Jahn, H. J., Li, J., Ling, L., Guo, H., Zhu, X., Preedy, V., Lu, H., Bohr, V. A., Chan, W. Y., Liu, Y., & Ng, T. B. (2015). A research agenda for aging in China in the 21st century. *Ageing Research Reviews*, 24, 197–205. doi: 10.1016/j.arr.2015.08.003.
- Gao, M. (2022). Population aging in rural China: Key implications, coping strategies and policy construction. *Journal of Nanjing Agricultural University, Social Science Edition*, 22(4), 8–21. doi: 10.19714/j.cnki.1671-7465.2022.0052.
- Guo, G., Wen, Q., & Zhu, J. (2015). The impact of aging agricultural labor population on farmland output: From the perspective of farmer preferences. *Mathematical Problems in Engineering*, 2015, e730618. doi: 10.1155/2015/730618.
- He, G., & Yi, H. (2024). Does intergenerational backfeeding promote the land transfer behavior of left-behind elderly? – an empirical study based on CHARLS data. *China Land Science*, 38(1), 84–93 (in Chinese).

- Hu, X., & Zhong, F. (2012). The impact of aging rural population on grain production: An analysis based on data from fixed rural observation sites. *China Rural Economy*, 7, 29–39 (in Chinese).
- Li, F., Feng, S., Lu, H., Qu, F., & D'Haese, M. (2021). How do non-farm employment and agricultural mechanization impact on large-scale farming? A spatial panel data analysis from Jiangsu Province, China. *Land Use Policy*, 107, 105517. doi: 10.1016/j.landusepol.2021.105517.
- Li, L., & Li, Y. (2009). Study on the aging of China's agricultural labor force: An analysis based on the second national agricultural census data. *Agricultural Economics*, 30(6), 61–66 + 111 (in Chinese).
- Li, M., & Sicular, T. (2013). Aging of the labor force and technical efficiency in crop production: Evidence from Liaoning Province, China. *Economic Review*, 5(3), 342–359. doi: 10.1108/CAER-01-2012-0001.
- Li, M., & Zhao, L. (2009). Agricultural labor force “aging” and its impact on agricultural production: An empirical analysis based on Liaoning Province. *Agricultural Economic Issues*, 30(10), 12–18 + 110 (in Chinese).
- Lin, B., & Deng, H. (2012). An empirical analysis of the impact of aging agricultural labor on land use efficiency: Based on data from fixed observation sites in rural Zhejiang Province. *China Rural Economy*, 4, 15–25 + 46 (in Chinese).
- Liu, D., & Lei, H. (2020). Employment quality, relative deprivation and status hierarchy identity of migrant workers. *Learning and Practice*, 9, 85–97. doi: 10.19624/j.cnki.cn42-1005/c.2020.09.010.
- Liu, J., Du, S., & Fu, Z. (2021). The impact of rural population aging on farmers' cleaner production behavior: Evidence from five provinces of the North China Plain. *Sustainability*, 13(21), 12199. doi: 10.3390/su132112199.
- Lu, Q. N., Zhang, C. S., & Qiu, H. G. (2017). The impact of aging agricultural labor force and part-time non-farm labor on outsourcing of agricultural production chain. *Issues in Agricultural Economics*, 38(10), 27–34. doi: 10.13246/j.cnki.iae.2017.10.004.
- Lu, Q., Du, X., & Qiu, H. (2022). Adoption patterns and productivity impacts of agricultural mechanization services. *Agricultural Economics*, 53(5), 826–845. doi: 10.1111/agec.12737.
- Ma, Y., Gao, Q., & Yang, X. (2023). Rural labor force aging and agricultural industry structure upgrading: A theoretical mechanism and empirical test. *Journal of Huazhong Agricultural University, Social Science Edition*, 2, 69–79. doi: 10.13300/j.cnki.hnwxkb.2023.02.007.
- Nie, W. J., & Li, T. (2015). Research on farmers' land transfer behavior in the context of rising agricultural product prices and production costs. *Journal of Agricultural and Forestry Economics and Management*, 14(5), 445–452. doi: 10.16195/j.cnki.cn36-1328/f.2015.05.001.
- Peng, X., & Hu, Z. (2011). Public policy perspectives on population aging in China. *China Social Science*, 3, 121–138 + 222–223 (in Chinese).
- Qin, L. J., Zhang, N. N., & Jiang, C. I. (2011). Land fragmentation, labor migration, and grain production of Chinese farmers: A survey based on Anhui Province. *Agricultural Technology Economics*, 11, 16–23. doi: 10.13246/j.cnki.jae.2011.11.007.
- Ren, C., Zhou, X., Wang, C., Guo, Y., Diao, Y., Shen, S., Reis, S., Li, W., Xu, J., & Gu, B. (2023). Ageing threatens sustainability of smallholder farming in China. *Nature*, 616(7955), 96–103. doi: 10.1038/s41586-023-05738-w.
- Song, J., & Gao, C. (2022). Population aging and income disparity in China: An analysis of the impact and mechanism: An empirical study based on redistribution in the context of common wealth. *Northwest Population*, 43(4), 104–117. doi: 10.15884/j.cnki.issn.1007-0672.2022.04.009.
- Sui, F., Yang, Y., & Zhao, S. (2022). Labor structure, land fragmentation, and land-use efficiency from the perspective of mediation effect: Based on a survey of garlic growers in Lanling, China. *Land*, 11(6), 952. doi: 10.3390/land11060952.
- Teng, Y., Chen, X., Yu, Z., & Wei, J. (2021). Research on the evolutionary decision-making behavior among the government, farmers, and consumers: Based on the quality and safety of agricultural products. *IEEE Access*, 9, 73747–73756. doi: 10.1109/ACCESS.2021.3078561.
- Wang, B., & Luo, T. (2022). Study on the role of agricultural “ballast” in the new era. *Rural Economy*, 9, 1–9. 37 (in Chinese).
- Wang, J., Cai, C. J., & Qin, X. (2021). The impact of aging rural labor force and its family structure differences on farmland transfer decision. *Resource Science*, 43(9), 1876–1888 (in Chinese).
- Wang, W., & Ai, C. (2015). Population aging and the dynamic evolution of China's savings rate. *Management World*, 6, 47–62. doi: 10.19744/j.cnki.11-1235/f.2015.06.005.
- Wang, Y., & Liu, G. (2023). Analysis of the impact of farmers' characteristics on the willingness of intergenerational inheritance of land contract management right – Based on the survey data of 958 farmers' households in Xinjiang. *Resource Development and Market*, 39(9), 1098–1105 (in Chinese).
- Wang, Z., Wang, Y., Lv, Q., & Wu, Y. (2024). Impact of aging rural labor force on food production and the mechanism of action. *Journal of Agricultural and Forestry Economics and Management*, 1–13. <http://kns.cnki.net/kcms/detail/36.1328.F.20240112.0941.002.html>.
- Xia, X., Xin, X., & Ma, L. (2017). What are the determinants of large-scale farming in China? *China & World Economy*, 25(4), 93–108. doi: 10.1111/cwe.12208.
- Xiao, J., & Luo, B. (2019). An important issue in Chinese agricultural modernization: Who will transform traditional agriculture? – Evidence from the impact of returning migrant workers on agricultural specialization. *Reform*, 1–19, 31 (in Chinese).
- Xu, Z., & Zhao, X. (2022). Practical patterns, causes and impacts of differentiated technology adoption behavior of agricultural operators. *China Science and Technology Forum*, 2, 178–188. doi: 10.13580/j.cnki.fstc.2022.02.019.
- Yang, J., Zhong, F. N., Chen, C. G., & Peng, C. (2016). Impact of rural labor price and demographic changes on grain cultivation structure. *Management World*, 1, 78–87. doi: 10.19744/j.cnki.11-1235/f.2016.01.008.
- Yang, R., & Zuo, S. (2015). Analysis of career paths of rural youth in the context of urban-rural development: A questionnaire survey based on social networks. *Youth Exploration*, 5, 99–106. doi: 10.13583/j.cnki.issn1004-3780.2015.05.016.
- Yi, X., Yan, Y., & Zhang, T. (2023). Rising labor price, mechanization of grain production and its output effect. *Journal of Huazhong Agricultural University(Social Science Edition)*, 6, 14–25. doi: 10.13300/j.cnki.hnwxkb.2023.06.002.
- Zhang, J., Dou, Y., & Zhao, D. S. (2023). Research on hometown entrepreneurship 2001-2021: Stage division, theme evolution and future outlook. *Contemporary Economic Management*, 45(1), 39–48. doi: 10.13253/j.cnki.ddjgl.2023.01.005.
- Zhong, F. N., & Hu, X. M. (2008). Economic analysis of cotton farmers' cotton sowing area decisions in China. *China Rural Economy*, 6, 39–45 (in Chinese).