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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 urbanization 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 on this sector. This study utilizes 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 mechanization 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 labor 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 mechanization.

Keywords: Aging; Large-Scale Agriculture; Agricultural Mechanization; Migrant Workers； Moderating Effects

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 (WHO) classification criteria, China's elderly population will exceed 400 million in 2037, and China will gradually become an older society (Peng et al., 2011; Wang and Ai, 2015; Fang et al., 2015). In the last two decades, China's urbanisation 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 et al., 2007; Cai et al., 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 et al., 2013; Hu et al., 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 (Qin et al., 2011; Guo et al., 2015) and agricultural output (Li et al., 2009; Li et al., 2013). In addition, studying the effects of aging on land use efficiency (Lin et al., 2012; Sui et al., 2022) and the impact of aging on agricultural production behavior decisions (Hu et al., 2012; Zhong et al., 2008; Li et al., 2009) has also been the focus of research. 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). It can be argued that large-scale agriculture is extremely important for enhancing agricultural productivity and modernizing agricultural development (Teng, 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 mechanisation can fully compensate for the impact of aging on large-scale agriculture (Yang et al.,2016; Lu et al., 2022).

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 logit 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 mechanisation.

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 mechanisation 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 declines, 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 et al., 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 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 (Hu et al., 2012; Gao et al., 2022). 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 et al., 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 (Xiao et al., 2019; Nie et al., 2015). 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 et al., 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 et al., 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 et al., 2022; Wang et al., 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 et al., 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.

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 organizational 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

(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. As can be seen from Table 1, 98% of rural households 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 to 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.

Table 1 Descriptive statistics of variables

Variables	Definition	Mean (SD)	*n*
Predicted variable			
Whether to participate in large-scale agriculture	Yes=1; No=0	0.17(0.38)	23948
Key explanatory variables			
Age	Average age of adult males in farm households	56.12(12.42)	23948
Proportion of population aged 20 to 30	Proportion of household registration population by age group in the county city	0.22(0.04)	23948
Proportion of population aged 30 to 40		0.19(0.04)	23948
Proportion of population aged 40 to 50		0.24(0.04)	23948
Proportion of population aged 50 to 60		0.2(0.04)	23948
Proportion of population aged 60 to 70		0.15(0.04)	23948
Whether to go out	Whether to leave the countryside for more than six months Yes=1; No=0	0.07(0.25)	23948
Proportion of migrant workers aged 20 to 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)	23948
Proportion of migrant workers aged 30 to 40		0.26(0.17)	23948
Proportion of migrant workers aged 40 to 50		0.15(0.12)	23948
Proportion of migrant workers aged 50 to 60		0.09(0.08)	23948
Proportion of migrant workers aged 60 to 70		0.05(0.05)	23948
Control variables			
Did not attend school	Education level Did not attend school = 1; elementary school = 2; junior high school = 3; high school or junior college = 4; college and above = 5	0.03(0.16)	23948
Elementary School		0.3(0.46)	23948
Junior high school		0.56(0.5)	23948
High School or Junior College		0.09(0.29)	23948
College and above		0.02(0.12)	23948
Unmarried	Marital Status	0.08(0.27)	23948
Spouse		0.87(0.34)	23948

Divorced	Unmarried=1; Spouse=2; Divorced=3; Widowed=4	0.02(0.15)	23948
Widowed		0.03(0.16)	23948
Not working in non-farm industry	Whether working in non-farm industry No=1; Employer=2; Self-employed=3; Employee=4; Civil servant=5; Other=6	0.55(0.5)	23948
Employer		0.01(0.08)	23948
Self-employed		0.07(0.25)	23948
Employee		0.33(0.47)	23948
Civil servant		0.01(0.09)	23948
Other		0.04(0.2)	23948
Agricultural production and management time	No = 1; 1 to 14 days = 2; 15 to 29 days = 3; 30 days and over = 4	3.66(0.69)	23948
Whether the household is engaged in agriculture for 30 days or more outside the household	Yes=1; No=0	0.05(0.22)	23948
Whether the household registration in the township	Yes=1; No=0	0.99(0.11)	23948
Number of household members	Number of members in the farm household	4.11(1.67)	23948
Number of properties	Number of properties in farming households	1.15(0.4)	23948
Number of cars	Number of cars in farm households	0.29(0.5)	23948
Area of confirmed (contracted) arable land	Area of farmland in the household with contractual rights	9.96(31.06)	23948
Whether there is agricultural machinery	Yes=1; No=0	0.36(0.48)	23948

3.3 Estimation model

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

$$\ln\left(\frac{p_i}{1-p_i}\right) = \alpha_0 + \alpha_1 age_i + \alpha_2 city\_age_j + \alpha_3 city\_out_j + X_i + \mu \quad (1)$$

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. age_i denotes the age of adult males in rural households, $city\_age_j$ is the age structure of the household population in cities, and $city\_out_j$ is the age structure of migrant workers in cities. α_1,α_2 and α_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. μ 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 to 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 is 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 young and middle-aged population and increasing the share of 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 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.

Table 2 Impact of Aging on Large-scale agriculture

explanatory variables	Predicted variable				
	(1)	(2)	(3)	(4)	(5)
Age	-0.0249***			-0.0214***	-0.027***
	(0.00661)			(0.00702)	(0.010)
Proportion of population aged 60 to 70 (Reference group)					
Proportion of population aged 20 to 30		0.533*		0.681*	0.301
		(0.556)		(0.579)	(0.616)
Proportion of population aged 30 to 40		1.709**		1.258**	0.949
		(0.601)		(0.620)	(0.672)
Proportion of population aged 40 to 50		20.27***		17.65***	7.596***
		(0.490)		(0.494)	(0.707)
Proportion of population aged 50 to 60		15.00***		11.67***	7.666***
		(0.441)		(0.467)	(0.814)
Whether to go out			-0.757***	-0.778***	-0.639***
			(0.0501)	(0.0511)	(0.121)
Proportion of migrant workers aged 20 to 30			1.973***	0.991***	0.924***
			(0.146)	(0.154)	(0.218)
Proportion of migrant workers aged 30 to 40			-1.640***	-1.587***	-1.491***
			(0.162)	(0.166)	(0.227)
Proportion of migrant workers aged 40 to 50			-4.849***	-2.408***	-1.931***
			(0.268)	(0.284)	(0.393)
Proportion of migrant workers aged 50 to 60			-2.626***	-2.754***	-1.878***
			(0.333)	(0.342)	(0.465)
Proportion of migrant workers aged 60 to 70			0.792**	0.344	1.623***
			(0.385)	(0.402)	(0.507)
Did not attend school (Reference group)					
Elementary School					0.749***
					(0.194)
Junior high school					1.165***

					(0.192)
High School or Junior College					1.389***
					(0.201)
College and above					1.749***
					(0.245)
Unmarried (Reference group)					
Spouse					0.075
					(0.087)
Divorced					-0.362**
					(0.178)
Widowed					-0.291*
					(0.169)
Agricultural production and management time					0.462***
					(0.044)
Whether the household is engaged in agriculture for 30 days or more outside the household					0.051
					(0.094)
Not working in non-farm industry (Reference group)					
Employer					0.839***
					(0.208)
Self-employed					0.103
					(0.081)
Employee					-0.890***
					(0.055)
Civil servant					-0.361
					(0.251)
Other					-0.081
					(0.110)
Whether the household registration in the township					-1.973***
					(0.143)
Number of household members					-0.008
					(0.015)
Number of properties					0.168***
					(0.050)
Number of cars					0.672***
					(0.040)
Area of confirmed (contracted) arable land					0.031***
					(0.002)
Whether there is agricultural machinery					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.

5. Discussion

Based on the findings of the baseline regression, we discuss whether arable land area and agricultural mechanisation 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 mechanisation, 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 mechanisation by the percentage of households owning agricultural machinery. In addition, arable land size and mechanisation 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 mechanisation level per capita in the region. The results are summarised in Table 3.

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

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 mechanisation 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 mechanisation is significantly negative, indicating that the negative impact of aging on large-scale agriculture is strengthened in areas with higher levels of mechanisation. 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. By contrast, rural households participate in cooperative farming mostly because it is more difficult to manage 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 to 40	-1.343***	-0.332***
	(0.300)	(0.054)
Local arable land per capita	0.023***	
	(0.003)	
Percentage of local migrant workers aged 20 to 40 × Local arable land per capita	0.044	
	(0.028)	
Percentage of local migrant workers aged 40 to 60	-2.477***	-1.470***
	(0.545)	(0.041)
Percentage of local migrant workers aged 40 to 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 to 40×Local arable land per capita × Percentage of local households with farm machinery		-2.743
		(1.695)
Percentage of local migrant workers aged 40 to 60×Percentage of local households with farm machinery		-6.450**
		(3.224)
Other control variables	YES	YES
Constant	-3.793***	-5.367***
	(0.683)	(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.

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. 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.

5.3 Policy implications

Based on these findings, we propose the following policy recommendations: First, we should pay attention to the important role played by young and middle-aged people aged 30–40 years in the field of rural large-scale agriculture, and provide more precise policy support. They are the most active participants in land transfer, have business and management knowledge, and are the most likely to participate in large-scale agriculture. Second, we need to improve the publicity of cooperative agricultural policies for the youth. They are less concerned about large-scale agriculture than middle-aged people but have the innate advantage of participating in large-scale agriculture. Third, we should continue to reconfirm land contract rights and build high-standard farmland to increase the size of arable land per capita. It is recommended that government subsidies for agricultural machinery be paid to agricultural business entities rather than directly to farmers.

6. Conclusion

In this study, based on microdata from the Third National Agricultural Census of 2016, a logit 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 rural household labor 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.

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Data Availability Statement: Publicly available datasets were analyzed in this study. This data can be found here: http://www.stats.gov.cn/sj/tjgb/nypcgb/

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

The appendix is an optional section that can contain details and data supplemental to the main text—for example, explanations of experimental details that would disrupt the flow of the main text but nonetheless remain crucial to understanding and reproducing the research shown; figures of replicates for experiments of which representative data is shown in the main text can be added here if brief, or as Supplementary data. Mathematical proofs of results not central to the paper can be added as an appendix.

Appendix B

All appendix sections must be cited in the main text. In the appendices, Figures, Tables, etc. should be labeled starting with “A”—e.g., Figure A1, Figure A2, etc.

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