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The Impact of Rural Population Aging on Agricultural Cropping Structure: Evidence from China's Provinces

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Abstract: Agricultural cropping structure is related to the quality of the agricultural supply system and is a key element of the structural reform of the agricultural supply side. Based on China's provincial panel data from 2000 to 2021, this paper empirically examines the impact and mechanism of rural population aging on the planting structure of food and cash crops by using a two-way fixed-effects model, which fills the gap in the research on the impact mechanism of the rural population aging on agricultural planting structure. The conclusions of the study show that: as the aging of the rural population deepens, the proportion of food crops planted will further increase, while the proportion of cash crops planted will decrease; agricultural mechanization will promote the further increase of the proportion of food crops planted while the proportion of cash crops planted will decrease in the deepening of the aging of rural population; the aging of the rural population has a more significant impact on the structure of agricultural planting in the eastern region and does not have a significant impact on the central and western provinces. The aging of the rural population has a significant impact on the agricultural planting structure in the eastern region, but not in the central and western provinces. This paper argues that we should fully respect the willingness of agricultural management subjects to choose planting varieties, increase the research, development, and promotion of agricultural machinery, continuously improve the level of farmers' human capital, and further enhance the degree of organization, scale, and specialization of agricultural production.

Keywords: rural population aging; agricultural mechanization; agricultural cropping structure; rural China

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1. Introduction

In recent years, the age structure of populations in most countries, including North America, Europe, and China and Japan in East Asia, is undergoing rapid changes, and aging is gradually becoming one of the focuses of extensive academic and governmental attention [1–5]. It is widely believed that population aging leads to adverse consequences such as declining fertility [6] and declining quality of labor force [7], which adversely affect economic prosperity [8–11]. According to the United Nations report, the proportion of people over 65 years of age in the global population in 2021 was 761 million, and rapid population aging has become one of the most challenging demographic transitions worldwide [12,13]. However, most studies on population aging have focused on developed countries, while fewer studies have been conducted on the aging trend in China and its potential impact on the economy [14–16]. China entered an aging society in 2000, and the degree of aging has been deepening year by year since then [12]. Data from the seventh national census show that the proportion of the Chinese population aged 60 and above has increased from 5.44% in 2010 to 18.70% in 2020. In addition, as a large number of young

and strong rural laborers flock to cities and non-agricultural sectors, the age structure of the agricultural labor force is aging [17], the level of human capital is low, and there is an increasing lack of effective labor force [18], resulting in the problem of population aging in China's rural areas and agricultural sectors becoming even more pronounced [19–23]. The 2015 National 1% Population Sampling Survey found that from 1982 to 2015, China's rural population over 60 years old increased by 2.37 times [24]. According to the China Population and Employment Statistical Yearbook, during the period of 2000–2020, the proportion of the rural population aged 65 years and above in China has more than doubled from 7.50% in 2000 to 17.72% in 2020, which is more than double the proportion of the rural population aged 65 years and above, and according to the international standard of aging, China's rural areas have already entered the stage of deep aging [25,26].

Agricultural cropping structure mainly refers to the proportion of various types of crops, such as food crops, cash crops, fodder crops, and so on [27]. Grain crops mainly include: cereal crops such as rice, corn, wheat, oats, barley, grain, sorghum, and barley; potato crops such as sweet potatoes and potatoes; and legumes such as soybeans, fava beans, mung beans and peas. In addition, the main cash crops include vegetable crops, fiber crops, oil crops, sugar crops, beverage crops, medicinal crops, hobby crops, and tropical crops. In order to form an effective supply pattern of agricultural products with reasonable structure and a strong guarantee, the Central Rural Work Conference in December 2015 put forward the structural reform of the agricultural supply side, and the structural adjustment of the planting industry has been the focus of China's structural reform of the agricultural supply side [28]. Changes in the endowment of factors of production affect the structure of crop planting by farmers, and the adjustment of the structure of the planting industry should take into account the full consideration of the adjustment of the agricultural production labor and capital. The adjustment of the planting structure should fully consider the changes in the factors of endowment of agricultural production labor, capital, and other factors. The new structural economics proposed by the former chief economist of the World Bank, Justin Yifu Lin, shows that the economic structure is endogenously determined by the structure of factor endowments [29,30], and the changes in the structure of agricultural production factors determine the changes in the structure of agricultural production [31,32]. At present, due to the decline in the birth rate in rural areas, the per capita life expectancy has increased, and the rural young and strong labor force is contributing to urban mobility. The problem of rural population aging is becoming increasingly serious [33,34], and as an important factor, the endowment of agricultural development will inevitably have an impact on the structure of the agricultural industry [26]. There are differences in physical strength among laborers of different ages, and the impact of aging of the agricultural population on the structure of agricultural cultivation lies in the degree of its dependence on the physical strength of farmers [35].

Scholars have explored the causal factors or paths of change in the agricultural cropping structure from the following aspects: Firstly, rural demographic change affects the crop planting structure by changing the quantity and quality of agricultural labor. The formation and change of planting structure within crops is actually the result of farmers' choices based on the comparative returns of different crops under the constraints of natural conditions, labor factors, and agricultural capital factors [36,37]. Under the constraints of natural factors such as climatic conditions and soil and water resources, the main factors constraining farmers' planting decisions are the quantity and quality of farmers' labor inputs. The shortage of labor makes the price of labor rise, and thus the cost of labor inputs increases, and the constraints on the inputs of agricultural factors of production for farmers are tightened [38]. Under these circumstances, farmers will inevitably adjust the crop planting structure to maximize household economic benefits [39]. Second, aging has a certain impact on the agricultural planting structure by affecting the level of mechanization. With a large number of young and strong rural laborers transferred to the city, the labor shortage problem of agricultural production is constantly highlighted, which promotes the continuous substitution of agricultural machinery for the rural labor force [40], and farmers

will further improve the level of mechanized production [41,42], which will promote the transformation of agricultural planting structures [43,44]. In addition, due to the survival security function of farmland for elderly farmers, as well as psychological and emotional dependence [45], adjusting crop structure or changing production methods becomes a realistic choice for rural elderly [36]. Third, aging affects the agricultural cropping structure by influencing the crop cultivation decisions of different farm households [46]. Because different crops have different physical and human capital constraints on laborers, aging affects different crop cultivation decisions to different degrees [47]. Another study showed that the proportion of older laborers had no significant effect on the proportion of food cultivation, but the increase in the price of rural labor had a significant negative effect on the proportion of food crops cultivated and a significant positive effect on the proportion of cash crops cultivated [47].

Existing research on the analysis of the impact of the aging of the workforce on the structure of agricultural planting, mainly based on the perspective of labor shortages, has not yet reached a consistent opinion, and the relationship between the theoretical logic of the two is still being explored. There are few specific paths to the comprehensive sorting and summary. China's food production is facing the pressure of reduced planting area and the threat of internal structural imbalance caused by "non-agriculturalization" and "non-food" at the same time. The urgency of actively coping with aging in agricultural production is becoming more and more prominent. Under the irreversible trend of population aging in China and the key period of structural reform on the agricultural supply side, it is of great practical significance to carry out research on the relationship between aging and the agricultural cropping structure in order to optimize the structure of the supply of agricultural products, promote the stability of food security, and realize the strategy for the revitalization of the countryside, etc. [48].

The rest of this study is structured as follows: Section 2 carries out the theoretical analysis of the impact of rural population aging on agricultural cropping structure and formulates the research hypothesis. Section 3 details the methodology used in the study as well as the variable indicators. Section 4 presents the results related to the baseline regression, robustness test, heterogeneity, and moderating effect tests of this study. Section 5 summarizes the paper and suggests relevant countermeasures.

2. Theoretical Analysis and Research Hypotheses

For the change in population age structure, it is generally believed that with the increase in age, the physical strength of the working population will be weakened, the amount of labor input will be reduced, and the labor skills of the older labor force will be lower [11,49]. Therefore, the change in population age structure will affect the quantity and quality of agricultural labor [50]. In addition, the burden of population support brought by population aging also affects the amount of labor input of the normal labor force [51,52]. Rural age structure changes mainly affect the crop planting structure by affecting the quantity and quality of agricultural labor. The formation and change of the cropping structure within crops is actually the result of farmers' choices based on the comparative returns of different crop cultivation under the constraints of natural conditions, labor elements, and agricultural capital elements, and the main factors constraining farmers' planting decisions are the quantity and quality of labor inputs and agricultural capital under the constraints of natural factors such as climatic conditions and soil and water resources. Changes in rural demographics can alter the constraints on the quantity and quality of agricultural labor and even agricultural capital [53–55]. In addition, the agricultural capital input constraints of farmers may also tighten due to labor shortages that increase labor prices and thus labor input costs, as well as increased household expenditures due to the increased burden on the elderly population [56]. Under these circumstances, farmers will inevitably adjust the crop planting structure based on the quantity and quality of household labor and agricultural capital in order to maximize household economic efficiency [57].

Specifically, aging affects the structure of agricultural cultivation through the labor drain effect. For farm households that farm on a household basis, the flow of labor resources into non-farming industries implies a reduction of labor inputs in agricultural production [40,58]. Relative to labor-intensive cash crops, grain crops are typically land-intensive products that require relatively less labor, while cash crops require more labor. In the context of a labor shortage, grain crops are more suitable for rough management. At the same time, in the production of grain crops, alternative elements such as agricultural machinery can effectively replace lost labor, which also helps to motivate farmers to increase grain cultivation. Thus, in the context of a shortage of agricultural labor, farmers are likely to reduce cash crop cultivation, resulting in a "grain-oriented" cropping structure.

Agricultural mechanization operations can significantly reduce labor costs, significantly improve production efficiency [59], and, to a certain extent, promote cropping structure through grain adjustment [60]. With the accelerated transfer of agricultural land and the development of agricultural socialized services, moderate-scale operation has become an important way of modern agricultural development [61–63]. However, the high profitability of cash crops is often accompanied by high risk, and large-scale operations need to be guaranteed by financial and insurance policies [64]. This is also one of the important triggers for the "grain trend" in some areas. As the adjustment of cropping structure may face many risks and impacts, agricultural mechanization can help to improve the benefits of cropping structure adjustment for the elderly working groups and reduce the risks they may face, which may affect the agricultural cropping structure of the whole region [65]. In fact, the degree of comprehensive agricultural mechanization and the degree of mechanization of different segments in different regions tend to have different characteristics, and the degree of mechanization of different segments and different degrees of mechanization may differ in the impact of aging on agricultural cropping structure [66]. Therefore, exploring the relationship between aging, mechanization, and cropping structure adjustment can help reveal the mechanism of aging's influence on cropping structure adjustment.

Based on the above analysis and Figure 1, this paper proposes three research hypotheses:

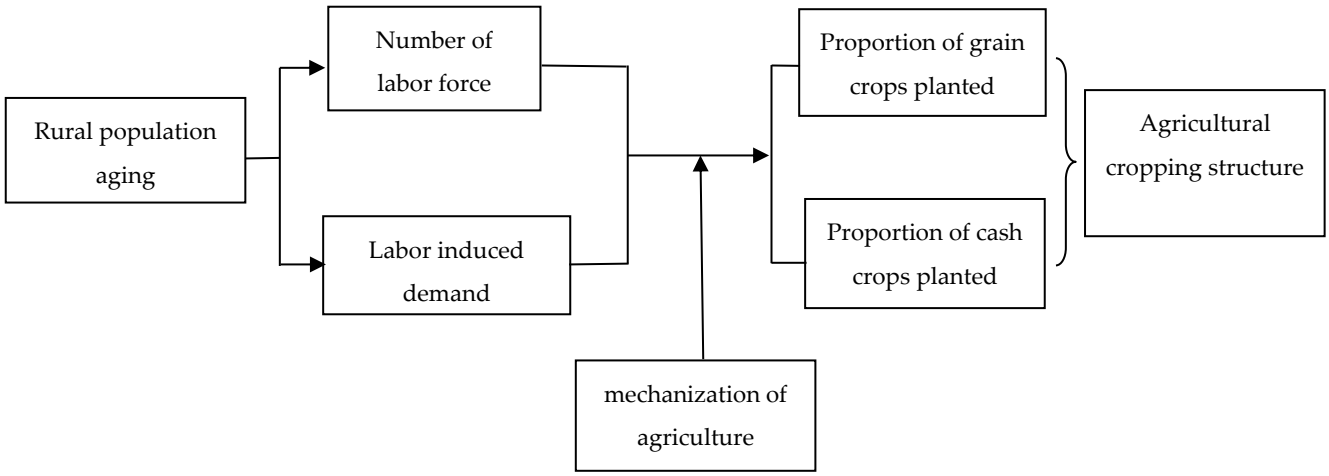

Figure 1. Mechanism of population aging impact on agricultural cropping structure.

H1. *When other conditions are constant, rural population aging has a positive effect on the proportion of grain cultivation and a negative effect on the proportion of cash crop cultivation.*

H2. *When other conditions are constant, the level of agricultural mechanization has a positive effect on the proportion of grain cultivation and a negative effect on the proportion of cash crop cultivation.*

H3. *Agricultural mechanization has a positive moderating effect on the impact of rural population aging on the proportion of grain crops planted, and a negative moderating effect on the impact of*

the proportion of cash crops planted and the moderating effect of the level of mechanization in the mechanized plowing, seeding, and harvesting segments of grain crops and cash crops is different.

3. Data Sources and Variable Settings

3.1. Model Setup

3.1.1. Two-Way Fixed Effects Model

In order to empirically test the impact of rural population aging on agricultural cropping structure, this paper constructs the following benchmark regression model:

$$Y_{it} = \alpha_1 + \alpha_2 old_{it} + \alpha_j X_{it} + \mu_i + \eta_t + \lambda_{it} \quad (1)$$

In Equation (1), i denotes province; t denotes year; Y_{it} denotes agricultural planting structural, measured by the proportion of area sown to grain crops and the proportion of area sown to cash crops; old_{it} denotes the level of rural population aging, measured by the ratio of the total rural population aged 65 and above to the total population in rural areas; and X_{it} denotes a set of control variables affecting the structure of agricultural planting, including the level of rural residents' income, the proportion of agricultural employment, the area of effective irrigation, the amount of agricultural fertilizer application, the financial support for agriculture, the proportion of crop damage, and the urbanization rate. α_1 denotes the constant term, α_2 and α_j are the coefficients to be estimated, μ_i is a provincial fixed effect that does not vary over time to control for the bias in the estimation results caused by factors such as natural endowments and cultural traditions in each province; η_t is a time fixed effect that does not vary with individuals; and λ_{it} is the random interference term.

3.1.2. Moderating Effects Test

Drawing on existing research [66], the moderating effect model is constructed with the agricultural mechanization rate as the moderating variable, and when conducting the moderating effect analysis, the agricultural mechanization rate is treated as a continuous variable, and the significance of the coefficient of the interaction term is used to determine whether the moderating effect exists. The specific model is as follows:

$$Y_{it} = \alpha_1 + \alpha_2 old_{it} + \alpha_3 old_{it} \times N_{it} + \alpha_j X_{it} + \mu_i + \eta_t + \lambda_{it} \quad (2)$$

In Equation (2), Y_{it} is the explanatory variable, indicating the agricultural cropping structure, measured by the proportion of grain crops grown and the proportion of cash crops grown; old_{it} is the explanatory variable, indicating the level of aging of the rural population, measured by the ratio of the total number of people aged 65 and above to the total population in rural areas; N_{it} is the moderating variable, indicating the rate of agricultural mechanization, measured by the integrated mechanization rate, mechanized cultivation rate, mechanized seeding rate, and mechanized harvesting rate; $old_{it} \times N_{it}$ is the interaction term; α_3 is the coefficient of the interaction term, which, if the coefficient is significant, indicates that the moderating effect exists, and vice versa, it does not exist; X_{it} denotes the control variable; α_1 denotes the constant term; α_2 and α_j are the coefficients to be estimated; μ_i and η_t are province-fixed and time-fixed effects; λ_{it} is the random interference term.

3.2. Variable Selection and Data Description

In this paper, panel data from 31 provinces from 2000–2021 are used to analyze the relationship among rural population aging, agricultural mechanization, and agricultural cropping structure. The data are mainly obtained from the China Rural Statistical Yearbook, China Statistical Yearbook, China Population and Employment Statistical Yearbook, and China Agricultural Machinery Industry Yearbook of past years. Some variables have had missing data for some years, and this paper adopts the linear interpolation method to make up the missing data, and the explanation of specific indicators and descriptive statistics

are shown in Table 1 below. In addition, the explanatory variables are logarithmized to reduce the heteroskedasticity of the model, attenuate the multicollinearity of the data, and enhance the smoothness of the panel data.

Table 1. Variable definitions and descriptive statistics.

	Variables	Definition	Mean	SD
Explanatory variables	Aging rural population	Population over 65 years old/total population (%)	0.106	0.039
Explained variables	Proportion of grain crops planted	Grain crops sown area/total sown area of crops (%)	0.661	0.133
	Proportion of rice planted	Rice sown area/total sown area of crops (%)	0.311	0.303
	Proportion of wheat planted	Wheat sown area/total sown area of crops (%)	0.200	0.172
	Proportion of corn planted	Corn sown area/total sown area of crops (%)	0.272	0.215
	Proportion of cash crops planted	Cash crops sown area/total sown area of crops (%)	0.271	0.112
	Proportion of oil crops planted	Oil crops sown area/total sown area of crops (%)	0.083	0.090
	Proportion of vegetables planted	Vegetable sown area/total sown area of crops (%)	0.135	0.090
Moderator variables	Comprehensive mechanization rate	Full mechanical operation level (%)	0.452	0.231
	Mechanized plowing rate	Machine plowed area/total sown area of crops (%)	0.582	0.242
	Mechanized seeding rate	Machine seeded area/total sown area of crops (%)	0.388	0.308
	Machine harvesting rate	Machine harvested area/total sown area of crops (%)	0.365	0.267
Control variables	Income level of rural residents	Per capita disposable income of rural residents (in millions of dollars)	0.857	0.641
	Proportion of agricultural employment	Employment in primary industry/total employment in the whole society (%)	0.555	0.166
	Effective irrigation area	Effective irrigation area (million hectares)	197.233	154.873
	Agricultural fertilizer application	Discounted amount of agricultural fertilizers applied (million tons)	159.567	138.194
	Financial support for agriculture	Financial Expenditure on Agriculture, Forestry and Water Affairs (billions of dollars)	450.654	295.602
	Proportion of crops affected by disasters	Crop-affected area/total sown area of crops (%)	0.222	0.171
	Agricultural policy	Yes = 1, No = 0	0.773	0.419

1. Explained variable: agricultural cultivation structure, measured using the ratio of area sown under grain crops to total area sown under crops and the ratio of area sown under cash crops to total area sown under crops together, i.e., the ratio of area planted to grain crops and the ratio of area planted to cash crops. Meanwhile, grain crops investigate the cropping structure of rice, wheat and corn, and cash crops mainly investigate the cropping structure of oil crops and vegetables. The data for this indicator comes from the China Rural Statistics Yearbook.
2. Core explanatory variable: level of aging of the rural population, measured by the ratio of the total number of people aged 65 and above to the total population in rural areas, with data from the China Population and Employment Statistical Yearbook of past years.

3. Moderating variables: the development level of agricultural mechanization. First, the comprehensive mechanization rate of agriculture in province i (autonomous regions and municipalities directly under the central government) in year t is used to reflect the level of full-scale mechanized operation, calculated according to the formula (ploughing rate × 40% + sowing rate × 30% + harvesting rate × 30%); second, indicators of the rate of ploughing, sowing, and harvesting are used, expressed as the ratios of the area of mechanized ploughing, sowing, and harvesting to the total area of sowing of crops, respectively, to reflect the level of mechanized operation of different production segments. mechanized operation level of different production stages. The data for this indicator are from the China Agricultural Machinery Industry Yearbook.
4. Control variables. Referring to the existing studies [39,41], the control variables include the income level of rural residents (per capita disposable income of rural residents), the proportion of agricultural employment (number of people employed in the primary industry/total employment of the whole society), the effective irrigation area, the amount of fertilizer applied to agriculture (discounted amount of fertilizer applied to agriculture), the financial support to agriculture (financial expenditures on agriculture, forestry, and water), the proportion of crops affected by disasters (crop affected area/total sown area of crops), agricultural policy, all the above indicators are from the China Rural Statistical Yearbook.

4. Results and Analysis

4.1. Baseline Regression

Table 2 shows the regression results of the data observations of annual rural population aging and agricultural cropping structure in 31 provinces of China from 2020 to 2021 using a two-way fixed-effects model. From the results, it can be seen that rural population aging has a significant effect on agricultural cropping structure. Among them, the effects of rural population aging on grain cultivation structure and cash crop cultivation structure passed the significance test. Table 2 (1) and (3) columns are the results of unadded control variables. From the perspective of economic implications, whenever the aging of rural population increases by one percentage point, the proportion of grain cultivation increases by 0.731 percentage points, while the proportion of cash crop cultivation decreases by 0.378 percentage points, indicating that the aging of rural population is positively correlated with the proportion of grain cultivation and negatively correlated with the proportion of cash crop cultivation, and that the proportion of grain cultivation expands with the increase of the aging of rural population and the area planted with cash crops will shrink. Table 2 (2), (4) columns to join the proportion of agricultural employment, agricultural production conditions, disaster and agricultural policy control variables, the results show that the aging of the rural population on the structure of grain cultivation and the structure of cash crop cultivation is still through the significant, the proportion of grain cultivation of the estimation of the results of the columns of (1) a slight decrease from 0.731 to 0.634, the proportion of cash crop cultivation of the estimation of the results of the columns of (1) slightly decreased from 0.731 to 0.634, cash crop cultivation of the proportion of the estimation of the results of the columns of Column (2) has slightly increased, indicating that after controlling for variables such as the proportion of agricultural employment in each province, agricultural production conditions, disaster situations and agricultural policies, the impact of rural population aging on the proportion of grain and cash crop cultivation is still significant, with the impact of rural population aging on the proportion of grain cultivation remaining positive, while the impact on the proportion of cash crop cultivation is negative.

Table 2. Baseline regression results.

	Proportion of Grain Crops Planted		Proportion of Cash Crops Planted	
	(1)	**(2)**	**(3)**	**(4)**
Aging rural population	0.731 ***	0.634 ***	−0.378 *	−0.345 *
	(4.57)	(4.12)	(−2.21)	(−2.09)
Proportion of agricultural employment		0.103 **		−0.103 *
		(3.03)		(−2.52)
Agricultural fertilizer application		−0.0229		0.0425
		(−1.69)		(1.95)
Effective irrigation area		0.0186		−0.0330
		(0.89)		(−1.56)
Proportion of crops affected by disasters		−0.00443		0.00987
		(−0.32)		(0.54)
Income level of rural residents		0.0172		−0.0321
		(1.47)		(−1.43)
Financial support for agriculture		−0.0213 ***		0.0121 **
		(−6.05)		(3.00)
Agricultural policy		−0.0211		0.0367
		(−0.79)		(0.59)
Constant	0.576 ***	0.418 **	0.336 ***	0.679 **
	(24.86)	(2.92)	(12.48)	(3.06)
Province-fixed effects	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes
R^2	0.8887	0.887	0.8072	0.797
Observations	681	680	680	679

Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.2. Robustness Check

Table 3 shows the results of the regression with robustness tests by replacing the explanatory variables. The rural population aging rate is used as a proxy variable for rural aging in the baseline regression. In this paper, we use the rural old-age dependency ratio to replace rural population aging for a robustness test to test the stability of the impact of rural population aging on agricultural cropping structure. Table 3 (1), (3) shows the impact of rural old-age dependency ratio on agricultural cropping structure when no control variables are added, and from the results, it can be seen that the impact of rural old-age dependency ratio on agricultural cropping structure also passes the test of 1% level of significance, which further indicates that the aging of the rural population has a significant impact on agricultural cropping structure. Table 3 (2) and (4) show the impact of rural old-age dependency ratio on agricultural cropping structure when control variables are added, and the results show that its impact on agricultural cropping structure also passes the significance test, indicating that the impact of rural old-age dependency ratio on the proportion of grain and cash crop planting is still significant after controlling the variables of the proportion of agricultural employment in each province, the conditions of agricultural production, the disaster situation, the agricultural policy, and so on. It can be seen that the conclusion of this paper still holds after replacing the explanatory variables.

Table 3. Robustness test.

	Proportion of Grain Crops Planted		Proportion of Cash Crops Planted	
	(1)	**(2)**	**(3)**	**(4)**
Rural elderly dependency ratio	0.00348 ***	0.00360 ***	−0.00302 ***	−0.00313 ***
	(4.88)	(5.16)	(−3.55)	(−3.51)
Proportion of agricultural employment		0.0823 *		−0.0918 *
		(2.13)		(−2.35)
Agricultural fertilizer application		−0.0255		0.0430 *
		(−1.89)		(2.02)

Table 3. *Cont.*

	Proportion of Grain Crops Planted		Proportion of Cash Crops Planted	
	(1)	(2)	(3)	(4)
Effective irrigation area		0.0226		−0.0387
		(1.07)		(−1.84)
Proportion of crops affected by disasters		0.00103		0.0047
		(0.08)		(0.26)
Income level of rural residents		0.0044		−0.0154
		(0.34)		(−0.66)
Financial support for agriculture		−0.0208 ***		0.0114 **
		(−4.38)		(2.84)
Agricultural policy		−0.0353		0.0528
		(−1.34)		(0.87)
Constant	0.556 ***	0.500 ***	0.372 ***	0.602 **
	(21.84)	(3.40)	(15.95)	(2.76)
Province-fixed effects	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes
R^2	0.8895	0.8994	0.8121	0.8201
Observations	681	680	680	679

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.3. Heterogeneity Analysis

The above verifies that the aging of rural populations has a significant effect on agricultural cropping structures. Next, grouping and heterogeneity analyses will be conducted according to crop varieties and regions, respectively. Different varieties of grain crops and cash crops have different labor requirements, so there may be heterogeneity in the impact of rural population aging on different varieties of crop cultivation, and with the differences in natural resource endowment of farmers in different regions, there may also be different impacts of rural population aging on the structure of agricultural cultivation in different regions.

4.3.1. Analysis of Crop Variety Heterogeneity

As can be seen from Table 4, the impact of rural population aging on the proportion of wheat, corn, and rice cultivation is not significant, indicating that rural population aging does not have a significant impact on the structure of different varieties of grain crops. As the country continues to promote the construction of high-standard farmland, the modernization level of China's three major staple grain productions continues to improve. In 2022, China's three major grain crops, wheat, corn, and rice, had a comprehensive mechanization rate of ploughing, planting, and harvesting exceeded 97%, 90%, and 85%, respectively, and the substitution of agricultural machinery for labor continues to improve. In addition, in terms of labor demand per unit of land area, the three major staple crops of wheat, corn, and rice are more likely to adopt labor-saving intensive management modes. In addition, due to the continuous promotion of agricultural socialization services in grain cultivation, which helps to realize the mechanization of the whole process of different varieties of grain cultivation, grain cultivation is less dependent on labor than before. As a result, and because the differences in labor demand among the three major staple grains are small, the differences in the aging of the rural population in different provinces do not have a significant differential impact on the proportion of different varieties of grain crops planted.

As can be seen from Table 5, compared with grain crops, the aging of the rural population has a significant impact on the proportion of vegetables and oil crops planted in cash crops, with the aging proportion of vegetables having a more significant negative impact and the proportion of oil crops having a more significant positive impact. This shows that the aging of the rural population on the cropping structure of different varieties of cash crops has a more significant differential impact, and the higher the degree of

population aging, the smaller the proportion of vegetable planting, and the higher the degree of population aging, the larger the proportion of oilseed crop planting. According to the reality of China's agricultural production, vegetables are a higher value-added cash crop than oil crops, resulting in a greater demand for labor. Moreover, vegetables, as labor-intensive cash crops, are less easy to mechanize than oil crops. Therefore, the aging degree of the rural population affects the proportion of vegetable and oilseed cultivation in the opposite direction, which is also consistent with the results of the benchmark regression of the impact of partial aging on the proportion of grain and cash crop cultivation.

Table 4. Heterogeneity analysis of grain crop varieties.

	Proportion of Wheat Planted	**Proportion of Maize Planted**	**Proportion of Rice Planted**
	(1)	**(2)**	**(3)**
Aging rural population	−0.0232	0.145	−0.0191
	(−0.20)	(1.45)	(−0.16)
Proportion of agricultural employment	−0.0245	0.0558	0.234 ***
	(−0.48)	(1.69)	(4.13)
Agricultural fertilizer application	−0.00413	0.0879 ***	−0.0483 ***
	(−0.37)	(8.51)	(−4.88)
Effective irrigation area	0.0175	−0.0449 *	0.0733 ***
	(1.35)	(−2.27)	(9.09)
Proportion of crops affected by disasters	0.0214	−0.0477 ***	−0.0150
	(1.81)	(−3.48)	(−1.57)
Income level of rural residents	0.00334	0.0152	−0.0226 **
	(0.38)	(1.71)	(−2.78)
Financial support for agriculture	−0.0174 ***	−0.00358	0.00471
	(−5.26)	(−1.12)	(1.42)
Agricultural policy	−0.00365	0.0124	0.00175
	(−0.21)	(0.76)	(0.12)
Constant	0.231 **	0.470 ***	−0.159 *
	(2.69)	(4.15)	(−2.06)
Province-fixed effects	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes
R^2	0.9679	0.9732	0.9923
Observations	658	680	658

Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 5. Heterogeneity analysis of cash crop varieties.

	Proportion of Vegetables Planted (1)	**Proportion of Oilseed Planted (2)**
Rural population aging	−0.228 **	0.169 ***
	(−2.44)	(2.83)
Proportion of agricultural employment	−0.108 ***	−0.0367 **
	(−5.17)	(−2.49)
Agricultural fertilizer application	−0.0340 ***	0.0271 ***
	(−3.63)	(3.63)
Effective irrigation area	0.0199	−0.0143 **
	(1.44)	(−2.20)
Proportion of crops affected by disasters	0.0151	−0.00201
	(1.46)	(−0.34)
Income level of rural residents	−0.000826	−0.00709
	(−0.09)	(−0.64)
Financial support for agriculture	0.0130 ***	−0.00241
	(4.68)	(−1.53)
Agricultural policy	−0.00943	0.0132
	(−0.56)	(1.01)

Table 5. *Cont.*

	Proportion of Vegetables Planted (1)	Proportion of Oilseed Planted (2)
Constant	0.255 **	0.119
	(2.62)	(1.14)
Province-fixed effects	Yes	Yes
Year-fixed effects	Yes	Yes
Observations	680	680

Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$.

4.3.2. Analysis of Regional Heterogeneity

As can be seen from Table 6, the aging of the rural population has a significant impact on the structure of agricultural cultivation in different regions, but there are some differences in the impact in different regions. Among them, rural population aging has a greater impact on the agricultural cropping structure (the proportion of grain crops and cash crops) in the eastern provinces than in the central and western regions. Rural population aging has a positive impact on the proportion of grain crops grown in the eastern and central regions and a negative impact on the proportion of cash crops grown in the western regions, while the direction of the impact is the opposite. The main reason may be that the eastern region of China, compared with the central and western regions, has a higher level of economic development and agricultural machinery market-oriented services are more developed. When the degree of aging is deepened, mechanization is easier to replace the missing labor force supply, so the eastern region's aging population and its grain and cash crop planting structure have a greater impact. In the western region, the level of economic development is lower, and the topographic conditions lead to a lower level of socialized agricultural machinery in most areas, and agricultural income is still an important part of the total income of farmers in the western region. Therefore, the higher the degree of aging of the rural population in the western region, the easier it will be for farmers to give up grain cultivation and switch to higher value-added cash crops.

Table 6. Regional Heterogeneity.

	Eastern Region		Central Region		Western Region	
	Cereals	Cash Crop	Cereals	Cash Crop	Cereals	Cash Crop
	(1)	(2)	(3)	(4)	(5)	(6)
Aging rural population	1.083 ***	−0.772 ***	0.474 **	−0.253 **	−0.204 **	0.122 **
	(3.94)	(−3.38)	(1.88)	(−0.73)	(−1.38)	(0.36)
Proportion of agricultural employment	0.0431	−0.129 **	−0.101	0.130	0.179 ***	−0.0619
	(0.89)	(−2.89)	(−1.17)	(1.13)	(3.41)	(−0.53)
Agricultural fertilizer application	0.0522	−0.0317	−0.0232	−0.00638	0.0507 *	−0.0104
	(1.15)	(−0.70)	(−1.09)	(−0.19)	(2.44)	(−0.25)
Effective irrigation area	−0.104 *	0.117 *	0.0400 **	−0.0533 **	−0.0367	−0.0306
	(−2.13)	(2.60)	(3.20)	(−2.70)	(−1.85)	(−0.72)
Proportion of crops affected by disasters	−0.0220	0.00259	0.00265	−0.0163	0.00416	−0.00278
	(−0.86)	(0.10)	(0.20)	(−0.84)	(0.27)	(−0.08)
Income level of rural residents	0.0282	−0.405 ***	0.00861	−0.0244	−0.108 *	0.0811
	(0.72)	(−3.64)	(0.78)	(−1.38)	(−2.55)	(0.93)
Financial support for agriculture	−0.0187 **	0.0130	0.0163 ***	−0.0166 ***	−0.0481 ***	−0.0103
	(−3.19)	(1.84)	(5.12)	(−3.49)	(−5.52)	(−0.57)
Agricultural policy	−0.0167	−0.0647	−0.00739	0.0651 *	0.398 ***	−0.115
	(−0.41)	(−0.72)	(−0.57)	(2.32)	(4.10)	(−0.56)
Constant	0.772	3.263 ***	0.551 ***	0.759 **	1.650 ***	−0.156
	(1.81)	(3.39)	(5.66)	(3.19)	(4.14)	(−0.15)
Province-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.8587	0.7648	0.9804	0.9572	0.9563	0.8344
Observations	241	240	175	175	264	264

Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

4.4. Mechanism Testing

The results of the benchmark regression show that the aging of the rural population has a significant impact on the structure of agricultural cultivation, and there is a difference in the impact on grain crops and cash crops. Then, why does rural population aging have a significant impact on agricultural cropping structure? First of all, the impact of rural population aging on the structure of agricultural cultivation for farmers is inevitably affected by the impact of agricultural mechanization, and this impact will change with the changes in the degree of agricultural mechanization. Deepening aging means that agricultural labor may leave agricultural production, as rational farmers prefer to choose to grow crops that are easy to mechanize. Therefore, the development level of agricultural mechanization in farm households can be regarded as a moderating variable of aging and agricultural cropping structure. Research by many scholars has shown that the current cropping structure of small farmers has a clear tendency toward "grain-orientation".

Second, cropping structure adjustment can be seen as a way for farmers to diversify their own agricultural business risks. However, subject to the rigid constraints of labor factors engaged in agricultural production, farmers choose to diversify the planting of more labor factors that need to be invested, making them more vulnerable to the impact of the replacement of agricultural machinery. On the one hand, from the cost-benefit point of view, planting crops with a higher degree of agricultural mechanization can better achieve the reduction of production costs, which in turn releases the agricultural labor force to engage in non-agricultural employment; on the other hand, with the rapid development of the agricultural machinery leasing market, more and more farmers are choosing to purchase agricultural machinery socialized services for agricultural production. Taking into account the asset-specificity of the agricultural machinery operation services, farmers may also restructure due to the status of socialized service supply. Therefore, this paper focuses on exploring the impact mechanism of aging on agricultural cropping structure from the perspective of agricultural mechanization.

Table A1 shows the estimation results of rural population aging on agricultural cropping structure (proportion of grain crops) based on the moderating effect of agricultural mechanization. In Table A1, models (1) and (2) are the estimation results of aging and agricultural mechanization on the proportion of grain crops planted. Models (3) to (4) are the estimation results of the two-way fixed effects model for panel data with agricultural mechanization as a moderating variable. The estimated coefficient of the integrated agricultural mechanization variable in model (1) is 0.2347, which passes the significance level test at the 1% level, i.e., the higher the degree of agricultural mechanization, the more farmers tend to increase the cultivation of grain crops. The estimated coefficients of machine seeding rate and machine harvesting rate in model (2) are positive indicating that which machine seeding rate passes the significance level test. After adding the agricultural mechanization variable, the estimated coefficient of integrated agricultural mechanization in model (3) is negative and passes the significance level test, which indicates that the higher the level of agricultural mechanization, the more farmers tend to specialize in planting. When adding the interaction term of aging and agricultural mechanization, the estimated coefficients of the interaction term are positive and have passed the significance level test at the 10% level, which indicates that the higher the degree of aging, the higher the tendency of farmers to plant crops with a higher level of agricultural mechanization (such as grain crops) and thus increase the proportion of crops (grain crops) planted, and agricultural mechanization has a positive moderating effect on the impact of aging on the proportion of grain crops planted. positive moderating effect, and there are differences in the moderating effect of mechanization level in different segments.

Table A2 shows the estimation results of rural population aging on agricultural cropping structure (proportion of cash crops planted) based on the moderating effect of agricultural mechanization. In Table A2, models (1) and (2) are the estimation results of aging and agricultural mechanization on the proportion of cash crop cultivation. Models (3) to (4) are the estimation results of the two-way fixed effects model for panel data with agricultural

mechanization as a moderating variable. The estimated coefficient of the composite agricultural mechanization variable in model (1) is −0.2277, which passes the significance level test at the 5% level, i.e., the higher the degree of agricultural mechanization, the more farmers tend to reduce the cultivation of cash crops. The estimated coefficients of machine seeding rate and machine harvesting rate in model (2) are negative, where machine seeding rate passes the significance level test. After adding the variable interaction term of aging and comprehensive agricultural mechanization rate, the estimated coefficient of comprehensive agricultural mechanization in model (3) is positive and passes the significance level test, which indicates that the higher the level of comprehensive agricultural mechanization, the more farmers tend to plant cash crops. When adding the interaction term of aging and agricultural mechanization, the estimated coefficients of the interaction term are negative and have passed the significance level test at the 1% level, which indicates that the higher the degree of aging, the more farmers tend to plant crops with lower levels of agricultural mechanization (e.g., cash crops) and thus reduce the proportion of planting of this type of crop, and the agricultural mechanization of the aging impact on the proportion of cash crop planting has a negative regulatory The effect of agricultural mechanization on the impact of aging on the proportion of cash crop planting has a negative regulatory effect, and the regulatory effect of mechanization in different segments varies.

5. Discussion and Conclusions

5.1. Discussion

5.1.1. Similarities and Differences with Existing Studies

Changes in the demographic structure will change the quantity and quality of labor factors in farming households, and in order to adapt to demographic changes and maximize the economic benefits of the household, farming households will adjust the structure of factor inputs and the structure of cultivation, which will inevitably affect changes in the structure of crop cultivation, including food. Firstly, rural population aging has a significant effect on agricultural cropping structure after controlling variables, and the robustness test still supports this conclusion. China, as a country with a small farming economy with many people and little land, experiences land fragmentation, which increases the cost of agricultural cultivation. With the aging of the rural population, people will shift to planting grain crops that are easy to replace by machinery and produced on a large scale, and the planting area of cash crops that are more labor-demanding will be reduced, i.e., the aging of the rural population will lead to the tendency of "grain-convergence", which is consistent with the findings of related studies [46,67–69]. Secondly, in terms of the heterogeneity of varieties and regions affected by rural population aging, as different grain crops are easy to replace labor with machinery, under tightening labor factor constraints, rural population aging has no significant impact on the structure of different varieties of grain crops. However, due to the variety of cash crops and the difficulty of replacing labor with machinery for different cash crops, the aging of the rural population has a significant impact on the structure of cash crop varieties. The aging of rural populations has a more significant impact on the structure of agricultural cultivation in the eastern region, while it does not have a significant impact on the structure of agricultural cultivation in the central and western provinces [41]. Finally, the higher the degree of agricultural mechanization, the more farmers tend to increase the cultivation of grain crops and tend to reduce the cultivation of cash crops, which is consistent with the findings of other scholars [23,41,70]. Agricultural mechanization has a positive moderating effect on the impact of aging on the proportion of grain crops planted and a negative moderating effect on the cropping structure of cash crops, and there are differences in the moderating effect in different segments of mechanization. In addition, there are many other countries in Asia, such as Japan and South Korea, which, like China, have a small-farming economy with scarce arable land resources and are also facing the threat of population aging, so the conclusions of the study on the aging of China's rural population on the structure of agricultural cultivation are also of reference value to these countries.

Compared with the existing literature, this study is different in the following ways: (1) This study further explores the impact of aging on agricultural cropping structure by dividing crops into grain and cash crops and further subdividing them according to varieties. (2) While testing the moderating effect of agricultural mechanization on the impact of aging on the structure of agricultural cultivation, this study further examines this according to the different segments of crop adoption of machinery. (3) This paper also adopts the old-age dependency ratio as a proxy variable for aging to conduct a robustness test, which greatly enhances the credibility of the research results. (4) Aiming at the reality of the uneven regional spatial distribution of the aging population and agricultural cropping structure in China's rural areas, full consideration is given to the regional heterogeneity of the impact of aging on agricultural cropping structure in different provinces that may be brought about by the differences in regional economic development levels. The above content adopts a new perspective for possible future research related to the impact of population aging on agricultural cropping structure.

5.1.2. Limitations and Future Recommendations

This study still has some limitations due to data availability. We were only able to obtain data on the aging of the rural population and the structure of agricultural cultivation at the provincial level in China, and given the vastness of China and the diversity of its agricultural and rural development patterns, the aging and cultivation characteristics at the provincial level may not be fully representative of the overall development of China's agricultural and rural areas, and thus there are some limitations in terms of representativeness and diversity of the study. In addition, the current study only uses the proportion of people over 65 years old to characterize the degree of aging of the rural population, while the structure of the rural working-age population varies in different regions, so it is not possible to obtain the impact of the structural differences in working age on the structure of agricultural cultivation within the aging population. Meanwhile, due to the large number of factors affecting the structure of agricultural planting and the limited availability of data, this study was unable to select control variables, such as the level of farmers' education, for the study. In the future, the factors affecting the structure of agricultural planting will be considered and controlled as fully as possible. In addition, it will be possible to further explore the impact of aging on the structure of agricultural cultivation according to the proportion of different ages in the rural population by region in order to draw more detailed conclusions.

5.2. Conclusions and Policy Recommendations

5.2.1. Conclusions

Against the background of increasing rural aging in China, this paper explores the impact of rural aging on agricultural cropping structure based on data on rural aging and agricultural cropping structure at the provincial level in China from 2000 to 2021 and tests the moderating effect of agricultural mechanization on the impact by comprehensively applying a two-way fixed-effects model. The results show that.

The aging of the rural population has a positive impact on the proportion of grain cultivation and a negative impact on the proportion of cash crop cultivation; agricultural mechanization has a positive regulatory role in the impact of the aging of the rural labor force on the proportion of food crop cultivation and a negative regulatory role in the impact of the proportion of cash crop cultivation; and there is a difference in the regulating effect of the different segments of the degree of mechanization. In addition, the aging of the rural labor force has heterogeneity on the agricultural cropping structure, in which the impact of aging of the rural labor force on different varieties of grain crops is not significant, and the impact of aging of the rural labor force on different varieties of cash crops is significant, and there are certain differences, and the impact of aging of the rural labor force on agricultural cropping structure in different regions is also different.

5.2.2. Policy Recommendations

The following countermeasures are proposed in response to the results of the above study: First, the will of agricultural business subjects to choose agricultural varieties should be fully respected. In the context of the aging of the rural population and the continuous development of marketization, the changes in the cropping structure of agricultural production should fully follow the laws of realistic development. Actively play the role of the market's self-regulation, reduce the government's administrative intervention in the change of agricultural cropping structure, and strive to provide policy support for the continuous optimization of agricultural cropping structure. Second, accelerate the mechanization of agriculture and increase the research, development, and promotion of agricultural machinery suitable for the elderly. The increase in the proportion of the elderly population limits the promotion and use of advanced technology. The government should strengthen the research and development of small and medium-sized agricultural machinery suitable for different terrain areas and the labor characteristics of the elderly and give some policy preference to it [24,39]. Third, the level of farmers' human capital should be continuously improved, not only through agricultural training to raise the cultural level of existing farmers but also through the adoption of various incentive policies by the government to cultivate agricultural personnel with knowledge of high-quality agricultural product production technology and business management, so as to attract high-quality personnel to stay in and flow into the countryside to adapt to the production of modern high-quality agricultural products as well as to the development of modern agriculture. Finally, cultivate new agricultural management bodies to further enhance the organization, scale, and specialization of agricultural production. Accelerate the transfer of land, vigorously develop family farms, agribusinesses, and other new agricultural management subjects, expand the scale of agricultural production and operation [27], and continuously promote the modernization of agriculture and the upgrading of crop cultivation.

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Appendix A

Table A1. Impact of aging on the proportion of grain planted: based on the moderating effect of agricultural mechanization.

	(1)	(2)	(3)	(4)
Aging rural population	0.5198 ***	0.3996 ***	−1.7478 ***	−0.7443 ***
	(0.1648)	(0.1296)	(0.2268)	(0.2210)
Comprehensive mechanization rate	0.2347 ***		−0.3068 ***	
	(0.1261)		(0.0432)	
Mechanized plowing rate		−0.1647 ***		−0.1823 ***
		(0.0169)		(0.0340)
Mechanized seeding rate		0.3174 ***		0.1980 ***
		(0.0299)		(0.0402)
Mechanized harvesting rate		0.0178		−0.0434 *
		(0.0176)		(0.0231)

Table A1. *Cont.*

	(1)	(2)	(3)	(4)
Rural population aging × Comprehensive mechanization rate			3.8311 *** (0.3363)	
Rural population aging × Mechanized plowing rate				0.5945 ** (0.2550)
Rural population aging × Mechanized seeding rate				0.6775 * (0.3496)
Rural population aging × Mechanized harvesting rate				0.6973 * (0.3816)
Proportion of agricultural employment	0.0998 ** (0.0386)	0.0302 (0.0360)	−0.0060 (0.0318)	−0.0176 (0.0327)
Agricultural fertilizer application	−0.0166 (0.0167)	−0.0597 *** (0.0106)	−0.0200 (0.0150)	−0.0540 *** (0.0097)
Effective irrigation area	0.0114 (0.0220)	0.0334 ** (0.0163)	−0.0047 (0.0180)	0.0211 (0.0151)
Proportion of crops affected by disasters	−0.0134 (0.0160)	0.0188 * (0.0114)	0.0038 (0.0156)	0.0240 ** (0.0120)
Income level of rural residents	−0.0455 (0.0464)	0.0130 * (0.0076)	0.0704 * (0.0413)	0.0163 ** (0.0080)
Financial support for agriculture	−0.0206 *** (0.0037)	−0.0080 *** (0.0027)	−0.0144 *** (0.0032)	−0.0065 ** (0.0027)
Agricultural policy	−0.0195 (0.0285)	−0.0224 (0.0241)	−0.0329 (0.0214)	−0.0270 (0.0217)
Constant	0.9702 ** (0.4020)	0.3386 *** (0.1009)	0.3017 (0.3522)	0.4923 *** (0.1035)
Province-fixed effects	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes
Observations	650	680	650	680
R^2	0.8875	0.9347	0.9133	0.9419

Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A2. Impact of aging on the proportion of cash crop planted: based on the moderating effect of agricultural mechanization.

	(1)	(2)	(3)	(4)
Rural population aging	−0.3502 ** (0.1738)	−0.1412 (0.1594)	1.8397 *** (0.3051)	1.1288 *** (0.3081)
Comprehensive mechanization rate	−0.2277 ** (0.0646)		0.3012 *** (0.0526)	
Mechanized plowing rate		0.1571 *** (0.0173)		0.1992 *** (0.0388)
Mechanized seeding rate		−0.2666 *** (0.0312)		−0.1016 ** (0.0446)
Mechanized harvesting rate		−0.0297 (0.0184)		−0.0341 (0.0305)
Rural population aging × Comprehensive mechanization rate			−3.6998 *** (0.4192)	
Rural population aging × Mechanized plowing rate				−0.9442 *** (0.3104)
Rural population aging × Mechanized seeding rate				−1.3336 *** (0.3573)
Rural population aging × Mechanized harvesting rate				0.2460 (0.4073)
Proportion of agricultural employment	−0.1146 ** (0.0448)	−0.0424 (0.0411)	−0.0124 (0.0405)	0.0395 (0.0430)
Agricultural fertilizer application	0.0447 ** (0.0225)	0.0765 *** (0.0209)	0.0480 ** (0.0213)	0.0725 *** (0.0209)

Table A2. *Cont.*

	(1)	(2)	(3)	(4)
Effective irrigation area	−0.0189	−0.0473 ***	−0.0034	−0.0337 *
	(0.0214)	(0.0176)	(0.0184)	(0.0175)
Proportion of crops affected by disasters	0.0131	−0.0106	−0.0036	−0.0202
	(0.0201)	(0.0176)	(0.0205)	(0.0180)
Income level of rural residents	−0.0096	−0.0288	−0.1216 ***	−0.0296
	(0.0471)	(0.0253)	(0.0442)	(0.0261)
Financial support for agriculture	0.0122 ***	0.0005	0.0062	−0.0003
	(0.0042)	(0.0032)	(0.0038)	(0.0033)
Agricultural policy	0.0389	0.0384	0.0519	0.0451
	(0.0618)	(0.0599)	(0.0546)	(0.0576)
Constant	0.4126	0.7508 ***	1.0581 ***	0.5433 **
	(0.4058)	(0.2248)	(0.3722)	(0.2234)
Province-fixed effects	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes
Observations	650	679	650	679
R^2	0.8025	0.8516	0.8360	0.8625

Standard errors are in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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