https://doi.org/10.17221/273/2024-AGRICECON

A study on the impact of aging and agricultural infrastructure construction on the agricultural green total factor productivity

*Meng Meicui, Mu Shaoyan, Cao Yanqiao**

School of Economics and Management, Qingdao Agricultural University, Qingdao, P.R. China

**Corresponding author: 339678559@qq.com*

Citation: Meicui M., Shaoyan M., Yanqiao C. (2025): A study on the impact of aging and agricultural infrastructure construction on the agricultural green total factor productivity. Agric. Econ. – Czech, 71: 113–129.

Abstract: In an era marked by an aging agricultural workforce and intensifying environmental pressures, agricultural infrastructure plays a crucial role in enhancing green productivity. This study investigates the impact of agricultural infrastructure construction and population aging on agricultural green total factor productivity (agricultural GTFP), utilizing provincial panel data from 2004 to 2022 in China. Our findings reveal that the agricultural infrastructure construction significantly boosts agricultural GTFP and significantly mitigates the negative effects of aging on agricultural green production at the 0.01 level. Notably, different types of infrastructure exhibit varying impacts, with electricity and irrigation infrastructure demonstrating the most significant positive effects. We further identify a strong mediating effect of farmland transfer and agricultural mechanisation in facilitating infrastructure-driven agricultural GTFP growth. Our analysis reveals a pronounced regional heterogeneity, with non-food producing, central, western regions of China benefiting most from agricultural infrastructure investments. To address the challenges posed by aging, we recommend giving priority to expanding agricultural infrastructure construction, fostering agricultural socialised services, and tailoring infrastructure programs to regional resource endowments. These strategies aim to compensate for labor shortages, enhance resource utilisation, and ultimately drive improvements in agricultural green productivity.

Keywords: population aging; panel data analysis; sustainability

The road of agricultural green development is the necessary way for China's agricultural development. The 14th Five-Year National Agricultural Development Plan clearly puts forward that 'green development of agriculture is an important goal for comprehensively promoting rural ecological revitalisation', and the report of the 20th Party Congress in 2022 puts forward that 'to promote Chinese-style modernisation and build a strong agricultural country is necessary to adhere to the green and high-quality development of agriculture'. However, the reality still is that the massive application of chemical fertilisers and pesticides leads to the decline of farmland fertility and the aggravation of agricultural area pollution, etc. Total factor productivity (TFP), especially green total factor productivity (GTFP), is a key indicator for measuring economic development and is currently mainly used in studies of the industrial economy (Xinhai et al. 2020; Yufeng et al. 2021), with fewer studies on agricultural GTFP (Dongdon et al. 2021). Considering the constraints of agricultural resources and environmental pollution, many scholars have favoured to use agriculture GTFP based on the framework of the neo-classical development model for assessing green development in agriculture (Hongjie et al. 2023). At the present time, the aging problem of agricultural labor force is becoming more and more prominent, which has become an obstacle to the enhancement of agricultural GTFP (Liu et al. 2023, Zhu 2023), and the construction of agricultural infrastructure is a way to improve agricultural GTFP (Li et al. 2022). Then, it is worth studying whether

https://doi.org/10.17221/273/2024-AGRICECON

agricultural infrastructure construction can alleviate the inhibiting effect of aging on agricultural GTFP.

Research on the relationship between aging and agricultural GTFP concludes that older farmers are lower than younger farmers in terms of the use and innovation of agricultural green technology (Du et al. 2023), and the value perception of green production behavior (He et al. 2023; Li et al. 2022), in short, aging to a certain extent can inhibit the enhancement of agricultural GTFP, and this inhibition has obvious regional heterogeneity.

Agricultural infrastructure is an important guarantee of agricultural productivity, and its impact on agricultural GTFP cannot be ignored. Studies on the relationship between the two that have concluded that strengthening the construction of agricultural infrastructure is the key to green and high-quality development of agriculture (Cheng and kong 2022), which can effectively promote the enhancement of agricultural GTFP (Ma et al. 2023). Some scholars have studied the role of different types of infrastructure on agricultural GTFP, among which, the role of transportation infrastructure construction (Xu et al. 2023; Li 2023), agricultural irrigation and electric power infrastructure (Liang and Li 2020) and the promotion of agricultural GTFP has been proved, but these studies are all from the perspective of a specific type of infrastructure. There is a lack of understanding and empirical verification of the relationship on the whole, and a lack of research on the impact of information and communication infrastructure on agricultural GTFP.

There is also a mutually reinforcing relationship between aging and agricultural infrastructure construction, and Gonzáles-Gonzáles and Nogués (2019) have shown that aging can affect rural transportation infrastructure investment through multiple channels, but the literature of the same type of research needs to be further enriched. From the literature, aging has an inhibitory effect on the enhancement of agricultural GTFP, while the construction of agricultural infrastructure can effectively enhance agricultural GTFP, so can the positive effect of the latter offset the negative inhibitory effect of the former? In other words, whether strengthening agricultural infrastructure construction can alleviate the inhibitory effect of aging on the increase of agricultural total factor productivity, and how to realise these effects need to be analysed theoretically and verified empirically.

The idea of this paper is to theoretically analyse the relationship between aging, agricultural infrastructure construction and agricultural GTFP, based on provincial panel data from 2004 to 2022, adopt the super-efficient EBM-GML model to measure agricultural GTFP as an independent variable, and use the individual fixed-effects model to carry out the aging, agricultural infrastructure construction and control variables in a regression to verify the relationship between the three; analyse the mechanism of the role of agricultural infrastructure construction in promoting agricultural GTFP and analyse the heterogeneity of the role from two perspectives: east, central and west and main food-producing areas and non-main food-producing areas. The marginal contributions of this paper are as follow:

i) It is found that agricultural infrastructure construction has the effect of alleviating the aging inhibition of the increase of agricultural GTFP.

ii) Different agricultural infrastructure construction has different effects on the promotion of agricultural GTFP.

iii) The promoting effect of agricultural infrastructure construction on agricultural GTFP is realised by promoting farmland transfer and the development of agricultural mechanisation.

MATERIAL AND METHODS

Theoretical analysis and research hypothesis

The relationship between aging, agricultural infrastructure development and agricultural GTFP. With the development of urbanisation and a large number of rural labor force non-agricultural transfer, the current agricultural production operators are still mainly old farmers. The aging of agricultural labour force has caused serious impacts on agricultural production, and the decline in the quantity and quality of agricultural labor inputs, caused by the diminishing capacity of the aging labor force has caused agricultural production to face unprecedented challenges. Especially in terms of agricultural GTFP, the inhibition brought by aging has become more obvious. Agricultural infrastructure construction can effectively improve agricultural production efficiency, promote green agricultural practices and enhance the ability of agriculture to withstand risks. Therefore, in the deepening degree of aging, strengthening the construction of agricultural infrastructure can provide a platform for agricultural socialised services, improve the accessibility of services and reduce the cost of services. The involvement of agricultural socialised services that can effectively help elderly farmers to ensure agricultural production efficiency, realise green agricultural production and enhance the ability of agriculture to resist risks, etc. For example, the construction of irrigation infrastructure and elec-

https://doi.org/10.17221/273/2024-AGRICECON

tric power infrastructure can provide a platform for agricultural socialised services to effectively provide services to elderly farmers, and the construction of rural information and communication infrastructure can enable farmers to access agricultural socialised services remotely. Agricultural socialised services can effectively offset the dampening effect of aging on agricultural GTFP through the platform provided to them by the construction of agricultural infrastructure.

Therefore, this paper presents the following hypothesis:

H_1: Agricultural infrastructure construction can promote the improvement of agricultural green total factor productivity.

H_2: Agricultural infrastructure construction can alleviate the inhibiting effect of aging on agricultural GTFP to a certain extent.

The relationship between different types of agricultural infrastructure construction and agricultural GTFP. The agricultural infrastructure in the text can be divided into agricultural water conservancy, rural electricity and rural information and communication infrastructure. The aging of the agricultural labor force is becoming more and more prominent, the relationship between different types of agricultural infrastructure construction and agricultural GTFP has differences.

i) A perfect rural electricity infrastructure can provide power for agricultural machinery, which can reduce the operating costs of agricultural machinery and environmental pollution while also improving operational efficiency and can also solve the problem of insufficient input of agricultural labor due to aging. Therefore:

$H_{1\text{-}1}$: Rural electricity infrastructure construction can promote the improvement of agricultural green total factor productivity.

ii) Perfect agricultural water conservancy infrastructure can promote the development of agricultural green total factor productivity (Zhang and Wu 2024), which can improve the efficiency of water resource utilisation and optimise the input structure. Such as: water storage projects and water resource management systems, which can guarantee the normal supply of water for agricultural production while also effectively preventing the waste of water resources; Water-saving drip irrigation systems and sprinkler irrigation systems can accurately control the supply of water and nutrients, which can reduce the cost of irrigation while also reduce environmental pollution. In the face of the elderly labor force who are difficult to engage in labor-intensive agricultural irrigation activities. Efficient agricultural water conservancy infrastructure can help elderly farmers achieve effective irrigation through factor substitution, effectively promoting the green total factor productivity of agriculture. Therefore:

$H_{1\text{-}2}$: Agricultural water conservancy infrastructure construction can promote the improvement of agricultural green total factor productivity; promote agricultural green total factor productivity improvement is proposed.

iii) Adequate rural information and communication infrastructure construction can enable farmers to obtain accurate agricultural production and market information, improve the efficiency of agricultural production factor inputs, which can reduce production costs and the degree of mismatch of production resources, reduce environmental pollution in agricultural production while increasing output value. However, the old farmers have biggish digital divide compared with younger farmers, this leads to the lack of them with familiarity, willingness to learn and cognitive ability of information and communication equipment. So, for the old farmers, there may not be obvious or absent the promotion effect of rural information and communication infrastructure construction on agricultural green total factor productivity improvement. Therefore:

$H_{1\text{-}3}$: There is no significant relationship between rural information and communication infrastructure and agricultural green total factor productivity.

Data sources

This study collects provincial panel data of 31 provinces from 2004 to 2022 (among them, Hong Kong, Macao and Taiwan Special Administrative Regions are excluded from this paper because of the large number of missing data). The data are mainly from Chinese Statistical Yearbook, China Population and Employment Statistical Yearbook, Ministry of Agriculture and Rural Affairs of China, Chinese Transportation Statistical Yearbook, Chinese Agricultural Machinery Industry Yearbook, Chinese Rural Statistics Yearbook and the official websites of the statistical bureaus of various provinces and cities. Some missing values or outliers in the presence of data were smoothed, supplemented and corrected by the mean method. Since most of the data in this paper are relative indicator variables such as percentage, proportion and ratio, the absolute indicator variables are logarithmised in order to reduce the heteroskedasticity among the variables.

Variable selection and measurement

Dependent variable: Agriculture GTFP. Regarding the measurement of GTFP, it can be traced back

https://doi.org/10.17221/273/2024-AGRICECON

as far as 1997, when Chung et al. (1997) introduced non-expected outputs into the measurement of directional distance functions when measuring GTFP. In the early domestic research, the measurement of GTFP mostly followed such methods, but with the deepening of research, its measurement methods have become increasingly diversified. There are mainly the Solow's method of residual values (Liu et al. 2021), the data netback as far as 1997, the data envelopment analysis method (Guo et al. 2020; Wang et al. 2017; Li et al. 2020) and the stochastic frontier method (Liu et al. 2024), and at the present, the data envelopment analysis method and its derivatives are mainly used to measure the agricultural GTFP, Includes radial and hybrid distance functions from relaxing linear constraints or making angular corrections (Liu et al. 2021). Since traditional data envelopment analysis (DEA) models do not take into account non-expected outputs, the measured results may be biased, and the improved super-efficient slack-based reference (SBM) is clearly a non-radial model and cannot deal with the radial problem (Lei et al. 2020). Coupled with the fact that factor inputs such as labor, capital, and land have a non-radial relationship with outputs, and environmental pollution has a radial relationship with outputs, this study adopts the super-efficient epsilon-based measure (EBM) model that can be compatible with both radial and non-radial distance functions (Pastor 2005; Fan et al. 2022), while the global Malmquist-Luenberger (GML) index can effectively circumvent the problem of the possible absence of a feasible solution, and also satisfy the requirements of circularity and transferability. Therefore, the paper constructs the super-efficiency EBM-GML model including non-expected output to measure agricultural GTFP index.

First, the formula of the super-efficiency EBM model is as follows:

$$\gamma = \min \frac{\theta - \omega_x \sum_{r=1}^{n} \frac{\omega_r^- S_r^-}{x_{rh}}}{\varphi + \omega_{y_G} \sum_{c=1}^{n} \frac{\omega_c^+ S_c^+ - \mu}{x_{rh}} + \omega_{y_G} \sum_{z=1}^{1} \frac{\omega_z^- S_z^-}{y_{Bzh}}} \tag{1}$$

$$s.t. \begin{cases} X\delta + s_r^{\ -} = \theta x_r, r = 1,2,\ldots,n \\ Y_G\delta - s_c^{\ +} = \varphi y_{Gh}, c = 1,2,\ldots,m \\ Y_B\delta + s_z^{\ -} = \varphi y_{Bh}, z = 1,2,....,l \\ \sigma \geq 0, s_r^{\ -}, s_c^{\ +}, s_z^{\ -} \geq 0 \end{cases}$$

where: y(0 ≤ y ≤1) – optimal efficiency value; X, Y_G and Y_B – r kind of input, c kind of desired output and z kind of non-desired output respectively, all of them are positive numbers; ω_r^-, ω_c^+, ω_c^+ and S_r^-, S_c^+, S_z– weights and the relaxation variables of the r kind of input, c kind of desired output and z kind of non-desired output respectively; $\omega(0 \leq \omega \leq 1)$ – integrated radial efficiency value ω and the important parameters of the non-radial slack variables; h – number of decision units.

Combining technical efficiency γ, the GML index has been constructed as follows:

$$G^{t,t+1}(x^t \times y_G^{\ t} \times y_B^{\ t} \times x^{t+1} \times y_G^{\ t+1} \times y_B^{\ t+1}) = = \frac{\gamma^{G,t+1}(x^{t+1} \times y_G^{\ t+1} \times y_B^{\ t+1})}{\gamma^{G,t}(x^t \times y_G^{\ t} \times y_B^{\ t})} \tag{2}$$

where: $y^{G,t}$ and $y^{G,t+1}$ – global efficiency values in period; t and period $t+1$ respectively; t – year; $G^{t,t+1}$ – agricultural GTFP index from period t to period $t+1$. Taking 2004 as the base period, the results of the calculations of the following years are cumulatively accumulated, and then agricultural GTFP of each province can be obtained.

Input indicator

Referring to previous studies (Zhu et al. 2022; Luo et al. 2023), fertilisers, pesticides, agricultural films, agricultural machinery, agricultural labor and land resources were selected as agricultural production input indicators, the green full factor production efficiency indicator system for agriculture was constructed (Table 1).

Non-expected output indicator

Referring to the study of Gong et al. (2020) and Yu et al. (2023), the carbon emissions from agriculture were calculated from six aspects, including fertiliser, pesticide, irrigation, agricultural film, diesel fuel and tilling. The measurement formula has been constructed as follows:

$$E_{it} = \sum_{j=1}^{n} E_j = \sum_{j=1}^{n} T_j \varpi_j \tag{3}$$

where: E^{it} – total amount of carbon emissions from agricultural production activities in the ith province and year t; E_j – amount of carbon emissions from the j^{th} agricultural production carbon emission source in the agricultural generation carbon emission source; T_j – amount

https://doi.org/10.17221/273/2024-AGRICECON

of the j^{th} carbon emission source and denotes the carbon emission coefficient of the jth carbon emission source. The carbon emission coefficient of each carbon emission source is shown in Table 2.

Independent variables.

The core independent variables selected in the paper are as follows:

i) Level of agricultural infrastructure construction. The level of agricultural water conservancy, rural electric power and rural information and communication infrastructure construction are selected as the measurement indicator. As the entropy weight method objectively determines the weight of each indicator, it avoids the subjective interference of human factors and makes the evaluation results more objective and fairer. Therefore, this paper adopts the entropy weight method to measure the level of agricultural infrastructure construction, which first calculates the entropy value of each indicator to determine its weight, and then calculates the value of the comprehensive indicator and uses it to indicate the level of agricultural infrastructure construction. The same below.

The selected sub-indicator independent variables are as follows:

i) Rural electricity infrastructure construction. The comprehensive evaluation scores of rural power station distribution density and rural *per capita* annual electricity consumption are selected to indicate.

ii) Agricultural water conservancy infrastructure construction. The comprehensive evaluation scores of the effective irrigation rate of agriculture, the distribution density of agricultural reservoirs, and the rate of flood removal are chosen to represent it.

iii) Rural information and communication infrastructure construction. It is expressed by the comprehensive evaluation scores of the coverage rate of rural broadband access, the proportion of administrative vil-

Table 1. Agricultural green total factor productivity index system

First indicators	Elementary indicators	Secondary indicators	Methods of measurement	Unit
Input indicators	labor factor inputs	labour input	number of people working in agriculture	ten thousand people
	capital factor inputs	machinery input	gross power of agricultural machines	ten thousand kilowatts
		fertiliser input	agricultural fertilisers applied in pure form	ten thousand tons
		pesticide input	usage amount of pesticide	tons
		agricultural film input	usage amount of agricultural plastic film	tons
	land factor inputs	land input	agricultural sown area	thousand hectares
Expected output indicator	–	gross agricultural product	gross value of agricultural production	hundred million (EUR)
Non-expected output indicator	–	carbon footprint	total carbon emissions from agriculture	tons

Source: National Compendium of Cost-Benefit Information on Agricultural Products (2004–2022)

Table 2. Carbon emission coefficient of each carbon emission source

Carbon emission ources	Carbon emission coefficient	Carbon emission sources	Carbon emission coefficient
Fertiliser	0.8956 kg·kg^{-1}	diesel fuel	0.5927 kg·kg^{-1}
Pesticides	4.9341 kg·kg^{-1}	agricultural plastic film	5.1800 kg·kg^{-1}
Irrigation	266.4800 kg·hm^{-2}	tillage	312.6000 kg·hm^{-2}

Source: Gong et al. (2020); Yu at al. (2023)

https://doi.org/10.17221/273/2024-AGRICECON

lages with postal service, and the density of rural delivery routes.

ii) Aging. Which has been expressed by the rural elderly population dependency ratio. The rural elderly population dependency ratio is the ratio of the number of older persons to the number of persons of working age in the population, usually expressed as a percentage, indicating the number of older persons per 100 persons of working age. The dependency ratio of the rural elderly population is one of the indicators of the ageing of the rural population from an economic point of view. The formula is:

$$ODR_{rural} = \frac{P_{rural65+}}{P_{rural15-64}} * 100\% \quad (4)$$

where: ODR_{rural} – dependency ratio of the rural elderly population; $P_{rural\ 65+}$ – number of rural elderly population aged 65 and above; $P_{rural\ 15-64}$ – number of rural population of working age.

Control variables. Different agricultural labor input, agricultural development status and resource consumption degree in each province will lead to heterogeneity in agricultural GTFP. Referring to the studies of Cheng-kun (2021) and Sun and Zhang (2021) the following control variables are chosen to control the heterogeneity:

i) Agricultural labor force. The total number of people employed in agriculture is chosen to indicate it, In the context of the growing aging problem, the higher the total number of people employed, the more it offsets the depressing effect of insufficient labor inputs from aging farmers on agricultural GTFP.

ii) Economic structure. The ratio of agricultural gross domestic product (GDP) to local GDP is chosen to indicate it, the higher the ratio, indicating the more important agriculture is in the local economy, and the more importance local governments and all sectors of society attach to agriculture, the more it can promote the improvement of agricultural GTFP.

iii) Cultivation structure. The ratio of the sown area of cash crops to the total sown area of crops is chosen to indicate it, in the face of the aging problem that is becoming more and more prominent, since the unit economic benefit of cash crops is higher than that of food crops, therefore, in the face of the problem of insufficient labor inputs brought about by the aging problem, increasing the sown area of cash crops can increase the total value of agricultural output, and promote the enhancement of agricultural GTFP.

iv) Agricultural irrigation water utilisation rate. The ratio of the effective watering area to the total sown area of crops is chosen to indicate it. The agricultural irrigation water is an important input factor for agricultural production. Improving the utilisation rate of agricultural irrigation water that can not only meet the water demand of crops and increase agricultural production efficiency, but also reduce the cost of agricultural irrigation water. This reduces the cost of agricultural production and water pollution, protects the agro-ecological environment, and promotes the enhancement of agricultural GTFP.

v) Urbanisation rate. The ratio of urban population to total population is chosen to indicate it. The higher the urbanisation rate, the greater the non-agricultural transfer rate of agricultural labor force, the loss of agricultural labor force will inhibit the improvement of agricultural GTFP.

vi) Resource consumption. The consumption of diesel fuel in agriculture is chosen to represent, the increase in diesel fuel resource consumption will lead to the increase of carbon emission and the rise of production cost, which will inhibit the improvement of agricultural GTFP.

Mediating variables. The following mediating variables are selected in the paper.

i) Farmland transfer. The ratio of the total area of rural farmland transfer to the total cultivated area in each province is chosen to denote it.

ii) Agricultural mechanisation. The composite evaluation scores of machines plowing rate, machine sowing rate and machine harvesting rate were selected to denote it. The specific definitions of variables and descriptive statistics are shown in Table 3.

Model setting

i) In order to clarify the relationship between aging, agricultural infrastructure construction and agricultural green total factor productivity, a panel data model of aging, agricultural infrastructure construction and agricultural green total factor productivity is constructed in the paper as follows:

$$Lngtfp_{it} = \alpha_0 + \beta X_{it} + \eta Controls_{it} + u_i + \lambda_t + \varepsilon_{it} \quad (5)$$

where: i – region; t – year; $Lngtfp_{it}$ – logarithm of the construed variable agricultural green total factor productivity; α_0 – constant term; X_{it} – independent variable group; $Controls_{it}$ – control variable group; β and η – coefficients which need to be estimated; u_i – individual fixed effect; λ_t – time fixed effect; ε_{it} – random disturbance term.

https://doi.org/10.17221/273/2024-AGRICECON

Table 3. Variable definitions and descriptive statistics

Variable type	Variable name	Variable symbol	Mean	Standard deviation
Construed variables	agricultural green total factor productivity	*gtfp*	0.795	0.1940
Core independent variables	agricultural infrastructure construction	*infrast*	0.511	0.1640
	aging	*aging*	0.348	0.3280
Sub-indicator independent variables	agricultural water infrastructure construction	*water*	0.238	0.3700
	rural electricity infrastructure construction	*electric*	0.256	0.1540
	rural information and communication infrastructure construction	*internet*	0.164	0.0680
Control variables	agricultural labour force	*labour*	4.737	1.0680
	economic structure	*industry*	0.109	0.0580
	cultivation structure	*plant*	0.144	0.0950
	agricultural irrigation water utilisation rate	*iIrriga*	0.443	0.1980
	urbanisation rate	*urban*	0.551	0.1499
	resource consumption	*resour*	64.826	64.9050
Mediating variables	farmland transfer	*land*	0.782	0.1170
	agricultural mechanisation	*mechan*	0.078	0.1170

Source: Author's own calculation using STATA – statistical analysis app

ii) In order to investigate whether agricultural infrastructure construction can alleviate the inhibiting effect of aging on agricultural GTFP to a certain extent, the benchmark regression model constructed in the article is:

$$Lngtfp_{it} = \alpha'_0 + \beta'_1 infrast_{it} + \beta'_2 aging_{it} + \\ + \beta'_3 Lnaging.infrast_{it} + \eta Controls_{it} + u_i + \lambda_t + \varepsilon_{it} \quad (6)$$

where: $Lngtfp_{it}$ – logarithm of the constructed variable GTFP; $Lnaging.infrast_{it}$ – logarithm of the interaction term between agricultural infrastructure construction and aging; α'_0 – constant term; β' – coefficient to be estimated; η – constant to be estimated; u_i – individual fixed effect; λ_t – time fixed effect; ε_{it}– random disturbance term.

iii) In the context of the aging problem is increasingly prominent situation, in order to refine the impact of different types of agricultural infrastructure construction on the agricultural green full factor production efficiency. The baseline econometric model constructed in the paper is:

$$Lngtfp_{it} = a_0 + a_1 water_{it} + \eta Controls_{it} + u_i + \lambda_t + \varepsilon_{it} \quad (7)$$

$$Lngtfp_{it} = b_0 + b_1 electric_{it} + \eta Controls_{it} + u_i + \lambda_t + \varepsilon_{it} \quad (8)$$

$$Lngtfp_{it} = c_0 + c_1 iternet_{it} + \eta Controls_{it} + u_i + \lambda_t + \varepsilon_{it} \quad (9)$$

where: $water_{it}$ – agricultural water infrastructure construction; $electric_{it}$ – rural electric power infrastructure construction; $internet_{it}$ – rural information and communication infrastructure construction; *a, b* and *c* – coefficients to be estimated.

In order to avoid the bias of estimation results which caused by the correlation between variables, this text has used the variance inflation factor (VIF) index to test the problem of multicollinearity between variables. The test result shows that the average VIF is 2.6, and the maximum value is 3.86, all of them are less than 10, which are within the reasonable range of the test. So, there is no multicollinearity problem between variables.

RESULTS

Benchmark regression

This paper has used the individual fixed effects model to regress and analyse the relationship between aging, agricultural infrastructure construction and agricultural green total factor productivity. The regression results are shown in Table 4. Column (1) shows that the aging significantly inhibits the improvement of agricultural GTFP at the level of 0.01; Column (2) shows that after adding the agricultural infrastructure construction to the regression equation, the regression coefficient of agricultural infrastructure construction

https://doi.org/10.17221/273/2024-AGRICECON

is significantly positive at the level of 0.01, while the coefficient of aging is still negative at the level of 0.01, but the absolute value is reduced. Which indicates that agricultural infrastructure construction can promote the increase of agricultural GTFP significantly, and may also alleviate the inhibiting effect of aging on agricultural GTFP to a certain extent. At the same time, in order to verify whether agricultural infrastructure construction can alleviate the inhibitory effect of aging on agricultural GTFP. The interaction term (taking the natural logarithm) of aging and agricultural infrastructure construction is added into the regression equation (Equation 5) to analyse the alleviation effect of agricultural infrastructure construction on the inhibitory effect of aging on agricultural GTFP. The results show that the regression coefficient of the cross-multiplier term is significantly positive at the level of 0.01, at this time, the coefficient of agricultural infrastructure construction is still significantly positive. Which have indicated that, first, the agricultural infrastructure construction has a promotional effect on agricultural GTFP , verifying hypothesis H_1; second, the agricultural infrastructure construction also can indeed alleviate the inhibitory effect of aging on agricultural green total factor production to a certain extent, verifying hypothesis H_2.

Different agricultural infrastructure construction also has different effect on agricultural GTFP. Therefore, this paper used the agricultural infrastructure construction with agricultural water conservancy,

Table 4. Benchmark regression results of the impact of agricultural infrastructure construction on agricultural GTFP

Variant	(1) *Lngtfp*	(2) *Lngtfp*	(3) *Lngtfp*	(5) *Lngtfp*	(4) *Lngtfp*	(6) *Lngtfp*
Infras	–	0.2200*** (0.0509)	0.1750*** (0.0524)	–	–	–
Electric	–	–	–	0.1230*** (0.0254)	–	–
Water	–	–	–	–	0.0950** (0.0408)	–
Internet	–	–	–	–	–	–0.0509 (0.0460)
Aging	–0.2960*** (0.1020)	–0.2790*** (0.1000)	–0.3170*** (0.1000)	–0.2900*** (0.0999)	–0.2880*** (0.1020)	–0.3070*** (0.1020)
Lnaging.infrast	–	–	0.1460*** (0.0459)	–	–	–
Lnlabour	0.2720** (0.1370)	0.1970 (0.1360)	0.4320*** (0.1540)	0.2600* (0.1350)	0.2550* (0.1370)	0.2860** (0.1380)
Lnindustry	0.2400*** (0.0319)	0.2490*** (0.0315)	0.2210*** (0.0325)	0.2590*** (0.0315)	0.2440*** (0.0318)	0.2430*** (0.0320)
Plant	0.6500*** (0.1920)	0.6450*** (0.1890)	0.6960*** (0.1880)	0.6290*** (0.1880)	0.6140*** (0.1920)	0.6440*** (0.1920)
Irriga	0.3690*** (0.0828)	0.3360*** (0.0818)	0.3720*** (0.0820)	0.3130*** (0.0820)	0.3340*** (0.0839)	0.3640*** (0.0829)
Urban	0.7410*** (0.1440)	0.4840*** (0.1540)	–0.5670 (0.3640)	0.7390*** (0.1410)	0.7100*** (0.1440)	0.8470*** (0.1730)
Lnresour	–0.04320** (0.0187)	–0.0319* (0.0186)	–0.0356* (0.0185)	–0.0455** (0.0184)	–0.0442** (0.0187)	–0.0480** (0.0192)
Constant	–1.4150** (0.7020)	–0.9870* (0.6980)	–1.2910* (0.6990)	–1.3020* (0.6890)	–1.3200* (0.7010)	–1.4990** (0.7060)
N	589	589	589	589	589	589

*,**,*** denote significant at the 10, 5 and 1% levels, respectively, with standard errors in parentheses.
Source: Author's own calculation using STATA – statistical analysis app

https://doi.org/10.17221/273/2024-AGRICECON

rural electricity and rural information and communication infrastructure construction to replace the agricultural infrastructure construction, and making them respectively as independent variables (Equation 7–9). To refine and analyse the relationship between different types of agricultural infrastructure construction and agricultural GTFP under the situation of the aging problem becoming more and more prominent. The regression results are shown in Table 4: The coefficient of rural electric power infrastructure construction is positive at the level of 0.01, indicating that rural infrastructure construction significantly promotes agricultural GTFP under the situation of increasing aging problem, which verifies hypothesis H_{1-1}; The coefficient of agricultural water conservancy infrastructure construction is significantly positive at the level of 0.05, which indicates that under the situation of increasing aging problem, the agricultural water infrastructure construction significantly promotes agricultural GTFP enhancement, which verifies hypothesis H_{1-2}; But the coefficient of rural information and communication infrastructure construction is not significant, indicating that the relationship between rural information and communication infrastructure construction and agricultural GTFP is not significant under the situation of aging problem becoming more and more prominent, which verifies hypothesis H_{1-3}.

Among them, the promotion effect of rural electricity infrastructure development on agricultural GTFP is the largest and most obvious, followed by the agricultural water conservancy infrastructure construction. While the relationship between rural information and communication infrastructure construction and agricultural GTFP is not significant. This phenomenon may be due to the following reasons: First, the rural electricity infrastructure can provide reliable power for agricultural machinery, which can reduce the labor intensity of farmers while reducing the use of environmentally unfriendly energy sources, such as diesel gasoline, to improve agricultural productivity and protect the agro-ecological environment; Second, the difficulties of aging farmers in mastering and using information and communication technologies can limit their access to agricultural information and technologies.

Endogeneity test

In the paper, when studying the study of the relationship between aging background, agricultural infrastructure construction and agricultural GTFP, it is necessary to continue the endogeneity test because it was caused by the possible endogeneity between the independent variables and the dependent variable. Because agricultural infrastructure construction is a slow process that takes time to plan, finance, and build, lagged agricultural infrastructure construction is correlated with current agricultural infrastructure construction; And lagged agricultural infrastructure construction is not correlated with the error term, which is usually caused by short-term factors (example for weather, policy changes, or economic shocks); Furthermore, lagged agricultural infrastructure construction can only impact on agricultural GTFP through current agricultural infrastructure construction, and does not affect agricultural GTFP through other channels or directly.

Therefore, the lagged item of agricultural infrastructure construction is used as an instrumental variable for the independent variable agricultural infrastructure construction, and its endogeneity is tested by using Hausman test, and the test results show that the P-value is $0.0000 < 0.0500$, which indicates that there is endogeneity of the independent variable agricultural infrastructure construction. The weak instrumental variable test shows that the Cragg-Donald Wald F statistic was 96.85, which is greater than the 10% maximum IV size critical value of 16.38. This result indicates that the instrumental variable is well identified; The over-identification test shows that the Sargan statistic was 0.000, which means that the equation is just rightly identified. Overall, the instrumental variables selected in the paper are reliable.

The endogeneity test results are shown in Table 5, after considering endogeneity, the regression coefficient of agricultural infrastructure construction is 0.498 at the level of 0.01, which is within a reasonable range of a 2.26-fold change compared to the benchmark regression results. Therefore, after considering the problem of endogeneity of independent variables, agricultural infrastructure construction still significantly promotes the improvement of agricultural GTFP, which is consistent with the benchmark regression results, indicating that the benchmark regression results are reliable.

Further, regarding endogeneity due to mutual causality, drawing on Zhou et al. (2024), the lagged one-period of agricultural infrastructure construction is regressed as the core explanatory variable, and the fixed effect model is used for the regression. The results show (Table 5) that the lag one period is also positively significant at the 0.01 level, which is consistent with the baseline regression results, and once again verifies that

https://doi.org/10.17221/273/2024-AGRICECON

the construction of agricultural infrastructure can promote the improvement of agricultural GTFP.

Robusteness test

Since the use of different core independent variables and estimation methods can test whether the benchmark regression results are robust and whether the regression model is set up incorrectly. Therefore, this paper selected replacing the core independent variables and estimation methods to test the robustness of the benchmark regression results.

i) Replacing the core explanatory variable. Since only agricultural infrastructure construction and aging are selected as core independent variables in the paper, the simplicity of the variables may cause the empirical research results to have a certain degree of fortuity, therefore, the investment in agricultural infrastructure construction (using the rural fixed assets investment as a measurement index, and taking the natural logarithm) is selected to replace the core independent variable of agricultural infrastructure construction, to check the robustness of the results of the benchmark regression. The test results are shown in Table 6: The coefficient of investment in agricultural infrastructure construction is positive at the level of 0.1, which means it significantly promotes the improvement of the agriculture green full factors production efficiency. The test result is consistent with the benchmark regression result, indicating that the basic conclusions are robust.

ii) Replacing the estimation method. In the paper, replacing xtreg estimation with both xtgls and xtpcse estimation for testing the robustness of the benchmark regression result again. The test results are shown in Table 6: After changing the measurement method, the agricultural infrastructure construction is still significantly positive at the level of 0.01, which mean the agricultural infrastructure construction can significantly promote the improvement of agricultural GTFP. The two test results all are consistent with the baseline regression results, which again verifies that the basic conclusion is robust.

iii) Shrink-tailed treatment. In order to mitigate the interference of outliers on the regression analysis, this paper adjusts all variables by shrinking the tails at the 1% level. It aims to improve the stability of the data and the accuracy of the regression results. As can be seen from Column (4) of Table 6, the regression results are almost consistent with the benchmark regression, proving that building agricultural infrastructure can increase agricultural GTFP.

iv) Dependent variables lagged one period. The effect of agricultural infrastructure development on agricultural GTFP may have one lag. in order to test the robustness, the paper awards the dependent variables in the regression model with one lag. Column (5) of Table 6 shows that the regression results with one lag are still positive and significant at the 0.01 level, thus confirming the robustness of the benchmark regression results.

Mechanism of action analysis

The promotion effect of agricultural infrastructure construction on agricultural GTFP, which can also

Table 5. Results of the endogeneity test

Variant	Instrumental variable regression		One period lagged regression
	(1) first stage	(2) second stage	(3) third stage
	Infrast	*Lngtfp*	*Lngtfp*
Infrast	–	0.4980*** (0.1280)	–
L. infrast	0.4140*** (0.4210)	–	0.2080*** (0.0516)
Aging	–0.0930 (0.0800)	–0.2250** (0.1010)	–0.2920*** (0.0993)
Controls	YES	YES	YES
R2	–	0.2000	0.2430
Prob>F	0.000	–	0.0000
N	589	589	589

*,**,*** denote significant at the 10, 5 and 1% levels, respectively, with standard errors in parentheses.
Source: Stata/SE 15.1

https://doi.org/10.17221/273/2024-AGRICECON

Table 6. Robustness test results of the impact of agricultural infrastructure on agricultural GTFP

Variant	Replacing independent variables	Replacing estimation methods		Shrink-tailed treatment	Dependent variables lagged one period
	(1) cloglog	(2) xtgls estimates	(3) xtpcse estimates	(4) cloglog estimates	(5) cloglog estimates
Infrastr	–	0.05200*** (0.01520)	0.17200*** (0.04620)	0.23100*** (0.05040)	0.22600*** (0.05050)
Invest	0.03410*** (0.00697)	–	–	–	–
Aging	–0.24800** (0.10000)	-0.08770*** (0.02830)	-0.35700*** (0.10200)	-0.30000*** (0.10100)	-0.12800* (0.10100)
Cnontrols	YES	YES	YES	YES	YES
Constant	-1.14600* (0.69000)	0 (0)	-42.71000*** (9.93900)	-0.87900 (0.67800)	-1.02900 (0.72400)
N	589	589	589	589	558

*,**,*** denote significant at the 10, 5 and 1% levels, respectively, with standard errors in parentheses.
Source: Stata/SE 15.1

be realised by promoting the farmland transfer and the agricultural mechanisation development.

The aging of agricultural labor force can increase the probability of farmers quitting agricultural production, which main ways are to abandon and transfer out the farmland (Qiu et al. 2023). As the agricultural labor force enters into the low old-age period from the non-old-age period, then to the high old-age period, the probability of old-age farmers who transfer out or abandoning farmland will become significantly higher (Wang et al. 2017). Perfect agricultural infrastructure construction can better promote the orderly transfer of rural land (Ding and Zhong 2017), and the concentrated scale operation of farmland can effectively promote the enhancement of agricultural GTFP (Song et al. 2024). Therefore, perfect agricultural infrastructure construction can promote the transfer of farmland, and change the situation of the decline of agricultural GTFP caused by the low utilisation of farmland resources of the aging labor force.

In addition, the aging farmers diminishing ability in all aspects will make their labor inefficient in the labor of plough, sowing and harvesting, and the agricultural machinery can make up for this shortage well. Perfect agricultural infrastructure construction can provide better operating conditions for agricultural mechanisation, change the situation of high production cost and low agricultural green full factor production efficiency which caused by the aging laborers due to their diminished capacity. For example, the rural power infrastructure construction can provide the necessary energy guarantee for agricultural mechanisation operations. Therefore, perfect agricultural infrastructure construction can improve the agricultural green full factor production efficiency by promoting the development of agricultural mechanisation.

In the circumstance that aging problem is increasingly prominent situation, in order to test farmland transfer and agricultural mechanisation whether have mediating effect in the promotion effect of agricultural infrastructure construction on agricultural GTFP. This paper constructed the mediating effect model as folows:

$$\begin{cases} Lngtfp_{it} = \theta_1 + dinfrast_{it} + \eta Controls_{it} + e_1 \\ M_{it} = \theta_2 + \kappa infrast_{it} + \eta Controls_{it} + e_2 \\ Lngtfp_{it} = \theta_3 + d' infrast_{it} + d'' M_{it} + \eta Controls_{it} + e_3 \end{cases} \quad (10)$$

where: M_{it} are the mediating variables; θit – constant term; *d, d'* and *d''* – coefficients to be estimated, e – random error term.

The analysis of the mechanism of action found that, In the circumstance that aging problem is increasingly prominent situation, the agricultural infrastructure construction promotes the increasing of agricultural GTFP, which can also be achieved by promoting the farmland transfer and agricultural mechanisation development. For this reason, this paper adopts mechanism of action tests the model (Equation 10) to test the mediating effect role of farmland transfer and agricultural mechanisation development in the

https://doi.org/10.17221/273/2024-AGRICECON

impact of agricultural infrastructure construction on agricultural GTFP. In order to ensure the comparability of the regression results, this paper adopts the individual fixed effect model as regression estimation in the mechanism of action too.

As shown in Table 7: In the circumstance that aging problem is increasingly prominent situation. Column (2) reflects that the agricultural infrastructure construction significantly promotes farmland transfer at the level of 0.01; Column (3) reflects that the investment in agricultural infrastructure significantly promotes the transfer of farmland at the level of 0.01, which indicates that the regression results of column (2) is robust and reliable; Column (4) reflects that farmland transfer significantly promotes the increasing of agricultural GTFP at the level of 0.01. At the same time, the agricultural infrastructure construction also significantly promotes agricultural GTFP at the level of 0.01, which indicates that, in the circumstance that aging problem is increasingly prominent situation, the farmland transfer has a significant mediating effect in the influence of the agricultural infrastructure construction on agricultural GTFP.

As shown in Table 8: In the circumstance that aging problem is increasingly prominent situation. Column (2) shows that the agricultural infrastructure construction significantly promotes the development of the agricultural mechanisation at the level of 0.05; Column (3) shows that the investment in agricultural infrastructure significantly promotes the development of the agricultural mechanisation at the level of 0.01, which can indicate that the regression results of column (2) are robust and reliable; Column (4) shows that the agricultural mechanisation significantly promotes the increasing of agricultural GTFP at the level of 0.01, at the same time, agricultural infrastructure construction also significantly promotes the increasing of agricultural GTFP at the level of 0.01. Those results all can indicate that in the circumstance that aging problem is increasingly prominent situation, the agricultural mechanisation development has a significant mediating effect in the influence of the agricultural infrastructure construction on agricultural GTFP.

The Bootstrap method is then used to further verify that, in the circumstance that aging problem is increasingly prominent situation, the mediating effects of farmland transfer and agricultural mechanisation development in the impact of agricultural infrastructure on agricultural GTFP. The test results show that the confidence intervals of both direct and indirect effects do not contain zero value. i.e., the farmland transfer and agricultural mechanisation development not only have a direct effect on agricultural GTFP , but also hold their mediating effect. And the test results of the mediating effect show that both the farmland transfer and agricultural mechanisation are significant at the level of 0.01, which suggests that the promotion of the agricultural infrastructure on agricultural GTFP, to a certain extent, it is achieved by agricultural infrastructure construction by promoting the development of farmland transfer and agricultural mechanisation. The results again indicates that farmland transfer and agricultural mechanisation development have a significant mediating effect in the promotion effect of agricultural infrastructure construction on agricultural GTFP.

Further analysis

Because there are obvious differences in the level of economic development, natural resource endowment and topography and geomorphology of each region, which will lead to regional heterogeneity in the positive impact of agricultural infrastructure construction on agricultural GTFP in each region. In order to scientifically reflect the socio-economic development of different regions in China and provide a basis for the formulation of regional development policies, the National Bureau of Official Statistics of China divides China into four major economic regions, namely, eastern, central, western and northeastern China, and the study of agricultural GTFP through the division of the four major economic regions , which contributes to find out the gaps and potentials of the regions in the greening of agriculture and provides a basis for the adoption of targeted measures to promote the balanced development of the regional economy. This will provide a basis for taking targeted measures to promote balanced regional economic development: Because there are significant differences between major food-producing regions and non-major food-producing regions in natural conditions, national agricultural policies and subsidies, and agricultural production efficiency and sustainability, the division of major food-producing regions and non-major food-producing regions in the study of agricultural GTFP can help to gain a deeper understanding of the characteristics of and differences in agricultural production in different regions, and provide a scientific basis for formulating strategies to improve agricultural green production efficiency and sustainable development.

The regression results, as shown in Table 9: Compared with the main food-producing regions and the

https://doi.org/10.17221/273/2024-AGRICECON

Table 7. Test of the intermediary effect of farmland transfer in the influence of agricultural infrastructure construction on agricultural GTFP

Variant	(1) *Lngtfp*	(2) *Land*	(3) *Land*	(4) *Lngtfp*
Infrast	0.22000*** (0.05090)	0.01150*** (0.00316)	–	0.18700*** (0.05070)
Aging	–0.27900*** (0.10000)	0.03700*** (0.00623)	0.04560*** (0.00621)	–0.38700*** (0.10200)
Invest	–	–	0.00690*** (0.00100)	–
Controls	YES	YES	YES	YES
Land	–	–	–	2.91300*** (0.67600)
Constant	–0.98700 (0.69800)	0.28400*** (0.04330)	0.15500*** (0.04450)	–1.81500** (0.71400)
N	589	589	589	589

*,**,*** denote significant at the 10, 5 and 1% levels, respectively, with standard errors in parentheses.
Source: Author's own calculation using STATA – statistical analysis app

eastern region, in the non-main food-producing regions, the central and western regions, in the circumstance that aging problem is increasingly prominent situation, the agricultural infrastructure construction has a significant promotion on agricultural GTFP . The reasons for this phenomenon may be:

First, the cultivated land area in the main food-producing regions tends to be larger, and the scale of agricultural production is higher. In which case the marginal benefits of agricultural infrastructure development may be lower, as the agricultural production in this region has already reached a high level;

Second, the construction of agricultural infrastructure requires a large number of resources, including land, labor and capital, and those resources may be relatively scarce in the eastern region. The use of those resources for the agricultural infrastructure construction will crowd out the resources needed for agricultural

Table 8. Test of the intermediary effect of agricultural mechanisation in the influence of agricultural infrastructure construction on agricultural GTFP

Variant	(1) *Lngtfp*	(2) *Lnmechan*	(3) *Lnmechan*	(4) *Lngtfp*
Infrast	0.2200*** (0.0509)	0.7140** (0.3040)	–	0.19600*** (0.05010)
Aging	–0.2790*** (0.1000)	–1.1250* (0.6010)	–0.2220 (0.5920)	–0.24100** (0.09870)
Invest	–	–	0.6910*** (0.0957)	–
Controls	YES	YES	YES	YES
Lnmechan	–	–	–	0.03380*** (0.00698)
Constant	–0.9870 (0.6980)	–7.3250* (4.1810)	–19.4400*** (4.2450)	–0.73900 (0.68600)
N	589	589	589	589

*,**,*** denote significant at the 10, 5 and 1% levels, respectively, with standard errors in parentheses.
Source: Author's own calculation using STATA – statistical analysis app

https://doi.org/10.17221/273/2024-AGRICECON

Table 9. Heterogeneity analysis of the impact of agricultural infrastructure construction on agricultural GTFP

	(1)	(2)	(3)	(4)	(5)	(6)
Variant	central region	western region	eastern region	northeastern region	main grain producing regions	non-grain producing regions
Infrastr	0.2470** (0.1030)	0.2990*** (0.0981)	0.0300 (0.0501)	0.4130 (0.5900)	–0.0462 (0.0887)	0.2680*** (0.0556)
Aging	–1.2340*** (0.1930)	0.3830** (0.1480)	-0.8590*** (0.1420)	–0.6690 (0.5650)	–0.6850*** (0.1920)	–0.1090 (0.1120)
Controls	YES	YES	YES	YES	YES	YES
Constant	–8.3720*** (1.6030)	–10.7200*** (2.7130)	2.1810** (1.0330)	–4.8830 (4.4380)	–6.4180*** (2.0020)	–2.1360*** (0.8090)
N	152	190	190	57	152	437

*,**,*** denote significant at the 10, 5 and 1% levels, respectively, with standard errors in parentheses.
Source: Author's own calculation using STATA – statistical analysis app

production. As a result, there is competition between agricultural infrastructure construction and agricultural production in the use of resources, leading to an increase in the cost of agricultural production factors.

Thirdly, as an old industrial base, the northeast region's past approach to economic development may have put some pressure on the ecological environment. The construction and use of agricultural infrastructure needs to fully consider the needs of ecological environmental protection, otherwise it may exacerbate the deterioration of the ecological environment, which in turn affects the improvement of agricultural GTFP.

In this regard, the relevant departments should tailor their agricultural infrastructure construction efforts to maximise agricultural GTFP.

DISCUSSION

i) Low standards of agricultural infrastructure and aging of agricultural labor force are two prominent problems facing China's agricultural development. This study shows that insufficient labor inputs due to aging agricultural labor force, and insufficient agricultural inputs due to insufficient labor inputs inhibit the increase of agricultural GTFP , while agricultural infrastructure construction significantly contributes to the increase of agricultural GTFP. Further, the aging of agricultural labor force has a direct impact on agricultural GTFP, and the agricultural infrastructure construction plays a fundamental role in the improvement of agricultural GTFP. The links between these two prominent problems should be multifaceted, and this study only focuses on the fact that the increase in the level of infrastructure construction can compensate for the lack of agricultural inputs brought about by the aging of agricultural labor force.

ii) The findings of this study fit with existing studies and deepen on the basis of existing studies. While Qinghua et al. (2015), Nie (2021) and Lele (2017) have already mentioned the impact of agricultural infrastructure on GTFP, this study further reveals the mitigating role of agricultural infrastructure construction on the inhibitory effect of aging agricultural labor force, and analyses agricultural land transfer and agricultural mechanisation as the mediating mechanism of that facilitating effect. This opens up new perspectives for future research.

iii) Agricultural infrastructure contribution to agricultural GTFP shows variability across different types of infrastructure and geographic regions, suggesting the need for differentiated considerations in policy formulation.

Recommendations

i) Increasing efforts to construct agricultural infrastructure. Provide a platform for agricultural productive services so that aging farmers can more easily access agricultural productive services to make up for their shortage of labor inputs and alleviate the inhibiting effect of aging on the increase of agricultural GTFP; Promoting the transfer of farmland to change the situation of low utilisation of farmland resources and the increase of abandonment rate, which are caused by aging; Promote the development of agricultural mechanisation to change the situation of low agricultural productivity and high production costs, which caused by the diminishing capacity

https://doi.org/10.17221/273/2024-AGRICECON

of aging farmers. Increase agricultural productivity while improving the environmental friendliness of agriculture.

ii) Continuing to increase the construction of rural electricity and agricultural water infrastructure so that they can sustainably play a role in promoting agricultural GTFP. At the same time, more convenient agricultural information and communication services should be provided to provide older farmers with smart agriculture services with friendly interfaces and easy operation, and to lower the threshold of use for the elderly. In addition, smart agriculture training can be carried out to popularise knowledge and skills in smart agriculture, and to help older farmers become proficient in the use of smart agriculture platforms and equipment in order to improve agricultural productivity.

iii) Relevant authorities should recognise the differences in natural resource endowments, economic development levels and policy environments in different regions, and formulate targeted policies on agricultural infrastructure development according to the specific conditions of each region in order to fully realise its potential for promoting GTFP.

CONCLUSION

Comprehensively promoting the green and high-quality development of agriculture is the primary task of building a strong agricultural country, but the aging of the agricultural labor force is becoming more and more prominent so that it is facing unprecedented challenges, therefore, solving the aging impediment to the green development of agriculture is an urgent and realistic problem to be solved. In this regard, this paper proposes to strengthen the construction of agricultural infrastructure to promote the improvement of agricultural GTFP and alleviate the inhibiting effect of aging on agricultural GTFP. Based on provincial panel data, it empirically analyses the relationship between aging, agricultural infrastructure construction and agricultural GTFP by using the individual fixed effect model. And analyses its role mechanism by using the mediating effect model and Bootsrap method. mechanism of action. Then the paper further analysis the impact of different types of agricultural infrastructure construction on agricultural GTFP .

The research conclusions are as follows:

i) The construction of agricultural infrastructure can significantly promote the increase of agricultural GTFP in the circumstance that aging problem is increasingly prominent situation, and this promotion effect is heterogeneous.

ii) The impact of different agricultural infrastructure construction on agricultural GTFP is not the same in the circumstance that aging problem is increasingly prominent situation.

iii) Agricultural infrastructure construction can alleviate the inhibiting effect of aging on agricultural GTFP to a certain extent.

iv) The promotion effect of agricultural infrastructure construction on agricultural GTFP can be realised by promoting the transfer of farmland and the development of agricultural mechanisation.

REFERENCES

Cheng-kun L. (2021): Rural population aging and regional heterogeneity in agricultural total factor productivity. Journal of South China, Agricultural University (Social Science Edition), 20: 46–55.

Cheng Z.H., Kong S.Y. (2022): The effect of environmental regulation on green total-factor productivity in China's industry. Environmental Impact Assessment Review, 94: 106757.

China Agricultural Machinery Industry Yearbook Editorial Board (2004–2022): China Agricultural Machinery Industry Yearbook. Editorial Board of China Agricultural Machinery Industry Yearbook, Beijing. China Statistics Press: 2004–2022. Available at https://cnki.nbsti.net/CSYDMirror/trade/Yearbook/Single/N2006090367?z=Z009 (accessed Mar 28, 2024).

Chung Y.H., Färe R., Grosskopf S. (1997): Productivity and undesirable outputs: A directional distance function approach. Journal of Environmental Management, 51: 229–240.

Ding L., Zhong G.B. (2017): Research on the impact of rural land contracting right confirmation on land transfer: Empirical evidence from land confirmation in Hubei Province. Research on Agricultural Modernisation, 38: 452–459.

Du J.G., Li B., Yang H. (2023): Impact of agricultural human capital on agricultural green total factor productivity under population aging. China Population Resource Environment, 33: 215–228.

Fan M., Yang P., Li Q. (2022): Impact of environmental regulation on green total factor productivity: A new perspective of green technological innovation. Environmental Science and Pollution Research, 29: 53785–53800.

Gong R., Xie L., Wang Y.F. (2020): Interactive mechanism and empirical test of agricultural high-quality development and new urbanisation. Reform, 33: 145–159.

González-González E., Nogués S. (2019): Long-term differential effects of transport infrastructure investment in

https://doi.org/10.17221/273/2024-AGRICECON

rural areas. Transportation Research Part A: Policy and Practice, 125: 234–247.

He Z., Jia Y., Ji Y. (2023): Analysis of influencing factors and mechanism of farmers' green production behaviors in China. International Journal of Environmental Research and Public Health, 20: 961.

Hongjie B., Xiaoqian L., Xiaoyong X, et al. (2023): Spatial-temporal evolution and convergence analysis of agricultural green total factor productivity: Evidence from the Yangtze River Delta Region of China. PloS one,18: e0271642 – e0271642.

Lei Y.T., Zhang S.W., Sun J.J. (2020): The Influence Mechanism and Empirical Study of Environmental Regulation on the Green Transformation of Manufacturing Industry. Science & Technology Progress and Policy, 37: 63–70.

Lele U., Goswami S. (2017): The fourth industrial revolution, agricultural and rural innovation, and implications for public policy and investments: A case of India. Agricultural Economics, 48: 87–100.

Liang X., Li P.A. (2020): Empirical study of the spatial spillover effect of transportation infrastructure on green total factor productivity. Sustainability, 13: 326.

Li H., Cao C., Li L. (2022): Can green cognition promote farmers' green production behavior? Analysis of lock-in effect based on social norms. Journal of Arid Land Resources and Environment, 36: 18–25.

Li J.L. (2023): Study on the relationship between transportation infrastructure, foreign trade and green total factor productivity in agriculture. Wuhan, Huazhong Agricultural University, 1–73.

Li Q.N., Li G.C., Yin C.J. (2020): Dynamic Evolution of Agricultural Green Total Factor Productivity Growth. Jornal of Statistical Planning and Inference, 35: 119–128.

Li Z., Ye W., Mei D., Zheng C. (2022): Impacts of agricultural infrastructure on ecology total factor productivity of grain from the perspective of environmental regulation. Chinese Journal of Eco-Agriculture, 30: 1862–1876.

Liu C.K., Chen H., Zhang M.H. (2023): Impacts of rural population ageing on the quality development of agriculture and its path. Research on Modernisation of Agriculture, 44: 955–966.

Liu D.D , Zhu X.Y, Wang Y.F. (2021): China's agricultural green total factor productivity based on carbon emission: An analysis of evolution trend and influencing factors. Journal of Cleaner Production. 278: 123692.

Liu Y., Jiang H., Cui J. (2024): County-level total factor productivity of food in China and its spatio-temporal evolution and drivers. Frontiers in Sustainable Food Systems, 8: 1325915.

Liu Y.W., Ouyang Y., Cai H.G. (2021): Evaluation of China's agricultural green TFP and its spatiotemporal evolution characteristics. Jornal of Quantitative and Technical Economics, 38: 39–56.

Liu Y.X., Zhao Y.K., Zeng W.Y. (2021): A study on total factor productivity measurement in China – Based on the first-order difference logit model and the re-measurement of effective capital stock. Statistical Research, 38: 77–88.

Luo J., Huang M., Hu M., Bai Y. (2023): How does agricultural production agglomeration affect green total factor productivity? Empirical evidence from China. Environmental Science and Pollution Research, 30: 67865–67879.

Ma W.J., Bai M.Q., Aihemaiti A., Zhang D., Yang Z.G. (2023): Spatial-temporal differentiation and driving factors analysis of green total factor productivity of Xinjiang grain under the carbon peaking and carbon neutrality goals. Arid Land Geography, 46: 2029–2041.

Ministry of Transport of the People's Republic of China, Editorial Board (2004–2022): China Transport Statistical Yearbook. Beijing People's Traffic Press: 2004–2022. Available at https://cnki.nbsti.net/CSYDMirror/trade/Yearbook/Single/N2021040166?z=Z014 (accessed Mar 26, 2023).

National Bureau of Statistics (2004–2022): China Statistical Yearbook. Beijing, China Statistics Press: 2004–2022. Available http://www.stats.gov.cn/ (accessed Mar 5, 2024).

National Bureau of Statistics, Department of Population and Employment Statistics (2004–2022): China Population and Employment Statistics Yearbook. Beijing, China Statistics Press: 2004–2022. Available at https://cnki.nbsti.net/CSYDMirror/Trade/yearbook/single/N2022040097?z=Z001 (accessed Mar 15, 2024).

National Bureau of Statistics, Department of Rural Socio-Economic Surveys (2004-2022): China Rural Statistical Yearbook. Beijing. China Statistics Press: 2004–2022. Available at http://60.16.24.131/CSYDMirror/area/Yearbook/Single/N2024010048?z=D27 (accessed Apr 1, 2024).

Nie S. (2021): Influence of rural infrastructure construction on agricultural total factor productivity. Agriculture and Forestry Economics Management, 4: 65–68.

Pastor L. (2005): A global malmquist productivity index, Economic Letters, 88: 266.

Qinghua W., Zhongzhao F., Hongying H. (2015): The impact of rural infrastructure on agricultural productivity: A perspective based on factor inputs. Systems Engineering Theory and Practice, 35: 3164–3170.

Qiu T.W., Peng C.Y. (2023): The impact of aging agricultural population on farmland allocation and grain production decision: evidence from the China Household Finance Survey, 44: 129–150.

Song M., Wu Q., Zhu H. (2024): Could the aging of the rural population boost green agricultural total factor productivity? Evidence from China. Sustainability, 16: 6117.

Sun T.L., Zhang Y.C. (2021): The impact of environmental regulation on agricultural green total factor productivity:

https://doi.org/10.17221/273/2024-AGRICECON

evidence from China. International Journal of Environment and Pollution, 70: 203–222.

Wang Y H., Li X B, Xin L J. (2017):The impact of agricultural labor force age on land transfer according to CHIP2013. Resource Science, 39: 1457–1468.

Wang Z., Rui S., Wang T., Yalian Z., Wu N., Gong Y., Fu Q. (2017): Reproduced with permission of copyright owner. Further reproduction prohibited without permission. Journal of Irrigation and Drainage, 36: 107–114.

Xinhai L., Jiang X., Mengqi G. (2020): How land transfer marketization influence on green total factor productivity from the approach of industrial structure? Evidence from China. Land Use Policy, 95: 104610.

Xu J., Wang Y., Zhao X., Etuah S., Liu, Z., Zhu H. (2023): Can agricultural trade improve total factor productivity? Empirical evidence from G20 countries. Frontiers in Sustainable Food Systems, 7: 1100038.

Yufeng C., Jiafeng M., Zhitao Z. (2021): Measuring green total factor productivity of China's agricultural sector: A three-stage SBM-DEA model with non-point source pollution and CO2 emissions. Journal of Cleaner Production. 318: 128543.

Yu Z.G., Sun Z.Y., Xin J. (2023): Straw incorporation and agricultural green total factor productivity: Promotion or inhibition. Journal of Arid Land Resources and Environment, 37: 36–45.

Zhang F.B., Wu D. (2024): Has the construction of agricultural industrial parks improved the total factor productivity of agriculture? A quasi-natural experiment based on 'National modern agricultural demonstration zones'. World Agriculture, 11: 78–90.

Zhou W., Zhang X., Wu, X. (2024): Digital inclusive finance, industrial structure, and economic growth: An empirical analysis of Beijig-Tianjin-Hebei region in China. Plos one, 19: e0299206.

Zhu L., Shi R., Mi L., Liu P., Wang N.G. (2022): Spatial distribution and convergence of agricultural green total factor productivity in China. International Journal of Environmental Research and Public Health, 19: 8786.

Zhu Y. (2023): Research on the Enhancement Mechanism of Green Total Factor Productivity in Northeast China Under Structural Perspective. Heilongjiang. Harbin. Harbin Institute of Technology. 184.

Yu Z.G., Sun Z.Y., Xin J. (2023): Straw incorporation and agricultural green total factor productivity: Promotion or inhibition. Journal of Arid Land Resources and Environment, 37: 36–45.

Received: August 1, 2024
Accepted: December 9, 2024
Published online: March 21, 2025