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Study on the Effect of Agricultural Technological Progress on Agricultural Carbon emission effectualness

Xinqi Ge*
Department of Economics and Management, Dongguan polytechnic, Dongguan 523800, China
*Corresponding Author.

Abstract:

The fourth assessment report released by the IPCC in the year of 2007 pointed out that agricultural production is the second largest source of global greenhouse gas emissions, and agricultural carbon emissions are gradually attracting attention. To reduce agricultural input and carbon effectualness, it is mainly necessary to improve the effectualness of agricultural carbon emissions, while the progress in agricultural technology has the greatest impact on the effectualness of agricultural carbon emission. This study took the Statistical Yearbook of Xinjiang Production and Construction Corps from 1998 to 2017 as the data source, and took 13 divisions of the Corps as samples, using the threshold panel model to test the nonlinear relationship between agricultural technological progress and agricultural carbon emission effectualness, and further estimated the partial effect by using generalized least squares (FGLS).The study found that there is threshold level of human capital and agricultural economic development effect. Under different levels of human capital and the threshold conditions of agricultural economic development stage, the impact of agricultural technological progress on agricultural carbon emission effectualness is significantly different. There is a nonlinear relationship between the two, and there is a partial effect on the degree of agricultural carbon emission effectualness.

Keywords*: Technological progress, Carbon emission effectualness, Threshold effect.*

I. INTRODUCTION

The fourth assessment report released by the IPCC (United Nations Intergovernmental Panel on Climate Change) in 2007 pointed out that agricultural production is the second largest source of global greenhouse gas emissions, and the issue of agricultural carbon emissions has gradually attracted attention from all walks of life [1]. Wei Wei (2018) proposed that my country's agricultural carbon emissions will grow rapidly from 2012 to 2030, far exceeding the growth rate of agricultural output. According to the baseline scenario, the annual average agricultural carbon emissions will increase from 160 million tons of CO_2 in 2011. To 357 million tons of CO_2 by the end of 2030, an increase of 123%, of which agricultural materials such as fertilizers, pesticides, and agricultural films have become the main carbon sources [2]. Taking the Xinjiang Production and Construction Corps (hereinafter referred to as the Corps) as an

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example, the total agricultural carbon emissions of the Corps in 2016 was 2,488,400 tons. The carbon emissions generated by agricultural materials accounted for 81.5% of the total, and the carbon emissions generated by chemical fertilizers and pesticides accounted for 61% of the total. Since 2015, the Ministry of Agriculture and Rural Affairs has organized a zero-growth action for the use of fertilizers and pesticides. By the end of 2020, China's fertilizer and pesticide use reduction and efficiency increase have successfully achieved the expected goal [3]. To reduce agricultural input and agricultural carbon emissions, it is mainly to improve the efficacy of agricultural carbon emissions. Among the efficacy of agricultural carbon emissions, agricultural technological progress has contributed the most [4]. The planning goal of the Ministry of Science and Technology of China is: By 2022, the contribution rate of China's agricultural science and technology progress will reach 61.5% and achieve the goal of agricultural science and technology innovation to support the building of a well-off society in an all-round way. Therefore, it is of practical significance to study the related issues of agricultural technological progress and agricultural carbon emission efficacy.

At present, there is still controversy about the impact of agricultural technology progress on agricultural carbon emissions. Scholars generally believe that the advancement of agricultural technology can significantly improve resource utilization and production efficacy, reduce agricultural energy consumption and carbon emissions, and are the main factors in reducing the intensity of agricultural carbon emissions [5-7]. Gerlagh (2007) proposed that the advancement of agricultural technology will have a learning effect, which will significantly reduce the cost of carbon emission reduction and increase the social benefits of carbon emission reduction [8]. Lu Zhaoyang (2013) pointed out that the improvement of agricultural technology can significantly reduce agricultural carbon emissions [9]. Dai Xiaowen (2015) found that low-carbon agricultural technology has a more significant impact on improving agricultural carbon emission efficacy than general technology [10]. Huang Linqing (2016) found that advances in agricultural science and technology can not only reduce agricultural carbon emissions, but also promote agricultural economic development [11]. Chen Yin'e (2017) pointed out that agricultural mechanization can promote industrial upgrading and reduce agricultural carbon emissions [12]. Wei Wei (2018) proposed that under the technological progress scenario, less agricultural carbon emissions will be generated than under the baseline scenario. If agricultural total factor technology progress and energy-enhancing technology progress can be achieved at the same time, the annual agricultural carbon emissions will be achieved by the end of 2030. Will reduce more than 21 million tons of CO_2.

However, some scholars hold different views. Acemoglu (2009) believe that technological progress may increase carbon dioxide emissions or reduce carbon dioxide emissions [13]. Yang Jun (2013), Dai Xiaowen (2015) emphasized that while the advancement of agricultural technology improves the effectualness of agricultural production, it may reduce the price of energy products and increase the input of agricultural machinery, fertilizers, pesticides, and agricultural film through the expansion of production scale. Consumption and agricultural carbon emissions [14]. Wu Xianrong (2014) pointed out that there are differences in the factors that cause changes in agricultural carbon emission efficacy. The improvement of carbon emission efficacy in the eastern region is mainly driven by technological progress, and the central and western regions mainly rely on the improvement of technical efficacy [15]. Tian Yun (2016) believe that the improvement of economic development level will bring about changes in agricultural production technology, and the positive effect of the double growth of agricultural output and ecological output brought about by agricultural technology progress is more prominent, which is conducive to the development of low-carbon agriculture, and vice versa[16]. Obviously, the impact of agricultural technological progress on agricultural carbon emissions is complex. For this reason, it is worth thinking about under what circumstances will the advancement of agricultural technology reduce agricultural carbon emissions and increase the effectualness of agricultural carbon emissions? Is there a non-linear relationship between agricultural technological progress and agricultural carbon emission efficacy? Is the effect of agricultural technological progress on agricultural carbon emission efficacy restricted by other factors? If affected by other factors, under different restricted conditions, how does agricultural technological progress affect agricultural carbon emission efficacy?

The agricultural modernization level of the Chinese Corps is in a leading position in the world, but the agricultural development of the Corps is still taking a high-carbon emission path, which is more significant in other parts of the country. Therefore, it is more scientific to use the Corps as a sample and can also provide reference for other regions. Based on this, this research takes the Corps as the research object, theoretically clarifies the mechanism of agricultural technology progress on agricultural carbon emission efficacy and proposes research hypotheses; adopts the threshold panel model to test the nonlinear relationship between agricultural technology progress and agricultural carbon emission efficacy, and Further use Generalized Least Squares (FGLS) to estimate its partial effect.

II. MANUSCRIPT PREPARATION

2.1 Analysis of Influence Mechanism and Theoretical Hypothesis

The research on the effect of the industrial field on carbon emission efficacy is relatively early, and there are many research results, which laid the research foundation for the research on agricultural carbon emission effectualness. Zhang Youguo (2010) emphasized that technological progress is still the main factor to improve carbon emission efficacy, and the relationship between technological progress and carbon emission efficacy is nonlinear [17]. Technological progress requires certain accumulation of external conditions, which may be affected by human capital and economic development, industrial structure, energy consumption structure, energy intensity and opening-up level [18, 19]. According to the theory of endogenous economic growth, technological progress mainly comes from R&D investment and human capital production [20]. Technological progress is the core driving force of economic growth, and the level of economic development can reflect the technological level of a region [21]. Therefore, this article selects human capital and agricultural economic development level as threshold variables to analyze the impact of agricultural technological progress on agricultural carbon emission efficacy.

Human capital refers to the sum of knowledge, technical skills, abilities, and qualities that can create economic and social value that are condensed on workers through teaching, training, and learning [22]. Higher human capital, to a certain extent, enhances farmers' ability to master new knowledge, modern

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agricultural production skills, and production and management, helps improve their independent innovation capabilities and the efficacy of using foreign technologies, and promotes the upgrading and transformation of agricultural technology And accumulation [23]. The improvement of human capital level will also help farmers establish awareness of ecological and environmental protection and energy conservation and emission reduction, and follow higher environmental standards to carry out low-carbon production [24]. At the same time, higher investment in human capital can be transformed into better consumption distribution. Technological progress can be used to improve the factor input structure, promote the substitution of non-material factors for energy and other material factors, and promote the development, update, promotion and promotion of energy-saving and low-carbon technologies. Application to improve the effectualness of agricultural carbon emissions [25]. Carbon emission efficacy is also affected by the matching degree of human capital and technological progress. Lower human capital is prone to mismatch between human capital and technological progress, and the best output efficacy cannot be obtained. The main body of agricultural production has weak awareness of ecological and environmental protection, lack of knowledge and utilization of technology, and short-sightedness [26], which is not conducive to agricultural technological progress and carbon emission reduction.

The agricultural production equipment, technology and conditions are better in regions where the economic development level is developed [27]. A higher level of agricultural economic development is conducive to increasing investment in agricultural scientific research, training, and infrastructure, providing sufficient material, capital, talent and information flow for agricultural technological progress, and driving agricultural technological change, and agricultural technological progress can be achieved by improving new energy, the proportion of renewable energy in agricultural input will reduce agricultural energy consumption. In areas with a high level of agricultural economic development, people have a strong awareness of environmental protection and tend to consume low-carbon, ecological and green agricultural products. To a certain extent, they will also force the transformation of agricultural production technology to low-carbon. Low-carbon technologies improve the effectualness of agricultural carbon emissions through new energy substitution, production process optimization, and agricultural waste recycling. In areas with a low level of agricultural economic development, agricultural production is characterized by extensive, with the pursuit of maximizing economic benefits as the single goal. Economic growth is overly dependent on the expansion of production scale and the input of energy factors, which increases the difficulty of innovation and application of low-carbon technologies. It is not conducive to improving the effectualness of agricultural carbon emissions. The specific impact mechanism is shown in Figure 1.

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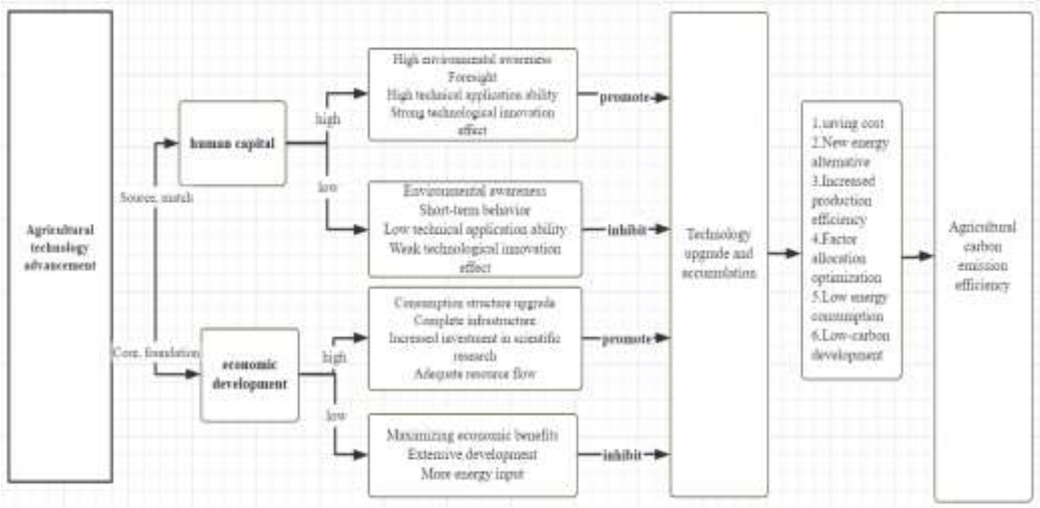

Fig 1: The diagram of the impact mechanism of agricultural technological progress on agricultural carbon emission efficacy.

In summary, this article proposes the following two hypotheses:

Hypothesis 1: The effect of technological progress on agricultural carbon emission efficacy is restricted by both human capital and economic development level.

Hypothesis 2: The higher the level of human capital and agricultural economic development, the more significant technological progress will increase the efficency of agricultural carbon emissions. On the contrary, the more significant the inhibitory effect will be.

2.2 Model and Variable Selection

2.2.1 Model selection

In order to test the impact of agricultural technological progress on agricultural carbon emission efficacy under different constraints, this paper uses the dual threshold model proposed by Hansen (1999) to conduct empirical research. The idea of the threshold panel model is to include a certain threshold value as an unknown variable into the regression model. Through constructing a piecewise function, empirically test and estimate the corresponding threshold value and "threshold effect", the model is as follows:

$$\begin{aligned} \ln EI_{it} &= \alpha_0 + \alpha_1 \ln lan_{it} + \alpha_2 \ln tra_{it} + \alpha_3 \ln ind_{it} + \alpha_4 \ln inc_{it} + \alpha_5 \ln tech_{it} I(q_{it} \le \gamma_1) \\ &+ \alpha_5 \ln tech_{it} I(\gamma_1 \langle q_{it} \le \gamma_2) + \alpha_7 \ln tech_{it} I(q_{it} \rangle \gamma_2) + \upsilon_i + \tau_i + \varepsilon_{it} \end{aligned} \tag{1}$$

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In the formula, EI is the explained variable, that is, agricultural carbon emission efficacy; $tech$ is technological progress; q_{it} is the threshold variable. This article selects human capital (hum) and agricultural economic development level (dev) as the threshold variables, γ is the specific threshold value, I(.) is the indicator function; control Variables include the scale of land management (lan); agricultural trade opening (tra), industrialization level (ind), agricultural per capital disposable income (inc); $i = 1,2,3,\cdots,13$, $t = 1,2,3,\cdots,20$, α is the parameter to be estimated, and υ_i is the individual The individual effect, τ_i is the time effect, ε_{it} is the interference item that conforms to the standard normal distribution.

After getting the estimated value of the parameter, we need to do the following two tests. One is to test whether the threshold effect is significant to F test; the other is the likelihood ratio LR test.

Among them, the null hypothesis of the F test is $H_0: \beta_1 = \beta_2$, the corresponding alternative hypothesis is $H_1: \beta_1 \neq \beta_2$, the test statistics are:

$$F = n\frac{S_0 - S_n(\tau)}{S_n(\tau)} \tag{2}$$

Among them, S_0 is the residual sum of squares obtained under the null hypothesis $H_0: \beta_1 = \beta_2$,Since the LM statistic does not conform to the χ^2 standard distribution, the asymptotic distribution is obtained through the self-sampling book ($Bootstrap$) to construct the P value, if the value is less than 0.01, it means that the null hypothesis is accepted at the 1% level and the test is passed; if it is 0.05, the null hypothesis is accepted at the 5% significance level, and so on.

The null hypothesis of the likelihood ratio LR test is $H_0: \gamma_1 = \gamma_2$, and the corresponding likelihood ratio statistic is:

$$LR_1(\gamma) = n\frac{S_n(\gamma) - S_n(\hat{r})}{S_n(\hat{r})} \quad (3)$$

Considering that the distribution of the above LR test is not a standard distribution, Hansen provides its confidence interval, when is $LR_1(\gamma) \leq c(\alpha)$ we accepts the null hypothesis, where is $c(\alpha) = -2\ln(1-\sqrt{1-\alpha})$, α is the significance level.

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2.2.2 Variable selection

2.2.2.1 Core variables

1) Agricultural carbon emission efficacy. At present, the measurement and calculation of agricultural carbon emission efficacy has not yet formed a unified standard. This article refers to the practice of Zhang Guangsheng (2014) and uses agricultural carbon emission intensity (EI), that is, the average carbon emission per 10,000 yuan of agricultural GDP (tons/10,000 yuan) to express the efficacy of agricultural carbon emissions, and the decline in agricultural carbon emission intensity represents agriculture The improvement of carbon emission efficacy[28].Combining IPCC and previous research results, the calculation function of agricultural carbon emissions is determined as[29, 30]:

$$E = \sum E_j = \sum T_j \times \delta_j \qquad (4)$$

In formula (4), E is the total agricultural carbon emissions; J is the type of carbon source; Ej represents the carbon emissions of various carbon sources; Tj represents the input of a certain element; δ_i represents the carbon emission coefficient. Combining the actual situation of XPCC's agriculture, this article determines specific carbon source factors and corresponding carbon emission coefficients from four aspects: agricultural materials, agricultural irrigation, plowed land, and animal breeding, as shown in Table I.

TABLE I. Carbon emission coefficients and specific indicators of carbon sources.

Types	Carbon source	Specific indicators	Emission factor	Data reference source
Agricultural materials	fertilizers(kg CE/kg)	Actual use of fertilizer (t)	0.8956	ORNL
	pesticides(kg CE/kg)	Pesticide usage (kg)	4.9341	ORNL
	agricultural films(kg CE/kg)	Amount of agricultural plastic film used (t)	5.18	IREEA
	diesel(kg CE/kg)	Diesel consumption (t)	0.5927	IPCC
Agricultural irrigation	irrigation(kg/km^2)	Effective irrigation area(km^2)	20.476	Dubey、WEST T.O
Plowing the land	plowing the soil(kg CE/km^2)	Actual sown area of crops(km^2)	312.6	IABCAU (College of Agronomy and Biotechnology, China Agricultural University)
Animal breeding	pig(kg CE/(head.year)	Number of pigs in stock at the end of the year (head)	34.091	IPCC

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	cattle(kg CE/(head.year)	Number of cattle at the end of the year (head)	415.91	IPCC
	sheep(kg CE/(head.year)	Number of sheep in stock at the end of the year (head)	35.1819	IPCC

2) Advances in agricultural technology. Drawing lessons from Yang Jun (2013), using the DEA-Malmqusit index to measure the total factor productivity of the 13 divisions of the Corps from 1997 to 2016 to characterize the progress of agricultural technology. This article selects the number of employees in the primary industry (persons), the fixed asset investment in the primary industry (10,000 yuan), the sown area of crops (thousand hectares), and the total power of agricultural machinery (kw) to characterize labor, capital, land, and machinery inputs; The value-added of the first industry (ten thousand yuan) is the output indicator.

2.2.2.2 Threshold variables

This article selects human capital and agricultural economic development level as threshold variables. Since the current data cannot fully reflect the heterogeneity of labor force, combined with the actual situation of the Corps, referring to the practice of Wang Hui (2015) , the number of people with junior high school education or above in the agricultural labor force of each division of the Corps (person) is selected as human capital. The level of agricultural economic development is expressed by the gross output value of the primary industry per capital (yuan).

2.2.2.3 Control variables

1) The scale of land management (lan). It is expressed in terms of the ratio of the sown area of crops to the number of employees in the primary industry (hectares).

2) Opening up of agricultural trade (tra). Expressed in terms of the ratio of the total value of imports and exports of agricultural products of each division of the Corps to the added value of the primary industry.

3) The level of industrialization (ind). The level of industrialization is obtained by calculating the ratio (%) of industrial added value to regional gross product.

4) Agricultural disposable income per capital (inc). Select the agricultural per capital disposable income (yuan) characterization of the Corps.

2.2.3 Data source

This paper selects 13 divisions of the Corps (except the 11th Division of the Corps and its direct subordinates) as samples. The data comes from the 1998-2017 "Statistical Yearbook of Xinjiang

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Production and Construction Corps". In order to make the data of different years comparable, this article uses 1997 as the base period, and uses the GDP deflator to eliminate the impact of price factors for the price measurement indicators involved in the article. After sorting out the descriptive statistical analysis of each variable, see Table II.

TABLE II Descriptive statistical analysis of variables (1997-2016).

Variable name	Number of observations	Mean value	Standard deviation	Minimum value	Maximum value
EI	260	0.61	0.29	0.16	1.33
tech	260	1.09	0.20	0.59	1.91
hum	260	12629.47	12629.47	909.00	36239
dev	260	34153.79	35550.40	2213.18	206292.28
lan	260	3288.97	2153.95	174.05	8666.98
tra	260	18.96	62.28	1	531.09
ind	260	20.75	10.47	1.82	51.58
inc	260	7636.59	4396.93	1305.00	17737

2.3 Empirical Research

2.3.1 Threshold effect test

In order to investigate the non-linear impact of agricultural technological progress on agricultural carbon emission efficacy under different threshold conditions, a threshold panel regression model is used, and human capital and agricultural economic development level are selected as threshold variables for empirical testing. In order to ensure the scientificity and rationality of the regression results, it is necessary to first test whether there is a threshold effect.

The threshold panel model needs to first check whether the threshold exists and the number of existing thresholds. If it fails the test, it indicates that there is no threshold effect. This paper uses the "self-sampling" (*Bootstrap*) method to estimate under the setting of no threshold, one threshold and two thresholds to obtain F statistics and P values.

TABLE III. Threshold panel inspection

Threshold variable	Model	*F* value	*P* value	Sampling times	Critical value		
					1%	5%	10%
Human capital	First threshold	7.817**	0.012	500	7.999	5.167	3.729
	Second threshold	12.831**	0.044	500	16.987	12.196	8.567
	Third threshold	4.964**	0.036	500	6.942	4.415	3.103
Agricultural economic	First threshold	24.528**	0.036	500	34.193	22.72	18.117

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development level	Second threshold	18.600**	0.002	500	10.908	6.054	3.633
	Third threshold	19.756**	0.012	500	20.201	12.612	8.204

Note: (1) The explanatory variables in the model are all in the form of natural logarithms; (2) ***, ** and * pass the significance test at the levels of 1%, 5%, and 10%, respectively.

Table III shows that human capital and agricultural economic development levels have passed the triple threshold test. In order to ensure the rationality and intuitiveness of the test results, we further use the likelihood ratio test chart to test.

In order to understand the construction process of the threshold value and the confidence interval more clearly, the likelihood ratio test diagrams under different threshold effects are drawn respectively. The selection criteria for the threshold effect estimate is the value when the likelihood ratio test is zero, as shown in Figures 2 and 3:

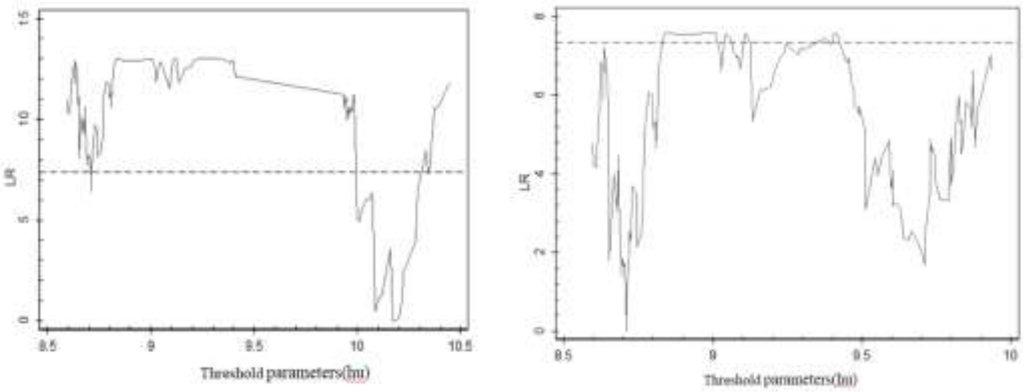

Fig 2: Estimated value and confidence interval of human capital threshold.

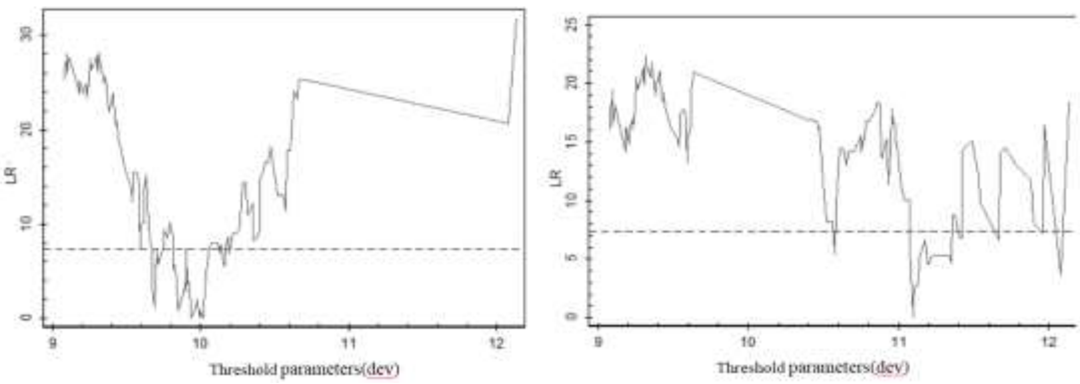

Fig 3: Estimated value and confidence interval of agricultural economic development level.

Comprehensively examining the confidence interval of the threshold value, we believe that there is a double threshold between human capital and the level of agricultural economic development. Through

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calculation, it is found that the threshold values of human capital are 8.711 and 10.172, and the corresponding actual values are 6,069 and 26,160, respectively; the threshold values of agricultural economic development level are 9.935 and 11.098, respectively, and the corresponding actual values are 20,640.28, respectively Yuan and 66038.95 Yuan, see Table IV for details.

TABLE IV. Threshold value solution.

Threshold variable		Estimated value	Actual value	95% confidence interval
Human capital	first threshold	8.711	6069	[8.595, 9.935]
	second threshold	10.172	26160	[8.711, 10.344]
Agricultural economic development level	first threshold	9.935	20640.28	[9.672, 10.196]
	second threshold	11.098	66038.95	[10.578, 12.076]

2.3.2 Empirical results of the threshold panel model

Through the threshold effect test, it can be seen that the two threshold indicators selected in this paper both have a threshold effect, and Hypothesis 1 has been verified. In order to further analyze the impact of agricultural technology progress on agricultural carbon emission efficacy under different threshold conditions, the article uses a threshold panel regression model to empirically test model (1). The specific results are shown in Table V.

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TABLE V Regression results of threshold panel.

variable	Agricultural carbon emission efficacy			
	Meaning	Threshold Return	Meaning	Threshold Return
tech	$\ln hum \le 8.711$	-0.0695*** (-8.82)	$\ln dev \le 9.935$	0.1253***(5.17)
tech	$8.711 < \ln hum \le 10.172$	-0.1026*** (-4.33)	$9.935 < \ln dev \le 11.098$	-0.2059***(-8.1)
tech	$\ln hum > 10.172$	0.0464*** (2.63)	$\ln dev > 11.098$	-0.1666***(-2.78)
$\ln dev$	Agricultural economic development level	-0.4621*** (-11.15)		---
$\ln hum$	human capital	---		0.1584***(-4.68)
$\ln lan$	Land scale management	-1.3812*** (-4.15)		-0.9644***(-2.15)
$\ln tra$	Openness to the outside world	-0.0036 (-0.50)		0.0032(-0.53)
$\ln inc$	residence income	-0.1581*** (-3.12)		-0.6699***(-20.78)
$\ln ind$	Industrialization level	-0.0733 (-1.57)		-0.1610***(-5.48)
C	Constant term	11.4934*** (8.56)		8.6240***(-5.24)
R^2		0.965		0.94
F		553.71		891.24
N	Number of samples	260		260

Note: ***, ** and * refer to the significance test at 1%, 5%, and 10%, respectively. The t-test value is in parentheses.

Under different thresholds of human capital levels, the regression coefficients of agricultural technology progress on agricultural carbon emission efficacy are -0.0695, -0.1026, and 0.0464 (all passed the significance test at the 1% level), that is, when the human capital level increases and exceeds a certain level At the threshold value, the advancement of agricultural technology has a positive effect on improving the effectualness of agricultural carbon emissions. When the level of human capital is low or in the middle, the production subject’s ability to use technology and environmental awareness is weak, short-term behavior is obvious, and the absorption and innovation effect of human capital on technological progress cannot be effectively brought into play. When the level of human capital is low, if the human capital and technological progress are not effectively matched, there will be a loss of effectualness due to the structural mismatch between the two, which weakens the effect of agricultural technological progress on the effectualness of agricultural carbon emissions. When the level of human capital is high, it is conducive to

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improving the level of internal independent innovation, enhancing the ability to absorb and utilize foreign technology, promote the upgrading and transformation of agricultural technology, optimize the allocation structure of factors, promote low-carbon agricultural production, and improve agricultural carbon emission efficacy.

At different stages of agricultural economic development, the coefficient of influence of agricultural technological progress on agricultural carbon emission efficacy is 0.1253, -0.2059, and -0.1666 (all passed the significance test at the 1% level), indicating the impact of agricultural technological progress on agricultural carbon emission efficacy The effect is also restricted by the stage of agricultural development. When the level of agricultural economic development is low, the input of agricultural materials is relatively small, and the positive effect of agricultural technological progress on agricultural output is greater than the negative effect of agricultural material consumption, that is, the output-pull effect of agricultural technological progress is far greater than the carbon emission. Negative externalities, although the effect is positive at this time, it is more reflected in the improvement of agricultural production effectualness, not the reduction of carbon emissions. With the gradual improvement of the level of economic development, the marginal effect of traditional agricultural technology on the development of agricultural economy will gradually decrease, and the negative externality of carbon emissions caused by it will gradually appear, and the negative externality of carbon emissions will gradually be in a dominant position. At this time, traditional agricultural technology has been unable to meet the requirements of agricultural ecologicalization and low-carbon development, so it will inhibit the effectualness of agricultural carbon emissions. When the level of agricultural economic development is relatively high, the economic growth mode will change to an intensive mode, and low-carbon technology will gradually penetrate into the field of agricultural production. The advancement of agricultural technology will be mainly manifested in the popularization and application of ecological and low-carbon technology. At this time, agricultural technology the effect of progress on the effectualness of agricultural carbon emissions is still negative, but its effect is obviously weaker than that of the middle level of economic development. From the regression results, it can be further seen that the XPCC's agricultural technology is in the process of transitioning from traditional to low-carbon, ecological and green. Traditional agricultural production technology has been unable to meet the needs of XPCC's agricultural ecological and low-carbon development.

As shown in Table VI, the article further divides the 13 divisions of the XPCC into three categories: high, medium, and low based on the threshold of human capital and agricultural economic development. Among them, the 9th, 12th, 13th, and 14th divisions have been in areas with low human capital levels for a long time; the 1st and 8th divisions have successively transitioned from areas with medium human capital levels to areas with high levels of human capital, and then back to areas with medium human capital levels; Each teacher is basically in the middle human capital level area. During the period 1997-2003, all 13 divisions of the XPCC were in the low-level stage of agricultural economy; except for the 14th division during the period from 2004 to 2010, the remaining divisions continued to leap from the low-level stage of the agricultural economy to the middle-level stage of the agricultural economy; the 2012-2016 period The 3, 5, and 14 divisions are still in the middle level of agricultural economy, and the remaining divisions

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have transitioned to the high level of agricultural economic development. In general, the human capital of the XPCC's divisions is basically at a low-to-medium level. The human capital level of the divisions with better agricultural economic development is significantly higher than that of the backward areas. These divisions have relatively complete agricultural infrastructure and a solid agricultural research foundation, which is conducive to the introduction and research and development of low-carbon new technologies. Teachers with backward economic development, backward agricultural teaching infrastructure, generally low quality of farmers and lack of ecological awareness, lack of agricultural science and technology personnel, are not conducive to the absorption and utilization of agricultural technology.

Table VI. Threshold values and regional distribution in 1997, 2007 and 2016.

Threshold interval	Regional distribution		
	1997	2007	2016
$hum < 6069$	7th, 10th, 12th, 13th, 14th divisions	9th, 13th, and 14th divisions	5th, 9th, 10th, 12th, 13th, 14th division
$6069 \le hum < 26160$	1st ,2nd,3rd,4th,6th,8 th,9th divisions	The remaining 8 divisions	1st,2nd,3rd,4th,6th, 7th,8th divisions
$26160 \le hum$	---	1st,8th divisions	---
$dev < 20640.28$	All 13 divisions of the Corps	3rd, 4th,12th 13th,14th divisions	---
$20640.28 \le dev < 66038.95$	---	1st,2nd,5th,6th 7th,8th,9th,10t hdivisions	3rd,5th,14thdivision s
$66038.95 \le dev$	---	---	The remaining 10 divisions

2.3.3 Analysis of impact effect

Through the above analysis, it can be seen that the progress of agricultural technology has a non-linear impact on the effectualness of agricultural carbon emissions. In order to thoroughly investigate the impact of agricultural technology progress on agricultural carbon emission efficacy under the conditions of different human capital and agricultural economic development levels, this article draws on the method of Chen Zizhen (2017), using human capital, agricultural economic development level and agricultural technology The progressive cross-multiplication term is analyzed as a control variable, and the specific model is:

$$\ln EI = \alpha_0 + \alpha_1 \ln tech_{it} + \alpha_2 \ln hum * \ln tech_{it} + \alpha_3 (\ln hum * \ln tech_{it})^2 + \alpha_4 \ln dev * \ln tech_{it} + \alpha_5 (\ln dev * \ln tech_{it})^2 + \alpha_{6-9} \ln X_{it} + \mu_{it} \quad (5)$$

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$\ln hum * \ln tech_{it}$ is the cross-product term of human capital and agricultural technology progress; $\ln dev * \ln tech_{it}$ is the cross-product term of agricultural economic development level and agricultural technology progress; X_{it} is the above 4 control variables; μ_i is the error term.

Since the sample data belongs to the long panel data, in order to improve the consistency and effectiveness of the panel regression, it is necessary to deal with the intranet-group auto correlation and inter-group auto correlation. Therefore, the article further adopts the feasible generalized least squares method (FGLS) to carry out the model (5). Regression processing, the results are shown in Table VII.

TABLE VII. Estimated results of the effect of agricultural technological progress on agricultural carbon emission efficacy.

Variable	Regression 1	Regression 2	Regression 3	Regression 4
$\ln tech$	-0.5172*** (0.1110)	-0.4999*** (0.1124)	1.4258***(0.0877)	1.5797***(0.0937)
$\ln hum * \ln tech$	0.0440*** (0.0123)	0.0332** (0.0154)		
$(\ln hum * \ln tech)^2$		0.0004 (0.0003)		
$\ln dev * \ln tech$			-0.1547***(0.0090)	-0.2157***(0.0138)
$(\ln dev * \ln tech)^2$				0.0020*** (0.0003)
$\ln lan$	-0.0444*** (0.0163)	-0.0453***(0.0163)	-0.0684***(0.0150)	-0.0850*** (0.0156)
$\ln tra$	0.0053** (0.0024)	0.0055**(0.0024)	0.0040* (0.0021)	0.0030 (0.0021)
$\ln ind$	-0.0683*** (0.0151)	-0.0661***(0.0150)	-0.0839*** (0.0144)	-0.0762***(0.0149)
$\ln inc$	-0.3570*** (0.0336)	-0.3550***(0.0334)	-0.2539***(0.0280)	-0.2443***(0.0272)
cons	90.7768*** (9.6988)	91.1295***(9.6510)	65.3105*** (6.8398)	64.5758*** (6.6795)
Wald chi2	3005.80	3028.89	2667.81	2677.77
Number of obs	260	260	260	260

Note: ***, **, and * indicate the significance test passed at 1%, 5% and 10%, respectively. The t-test value is in parentheses.

It can be seen from the results of regression models 1 and 2 that the coefficients of agricultural technology progress are negative, and they are both significant at the 1% significance level. Agricultural

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technology progress has a negative effect on agricultural carbon emission efficacy; under the influence of human capital, agricultural technology progress It has a positive effect on the improvement of agricultural carbon emission efficacy, but with the increase of human capital, the impact of agricultural technology progress on agricultural carbon emission efficacy is "inverted U-shaped", and the marginal effect of agricultural technology progress on improving agricultural carbon emission efficacy is diminishing. The trend shows that only when human capital and agricultural technology progress are effectively matched, can agricultural technology progress have a significant positive effect on agricultural carbon emission efficacy.

From the results of regression models 3 and 4, it can be seen that agricultural technology progress has a significant positive effect on agricultural carbon emission efficacy; under the influence of agricultural economic development level, agricultural technology progress has a negative impact on the improvement of agricultural carbon emission efficacy; With the improvement of the level of development, the impact of agricultural technology progress on agricultural carbon emission efficacy has shown a "positive U-shape", and the marginal contribution of agricultural technology progress to agricultural carbon emission efficacy has increased. The XPCC's agriculture is gradually developing towards low-carbon development. Through vigorous research and development and promotion of water-saving, fertilizer-saving and environmental protection technologies such as under-membrane droppers, degradable membranes, and water and fertilizer integration technologies, it is conducive to the development of low-carbon agriculture. However, the current agricultural development of the XPCC is still dominated by economic benefits, and it is inevitable that there will be excessive use of agricultural materials in the development of agricultural economy, leading to an increase in carbon emissions, so that the positive effect of agricultural technology progress on the improvement of agricultural carbon emission efficacy is not prominent.

Using the results of regression models 1 and 3 in Table VII to calculate the partial effect, the specific calculation formula is as follows:

$$\frac{\partial EI_{it}}{\partial tech_{it}} = \alpha_1 + \alpha_2 \ln hum_{it}, \quad \frac{\partial EI_{it}}{\partial tech_{it}} = \alpha_1 + \alpha_4 \ln dev_{it} \tag{6}$$

It is calculated that when human capital and agricultural economic development level increase by 1%, agricultural carbon emission efficacy will increase by 11.75% and 9.22%, respectively. It can be seen that agricultural technological progress has a significant effect on improving the effectualness of agricultural carbon emissions, but the impact is restricted by the level of human capital and agricultural economic development. When the level of human capital and agricultural economic development is relatively high, agricultural technological progress has an effect on increasing agricultural carbon emissions. Efficacy has a positive effect, hypothesis 2 is verified.

Regarding the control variables, in addition to the positive effect of agricultural trade opening on the effectualness of agricultural carbon emissions, the scale of land management, the level of industrialization and the per capital disposable income of agriculture all have a negative effect on the effectualness of

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agricultural carbon emissions. The scale of land management has the greatest inhibitory effect on the effectualness of agricultural carbon emissions. The expansion of the scale of land management means that more agricultural machinery, fertilizers, pesticides, and agricultural films need to be invested. Not only has the effect of land scale been not achieved, it has increased agricultural carbon emissions. The excessive development of traditional industrialization helps reduce the market price of energy products, encourages farmers to consume more products with high carbon emissions, and has a strong negative impact on the effectualness of agricultural carbon emissions. The main income of the farmers of the XPCC comes from agriculture. Out of personal rationality, farmers pay more attention to high yield and profit, and lack of ecological attention, which is not conducive to improving the effectualness of agricultural carbon emissions. The export quota of XPCC's agricultural products is much higher than the import quota. In order to comply with international trade standards, farmers will be more inclined to the production of green agricultural products and the use of ecological technologies in the production process to promote the improvement of carbon emission efficacy.

III. CONCLUSIONS AND POLICY IMPLICATIONS

The XPCC has an important strategic position in my country's agricultural development. Improving the effectualness of the XPCC's agricultural carbon emissions can make a certain contribution to my country's carbon emission reduction commitments. Through the above analysis, the following conclusions are obtained: (1) The effect of agricultural technological progress on agricultural carbon emission efficacy is affected by human capital and the level of agricultural economic development. When the level of human capital is high (that is, the number of agricultural laborers with an diploma level of junior high school and above>26160) and the level of agricultural economic development is low (the gross output value of the primary industry per capital is <66038.95 yuan), the progress of agricultural technology has a significant impact on the effectualness of agricultural carbon emissions. Positive effects; on the other hand, when the level of human capital is low (that is, the number of agricultural laborers with a junior high school and above diploma level is less than 26160) and the level of agricultural economic development is high (the total output value of the primary industry per capital> 66038.95 yuan), the progress of agricultural technology will affect agriculture Carbon emission efficacy has a negative effect. (2) With the increase of human capital, the impact of agricultural technology progress on agricultural carbon emission efficacy shows an "inverted U shape"; with the improvement of the level of agricultural economic development, the impact of agricultural technology progress on agricultural carbon emission efficacy shows a "positive U" shape type". (3) The level of human capital and agricultural economic development increased by 1%, and the XPCC’s agricultural carbon emission efficacy increased by 11.75% and 9.22%, respectively, indicating that higher levels of human capital and agricultural economic development are generally conducive to improving agricultural carbon emission efficacy. (4) Among the control variables, agricultural trade opening has a positive effect on agricultural carbon emission efficacy, and the scale of land management, industrialization level and agricultural per capital disposable income all have a negative effect on agricultural carbon emission efficacy.

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Based on the above analysis, this article has the following enlightenment: First, transform the agricultural economic development mode, change the "high input, high output, high emission" extensive development mode, and develop circular agriculture, energy-saving agriculture, water-saving agriculture and organic agriculture, Optimize the structure of agricultural production and agricultural inputs. Second, according to the specific conditions of each division of the XPCC, differentiated agricultural emission reduction measures shall be adopted. The divisions with high levels of agricultural economic development improve the effectualness of agricultural resources and energy consumption by introducing advanced agricultural technology and management concepts at home and abroad; divisions with backward agricultural economic development should actively break the regional and administrative limitations between divisions and groups, and develop The faster division learns and draws on its development experience, realizes the sharing of resources such as agricultural technology, talents, and information, improves agricultural production conditions and the environment, and develops early to low-carbon agriculture. Third, for agricultural technical talents, the government can use low-carbon subsidies and preferential measures to encourage scientific research institutions and leading agricultural enterprises to jointly train practical technical talents, and improve the independent innovation capabilities of technical talents; for farmers, indoor training is gradually adopted. Transform into field practice guidance, cultivate farmers' low-carbon concepts, improve farmers' ability to use low-carbon technologies, and realize the coordinated development of human capital and agricultural technology. Fourth, strengthen the research, development and promotion of low-carbon agricultural technologies. Establish an integrated research platform and management system of "production, study and research", give full play to the role of modern agricultural demonstration parks, establish a number of low-carbon agricultural technology demonstration sites and bases in all divisions of the XPCC, and improve the "division-regiment-company" agriculture at all levels Technology extension system to improve the conversion and extension of low-carbon agricultural technology.

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