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Exploring the relationship between agricultural technological progress, economic development and carbon emissions based on province data from the western region

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Abstract. As the world's largest emitter of greenhouse gases, China is currently facing severe pressure to reduce emissions. As a large agricultural country, its agricultural carbon emissions accounted for 17% of total carbon emissions in recent years, which is much higher than the international average. It is urgent to control agricultural carbon emissions. At the same time, the development of agriculture is inseparable from the support of agricultural science and technology, and the progress of agricultural science and technology is also the source of power for agricultural economic growth. This article uses Stata 12.0 to study agricultural carbon emissions, agricultural technological progress and agricultural economic development in western provinces in China. The results show that the progress of agricultural science and technology plays an important role in the development of low-carbon agriculture. It can not only help reduce agricultural carbon emissions, but also promote the development of agricultural economy, providing an important reference for the development of low-carbon agriculture.

1. Introduction

Environmental issues are a global issue that is generally concerned by countries in the world today. It is not only a very important social issue, but also has an important impact on the economic development of all countries [1]. The "greenhouse effect" is one of the most concerned environmental issues in recent years, the increase in the concentration of greenhouse gases such as CO_2 in the atmosphere is an significant factor leading to higher temperature [2]. Therefore, carbon emissions is now becoming the focus of attention all over the world. Relevant studies have shown that with the continuous improvement demand in energy consumption for agricultural development, the carbon emissions caused by agriculture have accounted for 1/4 of the total carbon emissions [3].

As the world's second largest economy and the largest greenhouse gas emitter, China promises that by 2030, the carbon emissions per unit of GDP will be reduced by 60% to 65% compared to 2005, which will inevitably require all industries to vigorously reduce emissions [4]. Although the secondary and tertiary industries are the leading sectors of carbon emissions, in a large agricultural country like China, a large amount of agricultural diesel, the use of chemical fertilizers and pesticides, and the burning of straw make the impact of agriculture on carbon emissions not to be underestimated: the proportion of total carbon emissions of Chinese agricultural carbon emissions has risen to 17% in recent years, which is much higher than the international average. It is urgent to control agricultural carbon emissions. How to promote agricultural development and find a way of low-carbon is an urgent problem to be solved at present [5].

Obviously, the progress of agricultural science and technology has a very important influence on agricultural carbon emissions and agricultural economic development. At present, China is in the middle of the western development. The agricultural economy in the western region accounts for a relatively high proportion of the overall western economy, and the rational and efficient development of the agricultural economy plays a vital role in the economic development. In addition, General Secretary Xi Jinping proposed the "Early Stage of the Rural Revitalization Strategy", emphasizing that the development of the agricultural industry economy would be the main development direction. Agriculture is in urgent need of transformation and upgrading, and taking a low-carbon road becomes an inevitable choice for future development. How to effectively reduce agricultural carbon emissions and understand the impact of agricultural technology progress on the development of low-carbon agriculture has important reference significance for achieving sustainable agricultural economic development. At the same time, the research also has a positive effect on agricultural carbon emissions for environmental issues such as global warming. Therefore, studying the relationship between the progress of agricultural science and technology, agricultural carbon emissions, and agricultural economic development has significant practical and theoretical contribution.

2. Research methods and experimental design

2.1. Research methods

Wright proposed the concept of path analysis, and the idea of Structural Equation Modeling (SEM) is originated in the 1920s. The variables in the structural equation model include two types: one is latent variables, also known as construct variables, that is, items that cannot be directly observed and measured but want to be studied and discussed; the other is explicit variables, also known as measurable variables, that can be directly observed and measured [6].

Structural Equation Model consists of two parts, structural model and measurement model. The relationship between latent variables is mainly described by structural models, and the equation is:

$$\eta=B\eta+\Gamma\xi+\zeta$$

Among them, η is the endogenous latent variable; ξ is the exogenous latent variable; ζ is the random interference term, which reflects the unexplained part of η in the formula; B is the endogenous latent variable coefficient matrix. Γ is an exogenous latent variable coefficient matrix, describing the relationship between the exogenous latent variable ξ and the endogenous latent variable η.

The measurement model is used to describe the relationship between latent variables and explicit variables, and the equation is:

$$x=\Lambda^*\xi+\delta \quad y=\Lambda^*\eta+\varepsilon$$

Among them, x is the index or measurable variable of the exogenous latent variable ξ; y is the index or measurable variable of the endogenous latent variable η; Λx is the factor loading matrix of x on ξ; Λy is the factor loading of y on η Matrix; δ is the measurement error of x; ε is the measurement error of y.

2.2. Sample selection and data source

This paper took economic development status as the regional division standard, and selected 12 provinces in the western of China as samples. Sichuan Province, Chongqing City, Guizhou Province, Yunnan Province, Tibet Autonomous Region, Shaanxi Province,Gansu Province, Qinghai Province, Ningxia Hui Autonomous Region, Xinjiang Uygur Autonomous Region,Guangxi Zhuang Autonomous

Region, Inner Mongolia Autonomous Region. The data mainly comes from the "China Statistical Yearbook", "China Agricultural Statistical Yearbook" and the national data website (2013-2016).

2.3. Variable selection

According to the calculation methods of the Oak Ridge National Laboratory in the United States, the agricultural carbon emissions are divided into six carbon sources: chemical fertilizers, pesticides, agricultural machinery (mainly represented as agricultural diesel), agricultural film, plowing, and irrigation. The emission factor is multiplied by the respective carbon source emissions to obtain the total agricultural carbon emissions, as shown in Table 1. The calculation formula for total agricultural carbon emissions is:

$$E = \sum E_i = \sum T_i \cdot \delta_i$$

where: E is the amount of agricultural carbon emissions; Ei is the amount of carbon emissions from various carbon sources (i = 1, 2,..., 6); Ti is the amount of various carbon emission sources; δi is the carbon emission coefficient of various carbon emission sources.

Table 1. Agricultural carbon emission sources, coefficients and reference sources.

Agricultural carbon emission sources	Carbon emission factor	References
fertilizer	0.8856 $kg(C) \cdot kg^{-1}$	[2]
pesticide	4.9241 $kg(C) \cdot kg^{-1}$	[4]
Agricultural diesel	0.592 7 $kg(C) \cdot kg^{-1}$	[4]
Agricultural film	5.17 $kg(C) \cdot kg^{-1}$	[3]
Plowing	312.5 $kg(C) \cdot hm^2$	[6]
irrigation	266.38 $kg(C) \cdot hm^2$	[6]

Generally speaking, agricultural scientific and technological progress in the narrow sense only refers to the advancement of agricultural production technology, while in the broadly sense, agricultural scientific and technological progress includes agricultural production technology advancement, agricultural management systems and agricultural services, etc., as well as technical improvements in operation, management, and sales are the technological progress that runs through the entire agricultural process [7]. For convenience, this study uses agricultural science and technology expenditures to represent agricultural science and technology progress (ATP). The agricultural economy in a broad sense includes the economic development of all industries including agriculture, forestry, animal husbandry, by-products, and fishery. It reflects the total scale and results of agriculture, forestry, animal husbandry and fishery production for a certain period of time, and is highly comprehensive and representative. Therefore, in this study, the total agricultural output value, that is, the total output value of agriculture, forestry, animal husbandry, by-products, and fishery, represents the agricultural economic development (AED) [8].

2.4. Model constructing

First, the logarithm of the panel data are taken to eliminate the influence of heteroscedasticity, as shown in Table 2.

Table 2. Statistical description of variables.

Variable name	Number of samples	Mean	Standard deviation	Minimum	Max
lnE	120	7.0411	1.1111	4.0690	9.4271
lnATP	120	6.5908	1.1506	3.1351	8.9804
lnAED	120	4.4696	1.1636	1.2030	7.1028

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The analysis shows that there is not a single relationship between agricultural carbon emissions, agricultural technological progress, and agricultural economic development. Therefore, this study chooses to use a simultaneous empirical model, that is, SEM model for testing. The specific model expression is:

$$\ln E = C_1 + \alpha_1 \ln ATP_{it} + \beta_1 \ln AED_{it} + \varepsilon_{1it}$$
$$\ln ATP = C_2 + \alpha_2 \ln E_{it} + \beta_2 \ln AED_{it} + \varepsilon_{2it}$$
$$\ln AED = C_3 + \alpha_3 \ln E_{it} + \beta_3 \ln ATP_{it} + \varepsilon_{3it}$$

where: Eit represents the agricultural carbon emissions of the i-th province in year t; C is the same intercept between individuals; α and β are undetermined coefficients; ε1it, ε2it, and ε3it are error terms.

3. Results

The empirical test results are shown in Table 3.

Table 3. Test results of the relationship among agricultural carbon emissions, agricultural technological progress, and agricultural economic development in the western region.

Variable name	model	Number of observations	Regression coefficient (standard deviation)				R^2
			lnE	lnATP	lnAED	constant	
lnE	SEM	120		-0.6444*** (0.0406)	1.4304*** (0.0539)	-0.9669*** (0.1253)	0.9123
lnATP	SEM	120	-0.7950*** (0.0501)		1.5615*** (0.0693)	-1.3904*** (0.1269)	0.8963
lnAED	SEM	120	0.5895*** (0.0164)	0.5217*** (0.0161)		0.9541*** (0.0654)	0.9667

Note: *** means passing the 1% inspection level.

From the perspective of agricultural carbon emissions, the regression coefficients of agricultural scientific and technological progress and agricultural economic development on agricultural carbon emissions are -0.6444 and 1.4304, respectively, which are significant at the 1% test level. This shows that the greater the progress of agricultural science and technology, the lower the relative agricultural carbon emissions. The advancement of agricultural science and technology can effectively improve agricultural carbon emissions, while the development of agricultural economy will increase agricultural carbon emissions;

From the perspective of agricultural scientific and technological progress, the regression coefficients of agricultural carbon emissions and agricultural economic development on agricultural scientific and technological progress are -0.7950 and 1.5615, respectively, which are significant at the 1% test level. This shows that agricultural carbon emissions are not conducive to the progress of agricultural science and technology, and the development of agricultural economy can promote the progress of agricultural science and technology;

From the perspective of agricultural economic development, the regression coefficients of agricultural carbon emissions and agricultural technological progress on agricultural economic development are 0.5895 and 0.5217, respectively, which are significantly positive at the 1% test level. This shows that the increase in agricultural carbon emissions is conducive to promoting the development of agricultural economy to a certain extent. And the faster the advancement of agricultural science and technology, the higher the degree of agricultural economic development, indicating that the advancement of agricultural science and technology effectively promotes the development of agricultural economy.

4. Conclusion

Through empirical test results and preliminary analysis, it can be obtained that agricultural carbon emissions have a negative impact on agricultural scientific and technological progress and promote the development of agricultural economy; agricultural scientific and technological progress can not only reduce agricultural carbon emissions, but also contribute to the sustainable development of agricultural economy; The development of agricultural economy not only increases agricultural carbon emissions, but also promotes the progress of agricultural science and technology to a certain extent. In addition, this paper further analyzes the relationship and interaction between agricultural carbon emissions, agricultural technological progress and agricultural economic development.

(1) The impact of agricultural technological progress and agricultural economic development on agricultural carbon emissions. The high level of agricultural science and technology can make agricultural resources (fertilizers, pesticides, agricultural films, machinery and equipment, etc.) more reasonable and effective allocation, resource utilization efficiency is improved, and carbon emissions per unit of use are reduced, thereby reducing agricultural carbon emissions; The use of pesticides, chemical fertilizers, agricultural films, etc., or the expansion of plowing and irrigation areas can effectively promote the growth of agricultural products. The increase in the output of agriculture, forestry, animal husbandry, sideline, fishery and other products bring about the growth of the agricultural economy, and inevitably lead to an increase in agricultural carbon emissions.

(2) The impact of agricultural carbon emissions and agricultural economic development on the progress of agricultural science and technology. The chemical fertilizers, pesticides, and agricultural machinery used in the agricultural production process are the main sources of agricultural carbon emissions. The unreasonable and inappropriate use of these production materials is not conducive to the advancement of agricultural technology; and the agricultural economy is exposed in the development process. A series of ecological and environmental problems inevitably require the improvement of the utilization rate of agricultural resources. Technological progress is an effective way to improve efficiency. Therefore, the development of agricultural economy can play a role in promoting technological progress.

(3) The impact of agricultural carbon emissions and agricultural technological progress on agricultural economic development. In the process of agricultural production, out of the pursuit of profit, the use of pesticides and fertilizers has to be increased. As the agricultural economy develops, agricultural carbon emissions will also increase. Therefore, the increase in agricultural carbon emissions also reflects the development of agricultural economy to a certain extent, the advancement of agricultural science and technology can promote the efficiency of agricultural resource allocation, greatly improve the output efficiency and output of agricultural products, and can promote agriculture under other conditions of economic development.

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