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A quantitative study of the impact of scientific and technological progress in agriculture on rural economic growth

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ABSTRACT

This study aims to quantitatively analyze the impact of agricultural scientific and technological progress on rural economic growth. The contribution rate of agricultural scientific and technological progress in place A is measured through beyond logarithmic function model setting, data collection and processing. An agricultural carbon emission measurement model was built, in order to analyze the dynamic changes of total carbon emissions in place A. In addition, the gray correlation analysis algorithm was used to rank the correlation between agricultural science and technology indicators and economic growth in place A. Finally, a regression model is designed to analyze the impact of scientific and technological progress on rural economic growth. The coefficient of the t2 term of the contribution rate model of scientific and technological progress is 0.0013, which is greater than 0, indicating that there is scientific and technological progress in 2017-2023 in place A. The carbon emissions in place A decrease year by year with scientific and technological progress. All indicators in agricultural science and technology inputs can promote agricultural economic growth, and the gray correlation value in descending order is, T3>T9>T8>T1>T6>T4>T7>T2>T5. Scientific and technological progress has a different degree of promotion for the rural economic growth in place A.

Keywords: Beyond logarithmic function, carbon emission measurement, gray correlation analysis, regression model, agricultural scientific and technological progress

1. Introduction

Agriculture is the foundation of a country's economic development, and China, as a large agricultural country, the importance of agricultural development is even more self-evident. With the development of rural areas, the problems of irrational industrial structure, low agricultural productivity and failure to form large-scale production in traditional agricultural production seriously constrain the development of agriculture [1-3]. How to realize the high-quality growth of the agricultural economy

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is the problem faced by the current agricultural development.

In this era full of opportunities and challenges, the sustainable and high-quality development of agricultural economy can not be separated from the continuous innovation of agricultural science and technology, and only through continuous innovation can we realize the long-term development and sustained growth of agricultural economy [4-6]. The application of agricultural science and technology has changed the traditional mode of agricultural production, improved the efficiency of agricultural production, and realized the large-scale development of agricultural economy. It can be said that agricultural science and technology innovation has great social and economic benefits in the process of agricultural development. On the one hand, agricultural science and technology reduces the cost of agricultural production and improves the output of agricultural production value [7-8]. On the other hand, agricultural science and technology promotes the optimization and upgrading of the agricultural industrial structure, prompting the development of agriculture to scale and intensification [9-10]. In addition, agricultural science and technology has driven the transfer of rural surplus labor force, providing a new impetus for rural economic development [11-12]. In the context of the new era, the innovation and investment in agricultural science and technology is the driving force for the development of modern agriculture toward high-end, intelligent, and green development, so that the development of agriculture and rural areas has been secured in a long and effective way [13-15].

The essence of modern agriculture is to use modern science and technology to help agriculture develop at a high quality, through science and technology to help agricultural specialization, scale, intensification and social production, to improve the level of agriculture and promote the development of the agricultural economy. Literature [16] explains the key to the sustained growth of China's agricultural production from the perspective of division of labor and cooperation, leaving the energy-intensive production aspects of the agricultural production process to be executed by agricultural machinery, and these mechanized services are provided by a team of professionals, which significantly improves the efficiency of agricultural production. Literature [17] emphasizes the important role played by ICT in rural and agricultural economic development, showing that the Internet has been widely used in areas such as increasing agricultural productivity, facilitating agricultural decision-making, promoting rural credit, and developing rural e-commerce, accelerating rural and agricultural development in the digital age. Literature [18] shows that science and technology-supported agricultural digitization can achieve beneficial outcomes such as digital governance design, equal sharing of benefits, and business model change, for which technology can provide new and more effective digitization tools. Literature [19] discusses the significance of the development of agricultural automation, which is supported by existing technologies to provide low-cost, high-efficiency, and high-precision advantages in small-field farming, and that the economy, versatility, and robustness of the agricultural automation system will be significantly improved with technological development. Literature [20] introduces new plant breeding techniques based on transgenics and gene editing, which alleviate the world's food security problems to a certain extent, effectively avoid the shortcomings of the Green Revolution, and provide a new perspective for sustainable agricultural development. Literature [21] reveals the process and mechanism of rural economic restructuring driven by e-commerce, and e-commerce realizes the leap from traditional agricultural production to modern commercial services in the countryside, and creates diversified employment modes, providing opportunities for economic development in the countryside. Literature [22] points out that the development of agriculture cannot be separated from financial support, rural financial institutions with the help of science and technology to provide financial support for the key areas of agricultural development, through the allocation of more resources to the key areas of agriculture and weak areas, to realize the sustainable development of agriculture.

In this paper, the transcendental logarithmic function model is set to estimate the parameters of the contribution rate of scientific and technological progress in place A. The carbon emission measurement model is used to analyze the trend of carbon emission from multiple aspects (such as agricultural inputs, etc.) and the change of emission density and intensity in 2017-2023 in place A. And using the gray correlation algorithm, the strength of the impact of each agricultural science and technology on the rural economic growth of place A was assessed. Finally, the regression model was utilized to further predict the role of scientific and technological progress as an explanatory variable on rural economic changes.

2. Measurement of the contribution of scientific and technological progress in agriculture in location A

According to the definition of the contribution rate of agricultural technological progress, the measurement is mainly divided into two parts, one is the measurement of the output growth rate and the other is the measurement of the rate of technological progress. Measurement methods are mainly divided into two categories, the mathematical model method and the indicator system method, of which the former has been widely used due to its numerical quantification and high measurement accuracy.

2.1. Beyond logarithmic function modeling

The transcendental logarithmic function method, where the function is not set in a specific form, is an easy-to-estimate and very inclusive variable elasticity function model that is expanded according to the second-order Taylor's formula, and the expansion term includes both the Hicks-neutral technological advancement term and the interaction term between the technological advancement term and the factor term [23]. In this study, the model is set in the form:

$$\begin{aligned}\ln Y = {} & \alpha_0 + \alpha_1 t + \frac{1}{2}\alpha_2 t^2 + \beta K \ln K + \beta 4Kt \ln K + \beta L \ln L + \beta 4Lt \ln L + \beta N \ln N \\ & + \beta 4Nt \ln N + \beta KK \frac{1}{2}\ln^2 N + \beta LL \frac{1}{2}\ln^2 L + \beta NN \frac{1}{2}\ln^2 N + \beta KL \ln K \ln L \\ & + \beta KN \ln K \ln N + \beta LN \ln L \ln N + \eta disa + \nu - u\end{aligned} \tag{1}$$

Y represents the total agricultural output, t is a time trend variable, which represents the change of technological progress over time. K, L, and N represent the inputs of capital, labor, and land factors, respectively, and $\beta KL, \beta KN, \beta LN$ represents the interaction effect between the two inputs of material, labor, and land factors. $\beta AK, \beta AL, \beta AN$ represents the interaction effect between the three factors of production, capital, land, and labor, and the level of technology. $\beta KK, \beta L, \beta N$ There is no definite economic explanation, according to previous research, it can be interpreted as the factor itself reinforcing effect.

The derivation of t in equation (1) leads to the formula for the rate of technical progress in the narrow sense:

$$TP = \frac{\partial \ln Y}{\partial t} = (\alpha_1 + \alpha_2 t) + (\beta AK \frac{d \ln K}{dt} + \beta AL \frac{d \ln L}{dt} + \beta AN \frac{d \ln N}{dt}) \tag{2}$$

(2) where $(\alpha_1 + \alpha_2 t)$ represents the neutral technological progress over time and $(\beta 4K \frac{d \ln K}{dt} + \beta 4L \frac{d \ln L}{dt} + \beta 4N \frac{d \ln N}{dt})$ represents the sum of the total biased technological progress contribution.

From the above two equations, the contribution rate of technological progress in agriculture can be derived as:

$$TPC = \frac{TP}{\Delta Y / Y} \times 100\% \tag{3}$$

The formulas for the elasticity values of capital, labor, and land can be derived by taking the partial derivatives of LnK, InL, and InN, respectively, for equation (3):

$$\varepsilon_k = \frac{\partial \ln Y}{\partial \ln K} = \beta_k + \beta_{AK}t + \beta_{kk}\ln K + \beta_{KL}\ln L + \beta_{KN}\ln N \tag{4}$$

$$\varepsilon_L = \frac{\partial \ln Y}{\partial \ln L} = \beta_L + \beta_{AL}t + \beta_{LL}\ln L + \beta_{KL}\ln K + \beta_{LN}\ln N \tag{5}$$

$$\varepsilon_N = \frac{\partial \ln Y}{\partial \ln N} = \beta_N + \beta_{AN}t + \beta_{NN}\ln N + \beta_{KN}\ln K + \beta_{LN}\ln L \tag{6}$$

The Divisia total factor growth rate index formula is introduced to fully decompose generalized technological progress:

$$TFP = d\ln Y / dt - \Sigma_i S_i \cdot d\ln X_i / dt \tag{7}$$

where $S_i = \frac{\omega_i X_i}{\Sigma \omega_i X}$, ω_i are the prices of the i rd factor.

In the process of decomposition of generalized agricultural technological progress, the need to measure technical efficiency, therefore, the introduction of the stochastic frontier model, the error term is divided into two parts of the uncontrollable (v) and technical efficiency (u) factors, both sides of the logarithmic form of the function:

$$\ln Y = \ln f(X, t; \beta) + v - u \tag{8}$$

where $u > 0, t = 1, 2, \ldots, T$.

Finding the derivative with respect to time t for equation (8) gives:

$$\frac{d}{\ln} Ydt = TP + \Sigma_i \varepsilon_i \frac{d\ln X_i}{dt} + TE \tag{9}$$

Substituting the Divisia total factor growth rate index formula into equation (9) and assuming a zero rate of change in resource efficiency yields the simple Kumbhakar decomposition formula as:

$$TFP = TP + (\varepsilon - 1)\Sigma_i \frac{\varepsilon_i}{\varepsilon}\frac{d\ln X_i}{dt} + TE \tag{10}$$

where $\varepsilon = \Sigma\varepsilon_i$ is known as the returns to scale index. TP is the rate of technical progress in the narrow sense, TE is the rate of change in technical efficiency, and the middle term is the rate of return on the change in returns to scale; the sum of these three terms is the rate of technical progress in the broad sense.

2.2. *Data selection and processing*

This study uses 263 sets of panel data from 2017 to 2023 for Place A for estimation, all of which come from the Yearbook of Place A, the Yearbook of Development of Place A, and the Rural Yearbook of Place A. The data processing method of three-year smoothing is generally applicable to time series data, which basically eliminates factor heterogeneity and avoids large fluctuations between years that would make the results of technical progress rate measurement negative. This study, however, uses the panel data of Place A, which is more stable than the time series data, and the method used is not simply deducting the growth rate of gross output value, and three-year smoothing of the data will have an impact on the accuracy and validity of the results of the calculations, so this study does not apply three-year smoothing to the data.

2.2.1. Total outputs. The contribution rate of agricultural technological progress refers to the role of agricultural technological progress in contributing to agricultural output. Generally speaking, there are two main indicators for measuring agricultural output: one is the gross value of agricultural output, which includes the monetary expression and total value of all commodities in agriculture, forestry, animal husbandry and fisheries. The other is the value added of agriculture, i.e., the value added of agriculture, forestry, animal husbandry and fishery, which is equal to the difference between the total output value of agriculture, forestry, animal husbandry and fishery and the intermediate consumption of agriculture. In this study, the gross output value of agriculture, forestry, animal husbandry and fisheries is chosen as the output indicator, which can include all the factors of technological progress changes when measuring broad technological progress.

2.2.2. Inputs:

1) Material inputs (K). The material input K of this study adopts agricultural intermediate consumption, which refers to the value of goods and services consumed in the production and operation of agriculture, forestry, animal husbandry and fishery, and is equal to the difference between the total output value of agriculture, forestry, animal husbandry and fishery and the value added of agriculture. In order to eliminate the price factor impact to make the data comparable, the use of agricultural output value index to adjust the data: material cost comparable price = (the current year's relative index of agricultural output value / the current year's total agricultural output value) × the current year's agricultural material costs.

2) Agricultural labor (L). Labor input refers to the input of the amount of labor in the agricultural production process, and the labor time of standard labor intensity is generally used as its measurement index. This study uses the number of people employed in the primary industry at the end of the year as the number of agricultural labor force.

3) Cultivated land area (N). For planting, this study uses the sown area of crops to replace the area of cultivated land. For forestry, the forestry output value and its occupied area have a negligible weight compared to large-scale agriculture, so the forestry land input is not set. For fishery, since there is almost no fishery production in Site A, the fishery land area is ignored. As for livestock, Land A is mainly based on the captive breeding method and occupies little land, so the land input for livestock is not set.

Note that after examining agriculture, forestry, animal husbandry and fishery, this study takes the agricultural sown area as the land input variable, and in order to determine the share of land contribution more accurately, the variable of disaster area is introduced, usually about 30% of the disaster area of arable land is extinct, and the area of arable land in this study = the sown area of crops - 30% of the disaster area.

2.2.3. Climate variables (Disa). Climatic factors are crucial to agricultural production, and usually disasters such as hail, rain, snow, floods, and droughts are ultimately reflected in the affected area. Therefore, this study sets the climate variable as the ratio of the disaster area to the sown area of crops in the current year.

2.3. Analysis of parameter estimation results

The analysis software is used to estimate the panel data for the years 2017-2023, and the results of parameter estimation are shown in Table 1.

As can be seen from the table, the t-statistic values of most of the variables pass the test at the 1% significance level and γ is 0.97, indicating that there is a loss of efficiency in the model, which can be applied to the stochastic frontier model, or else only the transcendental logarithmic function can be used.

From the results of parameter estimation, the coefficient of the t2 term of the model is positive, indicating that there is technological progress in science and technology in 2017-2023 in place A. The lnKlnL term is positive, indicating that the interaction between capital and labor is positive, that is to say, in the period of the study, the factors of capital and labor have a complementary effect in agricultural production. lnKlnN and lnLlnN terms are negative, indicating that the period of the study The capital-land and labor-land interactions are negative, i.e., capital and land and labor and land have substitution effects.The Disa term is negative and consistent with the economic reality. The dummy variable T term is negative and passes the test at 5% level of significance, indicating that scientific and technological progress does have a significant impact on rural agriculture.

Table 1. Parameter estimation results

	Estimated value	Standard error	t statistical value
c	-3.673	0.34	-1.26***
t2	0.0013	0.001	3.41***
InK	0.43	0.024	4.71***
tInK	0.007	0.001	-2.23***
InL	1.23	0.37	3.79***
tInL	-0.011	0.003	-1.67***
InN	0.19	0.018	2.14
tInN	0.003	0	2.68
InKInK	0.17	0.011	7.35***
InLInL	-0.079	0.022	-3.17***
InNInN	0.062	0.016	4.98***
InKInL	0.025	0.005	2.46
InKInN	-0.036	0.015	-3.11***
InLInN	-0.059	0.008	-2.63***
Disa	-0.26	0.039	-9.42***
T	-0.041	0.017	-3.62***
γ	0.97	0.035	157.68***
log likelihood function=193.95 LR test of the one-side error= 132.76			

Note: * indicates that the parameter passes the test at the 10% level, ** indicates that the parameter passes the test at the 5% level, and *** indicates that the parameter passes the test at the 1% level.

3. Measurement of scientific and technological progress on total carbon emissions

3.1. *Modeling of Total Agricultural Carbon Emission Measurement*

Agricultural carbon emission is a general term for greenhouse gas emissions such as CO2, CH4, N2O and other greenhouse gases produced in the process of agricultural production and operation. In this paper, planting inputs such as pesticides, agricultural fertilizers and films, soil tilling agricultural irrigation, crop residue burning, and animal manure and enteric fermentation during livestock breeding such as cows, sheep and horses are selected as the main carbon emission source factors in agriculture in Site A.

3.2. *Models for measuring agricultural carbon emissions*

Regarding the measurement method of total agricultural carbon emissions, this paper chooses to measure it through the following model as follows:

$$E = \sum E_i = \sum T_i \cdot \theta_i \tag{11}$$

Where E is the total amount of carbon emissions, E_i is the amount of carbon emissions produced by each type of carbon source, T_i is the amount of carbon used by each type of carbon source, θ_i is the carbon emission coefficient, and i takes the values of 1, 2, 3,....

In order to facilitate the accounting of total agricultural carbon emissions in A, this paper converts each carbon source coefficient into a carbon emission coefficient based on the GWP to be measured. CO2eq is used as a unit of measure for greenhouse gas emissions and allows normalization of CO2 and non-carbon greenhouse gases. GWP(CO2)=1, GWP(N2O)=298, and GWP(CH4)=25, based on which, this paper converts the total measured agricultural carbon emissions from Site A, uniformly using CO2eq for the conversion study.

3.3. Processing of data sources

All data in the study are from the above mentioned. Based on data availability and research needs, the definition of agricultural carbon emission sources in this paper includes four main aspects: inputs from agricultural land, rice cultivation straw burning, and livestock breeding.

3.4. Analysis of the dynamics of total agricultural carbon emissions

This section evaluates the changes in carbon emissions in place A with the progress of agricultural science and technology from four components: agricultural material inputs, livestock and poultry farming, soil carbon sources and total carbon emission components from straw burning. Figure 1 shows the trend of carbon emission changes in place A from 2017 to 2023.

As can be seen from Figure 1, the change of carbon emissions in place A shows a decreasing trend in four aspects: agricultural material inputs, livestock and poultry farming, soil carbon sources and straw burning. Analyzed in 2023, the year with the most advanced agricultural technology, the agricultural carbon emitted by straw burning of major crops in place A is the most, accounting for 63.53% of the total carbon emissions. In terms of the composition of agricultural material inputs, fertilizer produces the most carbon emissions. Livestock and poultry farming carbon emissions are also a major component of carbon emissions in Site A. The most carbon emissions from livestock and poultry are enteric fermentation and manure emissions from cattle, pigs and sheep.

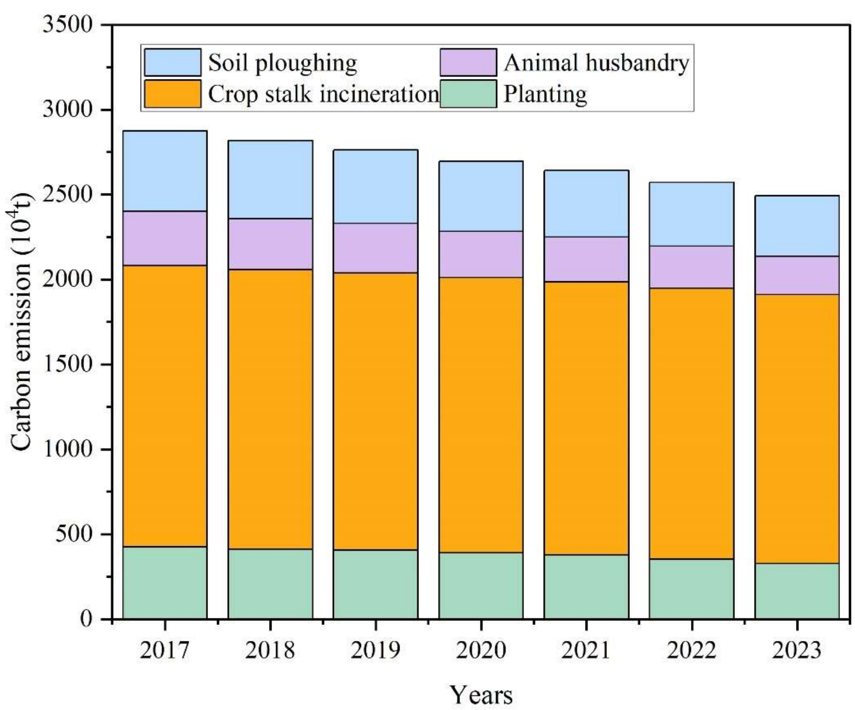

Fig. 1. A land change in carbon emissions

Carbon intensity refers to the amount of carbon emissions per unit of GDP, and the general carbon intensity indicator is reduced with economic growth and technological progress. Agricultural carbon intensity is the amount of emissions released per 10,000 yuan of agricultural and livestock production value in that year. The intensity of agricultural carbon emissions, on the other hand, is the amount of carbon emissions released per unit of crop sown area per year. Figure 2 shows the results of the dynamic change of carbon emission intensity and density in place A from 2017 to 2023.

The intensity of agricultural carbon emissions in place A The intensity of agricultural carbon emissions shows a tendency of phased fluctuation and decrease, of which the lowest was in 2023, when every 10,000 yuan of total output value of agriculture and animal husbandry in place A produced just 0.83 tons of carbon. Starting from 20017, the agricultural carbon emissions that can be generated per 10,000 Yuan of agricultural and animal husbandry gross output value has been decreasing, from 4.68 tons per 10,000 Yuan in 20017 to 0.83 tons per 10,000 Yuan in 2023, which is a significant decrease.

The density of agricultural carbon emission is changed by the actual sown area of crops as well as the total amount of carbon emission. Combined with the previous situation of the intensity of agricultural carbon emissions in place A, it can be seen that from the intensity of agricultural carbon emissions and the density of the changes can be derived from the results, indicating that the category of agricultural carbon emissions in place A is a “low-intensity-high-density” type, which indicates that with the continuous and good development of agricultural and rural economy and agricultural science and technology progress, the productivity of the agricultural and rural areas in place A has been improved. This shows that with the continuous development of the agricultural and rural economy and the progress of agricultural science and technology, the productivity of agriculture and rural areas in A has been improved, which has led to the rapid development of the agricultural economy in A, which is conducive to the reduction of the agricultural carbon emission in A and the improvement of the environmental sanitation in the rural areas, thus achieving the green and low-carbon agriculture.

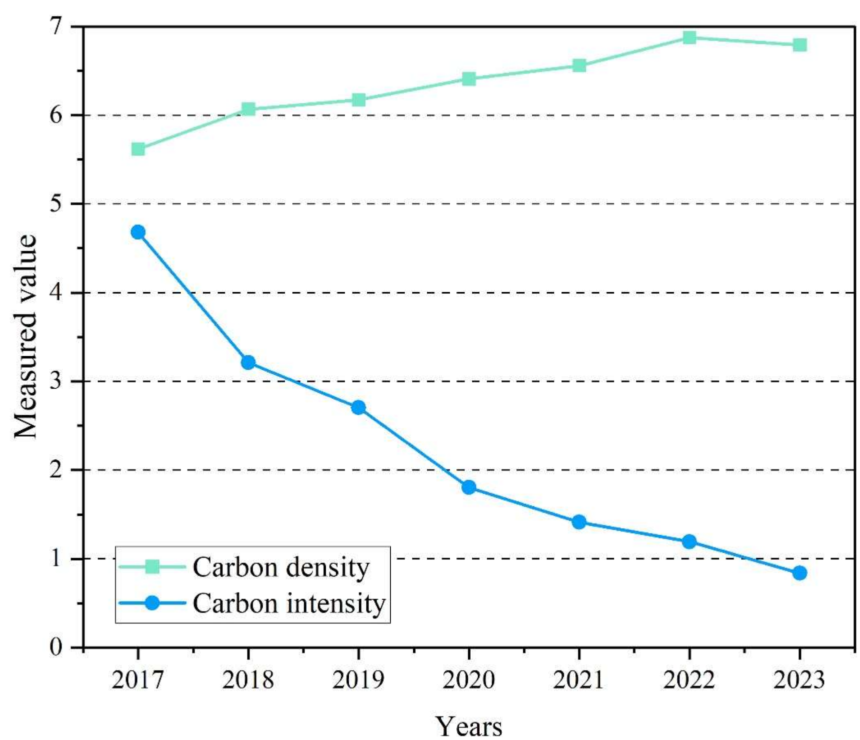

Fig. 2. Carbon emission intensity and density dynamic change results

4. Impact analysis of rural economic growth based on gray correlation

4.1. Gray correlation analysis

The basic idea of gray correlation analysis is [24-25]: by analyzing the dynamic evolution of a system, determine the degree of influence between factors or the contribution of each factor to the main behavior, and determine the relationship between the two by analyzing the similarity between the target and the time requirement curve.

The structure of financial support for agriculture belongs to gray system, which is characterized by complexity, uncertainty and incomplete information, etc. In this paper, the limited data of financial and agricultural support structure in Chongqing Municipality is fully considered, and the gray correlation analysis method is used to analyze the financial and agricultural support structure. The specific calculation steps of the correlation degree are as follows:

1) Determine the reference sequence and comparison sequence. Let the reference series be $y=\{y(t)\,|\,t=1,2,3\ldots n\}$ and the comparison series be, where i denotes agricultural expenditure, forestry expenditure, water conservancy expenditure, poverty alleviation expenditure, comprehensive agricultural development $x_i=\{x_i(t)\,|\,t=1,2,3\ldots n\}$ expenditure, comprehensive rural reform expenditure, inclusive financial development expenditure, and other agricultural, forestry and water expenditure, respectively. t denotes the time (20017-2023).

2) Data dimensionless processing. In this paper, the homogenization method is used for the treatment to eliminate the effect of each series of quantiles:

$$x_i^{'}(t)=\frac{x_i(t)}{\bar{x}_i} \tag{12}$$

3) Calculate the correlation coefficient:

$$\zeta_{ik}=\frac{\min\min\left|y'(t)-x_i^{'}(t)\right|+\rho\, max\,max\left|y'(t)-x_i^{'}(t)\right|}{\left|y'(t)-x_i^{'}(t)\right|+\rho\, max\,max\left|y'(t)-x_i^{'}(t)\right|} \tag{13}$$

ρ is the discrimination coefficient, which usually takes a value ranging from 0 to 1. Here the value 0.5 is taken.

4) Calculate the degree of correlation $\gamma_i=\frac{1}{..}\sum^{n}\zeta_{ik}\,(i=1,2,3\ldots m)$. The correlation coefficients of each point are combined into a single value using the above formula as an indicator of the degree of correlation between the reference sequence and the comparative sequence, which facilitates holistic comparison.

4.2. Data selection

This paper adopts the value added of agricultural production in place A as an indicator of agricultural economic growth, and the status of the distribution structure within agricultural science and technology inputs largely determines the effectiveness of total agricultural science and technology inputs. In this paper, the nine sub-projects promoting agricultural science and technology inputs are used as indicators to explore the structure of agricultural science and technology inputs in place A. In this way, the relationship between the nine sub-items of agricultural S&T inputs and the value added of agricultural production is examined, so as to prioritize different kinds of agricultural S&T inputs and provide a basis for formulating reasonable policies. Table 2 shows the number and description of each S&T-related indicator.

Table 2. Gray correlation analysis index

Sequence	Indexes	Symbols
Agricultural economic growth	Added value of agricultural production	T0
Agricultural machinery investment	Total mechanical power of agricultural machinery	T1
Agricultural science and technology personnel	Agricultural R&D personnel	T2
	Technical personnel of agricultural and forestry husbandry and fisheries	T3
Investment in agricultural science and technology	Basic research cost in agricultural R&D funds	T4
	Applied research fee in agricultural R&D funds	T5
	The cost of the development of agricultural R&D funds	T6
	Government funding for agricultural science and technology funds	T7
	The cost of the expenditure of the agricultural science and technology funds	T8
	Purchase cost of expenditure equipment for agricultural science and technology	T9

4.3. Gray correlation empirical analysis

Figure 3 shows the results of the gray correlation calculation of the impact of agricultural science and technology progress on rural economic growth in place A from 2017 to 2023. According to the data in the figure, the gray correlation values of each indicator of agricultural science and technology with agricultural economic growth are, in descending order, T3>T9>T8>T1>T6>T4>T7>T2>T5, and among the nine indicators measuring agricultural science and technology inputs in Place A, the total power of agricultural machinery, professional and technical personnel in agriculture, forestry, animal husbandry and fishery, experimental development costs in agricultural R&D funding, personnel labor costs in agricultural science and technology funding expenditures and equipment purchase cost of agricultural S&T expenditure have the largest correlation with agricultural economic growth, with the average correlation staying above 0.8, respectively 0.828, 0.908, 0.819, 0.835, 0.891. The next largest correlation with agricultural economic growth is that of agricultural R&D personnel, basic research cost of agricultural R&D expenditure, and government funds of agricultural S&T expenditure mobilized, which stays above 0.7, respectively 0.701, 0.795, 0.724. Finally, there is the cost of applied research on agricultural R&D experiments, with an average correlation of 0.64, a relatively large gap with the correlation of the other indicators.

Taken together, all indicators in agricultural science and technology input can promote agricultural economic growth, among which, basic research in the three expenditures of agricultural R&D funds has a greater impact on agricultural economic growth, and agricultural R&D personnel in agricultural science and technology manpower input has a greater impact than agricultural, forestry, animal husbandry and fishery professionals and technicians, which suggests that high-quality human resources are the core force of science and technology and economic development.

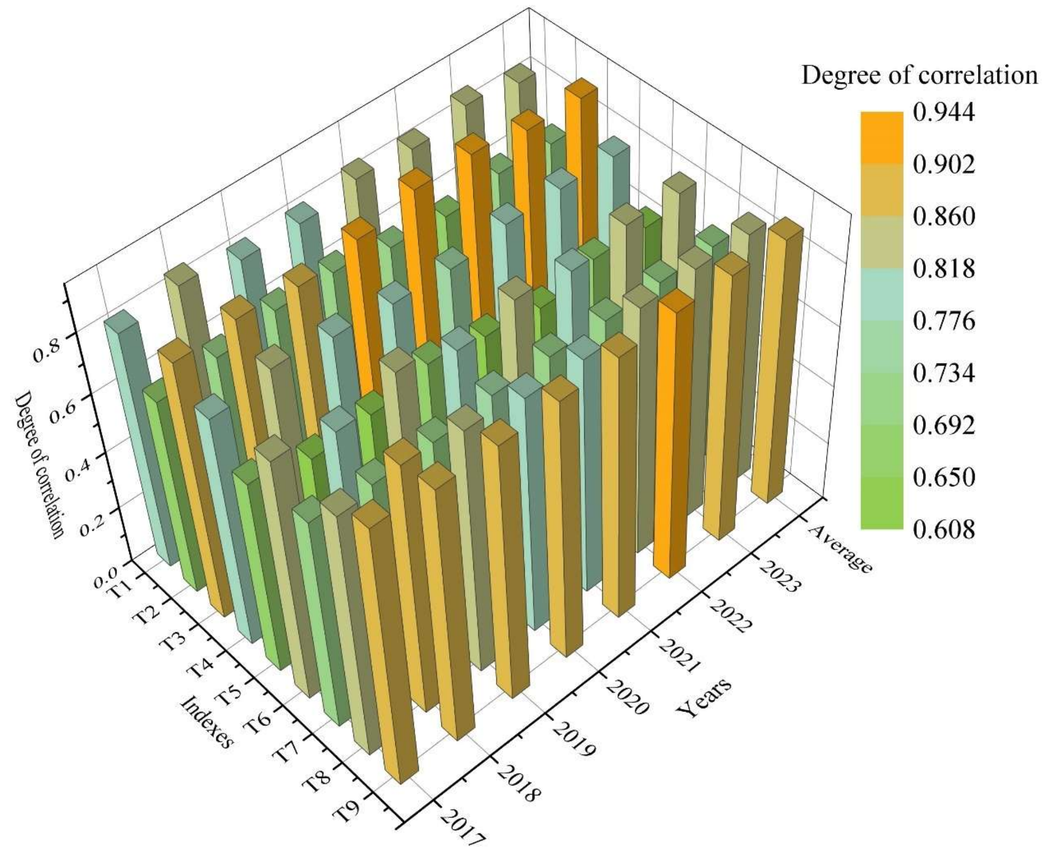

Fig. 3. Correlation analysis settlement results

5. Impact of scientific and technological progress in agriculture on rural economic growth

5.1. Data sources

Based on the principle of data availability and completeness, this paper still takes place A as the research object, and the time interval is 2017-2023. The interpolation method is used to deal with missing values, and in order to better measure the purchasing power of prices, it is necessary to exclude the impact of price changes, take the 2017 value as the base period, and deflate the per capita disposable income of rural residents, agricultural output value and other indicators. The data are mainly derived from the previous section.

5.2. Variable Settings

The study focuses on the analysis of agricultural economic development, which is divided into the dimensions of fair development and high-quality development, and analyzes the impact of agricultural science and technology innovation on agricultural economic development. The selection of variables in this paper mainly refers to previous research on agricultural economic development, so that the selection of variables is reliable.

5.2.1. Explained Variables. In this paper, the income ratio of urban and rural residents (llr) and the added value of agriculture, forestry, animal husbandry and fishery of the rural population (pcav) are used to indicate the equitable development. It also uses the gross output value of agriculture, forestry and fisheries (tov) and the real value added of agriculture, forestry and fisheries (aav) to indicate the growth status of the agricultural economy, which further indicates the high-quality development of the agricultural economy.

5.2.2. Explanatory variables. This paper represents this dynamic process in terms of agricultural science and technology inputs, agricultural science and technology outputs, and agricultural science and technology funding sources. The selected variables are: the intensity of internal expenditure of R&D funds, the source of funds for agricultural science and technology activities, and the number of agricultural topics.

The intensity of internal expenditure of R&D funds (iei) is the ratio of internal expenditure of research funds to researchers, which is used to indicate the amount of researchers' average allocation to the internal expenditure of research funds.

In this paper, the sources of funds for agricultural science and technology activities are categorized into financial allocations (afa) and funds received from undertaking government projects (ugp). The government supports the development of agricultural science and technology through financial allocations to realize the equitable and high-quality development of the agricultural economy. Funds from government programs are mainly funds applied by researchers or other scholars through applying for government programs, and the funds are mainly used for program expenses.

The output of agricultural science and technology is expressed in terms of the number of agricultural topics (nap).

5.2.3. Control variables. Agricultural machinery total power (pam) said mainly for agriculture, forestry, animal husbandry, fisheries, a variety of power machinery power sum, including farming machinery, irrigation and drainage machinery, harvesting machinery, etc. Agricultural machinery can speed up the process of agricultural production, reduce the cost of labor, greatly accelerate the efficiency of agriculture.

Agricultural plastic film use (cap) applied to agricultural production of plastic film, for the sowing period of moisture, heat preservation plays a very important role.

Effective irrigation area (eia) is a relatively flat plot of land, there are certain water sources, irrigation facilities supporting, in general under the year can carry out normal irrigation of farmland area. For can carry on the normal irrigation of paddy field and dry land in the water-consumed land area and the sum. The size of the effective irrigated area is an indicator of the degree of hydrolization of agricultural production units and regions and the degree of stability of agricultural production.

Per capita disposable income (pcdi) includes cash income as well as income in kind.

Grain crop production (gcy) is the total amount of food produced by an agricultural production operator during the calendar year.

Rural population (rp), the development of the agricultural economy is the need for the joint efforts of the rural population, but the technologization of agriculture is to reduce the population base, through agricultural mechanization to increase agricultural income, too much population and will result in redundancy of the labor force, so explore the relationship between the rural population and the development of the agricultural economy is a more important part.

Rural household fixed asset investment in agriculture, forestry, animal husbandry and fishery (ifa), the assets invested in agriculture, forestry, animal husbandry and fishery indicate the importance of agricultural households to the degree of agriculture, but also can be seen in the degree of importance of agricultural income to the income of farmers.

The area transferred to farming households (atf) refers to the area of land contracted by rural households that retains the contracted rights and transfers the management or use rights to other farming households or other economic organizations through legal forms.

5.3. Model construction

Constructing a panel model can effectively reduce the problem of data endogeneity and improve the estimation accuracy of the coefficients, based on which the panel model is constructed, the model is as follows:

$$\begin{aligned} Y_{it} &= \beta_1(\mathrm{iei}_{it}) + \beta_2(afa_{it}) + \beta_3(nap_{it}) + \beta_4(pam_{it}) + \beta_5(cap_{it}) + \beta_6(eia_{it}) \\ &+ \beta_7(pcdi_{it}) + \beta_8(gcy_{it}) + \beta_9(rp_{it}) + \beta_{10}(ifa_{it}) + \beta_{11}(atf_{it}) + \mu_i + \lambda_{it} \end{aligned} \tag{14}$$

5.4. Regression analysis of rural economic growth driven by scientific and technological progress

In order to conduct a quantitative analysis of the contribution of agricultural S&T progress to local economic growth in place A, this section brings the variables set above into the regression model to assess the contribution of S&T progress to economic growth in place A.

The explanatory variables in this section are the income ratio of urban and rural residents (llr), the added value of agriculture, forestry, livestock and fishery of rural population (pcav), the total output value of agriculture, forestry, livestock and fishery (tov), and the real added value of agriculture, forestry, livestock and fishery (aav).

The explanatory variables are internal expenditure intensity of R&D funding (iei), financial allocation (afa), funds received for undertaking government programs (ugp), and the number of agricultural topics for agricultural science and technology output (nap).

The control variables are selected as total power of agricultural machinery (pam), use of agricultural plastic film (cap), effective irrigated area (eia), per capita disposable income (pcdi), grain crop production (gcy), rural population (rp), rural household fixed asset investment in agriculture, forestry, animal husbandry, and fishery (ifa), and the area transferred to farm households (atf).

The results of the regression analysis to obtain the impact of agricultural scientific and technological progress on rural economic growth are shown in Table 3.

Model 1 shows the impact of agricultural scientific and technological progress on urban-rural income ratio (llr) after fixing the control variables factors. From the estimation results of the main explanatory variables, all of them, except nap, passed the 1% significant level test. For example, the estimated coefficient of iei and llr is -0.000125, which indicates that the intensity of internal expenditures on R&D funding suppresses the income ratio of urban and rural residents and promotes the equitable development of the agricultural economy. And the income from agricultural science and technology activities in afa and ugp both significantly promote the income ratio of rural and urban residents, and its increase by one unit respectively, llr rises by 0.0000061 and 0.0000117 respectively.

For the impact of rural population agriculture, forestry and fishery value added (pcav), model 2 data show that iei, afa, ugp all promote its growth at the 5% level, i.e., increase the value added of agriculture, forestry and fishery of rural people ou. And iei has the most significant impact, and for each unit of its increase, pcav can be elevated by 7.463.

In the case of gross value added of agriculture, forestry and fisheries (tov), only iei has a significant positive effect on it, and its increase by one unit raises the gross value added of agriculture, forestry and fisheries by 0.314.

Model 4 shows the correlation coefficients between the explanatory variables and the real value added of agriculture, forestry, livestock and fisheries (aav), and the data show that iei raises the real value added of agriculture, forestry, livestock and fisheries at the 1% level, and an increase of one unit in iei raises the aav by 0.211 accordingly. Afa and ugp also have a contributing effect and pass the 10% significance level test.

Table 3. Regression analysis of rural economic growth

Variable	Explained variable

		Model 1(llr)	Model 2(pcav)	Model 3(tov)	Model 4(aav)
Interpretation variable	iei	-0.000125***	7.463***	0.314***	0.211***
	afa	0.0000061***	0.00268***	0.000076	0.000039*
	ugp	0.0000117***	0.000396**	0.0000162	0.0000741*
	nap	-0.0000412	-0.413	0.0725	0.0474
Control variable	pam	-0.0000263	0.577***	0.0243	0.0126
	cap	-0.00000317**	0.0267***	0.0037**	0.000458**
	eia	-0.0000278	0.474***	0.0196**	0.0173**
	pcdi	0.000000394	-0.0251	-0.00234	-0.00251
	gcy	0.0000745	0.849	0.179***	0.0898***
	rp	0.000657***	-3.432***	-1.579**	-0.917***
	ifa	-0.0000297	-2.611	0.233	0.0791
	atf	-0.0000374	0.0000423	0.000063***	0.0000059***
R2		0.462	0.573	0.664	0.737
F		19.26	17.54	17.11	17.93

*, **, *** denote significance level at 10%, 5%, 1% respectively

6. Conclusion

This study designed a beyond logarithmic function model, a carbon emission measurement model, a gray correlation analysis algorithm, and a regression model, aiming to analyze the impact of agricultural scientific and technological progress on rural economic growth using quantitative methods.

The results of the parameter estimation of the contribution rate of scientific and technological progress show that the coefficient of the t2 term of the model is 0.0013, which indicates that the scientific and technological progress in place A exists.

With the progress of agricultural science and technology year by year, the carbon emissions of place A gradually decline, and in 2023, the total carbon emissions of place A in agricultural material inputs, livestock and poultry breeding, soil carbon source and straw burning is 2.49 × 107t. And its carbon emissions type is “low density - high intensity” type.

The total power of agricultural machinery, professional and technical personnel in agriculture, forestry, animal husbandry and fishery, experimental development expenses in agricultural R&D funds, personnel labor expenses in agricultural science and technology funds, and equipment purchase expenses in agricultural science and technology funds have the greatest correlation with the growth of the agricultural economy, which are 0.828, 0.908, 0.819, 0.835, and 0.891, respectively.

The regression results show that progress in agricultural science and technology can significantly drive rural economic growth.

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