A Study of the Economic Contribution Rate of Agricultural Mechanization in Jiangxi Province from the Perspective of Cobb-Douglas' Production Function

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Abstract: With the gradual transformation of traditional agriculture into modern agriculture, agricultural mechanization has played a very important role in the contribution rate of the whole people's economy in Jiangxi Province. Because of the wide application of Cobb-Douglas (C-D) production function in western economics, many scholars have used this method in practice in recent years. By establishing the C-D production function model, the agricultural mechanization data of Jiangxi Province from 2005 to 2019 are analyzed, and the factors such as agricultural output value, agricultural mechanization input, agricultural material consumption, labor input and land input play a key role in the economic growth of agricultural mechanization development.

Keywords: Agricultural mechanization in Jiangxi Province; C-D production function; Contribution rate

1. Introduction

It is said that: "Bread is the staff of life." The support of agricultural production is inextricably linked to all human activity and existence. China's science and technology have progressed steadily, and the economy has grown swiftly, thanks to the steady growth of the country's complete strength. Manual planting, on the other hand, cannot adapt to today's agricultural development. China's agriculture has steadily transitioned to agricultural mechanization in order to adapt to changing times. Agricultural mechanization is not only an important theoretical basis to promote the continuous innovation and development of China's agricultural productivity, but also an important guarantee to ensure the smooth implementation of the rural revitalization strategy. It plays an unparalleled role in China's agricultural development. In recent years, China has also made a qualitative breakthrough in the level of agricultural machinery manufacturing. During the 13th Five Year Plan period, China grasped this important period, comprehensively promoted the construction of a well-off society, and brought the development of China's agricultural mechanization to its peak. However, according to statistics, the degree of agricultural mechanization in China is only 63%, and the 13th Five-year Plan for the Development of National Agricultural Mechanization mentioned that it

is expected to reach nearly 70% by 2020. It can be seen that there is still a big gap between the level of agricultural mechanization in China and the expected value [1].

Jiangxi's agricultural economy occupies a certain position in the national economy. Facing the complex and changeable external economic environment, Jiangxi Province has always implemented the concept of new agricultural technology development and actively adapted to the new normal of economic development. While promoting the structural supply side structure, Jiangxi Province should fully implement the policies of stabilizing growth, promoting reform, adjusting structure, promoting ecology and promoting people's livelihood. According to preliminary accounting, in 2016, enterprises in Jiangxi Province could achieve a gross domestic product (GDP) of 1836.44 billion yuan, an increase of 9.0% over 2015. Among them, the primary industry increased by 190.45 billion yuan, an increase of 4.1%; The secondary industry increased by 903.21 billion yuan, an increase of 8.5%; The tertiary industry increased by 7427.8%, an increase of 11.0%; The contribution rates of the three industries to GDP growth are: 4.8%, 47.4% and 47.8%. The per capita GDP was 40106 yuan, an increase of 8.4%, which was converted into US $6038 at the average annual exchange rate [2]. The total output value of Jiangxi Province is rising. The development of agricultural mechanization and modernization is the key to improve the level of agricultural production. It can be seen that the level of agricultural mechanization has a certain impact on the contribution rate of GDP growth.

The Cobb Douglas production function takes into account the factors that influence the key indicators of total output value, such as the comprehensive technological level, labor force size, and capital. The contribution rate of agricultural mechanization to total agricultural production value may be computed systematically using this function. This paper investigates the contribution rate of agricultural mechanization to the total output value of agricultural production in Jiangxi Province using the Cobb Douglas production function model, and then investigates the research methods related to the development of agricultural machinery in Jiangxi Province.

2. Establishment of agricultural mechanization production model
2.1. Selection of agricultural mechanization production model

The difference between the cost and income while utilizing and not using agricultural machinery is referred to as the contribution value of agricultural mechanization. Many scholars and researchers have done extensive study on the contribution rate of agricultural mechanization to date. The C-D production function model is extensively used in economic mathematics, and numerous researches both at home and abroad have confirmed it. This model is one of the best for determining the rate of agricultural mechanization contribution [3]. This function model was used to determine the contribution rate of agricultural mechanization in Jiangxi Province from 2005 to 2019 based on predecessors.

In the late 20th century, the American mathematician C.W. Cobb and economist P.H. Douglas proposed the C-D production function in cooperation. According to the statistical data of American manufacturing industry, it is an empirical hypothesis to explain that the proportion of wages in American national income has remained relatively stable since the beginning of the 20th century [4]. C-D production function has a wide range of applications, such as: establishing the prediction and analysis model of social and economic development, economic production in a specific industry, measuring the role of technological progress and input in economic growth, and even studying the total input-output relationship of a country. Generally, input can be divided into two types: capital investment and labor input. The production function in the general expression [5] is:

$$Y = AK^{\alpha}L^{\beta} \text{ (1-1)}$$

Wherein: Y - output value;

A - comprehensive technical level;

K - capital investment;

L - labor input;

α - elasticity coefficient of capital investment;

β - elasticity coefficient of labor input.

The number of input and output elements will change with time. In order to accurately reflect the change relationship between enterprise input and output, the elasticity coefficient of each input element should also change with time [6]. In the 1940s, American economist Jan Tinbergen introduced the time variable t into the C-D production function, transformed A into a quantity varying with t, and corrected the function as follows:

$$Y = A_0 e^{\delta+1} K^{\alpha} L^{\beta} (1\text{-}2)$$

Wherein: δ -scientific and technological progress rate;

In the C-D production function, the value range of elastic coefficient is:

$$0 < \alpha < 1; \quad 0 < \beta < 1$$

Among them, the value of elastic coefficient can be divided into three cases [1]:

(1) $\alpha + \beta < 1$: shows that the rate of return of production function decreases, the production scale of enterprises increases continuously, and the economic benefits cannot get the same benefit growth.

(2) $\alpha + \beta = 1$: shows that the rate of return of the production function is constant, and the economic benefit cannot be improved by expanding the production scale.

(3) $\alpha + \beta > 1$: shows that economic benefits can be obtained by expanding the production scale and gradually increasing the yield of production function.

2.2. Model establishment

The inputs of agricultural mechanization production factors include agricultural machinery, chemical fertilizer, land, seeds, plastic film, irrigation and other inputs. The production model is:

$$Y = A_0 e^{\delta+1} M^{\alpha} K^{\beta} L^{\gamma} D^{\theta} (1\text{-}3)$$

Wherein: M - agricultural machinery input;

K - material consumption;

L - labor input;

D - land investment;

$\alpha, \beta, \gamma, \theta$- correlation coefficient of elasticity.

The error term [7] is selected by the method of multiplication error, that is:

$$\hat{Y} = A_0 e^{\delta t} M^{\alpha} K^{\beta} L^{\gamma} D^{\theta} e^{u} (1\text{-}4)$$

Wherein:

δ -scientific and technological progress rate;

u - other influencing factors.

Equation (1-4) is treated linearly and the logarithm on both sides of equation (1-4) is taken:

$$In(\hat{Y}) = In(A_0) + \delta t + \hat{\alpha} In(M) + \hat{\beta} In(K) + \hat{y} In(L) + \hat{\theta} In(D) + u \,(1\text{-}5)$$

Make $In(\hat{Y}) = \hat{y}$, $In(A_0)=a_0$, $In(M)=m$, $In(K)=k$, $In(L)=l$, $In(D)=$d

Equation (1-5) is deformed into:

$$y = a_0 + \delta t + \hat{\alpha} m + \hat{\beta} k + \hat{y} l + \hat{\theta} d + u_i \,(1\text{-}6)$$

The least square method is used for regression analysis to obtain the production function equation [4].

2.3. Variables and data sources

The data used in this paper are mainly from "Jiangxi Statistical Yearbook" of relevant years. The historical data of Jiangxi Province's total agricultural output value and input of various factors from 2005 to 2019 are selected to estimate the C-D production function model. Indicator selection and data processing are described as follows:

(1) Total agricultural output value (Y). It refers to the total amount of all agricultural, forestry, animal husbandry and fishery products existing in monetary form and the value of activities serving agricultural, forestry, animal husbandry and fishery production in a certain period (usually one year) [3].

(2) Agricultural machinery input (M). It refers to the total amount of all kinds of power in agricultural production process.

(3) Consumption of agricultural materials (K). It refers to the consumption of other materials in the production process of agriculture, forestry, animal husbandry and fishery except for the input of agricultural machinery.

(4) Labor input (L). It refers to input of actual agricultural labor force during the statistical period.

(5) Land input (D). It refers to the area of crops actually cultivated and sown.

Table 1. Total agricultural output value and input of various factors in Jiangxi Province from 2005 to 2019

Year / year	Total agricultural output value /100 million yuan	Agricultural machinery investment / 100 MW	Material consumption /100 million yuan	Labor input /Ten thousand people	Land investment; /Thousand hectares
2005	1142.99	178.13	632.52	907.50	2098.08
2006	1225.27	213.71	668.08	907.38	2126.70
2007	1423.28	250.63	805.67	900.77	2146.45
2008	1670.75	294.64	986.17	900.11	2827.19
2009	1719.76	335.89	1004.10	892.59	2819.77
2010	1880.16	380.50	1099.92	888.56	5457.70
2011	2175.14	420.00	1289.44	870.55	5486.79
2012	2359.96	459.97	1396.05	840.90	5525.89
2013	2529.69	201.41	1505.55	820.88	5553.03
2014	2670.18	211.84	1582.46	801.37	5570.55
2015	2808.37	226.08	1532.21	786.01	5579.09
2016	3019.87	220.16	1683.41	773.41	5561.59
2017	3069.01	230.96	1579.72	753.09	5596.91
2018	3148.57	238.20	1599.35	725.20	5555.93
2019	3481.29	247.15	1857.04	700.80	5521.18

Data source: Statistical Yearbook of Jiangxi Province

3. Regression analysis of contribution rate

3.1. Contribution rate formula

Agricultural contribution rate refers to the ratio of agricultural profit of agricultural machinery to total agricultural profit [8]. The formula for calculating the contribution rate of agricultural machinery is:

$$\delta = \alpha_1 \frac{\Delta X_1}{X_1} \frac{X}{\Delta X} \times 100\% = \frac{\alpha_1 x_1}{x} \times 100\% \quad \text{(2-1)}$$

Wherein: α_1 - elasticity coefficient of input-output of agricultural machinery;

ΔX_1 - total power increment of agricultural mechanization (input increment of agricultural machinery);

ΔX - agricultural output;

x_1 - growth rate of agricultural machinery investment;

x - growth rate of agricultural output.

Wherein:
(1) Annual average growth rate of agricultural machinery investment = (Agricultural machinery investment in reporting period - Agricultural machinery investment in base period) $^{(1/year)}$;[3]
(2) Average annual growth rate of agricultural profit = (Agricultural machinery profit in reporting period ÷ Agricultural machinery profit in base period) $^{(1/years)}$.[3]

3.2. Results of linear regression equation

Since the data in **Table 1** is the original data and comes from the Statistical Yearbook of Jiangxi Province, it needs to be standardized. That is, it is need to take the natural logarithm of total agricultural output value, agricultural mechanization input, material consumption, labor input and land input, use SPSS software system to analyze multiple regression, regression model fitting analysis and variance analysis, and then analyze and solve the best linear model. The analysis results are shown in **Table 2** and **Table 3**.

Table 2. Model summary

Model	R	R^2	Adjusted R^2	Error of standard estimation
1	0.998[a]	0.996	0.995	52.5246492

It can be seen from **Table 2** that the adjusted R^2 is 0.995, indicating that the interpretation rate of independent variable to dependent variable is 99.5%. The model simulation results show that the equation has good fitting and can explain the explained variable. When Sig(significance) > 0.05, the model should eliminate this factor. The best linear model is shown in **Table 3**:

Table 3. Multiple regression analysis results of total agricultural output value of Jiangxi Province from 2005 to 2019

Model	Standard value	Standard error	Standard coefficient α	t	sig
Constant	5116.026	632.448		8.089	0.000
Material consumption	0.987	0.157	0.512	6.283	0.000
Labor input	-5.110	0.629	-0.484	-8.131	0.000

Note: a. Dependent variable: gross agricultural output value.

After eliminating the insignificant factors, the output elasticity coefficient of Cobb Douglas production function variable is finally obtained. The elasticity coefficient distributions of material consumption and labor input are 0.987 and -5.110. Among them, the output elasticity coefficient of material consumption is positive, indicating a positive impact on the total agricultural output value; The input-output elasticity coefficient is negative, indicating a negative impact on the total agricultural output value. It can be seen

from the elasticity coefficient of material consumption of 0.987 and the elasticity coefficient of labor input of -5.110 that the material consumption increased by 1% and the agricultural output increased by 0.987%; the labor input increased by 1%, and the agricultural output increased by - 5.110%.

The regression equation is:

$$y = 5116.026 + 0.987 \ln K - 5.11 \ln L \ (2\text{-}2)$$

3.3. Calculation results of contribution rate

The average annual growth rate of agricultural development machinery and equipment investment and total agricultural economic output value is calculated according to the following average algorithms, that is:

Average annual growth rate of agricultural machinery input:

$$= (\sqrt[n]{\frac{Y_n}{Y_1}} - 1) * 100\% = (\sqrt[n]{\frac{247.15}{178.13}}) * 100\% = 2.207\%$$

Average annual growth rate of total agricultural output value:

$$= (\sqrt[n]{\frac{Y_n}{Y_1}} - 1) * 100\% = (\sqrt[n]{\frac{3481.29}{1142.99}}) * 100\% = 7.708\%$$

After calculation, the growth rate of agricultural machinery input in Jiangxi Province from 2005 to 2019 is 2.207%, and the growth rate of total agricultural output value is 7.708%. According to the parameter fitting, the output elasticity value of agricultural machinery input is 0.307, and the contribution rate calculated according to the output elasticity class of agricultural machinery is:

$$G = I \frac{W}{M} * 100\% = 0.307 * \frac{2.207}{7.708} * 100\% = 8.876\%$$

4. Summary

The development of agricultural mechanization in Jiangxi is conducive to the improvement of agricultural labor force and the adjustment of China's agricultural industry and economic and social structure. Based on the Cobb Douglas production function calculation model, the relevant data of agricultural output in Jiangxi Province from 2005 to 2019 are selected. It is calculated that the average annual contribution rate of agricultural mechanization in Jiangxi Province during this period is 8.876%.

According to the data in Table 1-1, the labor input in Jiangxi Province was 9.075 million in 2005 and 7.080 million in 2019, a decrease of 2.067 million, showing a decreasing trend. However, China's total agricultural output value maintained an increasing trend. It can be seen that agricultural mechanization has a significant impact on the agricultural development of Jiangxi Province, which reflects the process of optimization, adjustment and mutual promotion of agricultural economic structure [8].

Disclosure statement

The author declares no conflict of interest.

References

[1] Yang H, 2018, Research on Economic Contribution rate of Agricultural Mechanization in Sichuan Province based on C-D Production Function. Chengdu University of Technology.

[2] Jiangxi Provincial Bureau of Statistics, 2017, Jiangxi Investigation Team, National Bureau of Statistics. Statistical Bulletin of National Economic and Social Development of Jiangxi Province in 2016. Jiangxi Daily.

[3] Wu B, Meng W, 2018, Prediction of Contribution Rate of Agricultural Mechanization in Jiangxi Province Based on Cobb_Douglas Function. China Southern Agricultural Machinery, 49(13): 1, 7.

[4] Zhang F, Yao F, 2017, Analysis and Application of C-D Function in Contribution Rate of Agricultural Production Factors. Inner Mongolia Science technology& Economy, (11): 63-64, 66.

[5] Tang J, Zhuang S, Zhao T, 2015, Calculation of Contribution Rate of Technological Progress in Construction Industry Based on C-D Production Function. Journal of Civil Engineering and Management, (2): 74-77, 95.

[6] Sun F, Wang F, 2005, Method for Calculating Contribution Rate of Agricultural Mechanization by Variable Elastic C-D Production Function. Journal of Northeast Agricultural University, (1): 75-77.

[7] Lin Y, Wang W, 2005, Application of C-D Production Function in Calculating Contribution Rate of Agricultural Machinery to Agricultural Production. Journal of Agricultural Mechanization Research, (4): 207-208.

[8] Geng X, Zhang A, 2015, Contribution Rate of Agricultural Mechanization in Binzhou City Based on Grey Correlation and Cobb-Douglas Model. Journal of Anhui Agricultural Sciences, 43(29): 355-356, 377.

[9] Liu H, Xie Z, 2010, Study on Contribution Rate of Agricultural Scientific and Technological Progress to Economic Growth in Gansu Province. Journal of Northwest University for Nationalities (Natural Science), 31(4): 85-90.

[10] Li C, 2005, Research on the Contribution of Agricultural Mechanization to Agricultural Economic Growth. Shandong Agricultural University.