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Calculation Model of Contribution Rate Based on C-D Production Function

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Abstract **Review Article**

The contribution rate of agricultural machinery and equipment reflects the quantitative relationship between agricultural equipment and grain production. Determination of main factors affecting grain production by grey correlation degree algorithm. Production function relationship of grain production process based on Cobb Douglas production function. A model was established for calculating the contribution rate of agricultural machinery to grain production. According to the statistical data of 1995-2012 in reclamation area, the contribution rate of agricultural machinery equipment, grain sown area and fertilizer application amount to grain yield is 27.76%, 17.5% and 56.64% respectively. The growth of grain yield in reclamation area has a strong dependence on the grain sown area, agricultural machinery and fertilizer application, and is less dependent on the input of agricultural labor. It shows that the proposed contribution rate measurement model has certain accuracy.

Keywords: Ggricultural machinery equipment; Grain production; the contribution rate; Cobb Douglas production function (C-D).

INTRODUCTION

The contribution of agricultural machinery equipment to grain production， refers to the proportion of grain profits (output growth) created by agricultural machinery equipment in the total grain profits (total output growth) [1]. The contribution of agricultural machinery equipment to the algebraic sum of various factors of production. It is an important comprehensive index to reflect the function of agricultural machinery equipment. The main purpose of calculating the contribution rate of agricultural machinery equipment is to understand the actual effect of agricultural machinery equipment on increasing grain production and income from the quantitative relationship. The contribution analysis of agricultural machinery equipment to agricultural production is a question of measuring productivity, productivity is divided into partial factor productivity and total factor productivity. Partial factor productivity is the ratio of agricultural output to factor input in agriculture, including land productivity, labor productivity and capital productivity. Total factor productivity is the ratio of agricultural output to total agricultural factor input, and it reflects the amount of agricultural output per unit of total factor input. The reclamation area belongs to the area with less population and more cultivated land and higher degree of agricultural mechanization. In order to reduce labor intensity, save labor cost and increase grain production, people improve the contribution of agricultural machinery. However, it is difficult to calculate accurately the contribution rate of agricultural machinery equipment to grain production. At present, two methods of calculation are generally adopted:One is the indirect calculating. First calculate the output elasticity of input of agricultural machinery and equipment. Then computing the ratio of input growth rate to profit growth rate. Finally, the product of input elasticity of agricultural machinery equipment and relative growth rate of agricultural machinery equipment input is taken as the contribution rate of agricultural machinery and equipment. Another is the direct calculation. First, the sum of the profits created by agricultural machinery and equipment in agricultural fields is calculated, and then the sum of the profits is divided by the total agricultural profits as the contribution rate of agricultural machinery and equipment. According to the existing research results, Cobb-Douglas production function method [2, 3].

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Agricultural Machinery equipment is an important element of Grain production. Estimating the contribution of Agricultural Machinery equipment to Grain yield scientifically is an important problem in Agricultural Mechanization Management, and it is of great practical significance to strengthen the macro guidance of grain production mechanization development. This paper is based on the theories of economics, systematics and agricultural mechanization. First of all, using grey correlation method to determine important indexes affecting grain production. Selection of relevant statistical data and simple and easy to operate contribution rate calculation method. Estimating the contribution of Agricultural Machinery equipment to Grain yield in Heilongjiang Reclamation area. To provide reference for the relevant departments to make scientific decisions and formulate the development policy of grain production mechanization.

Calculation Model of Contribution Rate

The Determination of the Index

In the selection of variables, the factors that have a greater impact on agricultural production must be selected, and the factors that have a small impact can be omitted. Based on the important indexes of grain production determined by grey correlation method [2, 3], the variables are determined from five aspects: total agricultural output, agricultural machinery input, land input, material input and agricultural labor input.

Total Agricultural Output

Total grain output (including wheat, soybeans, rice, etc.) is selected to represent total agricultural output in recent years.

Input of Agricultural Machinery Equipment

Using the Total Power of Agricultural Machinery to reflect the input elements of Agricultural Machinery. The sum of the total power of agricultural machinery for grain production, including tillage, planting, drainage and irrigation, plant protection and harvest, in the current year's Reclamation area Statistical Yearbook.

Farmland Inputs

Land is the most important input factor in agricultural production. The total sowing area of grain can better explain the changing relationship between production land area and yield, agricultural machinery operation and grain output. In this paper, the grain sown area is selected as the input factor of land.

Material Input

Material input includes chemical fertilizer application, pesticide application and effective irrigation area. Therefore, the amount of agricultural chemical fertilizer is regarded as one of the input factors of grain production in this paper. The amount of pesticide used at the end of the last year, as reflected in the statistical yearbook. The proportion of the area under grain cultivation as a percentage of the area under crop cultivation. Effective irrigation area is an important input factor that affects grain yield.

Agricultural Labor Input

Agricultural labor input refers to the amount of labor actually invested in agricultural production in the calculation period.

Explained variable; grain yield (Y);

Explanatory variables: Agricultural fertilizer application rate reduction stock X_1,Number of workers in agriculture, forestry, animal husbandry and fishery X_2,Pesticide application rate X_3, effective irrigation area X_4,grain sowing area X_5,and total power of agricultural machinery X_6.

Contribution Rate Model

There are many ways to measure the contribution of agricultural mechanization to grain yield [4, 5]. This paper is based on the principle of simplicity and ease of operation. Based on the theories of systems engineering, agricultural mechanization and econometrics. Using the method of Cobb-Douglas production function, calculating the contribution of agricultural mechanization to grain yield in Heilongjiang Reclamation area. This calculation method assumes that the technical progress is Hicks neutral [6-10].

Y represents grain yield, The input elements of grain production process are represented by X_1, X_2, X_3, X_4, X_5, X_6 respectively. The production function model of grain production process is:

$$Y = A(t) f(X_1, X_2, X_3, X_4, X_5, X_6) \quad \text{……….} (1)$$

Where $A(t)$ represents the technical level of the t moment. According to Cobb-Douglas production function, Formula（1）can be converted to（2）

$$Y(t) = A_0 e^{\delta(t)t} X_1(t)^{\alpha_1(t)} X_2(t)^{\alpha_2(t)} X_3(t)^{\alpha_3(t)} X_4(t)^{\alpha_4(t)} X_5(t)^{\alpha_5(t)} X_6(t)^{\alpha_6(t)} \quad \text{……………...} (2)$$

$$LnY(t) = LnA_0 + \delta(t)t + \alpha_1(t)LnX_1(t) + \alpha_2(t)LnX_2(t) + \alpha_3(t)LnX_3(t) + \alpha_4(t)LnX_4(t) + \alpha_5(t)LnX_5(t) + \alpha_6(t)LnX_6(\mathrm{t})$$

Where $Y(t)$ represents grain output in the t year. A_0 is the technical level of the base year. $\delta(t)$ is the coefficient of technological progress in the t year. $X_i(t)(i=1,2,\cdots,n)$ represents the input load of the i input element in year t. $\alpha_i(t)(i=1,2,\cdots,n)$ represents the elastic modulus of the input element $X_i(t)$ at the t year. They are all undetermined parameters. The production function Model of the Upper expression is the Product form. Transform it into a logarithmic linear model for easy estimation. Taking logarithms on both sides of formula (2), we can get:

$$LnY(t) = LnA_0 + \delta(t)t + \alpha_1(t)LnX_1(t) + \alpha_2(t)LnX_2(t) + \alpha_3(t)LnX_3(t) + \alpha_4(t)LnX_4(t) + \alpha_5(t)LnX_5(t) + \alpha_6(t)LnX_6(\mathrm{t}) \quad (3)$$

If the production elasticity of each production function is invariant. When $\delta(t), \alpha_1(t), \cdots, \alpha_6(t)$ are constants in formula (3).

Let: $y(t) = \ln Y(t), \alpha_0 = \ln A_0, x_1(t) = \ln X_1(t), \cdots, x_6(t) = \ln X_6(t), x_7(t) = t, a_7 = \delta$ Convert formula (3) to:

$$y(t) = \alpha_0 + \alpha_1 x_1(t) + \alpha_2 x_2(t) + \alpha_3 x_3(t) + \alpha_4 x_4(t) + \alpha_5 x_5(t)_5 + \cdots + \alpha_7 x_7(t) \quad \ldots\ldots\ldots\ldots\ldots (4)$$

Converting C-D production function into linear function form. Using multivariate linear regression method to determine the output elasticity coefficient of each factor of production in formula (4). Calculate the average annual growth rate of each variable. Let y denote the output growth rate and $y_0, y_1, \cdots, y_n$ denote the output per year.We can get:

$$y = \left(\sqrt[n]{\frac{y_n}{y_{n-1}} \times \frac{y_{n-1}}{y_{n-2}} \times \cdots \frac{y_2}{y_1}} - 1\right) \times 100\% = \left(\sqrt[n]{\frac{y_n}{y_1}} - 1\right) \times 100\%$$

The contribution of explanatory variables to interpreted variables:

$$\delta = \alpha_i \times \frac{m}{y} \times 100\%$$

Among them, α_i represents the output elasticity of explanatory variables. $i = 1, 2, \cdots, 6$, m expressed the average annual growth rate of the input elements of the explanatory variables. y represents the average annual growth rate of grain production.

Calculation of Contribution Rate

According to the idea of C-D production function.Using the actual influencing factors of Grain production in Heilongjiang Reclamation area and the variables of Grain production Model that have been determined ,measuring the contribution of Agricultural Machinery and equipment to Grain yield. First of all, the output elasticity of agricultural mechanization elements in grain production should be calculated. The C-D production function model of grain production:

$$Y = AX_1^{\alpha_1} X_2^{\alpha_2} X_3^{\alpha_3} X_4^{\alpha_4} X_5^{\alpha_5} X_6^{\alpha_6} e^{\mu}$$

Among them: A, α_1, α_2, α_3, $\alpha_{,4}$, α_5, α_6 are undetermined parameters.

α_1, α_2, α_3, $\alpha_{,4}$, α_5, α_6 represents the output elasticity coefficient of each input factor in the grain production process. α_1 measures the change in grain yield when a unit of fertilizer application is changed. α_2 measured the impact of the agricultural labour force on food production. α_3 measures the change in grain yield when the amount of pesticide applied varies by one unit. α_4 measures the change in food production when an effective irrigation area changes by one unit. α_5 measures the change in grain yield when a unit of grain sown area changes. α_6 measures the effect of agricultural machinery total power on grain output. μ is a random perturbation term. The production function model of the above formula is a product form. By converting it into a linear model in the form of a logarithm, the logarithm of the two sides of the above formula can be obtained:

$$LnY = LnA + \alpha_1 LnX_1 + \alpha_2 LnX_2 + \alpha_3 LnX_3 + \alpha_4 LnX_4 + \alpha_5 LnX_5 + +\alpha_6 LnX_6 + \mu$$

Data Collection and Conversion

By using the statistical data needed in this paper from 1994 to 2016 are selected (see Table-1) and standardized.

Table-1

Year	grain output (million tons)	agricultural fertilizer (tons) X_1	agricultural machinery power (ten thousand kilowatts) X_2	grain sown area (1000 HA) X_3	agricultural labor force (thousands of people) X_4	effective irrigation area (ten thousand hectares) X_5	application of pesticides (tons) X_6
1994	460.3	174152	274.2	1636	44.2	16.66	5234
1995	366.6	181392	277.2	1647	45.2	18.36	5250
1996	374.9	189939	277.2	1463	46.2	20.35	5288
1997	402.0	178787	281.3	1635	40.3	23.35	6052
1998	414.4	179317	276.9	1621	36.97	22.38	4865
1999	514.6	198211	245.0	1609	38.96	28.60	5295
2000	715.6	229103	266.4	1732	40.83	43.82	5946
2001	852.0	243228	290.7	1812	41.75	61.22	6742
2002	868.8	257048	305.6	1861	42.19	71.98	7405
2003	905.3	256937	323.6	1846	40.92	76.33	7020
2004	814.1	259703	331.6	1819	42.17	77.41	6721
2005	860.8	254820	340.3	1832	45.20	78.99	6831
2006	810.6	260909	351.0	1793	43.78	82.98	6682
2007	755.3	261618	370.9	1639.9	44.0	74.9	7030
2008	937.5	300601	401.3	1875.9	46.6	89.2	8412
2009	1026.5	310988	433.6	1904.8	46.5	94.54	8364
2010	1132.2	339183	472.3	2083.7	49.7	105.97	9233
2011	1246.4	379139	519.3	2151.5	59.5	121.48	11022
2012	1420.6	394732	564.3	2296.4	61.1	125.39	11159
2013	1652.6	437102	604.5	2544.2	60.3	134.31	12103
2014	1818.0	483542	671.6	2702.9	60.2	155.74	13686
2015	2037.0	527655	745.6	2744.07	59.95	173.25	14846
2016	2105.0	579642	818.6	2797.784	59.87	184.09	14793

Model Optimization

Using the Eviews software, the least binary multiplication (OLS) is used for the regression analysis of the above data. The results of the analysis are obtained (see Figure-1). The results of the regression estimation results of the linear production function are:

$$\ln\hat{Y} = -8.491 + 0.535\ln X_1 - 0.413\ln X_2 + 1.107\ln X_3 \text{-} 0.046\ln X_4 + 0.282\ln X_5 + 0.182 X_6$$

Because $F = 278.6664, R^2 = 0.993464, \ DW = 2.823102$. As can be seen from Figure-1, the linear relationship between grain yield and explanatory variables is significant. However, only 2 of the 6 variables are significant, and most of the test values fail to pass the test. Therefore, there is a serious problem of multiplex collinearity. Although overall linear regression fitted well, the statistical values of explanatory variables were basically not significant. The coefficient symbols of X_2、X_4 are opposite to the actual economic meaning, which also shows that there is a serious multiple collinearity among the explanatory variables in the model. Therefore, the stepwise regression method is used to further analyze.

By using Eviews software to calculate the correlation coefficient among the explanatory variables, it can be seen that there is a high linear correlation between most of the explanatory variables. The method of stepwise regression is adopted.

$$\ln\hat{Y} = -8.773447 + 1.242413\ln X_1 \qquad F = 536.5595, \quad R^2 = 0.971044$$
$$(-12.912) \qquad (23.164)$$

The other explanatory variables are substituted into the above formulas one by one, and the contribution of the new variables in the model to the model and the effect on the other explanatory variables are compared. Remove some variables that do not have a significant effect on the explained variable. Any linear combination with other variables can not achieve the regression effect with X_1, X_2, X_5, X_6 as the explanatory variable. The optimal explanatory variables are given in Table (2), and the following models are finally determined:

$$\ln\hat{Y} = -12.597 + 0.751\ln X_1 - 0.249\ln X_2 + 0.457\ln X_5 + 0.327\ln X_6$$

$$(-4.595) \quad (-3.665) \quad (-3.359) \quad (3.199) \quad (3.671)$$

$$F = 261.5374, \quad R^2 = 0.987726$$

Table-2: Coefficient of stepwise regression analysis model

	C	X_1	X_2	X_3	X_4	X_5	X_6	$\bar{R}^2$	D.W
$Y = f(X_1)$	-8.773	1.232						0.971	1.71
t	-12.912	23.164							
$Y = f(X_1, X_2)$	-24.073	2.347	0.473					0.978	2.07
t	-3.031	12.091	3.582						
$Y = f(X_1, X_2, X_5)$	-11.39	5.384	0.453			1.355		0.983	2.12
t	-2.52	12.734	3.351	-3.821					
$Y = f(X_1, X_2, X_5, X_6)$	-12.597	0.751	0.249			0.456	0.326	0.987	2.04
t	-4.594	3.664	-3.359			3.199	3.671		
$Y = f(X_1, X_2, X_3, X_5, X_6)$	-13.712	1.986	-1.034	0.164		0.273	0.234	0.991	2.89
t	-6.090	6.664	-3.597	0.724		-4.21	1.093		
$Y = f(X_1, X_2, X_4, X_5, X_6)$	-13.724	1.983	-1.032		0.167	0.278	0.193	0.992	1.42
t	-6.091	3.664	-3.359		3.196	1.039	0.451		

Statistical Test

When the number of variables is 4, Sample size is 18. $F = 261.5374 > F_{0.05}(3,18) = 5.09$, The significance of variables is very high. $DW = 2.04$, According to Duben-Watson test criteria, the non-autocorrelation region is $[d_U, 4-d_U] = [1.69, 2.31]$. The equation has good statistics and no sequential autocorrelation. $R^2 = 0.987726$. And it has good fitting degree. In economic sense: $\alpha_1 + \alpha_2 + \alpha_5 + \alpha_6 > 1$. It is shown that the production function has an incremental rate of return. Under the existing production technology, the benefits can be increased by expanding the production scale.

The explanatory variables reserved after stepwise regression are agricultural fertilizer application (X_1), agricultural, forestry, animal husbandry and fishery labor (X_2), grain sowing area (X_5) and total power of agricultural machinery (X_6). The rest of the explanatory variables are removed. In the end, the regression model converts formula (7) into a nonlinear equation. So we get:

$$Y = 0.006 X_1^{0.75093} X_2^{-0.248576} X_5^{0.456668} X_6^{0.326065}$$

Formula 8 is the grain yield regression model of the C-D production function of Heilongjiang reclamation area from 1994 to 2016.

Calculation of contribution rate

Calculate the average annual growth rate of the variables between 1994 and 2016.

Growth rate of food production:

$$y = \left(\sqrt[n]{\frac{y_n}{y_1}} - 1\right) \times 100\% = \left(\sqrt[18]{\frac{2105}{514.6}} - 1\right) \times 100\% = 8.14\%$$

Investment growth rate of agricultural machinery equipment:

$$m = \left(\sqrt[n]{\frac{y_n}{y_1}} - 1\right) \times 100\% = \left(\sqrt[18]{\frac{818.6}{245}} - 1\right) \times 100\% = 6.93\%$$

The contribution of Agricultural Machinery and equipment to Grain yield:

$$\delta=\alpha_2\times\frac{m}{y}\times100\%=0.326065\times\frac{6.93}{8.14}\times100\%=27.76\%$$

According to the same algorithm, the contribution of Grain sowing area to Grain yield:

$$m_1=(\sqrt[n]{\frac{y_n}{y_1}}-1)\times100\%=(\sqrt[18]{\frac{2797.784}{1609}}-1)\times100\%=3.12\%$$

$$\delta_1=\alpha_3\times\frac{m}{y}\times100\%=0.456668\times\frac{3.12}{8.14}\times100\%=17.5\%$$

Contribution of fertilizer application to grain yield:

$$m_1=(\sqrt[n]{\frac{y_n}{y_1}}-1)\times100\%=(\sqrt[18]{\frac{579642}{198211}}-1)\times100\%=6.14\%$$

$$\delta_2=\alpha_1\times\frac{m}{y}\times100\%=0.750934\times\frac{6.14}{8.14}\times100\%=56.64\%$$

It can be seen that from 1994 to 2016, agricultural machinery and equipment contributed 27.76% to grain production in Reclamation region.

CONCLUSION

It can be seen from the regression model that the grain yield is mainly affected by the planting area of grain, the amount of agricultural fertilizer and the total power of agricultural machinery. From the results of the model simulation, $R^2=0.987$, It shows that the established model fits the sample data well as a whole. Explanatory variables explain most of the differences in the explained variables. Explanatory variables explain 98.7% of the interpreted variables. Model fitting effect is very good. $F=261.5374>F_{0.05}(3,18)=5.09$, therefore, the model variables basically passed the significance test.

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