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Modeling and Estimation of the Regional Contribution of Agricultural Science and Technology to the Total Agricultural Output in Anhui Province, China, During the Period of 1990-2012

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ABSTRACT
The aim of this study was to model and estimate the contribution of regional agricultural science and technology to the total agricultural output with the Cobb-Douglas equation and transcendental logarithmic production function model (e.g., the Cobb-Douglas production function model) in Anhui province, China with annual data obtained during the period of 1990-2012. The present study revealed that the contribution of regional agricultural science and technology increased significantly and appeared in an upward trend in Anhui province during the period of 1990-2012 while the rough and adjusted indexes of the regional contribution were estimated as 78.338 and 63.538%, respectively. Based on available annual data and data estimated and generated with the Cobb-Douglas production function model by the EViews 6.0 statistical software package, the impacts of four determinant elements and impacting factors of the total agricultural output were further analyzed in the study. The ultimate result was discussed to explore the economic and social impacts of regional agricultural science and technology and provide an empirical example and a data reference for relevant decision-makings.

Key words: Cobb-Douglas production function model, contribution, agricultural science and technology, total agricultural output, Anhui province

INTRODUCTION

Modern agricultural science and technology are at the core of agricultural sustainability and rural economic development. Fundamental and applied research in biology, chemistry, biotechnology and genetics has resulted in a constant flow of agricultural technology innovations and rural economic changes that have greatly influenced the national agricultural system of China. Thus the contribution of agricultural science and technology is regarded as one of the crucial indicators of the development level of contemporary agricultural science and technology in countries or areas. Considering the continued growth of agricultural productivity and the importance of technology innovation for raising the standard of living, it is not surprising that agricultural productivity growth and technology innovation have received substantial attention from the economic, social and political communities in developing countries. For instance, Yuan *et al.* (2009) reported a study on Chinese energy-saving effect of technological progress based on the Cobb-Douglas production function model. Wang *et al.* (2012) constructed an empirical analysis of agricultural science and technology enterprises investment risk evaluation index system based on the Cobb-Douglas production function model too. Tambo and Abdoulaye (2012) and Vermeulen *et al.* (2012) simultaneously analyzed the relationships of climate change and agricultural technology adoption in rural areas. Lamichhane (2013) analyzed the effectiveness of sloping agricultural land technology on the soil fertility status of mid-hills and farmers' incomes in Nepal. Pourzand and Bakhshoodeh (2014) analyzed the technical efficiency and agricultural sustainability and technology gap of maize producers in Fars province of

Iran, in terms of the sustainable agriculture development. It is self-evident that the innovation of agricultural science and technology is far more important in the processes of decision-making for both private and public sectors in China. Therefore, it is projected that modern agricultural science and technology is the foundation to ensure the national food security and the necessary choice to break through the resources and environment constraints. Furthermore, it is also regarded as the determinant element or impacting factor of rural economics and farmers' income to speed up the construction of national agricultural infrastructure.

In the project of 12th five years' plan of agricultural sustainability and rural economic development in Anhui province, it was suggested to obtain the achievement of agricultural science and technology progress rate at no less than 58% by 2015. How about the accomplishment of regional agricultural science and technology during the year 2015? This is an interesting issue of the contribution of regional agricultural science and technology and it's estimation has been the concerns of both the government sectors and many scholars. However, there were only a few researches or case studies available about the contribution and/or innovation of Chinese agricultural technology. Lezin and Long-Bao (2005) reported a case study of agricultural productivity growth and technology progress in Zhejiang province, China, with the Cobb-Douglas production function model and random sampled data from 1989~2002. They analyzed the impact of some production variables (input) on agricultural productivity growth (output) and found that all key parameters were significant and that capital and land had positive impact on the agricultural productivity growth. Sun *et al.* (2013) made a case study on the innovation of Beijing agricultural technology with the emphasis on improving the scientific and cultural qualities of farmers' lives. They analyzed and compared several sets of data gleaned from Chinese farmers or urban peasants in Beijing. In the present study, it is revealed that the contribution of regional agricultural science and technology increased significantly showing an upward trend in Anhui province, China. Based on the data analyzed with the Cobb-Douglas production function model of Solow (1956, 1957) with EViews 6.0 statistical software package, the elementary impact factors and their influence on the agricultural production and farmers' incomes were further analyzed and discussed.

MATERIALS AND METHODS

Data acquisition and pre-processing: In this study, all the data of agricultural output and input were the time series of annual data (1990-2012) collected with the references to "China Rural Statistical Yearbook" and "Anhui Province Statistical Yearbook". It should be noted that the logarithms of the prices were analyzed in this study. After the data processing and transforming based on the basic price of 1990 in order to eliminate possible hetero-scedasticities from the annual data with necessary adjustments (Table 1). The subsequent data processing and analysis were made by the EViews 6.0 statistical software package.

Unit root test: In the unit root tests, the null hypothesis is that a unit root exists and the sequenced variable or time series data is non-stationary. In the present study, the Augmented Dickey-Fuller (ADF) tests were used. For any sequenced variable, the general form of the ADF test is defined as the following:

$$\Delta x_t = a + bt + rx_{t-1} + \sum_{i=1}^{p} r_i \Delta x_{t-i} + \varepsilon_t$$

where, "a" was a constant, "t" was a variable of time trend and "p" meant the number of lags. The null hypothesis (H_0) of the test was that r = 0 while the alternative hypothesis (H_1) was that $r \neq 0$. If the null hypothesis was accepted, then there existed a unit root within the variable tested, i.e. non-stationary.

Co-integration test: The co-integration test was originally proposed to test the hypothesis whether there was the long-term regression or correlation relationship between two sequenced variables. The main idea of co-integration test was that there should be a long-term stable relationship and correlation among two or more variables (so-called co-integration), if these variables are in linear combination of stability. The common ways of the co-integration test are the EG two-step method and the Johansen method with the co-integration regression equation.

Cobb-Douglas production function model: The definition of contribution of agricultural science and technology and Cobb-Douglas production function model could be generally classified into the broad sense and the narrow sense. The contribution of the agricultural science and technology in the broad sense is defined as these factors including the progress of science and technology and policy, management and related services, social culture and science and technology and their changes, estimated as the shares of contribution to the regional growth index of agricultural output.

In the present study, all the data and indexes were calculated and estimated by the generalized contribution of agricultural science and technology and the generalized Cobb-Douglas production function model with the residual method by Solow (1956, 1957). Method and models were referred of Feng and Chen (2013) and Bhattacharya (2012) to estimate the contribution of agricultural science and technology to the regional agricultural output during the period of 1990-2012 in Anhui province, China.

The Cobb-Douglas function equation recommends itself as a possible macroeconomic production function through its simplicity. The generalized Cobb-Douglas production function model used in the study could be defined as the following (Eq. 1):

$$y = Ae^{\delta t} x_1^{\alpha} x_2^{\beta} x_3^{\gamma} = f(x_1, x_2, x_3) \quad (1)$$

where, y is the regional agricultural output while x_1, x_2 and x_3 denote the inputs of material cost, labor and land and other

Table 1: Agricultural data of Anhui province collected during 1990-2012

Year	Nominal regional GDP of total regional agricultural output (billion Yuan)	Final converted regional GDP of total agricultural output (billion Yuan)	Agricultural material cost (billion Yuan)	Agricultural labor force (ten thousand)	Annual actual arable land area (thousand hectare)
1990	370.94	371.41	131.12	1923.19	4367.68
1991	317.26	315.79	130.97	1970.01	4355.69
1992	390.05	384.44	145.94	1992.39	4355.92
1993	519.12	430.44	176.69	1946.58	4315.27
1994	774.43	444.63	281.90	1906.26	4302.82
1995	980.26	507.96	377.68	1930.26	4291.12
1996	1124.51	566.95	433.73	1953.57	4280.36
1997	1200.60	612.50	464.30	1964.78	4261.10
1998	1202.30	629.10	476.20	1992.92	4251.74
1999	1234.30	680.70	458.60	1991.07	4242.48
2000	1220.00	692.00	453.80	2001.82	4229.55
2001	1258.10	711.30	475.10	1975.55	4218.69
2002	1305.60	742.50	495.40	1931.49	4177.76
2003	1305.40	700.70	477.80	1860.57	4084.73
2004	1644.40	1421.90	601.10	1794.67	4108.86
2005	1666.20	1667.70	607.50	1766.94	4092.45
2006	1743.00	1774.20	640.50	1740.98	4116.94
2007	2070.00	1809.00	734.00	1639.67	4144.17
2008	2447.00	2200.00	862.00	1593.10	4144.98
2009	2569.50	2582.00	929.30	1566.05	4171.22
2010	2955.40	2684.20	1059.50	1521.85	4181.30
2011	3459.70	3072.20	1246.30	1493.01	4184.32
2012	3728.30	3652.50	1518.10	1465.88	4184.24

Nominal regional GDP of total regional agricultural output is the amount collected and indexed in the official statistical yearbooks while the converted regional GDP of total regional agricultural output is the real data after transition of nominal GDP adjusted for inflation

minor factors were usually ignored. Besides, A is a constant and t denotes the time variable while α, β and γ are the elasticity coefficients for the inputs of material cost, labor and land area, respectively. The letter δ representatives the rate of agricultural science and technology relevant to the annual regional input and output. The next step was to take the logarithm of Eq. 1 to eliminate all the hetero-scedasticity in the annual data. Thus, the following equation was yielded (Eq. 2):

$$\ln y = \ln A+\delta t+\alpha \ln x_1+\beta \ln x_3+\gamma \ln x_3 \quad (2)$$

The final steps were to get the derivation of variable t and change Eq. 2 into two new equations (Eq. 3 and 4):

$$\frac{dy/dt}{y} = \delta + \alpha\frac{dx_1/x_1}{dt} + \beta\frac{dx_2/x_2}{dt} + \gamma\frac{dx_3/x_3}{dt} \quad (3)$$

$$\mu = \delta+\alpha\mu_1+\beta\mu_2+\gamma\mu_3 \quad (4)$$

In Eq. 4, four new variables were defined as the following:

$$\mu = \frac{dy/dt}{y},\ \mu_1 = \frac{dx_1/x_1}{dt},\ \mu_2 = \frac{dx_2/x_2}{dt},\ \mu_3 = \frac{dx_3/x_3}{dt}$$

Finally, the contribution of agricultural science and technology could be defined as $S = \delta/\mu$ according to the equations above, i.e., the following (Eq. 5):

$$S = \frac{\delta}{\mu} = \frac{\mu - \alpha\mu_1 - \beta\mu_2 - \gamma\mu_3}{\mu} \quad (5)$$

where, S denotes the contribution of regional agricultural science and technology in agricultural output while $\alpha\mu_1/\mu$ is the contribution of agricultural material cost and $\beta\mu_2/\mu$ the contribution of agricultural labour force and $\gamma\mu_3/\mu$ the contribution of annual actual arable land.

RESULTS AND DISCUSSION

Unit root test: In this study, all the data (1990-2012) were dealt with the econometric software package EViews 6.0 (Quantitative Micro Software Inc., USA). The ADF test statistics were identified from the unit root test results (Table 2) that all the variables analyzed were stated in stationary sequences at the levels of the first-order and/or second-order differences, i.e., I(1) and I(2). Although it was indicated that some variables ($\ln x_1$ and $\ln x_2$) themselves were non-stationary, their first-order and/or second-order differences were stationary and the subsequent analyses were suitable and applicable.

Modeling with Cobb-Douglas production function model and the long-term regression under co-integration test: If the first-order or second-order differential variables for both the endogenous and exogenous variables are regarded as in stationary and/or possible co-integration, it could be deduced the following equation to estimate the long-term regression relationship among these variables studied:

$$\ln y = \ln A+\delta t+\alpha \ln x_1+\beta \ln x_2+\gamma \ln x_3$$

The corresponding resolved long-term regression equation under co-integration test could be expressed as the following regression equation (Eq. 6):

Table 2: Stationary tests of the annual regional data during the period of 1990-2012

Variable	Inspection (C, T, P)	t-statistic	t-statistics for thresholds (%) 1	5	10	Durbin-Watson statistic	Stationary or not
Δlny	C, T, 0	-5.247612**	-4.467895	-3.644963	-3.261452	1.975731	Yes
$\Delta \ln x_1$	C, T, 0	-2.669831	-4.467895	-3.644963	-3.261452	1.869545	No
$\Delta \ln x_2$	N, N, P	-3.065833	-4.467895	-3.644963	-3.261452	1.819460	No
$\Delta \ln x_3$	N, N, P	-4.167333*	-4.467895	-3.644963	-3.261452	2.006852	Yes
Δ(2)lny	N, N, P	-7.090583**	-4.498307	-3.658446	-3.268973	2.377205	Yes
$\Delta(2)\ln x_1$	N, N, P	-5.106339**	-4.498307	-3.658446	-3.268973	2.071284	Yes
$\Delta(2)\ln x_2$	N, N, P	-5.332651**	-4.532598	-3.673616	-3.277364	2.189702	Yes
$\Delta(2)\ln x_3$	N, N, P	-7.648666**	-4.498307	-3.658446	-3.268973	2.180290	Yes

C, T, P: Presence of a constant and time trend terms, N, N, P: Constant term and time trend does not exist. The marks * and **for relevant variables meant significant at the levels of 5 and 1%, respectively. The lag order P was determined in accordance with the AIC rules

Table 3: Indexes of agricultural output and agricultural science and technology estimated (before step-wise regressions) during the period of 1990~2012

Item	Total agricultural output	Agricultural material cost	Agricultural labour force	Annual actual arable land	Agricultural science and technology
Average growth rate per annum index	0.124943	0.12574	-0.01206	-0.00193	0.097877954
Annual contribution index	-	0.007890667	0.024975358	-0.005801166	0.783382023

Table 4: Step-wise regression model and its statistics

Parameters	Desorption
Dependent variable	LNY
Method	Stepwise Regression
Sample	1990 2012
Included observations	23
Regression	No always included regressors
Number of search regressors	5
Selection method	Stepwise forwards
Stopping criterion	p-value forwards/backwards = 0.5/0.5

Parameters	Coefficient	Std. error	t-statistic	Probability**
LNX1	0.112574	0.133542	-3.667394	0.0018
LNX2	-2.602755	0.527705	-4.932217	0.0001
t	127.455800	33.19093	3.840078	0.0011
C	-943.165000	254.0839	-3.712022	0.0015

R^2	0.975827	Mean dependent var	6.841400
Adjusted R^2	0.972011	SD dependent var	0.763967
SE of regression	0.127812	Akaike info criterion	-1.119747
Sum squared resid	0.310381	Schwarz criterion	-0.922269
Log likelihood	16.87709	Hannan-Quinn criter	-1.070082
F-statistic	255.6716	Durbin-Watson stat	1.556897
Prob (F-statistic)	0.000000		

**Significances were measured using the testing criterion of Mackinnon (Ericsson and MacKinnon, 2002) one-sided p-values

$$\ln y = -4.114276+0.083139t+0.062754\ln x_1 -2.070084 \ln x_2+3.007330 \ln x_3+\varepsilon \quad (6)$$

where, it was defined as $\alpha+\beta+\gamma = 1$ (i.e., $\alpha = 0.062754$; $\beta = -2.070084$; $\gamma = 3.007330$; $\delta = 0.083139$).

In Eq. 6, the statistics R_2, $\overline{R}^2$, DW (Durbin-Watson) statistic and F statistic were estimated as 0.979808, 0.976620, 1.353071 and 307.3200 (very significant) respectively. It was suggested that there were no autocorrelations in the variables according to the DW statistics analyzed above. Detailed results and data was put into Eq. 4 and the resultant indexes are presented in Table 3.

In Table 3, the contribution of agricultural science and technology to total agricultural output was estimated as 0.783382023 (78.3382023%) while the contribution of agricultural material cost was 0.007890667 (0.7890667%), the contribution of agricultural labour force was 0.024975358 (2.4975358%) and the contribution of annual actual arable land was -0.005801166 (-0.5801166%). Table 3 showed that Eq. 6 was very credible or believable as the statistics R_2 and $\overline{R}^2$ were revealed as 0.979808 and 0.976620, respectively. It was suggested that the Eq. 6 above was modeled as very significant with the F statistic (307.3200). However, we found there might be autocorrelations in the variables according to the DW statistic (1.353071) was insignificant. Therefore, it was necessary to do a step-wise regression (Table 4, Eq. 7).

Detailed results of the step-wise regressions were presented in Table 5. The contribution of agricultural science and technology to agricultural output was revealed as 0.63538 (63.538%) while the contribution of agricultural material cost was 0.01416 (1.416%) and the contribution of agricultural labor force was 0.03140 (3.140%) (Table 5). However, the contribution of annual actual arable land was not estimated in the step-wise regressions, as it was discarded and unselected in the step-wise regressions (Table 4, Eq. 7). That is to say, the contribution or influence of annual actual arable land in

Table 5: Indexes of agricultural output and agricultural science and technology estimated after adjustments with step-wise regressions during the period of 1990~2012 in Anhui Province, China

Item	Total agricultural output	Agricultural material cost	Agricultural labour force	Annual actual arable land	Agricultural science and technology
Average growth rate per annum index	0.124943	0.12574	-0.01206	-0.00193	0.07939
Annual contribution index	-	0.01416	0.03140	-	0.63538

agricultural output was negligible in practice. Thus, the adjusted contribution index with step-wise regressions was possible more suitable for relevant researches in practices.

According to Table 4 and 5 and Eq. 7, in combination with the data from Table 3, the elasticity coefficients of agricultural science and technology and agricultural material cost were positive while those of agricultural labor force and cultivated land were estimated as the same as negative in Anhui Province. These opposite estimates showed and reflect the fact of circulating nature and mass of agricultural labor force and cultivated land usage in rural areas of Anhui Province:

$$\ln y = -943.1650+127.4558t+0.112574\ln x_1-2.602755\ln x_2+\xi \quad (7)$$

In practice, the Cobb-Douglas specification is possibly the only linearly homogenous production function with a constant elasticity of substitution in which each factor's share of income is constant over time (Lee *et al*., 2012). Many researches assume the Cobb-Douglas specification for the aggregate production function with physical capital and labor or human capital adjusted labor serving as inputs. Nevertheless, some researchers have expressed doubts about the Cobb-Douglas orthodoxy. While Solow (1957) was perhaps the first academician to suggest the use of the Cobb-Douglas production function equation specification to characterize aggregate production, he noted that there was little in the way of evidence to support the choice of such a specification. Indeed, in his seminal growth papers, Solow (1956) presented the CES production function as one of the example technologies for the modeling of long-run growth.

Countermeasures and some suggestions: In summary, according to the data and analyses, some interesting points and countermeasures were suggested to take advantage of the estimates and shares of the contributions of the elementary factors in agricultural production and farmers' incomes. With the annual data of agricultural output and input collected and analyzed during the period of 1990-2012, some countermeasures and suggestions were pointed out and brought out according to the estimates and the issues analyzed too.

- Though there were a high contribution of agricultural science and technology to the total agricultural output, the input of agricultural material cost of farmers was still high for agricultural output

Through the analyses of data modeling and estimating above, the progress of agricultural science and technology (mainly the practical techniques) was enlarged in increasing paces during the last two five-year periods of 1990-2012 while the contribution of agricultural material consumption cost to total agricultural output was in steady growth deduced from the statistics of indexes in both Table 3 and 5. Although there are continuous trends of growth in both the total agricultural output and the progress of agricultural science and technology, the input of agricultural material cost for agricultural output was still increasing. For instance, the input of agricultural material costs recorded in 1990 and 1991 were 131.12 and 130.97 billion yuans while it was raised to 1246.3 and 1518.1 billion yuans in 2011 and 2012. Moreover, the investment in agricultural material consumption cost is still increasing, from which deduction may be drawn that the continuous stimulating of agricultural material consumption cost should be the main driver of regional agricultural economic growth. Although the contribution of agricultural material consumption cost to the agricultural output was regarded as in a dominant position, such as shares of the agricultural material consumption cost contribution estimated were 0.7890667 and 1.416% in Table 3 and 5, the gaps between the contributions of regional agricultural science and technology and agricultural material consumption cost to total agricultural output gap become smaller and smaller and diminishing. Therefore, the contribution and role of modern regional agricultural science and technology are increasingly significant in promoting the regional economic development, especially in agricultural production and agricultural industry.

- Negative effects of rural labor force loss and farmers' cultivated land decrease become increasingly apparent

During the period of 1990-2012, the growth rates of rural labor force and farmers' cultivated land in Anhui province were -1.206 and -0.193%, respectively (note: Negative indexes meant decreases) while their contribution indexes to total agricultural output were 2.4975358 and -0.5801166% in Table 3 or 3.140% and none (unavailable at present) in Table 4. The negative indexes showed that the decreasing growth rates of rural labor force and cultivated land while their contributions to total agricultural output were relatively decreasing with increasingly reduced positive indexes.

- Enlargement between extensive training of farmers and the current technical changes and technology innovation levels

According to the Ministry of Agriculture documents, the government currently needs to strictly implement the personnel training work plan including 10000 college specialized personnel, 30000 secondary leveled practical and technical personnel and high-quality workforce or high labor force. Through the improving of learning and innovative consciousness, Chinese farmers below 45 years of age will gradually achieve secondary vocational and technical degrees and the average level of rural farmers' education will be improved significantly. Meanwhile, rural cadre employees of technical jobs are the major force to promote door to door technical instruction and to solve agricultural production issues and rural live problems of farmers. The rural first-line manager plays a management role in farmers' trainings. By improving their competences and their own knowledge and management experience, they will be better to fit their roles and guide peasants to enrich their families and countries.

- Cultivated land protection policy should be effectively implemented

It was obvious that the average growth rate per annum index of agricultural output growth was steadily increasing while the growth indexes of rural labor force and farmers' cultivated land were decreasing, indicated in Table 3 and 4. This phenomenon suggested that the cultivated land protection policy should be strengthen and effectively implemented under the condition of the decreasing prophase of cultivated land proportion. As can be seen from the data in Table 3 and 5, it is difficult to implement the cultivated land protection policy in actual agricultural industry and development. It is really an issue and hot topic on the regional agricultural growth and rural economic development in Anhui province, China. In the future, there is still a long way for the government to walk for solving the problem of how to effectively protect and utilize the farmers' cultivated land.

CONCLUSION

The parametric Cobb-Douglas production function models are frequently used in econometrics. The present study established a parametric Cobb-Douglas production function model and empirically analyzed the correlation between the output variable (lny, defined as the regional agricultural output) and the input variables (agricultural material cost $\ln x_1$, agricultural labour force $\ln x_2$, annual actual arable land $\ln x_3$ and agricultural science and technology T(t), defined as the main impacting factors) in Anhui province, China, from 1990-2012. With the frequently used parametric Cobb-Douglas production function model using the residual method of Solow (1956, 1957), the impacts of determinant elements of the total agricultural output were analyzed and explored. It was revealed that the contribution of regional agricultural science and technology to total agricultural output increased significantly and appeared in an upward trend in Anhui province during the period of 1990-2012. The rough and adjusted contribution indexes of regional agricultural science and technology were estimated as 78.338 and 63.538%, respectively and the adjusted contribution index was deduced as more suitable for relevant researches in the future.

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