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Agricultural productivity growth and technology progress in developing country agriculture: case study in China

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Abstract: The goal of this investigation was to analyze the impact of some production variables (input) on agricultural productivity growth (output) in China from 1989~2002. We selected through random sampling Zhejiang Province for our disaggregate analysis with the use of Cobb-Douglas function. The estimation results showed that all key parameters are significant and are of the expected sign. Labor and that capital and land have positive impact on agricultural productivity growth.

Key words: Agriculture, Productivity growth, China, Technology
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INTRODUCTION

Considering the importance of agricultural productivity growth and technology for raising the standard of living it is not surprising that agricultural productivity growth and technology analyses receive substantial attention from the economic and political communities of developing countries.

The case of China's agricultural performance was impressive. The food production and increases in productivity are essential for meeting the growing demands for food in the future. There is widespread opinion that this growing demand can be met by increased use of inputs or increases in agricultural productivity (Fan, 1991). Productivity growth of agriculture in China over the past two decades was the result of a combination of factors such as new incentives to farmers offered by the government who considered them as autonomous economic agents, and physical factors such as land, labor, capital (in the form of machines, working animals, irrigation system, and so on), and intermediate inputs such as fertilizer. China's growth has been less dependent on the conventional inputs of capital and labor (Xu, 1999).

This paper is aimed at analyzing the impact of some production variables (input) on agricultural productivity growth (output) in Chinese agriculture from 1989~2002. We selected through random sampling Zhejiang Province for our analysis. The question here is whether or not these different variables have an impact on agricultural production.

The remainder of the paper is organized as follows.

Section II gives a brief overview of the progress of agricultural productivity and technology in Chinese agriculture. Section III explains the methodology used; results of the Cobb Douglas models and interpretations are given in Section IV, and conclusions are presented in Section V.

AGRICULTURAL PRODUCTIVITY GROWTH AND TECHNOLOGY PROGRESS IN CHINESE AGRICULTURE.

Agricultural productivity growth is one of the main facets of China's economic development and

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national food sufficiency policies. In China, production growth rates have outpaced population growth since the early 1950s, with the exception of the famine years of the late 1950s and early 1960s (Lin, 1992).

Even between 1970 and 1978, when much of the economy was reeling from the deplorable effects of the Cultural Revolution, grain production grew at 2.8 percent annually (Table 1). Oil crop production grew 2.1 percent annually and fruit and meat output increased by 6.6 and 4.4 percent respectively. Decollectivization, price increases, and relaxation of marketing restrictions on most agricultural products fueled China's food economy takeoff (1978 to 1984). Grain production increased 4.7 percent annually, and fruit output rose 7.2 percent (Table 1). Oil crop, livestock, and aquatic production all grew spectacularly, expanding annually in real value terms by 14.9 percent, 9.0 percent, and 7.9 percent respectively.

Table 1 Annual growth rate (%) of agricultural economy by sector and selected agricultural commodity, 1970~1997

	Pre-reform	Reform period		
	1970~1978	1979~1984	1985~1995	1996~1997
Agricultural output value	2.3	7.5	5.6	7.4
Crop	2.0	7.1	3.8	6.2
Forestry	6.2	8.8	3.9	4.5
Livestock	3.3	9.0	9.1	7.9
Fishery	5.0	7.9	13.7	12.7
Grain production	2.8	4.7	1.7	2.9
Rice	2.5	4.5	0.6	4.1
Wheat	7.0	7.9	1.9	9.8
Maize	7.0	3.7	4.7	–3.5
Soybean	–1.9	5.1	2.9	2.4
Cash crops				
Oil crops	2.1	14.9	4.4	–2.1
Cotton	–0.4	7.2	–0.3	–1.7
Fruits	6.6	7.2	12.7	9.9
Red meats	4.4	9.1	8.8	11.2
Pork	4.2	9.2	7.9	10.2

Note: Growth rates are computed using regression method. Growth rates of individual and groups of commodities are based on production data; sectoral growth rates refer to value added in real terms

Source: State Statistical Bureau, Statistical Yearbook of China, various issues; MOA, Agricultural Yearbook of China, various issues, 2000

Technology progress in Chinese agriculture

How important is the technology progress in China's agriculture? Taking into account the role that technology played in raising agricultural productivity and the recent deterioration of the research system, the Chinese government decided in the Long Term Plan for 2010 that China will rely on new technology, particularly new crop and livestock varieties, to raise future agricultural production. Technology is at the center of the "advancement of agricultural productivity growth in China" (Kejiao Xingnong). Technology has been the most important factor of Chinese agriculture. Many studies showed that institutional technical changes accounted for most contributions to the increase of total factor productivity of Chinese agriculture (Krugman, 1994).

Table 2 shows the rate of technology progress, the changes in technology efficiency and productivity. The relation between them is that improvement of productivity equals the total sum of technology progress and changes in technology efficiency.

A review of the trend of technology progress shows that it tends to grow steadily with time. From 1990 to 1997, the average value of technology progress, the changes in technology efficiency and productivity was positive, with technology progress playing a dominant role in the agricultural productivity of China and contributing positively to China's economic growth in the past two decades.

Table 2 Estimated rates of technological progress, efficiency improvement, and productivity growth in China

Year	Technology progress	Change in technology efficiency	Improvement of productivity
1990	1.29	–0.40	0.89
1991	1.30	–2.74	–1.44
1992	1.30	1.90	3.20
1993	1.30	1.00	2.30
1994	1.30	0.42	1.72
1995	1.30	0.64	1.94
1996	1.30	–1.53	–0.22
1997	1.31	0.27	1.58

Source: Research Department of Development Strategy and Regional Economy July 2002

METHODOLOGY

The Cobb-Douglas equation was used to analyze the impact of some production variables on agricultural productivity growth.

Production function in general form can be written as:

$$Y=F(X_i) \tag{1}$$

where Y is production output and X_i are measured physical production factor inputs. Eq.(1) of production function in log form is:

$$\log Y=\beta_0+\beta_1\log X_1+\beta_2\log X_2+\beta_3\log X_3+\ldots+\beta_n\log X_n+\varepsilon \tag{2}$$

$$\log Y=\beta_0+\sum_{i}^{n}(\beta_1\log X_i) \tag{3}$$

where X_i denote production factors and ε is the residual of the regression. In our analysis the agricultural production function (Cobb-Douglas) is specified as follows:

$$\log(GVAO)=\beta_0+\beta_1\log(labor)+\beta_2\log(capital)+\beta_3\log(land)+\varepsilon \tag{4}$$

$$\log(GVAO)=\beta_0+\beta_1\log L+\beta_2\log K+\beta_3\log M+\varepsilon \tag{5}$$

where $GVAO$ is gross value of agricultural output; L is agricultural labor force; K is capital input; M is agricultural land; The coefficients β_i (i=1,2,3) are the elasticities of the respective variables with respect to agricultural production, with the assumption that $\beta_i>0$.

Sources and description of data used in estimating the production function

The data used in this study were provincial level agricultural outputs and inputs for estimating the Cobb-Douglas production function of China agriculture from 1989~2002. We selected through random sampling Zhejiang Province for the purposes of our disaggregate analysis.

Documentary research was used in order to exploit various information from an analysis of available documents of statistical offices reported in Zhejiang Statistical Yearbook and Zhejiang Provincial Agricultural Bureau of Statistics. Statistics Bureau of China is the main source of data for economic studies and these data cover almost all economic activities.

Most previous studies on China's agricultural productivity used China's gross value of agricultural output (GVAO) as the total value of agricultural production. Zhejiang GVAO is defined as the sum of the total value of production from farming, forestry, animal husbandry and fishery. The sum of output value of all products of farming, forestry, animal husbandry, and fishery equals to GVAO and is expressed in 100 millions Yuan. The data on the gross value of agricultural output were taken from the Zhejiang Statistical Yearbook.

Labor, capital, and land are considered the three main inputs in Zhejiang Province agricultural production.

Labor input: Labor input is measured in person-year equivalent of workers directly engaged in production in farming, forestry, animal husbandry, and fishery. The labor used in rural industry is excluded from agricultural labor input and is expressed in 10000 persons. The data on rural labor force were taken from the Zhejiang Statistical Yearbook.

Capital input: refers to the sum of machinery and draught animals in Zhejiang agricultural production in this study.

Land input: refers to the total cultivated area (area under cultivation), and is measured by area sown rather than arable land because the arable land data is extremely inaccurate. Sown area is land on which crops are planted and from which a harvest is expected. The data on provincial cultivated land were taken from the Zhejiang Provincial Agricultural Bureau of Statistics.

ESTIMATED RESULTS AND INTERPRETATION

Results for the Cobb-Douglas estimates are reported below in Tables 3, 4 and 5.

The Estimated Agricultural Production Function in Zhejiang Province, based on data in period 1989~2002, can be expressed in the following mathematical form:

$$\log(GVAO)=60.353+0.977\log L+1.825\log K+0.177\log M$$

t=(3.474) (2.842) (4.188) (3.899)

R^2=0.997, n=14, $\bar{R}^2$=0.993, df=10,

α=5%, $t\alpha/2$=2.179.

where df is degree of freedom.

From the above equation, we can see that in Zhejiang Province agricultural sector in the period 1989~2002, the output elasticities of labor, capital

Table 3 Model summary

Model	R	R square	Adjusted R square	Std. error of the estimate
1	0.997	0.993	0.991	0.04717

Predictors: (Constant), LNM, LNL, LNK; Dependent variable: LNGVAO

Table 4 Analysis of variance (ANOVA)

Model		Sum of squares	df	Mean square	F	Sig.
1	Regression	3.165	3	1.055	474.196	0.000
	Residual	0.022	10	0.002		
	Total	3.187	13			

Predictors: (Constant), LNM, LNL, LNK; Dependent variable: LNGVAO

Table 5 Coefficients

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	Std. error	Beta		
1	(Constant)	60.353	17.370		3.474	0.006
	LNL	0.977	0.344	0.275	2.842	0.017
	LNK	1.825	0.436	0.769	4.188	0.002
	LNM	0.177	2.098	0.489	3.899	0.003

Dependent variable: LNGVAO

and land were 0.977, 1.825, 0.177, respectively. If β_1=0.977, and the labor input increases to about 1 percent, then the gross value of agricultural output increases to about 0.97%. Similarly β_2 and β_3 can be interpreted in the same way. The sum ($\beta_1+\beta_2+\beta_3$) gives information about the returns to scale, that is, response of output to a proportionate change in the inputs. In our case adding the three output elasticities we obtain 2.979, which gives the value of the returns to scale parameter. As we see the sum is greater than 1, thus there are increasing returns to scale. As is evident, over the period of the study, the Zhejiang Province agriculture sector was characterized by increasing returns to scale-doubling the inputs will more than double the output.

From a purely statistical viewpoint, the estimated regression line fits the data quite well. The R^2 value of 0.997 means that 99 percent of the variation in the (log of) agriculture output is explained by the (logs of) labor, capital and land. For adjusted R^2 ($\bar{R}^2$) the relation is 99 percent. This shows the statistical dependence of the (log of) agriculture output on the (logs of) labor, capital and land.

Globally the regression is significant. Let us determine the significance of each individual independent variable with a Student's test.

Let us postulate that β_1=0, $t\beta_1$=2.842.

If we assume α=0.05, $ta/2$=2.179 for 10 df. Since the computed t value of 2.842 far exceeds the critical t value of 2.179, we may reject the null hypothesis and say that β_1 is statistically significant, that is, significantly different from 0.

β_2=0, $t\beta_2$=4.188, $t\beta_2>ta/2$, we can reject the null hypothesis.

β_3=0, $t\beta_3$=3.899, $t\beta_3>ta/2$, we can reject the null hypothesis.

Thus, all of the elasticities are statistically significant at the 5% level ($t\beta_1$, $t\beta_2$, $t\beta_3>ta/2$).

In summary the analysis shows that labor, capital and land are positively related to output and statistically significant.

The positive and significant elasticities of labor can be explained by the fact that in Zhejiang Province like in all China labor forces shifts among sectors have been phenomenal.

Since China started reform and opening up in the late 1970s, the rural labor force in Zhejiang Province was in the agricultural sector. By 1998 more and more farmers in Zhejiang Province continued to work in the agriculture sector and today, Zhejiang provides job opportunities for over 10 million farmers in the province, who account for 40 percent of its rural laborers.

Capital was computed as the sum of the value of farm machinery and draft animals in Zhejiang Province agriculture. All are expected to have positive influence on agricultural productivity. The total value of machinery in 1997 was more than three times that used in 1989 and the total value of animals increased by 50 percent during the same period. The capital index in the mid 1990's was double the level in 1978. One might be able to attribute some of the increase in output value to machinery as well. The high production elasticities observed in the analysis often estimated for modern inputs in Zhejiang Province agriculture partially reflect the effects of new technology. The rapid expansion in the use of these inputs took place at the same time that new technology became widely available

Land played a significantly positive role in determining agricultural output in Zhejiang Province because the total area under cultivation has been increasing continuously since the late 1978s. Zhejiang Province has 1939 hectares of cultivated land for grain production. The land share has increased over time, indicating that land value has increased over time and land has become scarcer.

CONCLUSION

In this research we analyzed the impact of some production variables (input) on the agricultural productivity growth (output) in Zhejiang Province agriculture from 1989~2002 using Cobb-Douglas model.

The results of estimations led to the conclusion that labor, capital and land significantly impacted agricultural productivity growth.

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