An Analysis on Technical Efficiency of Paddy Production in China

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Abstract

Paddy is related with China's food security as the main food crop. This paper analyzes the efficiency of paddy production in China using BCC model of DEA method. The results show that the production efficiency of paddy is low and unstable from 1990 to 2008. The inputs of paddy production are unreasonable in many years. The pure technical efficiency is smooth when the scale efficiency isn't stable, and the scale efficiency is smooth when the pure technical efficiency is unstable. The tendencies of pure technical efficiency and scale efficiency are opposite. Overall, the pure technical efficiency has great impact on paddy production; the effect of scale efficiency is weak.

Keywords: Paddy, Technical efficiency, DEA

1. Introduction

Paddy occupies an important position in China's grain production as one of important food crop in agricultural production. It constitutes the main content of grain production. The fluctuation of it dominates the volatility of food security. China's grain output was 52870.8 ton in 2008, and paddy output was 19189.6 ton. The percent of paddy output is 36.30%. With the development of urbanization and industrialization, massive cultivated land was occupied by commercial and industrial use. By 2008, cultivated land area was only 121,715,900 hectares which has reduced 19,300 hectares compared with 2007. Paddy planting area has dropped from 33,064,500 hectares in 1990 to 2,924,100 hectares in 2008. With the reducing of paddy planting area, the output was also decreasing. China's grain import volume has reached 5044.4 ton from January to September in 2010 with growth of 28.1% by year. It is inevitable that the large import of grain will threaten to China's food security. Technology is the first productivity, so the improvement and development of paddy production technology has important means to improve quality and yield of paddy. It has important practical significance to analyze and research on China's paddy production technical efficiency and the characteristic and trend of changes in the realistic background that land and other natural resources are scarce and the trend is decreasing and in the important strategic premise of guaranteeing food security. The research may not only contribute to promote the growth of paddy production efficiency and improve the quality and benefit but also change our paddy production growth methods and realize sustainable development of paddy production.

Researches on the efficiency of paddy production in China have focused on calculating the efficiency and discussing the reasons for the improvement of efficiency. Since the 90s in 20^{th} century, it began to appear common large scale technical progress and technology efficiency loss, and agricultural productivity growth has been pushed by technology. Generally speaking, industries productivity growth was contributed basically by technology advance or efficiency drive alone, it didn't appear "double drive" pattern (Gucheng Li, Zhongchao Feng, 2010). Jikun Huang (1993) who analyzed decision factors in technological innovation and extending on the paddy yield increase and role of technical progress in production growth thought that the effect of systems and policies were disposable on production and the impulsion of China agricultural production growth would still be technological innovation and advancement in the future. The result indicated that it had a certain efficiency loss in the production of paddy. The technical efficiency of indica type rice (The average technical efficiency stays in 0.90-0.93) is higher than japonica rice (The average technical efficiency is 0.88). As a whole, there is no technology advancement of paddy in 1996-2004, instead of certain technology regress, but it may exist certain technology advancement in certain years (Xibao Luan, 2007). Mingli Wang, Xinye Lv (2006) used non-parametric Malmquist index method to measure paddy productivity in China from 1990 to 2003. They thought that paddy productivity growth was fluctuating during this time. Hong Zhou, Baojin Chu (2003) measured total efficiency, technical efficiency and scale efficiency of paddy production in 1981-2001. Chao Chen, Jisheng Li (2008) investigated dynamic changes of China's paddy TFP, technological progress and technical efficiency during 1978-2005, who found that the growth of paddy production efficiency was mainly from technology progress. Yuejie Zhang (2007) analyzed production efficiency changes of paddy for eight counties in Jilin province during 1994-2005 by using non-parametric HMB index methods, the result showed that total factor productivity (TFP) of paddy production declined mainly dues to low level of technological progress and scale inefficiency in Jilin province. Wei Tian (2009) measured production efficiency of early rice and late rice in Hunan province.

We can understand the research status of the efficiency of paddy production comprehensively from the literatures review. The foregoing studies provide a lot of essential information on the efficiency of paddy production. This paper was based on foregoing researches. Through sorting of literatures, we found that scholars researched production efficiency of paddy from overall and discussed the reasons of the paddy productivity growth. The analyses of production efficiency of paddy were basically based on constant return to scale model. Paddy production is a semi-open ecological system which is influenced by natural conditions. And in practice constant return to scale is unlikely to realize. This paper selected variable return scale model(also can be called BCC model for short) of DEA method to calculate paddy production efficiency in China, analyzed changes and trends of scale efficiency, pure technical efficiency and total efficiency from 1990 to 2008. It tried to put forward improvement strategy in some years, and give relevant suggestions at last.

2. Model specification, index selection and data collection

2.1 Model specification

The data envelopment analysis (DEA) method is mainstream method in solving decision making unit efficiency. It is a system analysis method in evaluating relative efficiency which was proposed by Charnes and Cooper in 1978. It has solved performance evaluation between the similar decision making units (DMU) which have different dimension, multiple inputs and outputs. DEA method can calculate the comprehensive efficiency of every DMU based on comprehensive analysis of the input and output data. Then sort and grade every DMU, determine the effective DMU whose relative efficiency is highest. And point out the reasons and degree for other DMUs which are ineffective. These can provide management information for competent department. There are two problems in evaluating production efficiency of every decision making unit, one is whether the put scale is appropriate, the other is whether production technology potential give full play to. But in the assumption of production technology for constant return to scale, these two problems become one. The efficiency score contains the pure technical efficiency and scale efficiency by using constant return to scale to calculate.

BCC model is based on variable returns to scale (VRS). The measurement of technical efficiency will be affected by scale efficiency when not all the decision making units operate in the best scale. But the measurement of technical efficiency won't be affected by scale efficiency through using variable returns to scale. And using BCC model we can measure scale efficiency respectively and pure technical efficiency. Total Efficiency (TE) = Pure Technical Efficiency (PTE) * Scale Efficiency (SE). So this paper used BCC model of DEA method, and the model is showed as below:

$$
\begin{aligned}
&\min_{\theta,\lambda} \theta,\\
&st\ -y_i + Y\lambda \geq 0,\\
&\theta x_i - X\lambda \geq 0,\\
&N_1^{'}\lambda = 1,\\
&\lambda \geq 0
\end{aligned}
$$

Assuming in production process that the number of input variables is K, the number of output variables is M, and the number of decision making units is N. X_i indicates input of decision making unit i^{th} and Y_i indicates output of decision making unit i^{th}. X is matrix of K*N input for all decision making units, and Y is matrix of M*N output for all decision making units. Where θ is scalar that indicates the value of technical efficiency for decision making unit ith, and $\theta \leq 1$. The actual production point was located in production frontier surface that indicates the technical efficiency is effective when $\theta=1$. λ is N + 1 constant vector.

2.2 Index selection

It needs to determine input and output indexes by using DEA model to evaluate our paddy productivity. According to the theory of Jean Baptiste Say, the three elements of production are land, capital and labor. In the process of production, land, capital and labor as major inputs reflect the production of input elements. The input indexes in this paper are material and service fee per mu, labor cost per mu and land cost per mu, the three indexes respectively represent capital, labor and land input. The output index is paddy total output value per mu. According to cost accounting system from "National Agricultural Products Cost-benefit Data Collection", material and service fees include direct expenses and indirect expenses. The direct expenses include seed fee, chemical fertilizer fee, pesticide fee, agricultural film fee, rental fee, fuel fee, technical service fee, tool and material fee, and repairing & maintenance fee. The indirect expenses include fixed assets depreciation, tax, insurance premium, management fee, financial expense and sale fee. Labor costs include family labor and hired labor costs. Land costs include transfer land rent and self-operated land rent.

2.3 Data collection

Data for the study was based on time-series data from 1990 to 2008. Since 1990s economy has developed rapid, selling grain difficulty, related agricultural policies making, food security problem has already become important national strategic in new period. So the study of paddy production in this time period has important practical significance. All the data are from "National Agricultural Products Cost-benefit Data Collection".

3. Empirical results and discussion

3.1 Descriptive statistical analysis

Paddy production has a long history and paddy planting area is wide in China. With the passage of time, the input and output of paddy production have increased. The total output value, material and service fees and labor costs in 2008 were triplication more than 1990, and land costs in 2008 was almost decuple compared with 1990. The land cost rising may be relevant to real estate heat in recent years. Material and service fees, labor costs and land costs almost had the same change trend. Each cost increased dramatically in 1993, reached maximum in 1996, and then began to drop slowly, became to increase after 2002. On the whole each cost was appeared to increase from 1990 to 2008. Relative to inputs, the fluctuation range of total value is large. The range of increase and decrease was larger than input. It may be relevant to agricultural policy environment, market price fluctuation, natural disasters and other factors. The external environment has great influence on total output value of paddy production.

3.2 Paddy production efficiency analysis

This paper used software DEAP2.1 to calculate our country paddy productivity during 1990-2008, and the results are shown in Table 1. Pure technical efficiency is the change of total efficiency when eliminating the influence of scale efficiency. It indicates that technical inputs change of paddy production under the condition of constant return to scale. Scale efficiency reflects scale level of paddy production. When the input scale of paddy production in China increases or decreases, the increase or decrease of total paddy production efficiency reflects scale efficiency.

3.2.1 Analysis on total efficiency, pure technical efficiency and scale efficiency

(1) Analysis on total efficiency effective. Total efficiency of paddy production was 1 in 1990 and 1994, which reached DEA effective. These two years, the input-output combination of paddy production was optimal. The inputs are not only reduced to overall proportional but also reduced partial inputs. Pure technical efficiency was effectively and scale efficiency was also effectively in the two years. The condition of paddy production was not only good but also optimal. In other years, total efficiency of paddy production was always less than 1, and the assessment result was inefficiency.

(2) Analysis on pure technical efficiency effective. In 1990, 1993, 1994, 1995 and 2008, pure technical efficiency was effective, and scale efficiency was invalid. It indicates that technology was used and developed effectively in the few years. It is no necessary to reduce inputs or increase output for pure technical efficiency. Total efficiency didn't reach 1, because its scale didn't match with its inputs and output. And it needs to increase scale or reduce scale.

(3) Analysis on scale efficiency effective. In the research scope of 19 years, scale efficiency just reached 1 in 1990 and 1994. In the two years, scales of paddy production matched with inputs and outputs, it has no need to

increase or reduce inputs and outputs. The reason for remarkable scale benefit may be the large effect of government subsidy policy in early 1990s. In the long run, scale efficiency of paddy production didn't realize DEA effective in China.

The mean total efficiency of paddy production was only 0.806 in 1990-2008, and the overall level was not high. The result is the same with some researches by scholars (Mingli Wang, Xinye Lv, 2006; Chao Chen, Jisheng Li, 2008). Pure technical efficiency for the average was 0.872, and scale efficiency for the average was 0.927. These indicated that low total efficiency of paddy production was mainly decided by low pure technical efficiency. With the deepening of marketization degree after 1990s, total efficiency of paddy production has also gradually improved. But selling grain difficulty were caused by twice grain harvest in the early and late of 1990s, it greatly hit farmer's enthusiasm for production, and made paddy production efficiency show drop posture in China. Paddy production in our country began to resume and increase, and kept stable development after 2004. The reason for that may be the rising of grain price, abolishing the agriculture taxes, and carrying out the grain subsidy policy. We can find that the changes of market price, system and policy have great effect on paddy production efficiency.

3.2.2 Correlation analysis on total efficiency, pure technical efficiency and scale efficiency

Figure 1 shows the trends of total efficiency, pure technical efficiency and scale efficiency. The trend of total efficiency (TE) curve was basic coincided with scale efficiency (SE) curve in 1990-1995. The change of total efficiency was decided by scale efficiency in this time. The total efficiency and scale efficiency went up consistently came after dropping, they all dropped in 1991, and went up after 1992. The total efficiency realized DEA effective until 1994. The total efficiency (TE) curve changed with the fluctuation of technical efficiency (PTE) curve from 1996 to 2006. In this period of time, the changes of total efficiency followed the changes of technical efficiency. This period can be divided into three stages which were 1996-2002, 2003-2004 and 2005-2006. Generally speaking, total efficiency gradually was reducing until dropped to the bottom (0.625) from 1996 to 2002. During two subsequent years, total efficient climbed to 1, which was pulled by improving technical efficiency. Total efficiency started to descend after 2004. The fluctuation of total efficiency (TE) curve was consistent with scale efficiency (SE) curve in 2007-2008. The period that the changes of total efficiency were decided by scale efficiency came back again. Total efficiency was basic stable; the fluctuation is low in 2005-2007. But in 2008, total efficiency began to decline again. Overall, the fluctuation of paddy productivity was large in China from 1990 to 2008, and determinant factors of total efficiency were different in each period.

In order to find out the accurate degree of correlation among total efficiency, pure technical efficiency and scale efficiency of paddy production in China, the study proceed with the correlation analysis (Table 2). We can see from Table 2 that the correlation coefficient between total efficiency and pure technical efficiency reached 0.8574; it explained the degree of them was relatively high. Total efficiency's difference was mainly decided by pure technical efficiency's. The correlation coefficient between total efficiency and scale efficiency was only 0.1835. Compared with scale efficiency, the influence of pure technical efficiency was much more significant, and which was consistent with the results from Chao Chen, JiSheng Li (2008). There was negative correlation between total efficiency and scale efficiency. Because Total Efficiency (TE) = Pure Technical Efficiency (PTE) * Scale Efficiency (SE). When the total efficiency was fixed, pure technical efficiency had opposite direction to scale efficiency, and this is the same with scale efficiency.

3.3 Analysis on improvement of paddy production efficiency

The projection on production efficiency frontier of decision making unit is DEA inefficiency, namely, through adjusting appropriately input or output of decision making unit which is DEA inefficiency can reach DEA effective. The study made projection of model assessment results (Table 3). According to it, we can find that the minimum amount of inputs under different outputs required when pure technical efficiency of paddy production achieving 1 in China. This can give reference information to improve paddy production efficiency. There are many data was given to analyze, and analysis method is similar. So this paper selects three typical years to analyze as below.

(1) 1992. The emergence of selling grain difficulty has great influence on later grain production in early 1990s. Market environment is certain to affect paddy production. In order to improve the production efficiency, make paddy production efficiency achieve optimal in 1992, namely, it reached DEA effective, it required to decrease corresponding 4.110 RMB of material and service fee, 15.530(3.013 + 12.517 = 15.530) RMB of labor cost and 3.379(0.574 + 2.796 = 3.370) RMB land cost, which can maintain original output unchanged. At the same time shortage of output also exists in 1991. Keeping original inputs, output needs to add 4.470 RMB so that production efficiency will to achieve optimal.

(2) 1998. In 1998, huge flood disaster happened in China, and the damage of crops was in severe case. Paddy production was influenced by external environment greatly, so it has to consider the influence of natural disasters. The redundancy of material and service fee was 45.445 RMB, the redundancy of labor cost was 70.394(34.555 + 35.839 = 70.394) RMB, and the redundancy of land cost was 30.709(12.214 + 18.495 = 30.709) RMB of paddy production in 1998. The excessive inputs may be related to the natural disasters which made production efficiency decrease. Compared with output, the inputs were obvious excess.

(3) 2004. In 2004 NO.1 document in Central Committee put forward direct subsidies for grain producers. The policy greatly increased grain producers' enthusiasm, production efficiency increased significantly. In 2004, the production efficiency achieved optimal, radial movement and slack movements were both zero. There is no need to put forward improvement strategy.

Similarly, we can analysis improvement strategy of paddy production efficiency in other years. Based on the above analysis of paddy production situation, we can see that the market environments, natural disaster and agricultural policy as external environment effect on paddy production. All kinds of natural and social environment factors influenced paddy production.

4. Conclusions and suggestions

Through the analysis and study above, the main conclusions and suggestions are obtained as follows. The paddy production efficiency was not high and stable, and the fluctuation was significant from 1990 to 2007. The average of China's production efficiency was only 0.806, and paddy production efficiency changed with the changes of technical efficiency sometimes or scale efficiency sometimes. But technical efficiency has great influencing on total efficiency; scale efficiency was in weak position.

The inputs and output was not match unreasonable in most time. There were serious overflow of material and service fee, labor cost and land cost except for a few years, and influenced the improvement of production efficiency. Paddy production in China is affected by natural disasters, market price and agricultural policy.

As the main food crop, paddy is related with China's food security. Effective measures should be taken as soon as possible for China to enhance the paddy production efficiency, we can commence to do following several aspects: 1, To realize industrialization operate, improve the overall paddy production efficiency, integrate production technology, achieve high efficiency in paddy production. 2, Drive the paddy productivity with scale efficiency to improve scale efficiency, achieve scale advantage. 3, Reducing the overflow of inputs, and ensure optimization of inputs and output to strengthen technological innovation, to achieve rational match of inputs and output by using technology. 4, Formulate and implement benefit policy of agricultural development, and constructing healthy and orderly market to promote the development of agriculture. Carry out agricultural insurance to decrease influence of the output by natural disasters.

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Table 1. Total efficiency, pure technical efficiency and scale efficiency of paddy production in China

Time	Total Efficiency	Pure Technical Efficiency	Scale Efficiency
1990	1.000	1.000	1.000
1991	0.781	0.960	0.814
1992	0.802	0.960	0.835
1993	0.939	1.000	0.939
1994	1.000	1.000	1.000
1995	0.928	1.000	0.928
1996	0.863	0.935	0.923
1997	0.767	0.770	0.995
1998	0.784	0.789	0.993
1999	0.673	0.702	0.959
2000	0.646	0.690	0.936
2001	0.691	0.728	0.950
2002	0.625	0.667	0.937
2003	0.706	0.732	0.964
2004	0.931	1.000	0.931
2005	0.806	0.842	0.956
2006	0.804	0.856	0.939
2007	0.809	0.938	0.863
2008	0.751	1.000	0.751

Table 2. Correlation coefficient of total efficiency, pure technical efficiency and scale efficiency

	total efficiency	pure technical efficiency	scale efficiency
total efficiency	1.0000	0.8474	0.1835
Pure technical efficiency	0.8474	1.0000	-0.3656
scale efficiency	0.1835	-0.3656	1.0000

Table 3. Projection of model assessment results

Decision making unit	Index	Original value	Radial movement	Slack movement	Projected value
1992	Total output value	259.970	0.000	4.470	264.440
	Material and service fee	102.670	-4.110	0.000	98.560
	Labor cost	75.270	-3.013	-12.517	59.740
	Land cost	14.350	-0.574	-2.796	10.980
1998	Total output value	593.360	0.000	0.000	593.360
	Material and service fee	215.580	-45.445	0.000	170.135
	Labor cost	163.920	-34.555	-35.839	93.526
	Land cost	57.940	-12.214	-18.495	27.231
2004	Total output value	739.730	0.000	0.000	739.730
	Material and service fee	226.240	0.000	0.000	226.240
	Labor cost	171.440	0.000	0.000	171.440
	Land cost	56.960	0.000	0.000	56.960

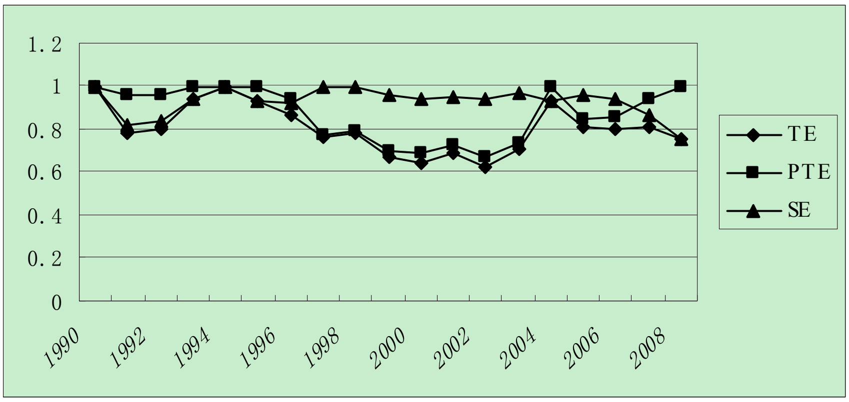

Figure 1. Line graph of total efficiency, pure technical efficiency and scale efficiency