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Appraisal of Agriculture Production Efficiency in Shandong Province Based on Data Envelopment Analysis

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Abstract: *This article carries on efficiency appraisal of agriculture production in Shandong Province based on data envelopment analysis (DEA) model. The CCR model analysis result indicates that the synthesis efficiency of agriculture production during 2007-2010 year is somewhat low, and there exists obvious difference among 17 districts in Shandong Province. We use BCC model to further calculate the agriculture production efficiency in 17 districts and find that 6 districts are at the stage of distant returns to scale, the other 11 districts are at the stage of decreasing returns to scale. The projection analysis of DEA model indicates that each input factor of non-DEA effective district has input redundancy at different degree. Input surplus is the main reason to result in low synthesis efficiency of agriculture production, while sown area of crops surplus and overpopulation are the two most important factors.*

Keywords: *Data Envelopment Analysis; Agriculture; Production Efficiency*

1. INTRODUCTION

To enhance the agricultural production efficiency is an efficient way to eliminate agricultural development bottleneck and promotion it to develop soundly and fast. At the same time, based on the fact of grain sown area reduction, aggravating environmental pollution and natural disaster increase, we must enhance the agricultural production efficiency to guarantee stable grain production. Although Shandong Province is a larger agricultural province in China, its agricultural production efficiency is at the low level comparing to other provinces. Based on the above background, this article uses DEA method to appraise the synthesis efficiency of agricultural production in Shandong Province during 2007-2010 year period, and calculates pure technical efficiency and scale efficiency of 17 Shandong districts in order to find the problems existing in agriculture production and provide reference to improve agricultural production efficiency.

2. LITERATURE REVIEW

Scholars in foreign countries have done quite comprehensive research to the agricultural efficiency. Kawagoe and Hayami(1985) made research of agricultural efficiency in different local and indicated that there existed less relation between agricultural production efficiency and labor force among the areas whose economy level is similar. Ball and so on (2001) had studied agricultural production efficiency of 10 countries including USA during 1973-1993 year, and their research proved capital accumulation and agricultural production efficiency promote mutually. Coelli and Rao(2005) used malmquist method based on DEA non-parameter model to measure and analyze the agriculture total factor productivity of 93 countries during 1980-2000. Vollrath D discussed the agricultural efficiency difference under unfair agricultural land assignment based on international data.

Although agricultural efficiency research started late in our country, it developed rapidly. Specially the introduction and utilization of data envelope analysis method (DEA) causes the agricultural efficiency research to be more effective and convenient. Huang Shaoan, Sun Shengmin and so on (2005) made empirical research on agricultural production efficiency from 1949 to 1978 year in our country, and indicated that different land property allocation system and

production inputs could cause large difference on agriculture efficiency. Song Zengji, Xu Yeqin and so on (2008) took data of 31 provinces of China in 2005 as sample, and carried on evaluation to the agricultural production efficiency by DEA method. They rank the synthesis efficiency of 31 provinces and used the cluster analysis to carry on the rank division and classification comparison. Fang Hong (2010) surveyed agricultural production technology efficiency of various provinces during 1988-2005 year and proved that agricultural production efficiency in majority areas in our country was generally low. The eastern area efficiency was higher than the western area. Guo Junhua, Li Bangyi (2011) discovered that, during 1985-2007 year, agricultural production efficiency in our country presented declined trend. Both scale efficiency and pure technical efficiency have large promotion space. Sun Jiang (2011) studied agricultural production efficiency of 18 districts in Henan Province with BCC model and confirmed that scale inefficiency is the main cause of different agricultural production efficiency. Yin Haidong (2011) analyzed agricultural production efficiency in Heilongjiang different areas with fuzzy quality synthetic evaluation method and located the first three areas was in turn Daxinanling, Yichun and Harbin.

3. APPRAISAL OF AGRICULTURAL PRODUCTION EFFICIENCY IN SHANDONG PROVINCE

There are many methods to appraise agricultural production efficiency, such as fuzzy quality synthetic evaluation method, analytic hierarchy process method, factor analytic method as well as DEA method, in which DEA method is widely used by its convenience practical merit. Therefore, this article chooses DEA method.

3.1. Principle of DEA Model

DEA model was found in 1978 by famous operation scientists A.Charnes and W.Cooper. It is a kind of system analysis method used to compare the relative efficiency among decision making units (DMU) through establishment linear programming model. Its basic theory is to take each appraised unit as DMU, then make general analysis of input and output factors of each DMU and estimate their weight. According to the weight calculate the efficiency value and determine the production frontier. And then decide each DMU is effective or not based on the distance between DMU and its production frontier. The DMU who is not on the frontier is called non-DEA efficiency. Simultaneously it can use projection method to point out the reason why the DMU is in inefficient state and how to improve.

The reason why this article chooses DEA model is that urbanization efficiency appraisal involves more than one input and output factors, while it is very convenient to deal with multi-input and output situation by DEA model. Also it is not necessary to know the concrete functional relation among the factors, so the appraisal result is quite objective.

The basic principle of DEA model is: Suppose the number of DMU is n. T $_{j\text{-th}}$ DMU is represented as DMU_j (j=l,2,…n). The input vector of DMU_j is $X_j=(X_{1j}, X_{2j}\ldots X_{mj})^T$, and the output vector is $Y_j= (Y_{1j}, Y_{2j}\ldots Y_{rj})^T$. Here, m is the number of input, r is the number of output. The corresponding weight coefficient is $V=(V_1, V_2\ldots V_m)$ and $U=(U_1, U_2\ldots U_r)$ respectively. Also suppose X_{ij} is the i-th input value of the j-th DMU, Y_{kj} is the k-th output value of the j-th DMU. V_i, U_k is the weight coefficient of the i-th and the k-th index respectively. Then the corresponding appraisal efficiency index of the j-th DMU is: $h_j = \frac{U^T Y_j}{V^T X_j} = \sum_{k=1}^{s} U_k Y_{kj} / \sum_{i=1}^{m} V_i X_{ij}$

Choosing the suitable weight coefficient V and U to let $h_j \le 1$. High h_j indicates that DMU can use relative less input to obtain relative more outputs. DEA model has several methods, CCR BCC model are used generally. CCR model can measure technical efficiency of DMU. Introducing the convexity supposition in the CCR model can obtain BCC model, whose effective frontier is a convex set. It can appraise the pure technical efficiency, which means the efficiency without considering the scale factor and the factor handling ability change. CCR and BCC model are shown as the following:

Take the j_0 decision-making unit efficiency index as a goal, take all policy-making unit efficiency index as the restraint, but structure following CCR model and BCC model:

$$\begin{cases} \min \theta - \varepsilon(\sum_{i=1}^{m} s_i^- + \sum_{k=1}^{s} s_k^+) \\ st \\ \sum_{j=1}^{n} \lambda_j X_{ij} + s_i^- = \theta X_{ij_0}, i = 1,2,3 \cdots m \\ \sum_{j=1}^{n} \lambda_j Y_{kj} - s_i^+ = Y_{kj_0}, k = 1,2,3 \cdots s \\ \lambda_j, s_i^-, s_k^+ \geq 0, j = 1,2,3 \cdots n \end{cases} \quad (1)$$

$$\begin{cases} \min \phi - \varepsilon(\sum_{i=1}^{m} s_i^- + \sum_{k=1}^{s} s_k^+) \\ st \\ \sum_{j=1}^{n} \lambda_j X_{ij} + s_i^- = \phi X_{ij_0}, i = 1,2,3 \\ \sum_{j=1}^{n} \lambda_j Y_{kj} - s_i^+ = Y_{kj_0}, k = 1,2,3 \cdots s \\ \sum_{j=1}^{n} \lambda_j = 1 \\ \lambda_j, s_i^-, s_k^+ \geq 0, j = 1,2,3n \end{cases} \quad (2)$$

(1) Describes CCR model, (2) describes BCC model.

Among them, λ、θ、ϕ are the decision variable, s^-、s^+ are slack variable of input and output respectively, ε is Archimedes infinitely great.

3.2. Target Choices

We choose farm machinery production, chemical fertilizer quantity, crops sown area as well as agriculture population during 2007-2010 year as input variables, and choose total output value of the first industry as output variable, establishing the multi-inputs—one output efficiency appraisal model. The sample data comes from "Shandong Province Statistics Yearbook" and "Shandong Province Urbanization Development Report" during 2008-2011 year.

Table1. *DEA target choice*

period	input	output
2007-2010	X_1:farm machinery production(ten thousand kilowatts)	Y: total output value of the first industry (Billion yuan)
	X_2:chemical fertilizer quantity (ten thousand tons)	
	X_3:crops sown area (Thousands of hectares)	
	X_4:agriculture population（Million people）	

3.3. Dynamic Comparison of Agricultural Production Synthesis Efficiency in Shandong Province

Table2. *Synthesis agriculture efficiency of 17 districts during 2007-2010 year*

DMU	2007		2008		2009		2010	
	eff	rank	eff	rank	eff	rank	eff	rank
Shandong	0.771	11	0.860	10	0.870	10	0.820	12
Jinan	0.943	4	0.998	6	0.995	6	0.986	7
Qingdao	0.870	9	0.948	9	0.923	9	0.964	8
Zibo	0.723	14	0.807	13	0.826	12	0.883	10
Zaozhuang	1.000	1	1.000	1	1.000	1	1.000	1
Dongying	0.940	5	1.000	1	1.000	1	1.000	1
Yantai	0.920	6	1.000	1	1.000	1	1.000	1
Weifang	0.771	11	0.832	11	0.823	13	0.769	14
Jining	0.884	7	0.964	8	0.940	8	0.928	9
Taian	0.980	3	1.000	1	1.000	1	1.000	1
Weihai	1.000	1	1.000	1	1.000	1	1.000	1
Rizhao	0.878	8	0.820	12	0.841	11	0.834	11
Laiwu	0.746	13	0.965	7	0.981	7	1.000	1
Linyi	0.781	10	0.799	14	0.810	14	0.727	15
Dezhou	0.467	17	0.569	17	0.573	17	0.571	17
Liaocheng	0.484	16	0.601	16	0.597	16	0.573	16
Binzhou	0.692	15	0.749	15	0.788	15	0.783	13
Heze	0.460	18	0.467	18	0.462	18	0.430	18
Average	0.796	——	0.854	——	0.856	——	0.850	——

Note: *"eff" represents synthesis agriculture efficiency.*

We select Deap2.1 software and calculate the agriculture efficiency of 17 districts in Shandong Province during 2007-2010 year by CCR model. The results are shown as table 2.

As shown in Table 2, during 2007-2010 year, the synthesis agriculture efficiency of Shandong Province is low, which shows that there exists input surplus or output insufficient. As economy growth pole in Shandong Province, the agricultural synthesis efficiency of Jinan and Qingdao,is not actually prominent. The agricultural synthesis efficiency value of Zaozhuang and Weihai t is 1 throughout the four years, which show these two areas' agricultural production resources disposition is reasonable. The agricultural production is efficiency in the recent three years in Dongying, Yantai and Tai'an. The agriculture synthesis efficiency in Laiwu promotes from 0.746 in 2007 to 1 in 2010, which explains the modernization achievement of agriculture is remarkable in recent years. The last four districts according to efficiency are in turn Binzhou, the Liaocheng, Dezhou as well as Heze. The agricultural synthesis efficiency of Heze presents the declined tendency year by year. These four districts have the pivotal status in agricultural production regardless of input and output. There are some problems existing in their agriculture production, such as slow transformation from traditional agriculture, backward modern agriculture development, low agricultural science and technology, large number of rural labor surplus and so on. Therefore, during the twelfth period, the government should support the above four areas specially, giving certain support and protect policy to promote agricultural production reform effectively and optimize investment structure in order to enhance production efficiency.

3.4. The Concrete Analysis of Agriculture Production Efficiency in Shandong Province in 2010

According to BCC model, we calculate the pure technical efficiency and scale efficiency of 17 districts in Shandong Province. The results are shown as the following.

Table3. *The results of agriculture production efficient in 2010*

DMU	TE	PTE	SE	RS	Redundancy of input					Insufficiency of output
					X1	X2	X3	X4	X5	Y
Shandong	0.820	1.000	0.820	drs						0.000
Jinan	0.986	1.000	0.986	drs						0.000
Qingdao	0.964	1.000	0.964	drs						0.000
Zibo	0.883	0.892	0.989	drs			50.225	21.122		0.000
Zaozhuang	1.000	1.000	1.000	-						0.000
Dongying	1.000	1.000	1.000	-						0.000
Yantai	1.000	1.000	1.000	-						0.000
Weifang	0.769	0.842	0.914	drs		3.425	82.505			0.000
Jining	0.928	0.967	0.960	drs		0.879	431.509	21.934		0.000
Taian	1.000	1.000	1.000	-						0.000
Weihai	1.000	1.000	1.000	-						0.000
Rizhao	0.834	0.855	0.975	drs				28.806		0.000
Laiwu	1.000	1.000	1.000	-						0.000
Linyi	0.727	0.796	0.913	drs		36.050	538.310	131.326		0.000
Dezhou	0.571	0.711	0.802	drs	207.313		298.666	11.351	207.313	0.000
Liaocheng	0.573	0.629	0.911	drs			326.891	38.377		0.000
Binzhou	0.783	0.790	0.992	drs			70.701	5.219		0.000
Heze	0.430	0.482	0.892	drs			444.265	7.708		0.000
Average	0.850	0.880	0.959	drs						0.000

According to Table 3, the synthesis efficiency of agriculture production in Shandong Province is lower than the average level. The pure technical efficiency value is 1, but its scale efficiency is decreasing. The value of pure technical efficiency and scale efficiency are both 1. The other districts are at the stage of decreasing to returns of scale. The synthesis efficiency of Weifang, Rizhao, Linyi, Dezhou, Liaocheng, Binzhou as well as Heze is lower the average value of 17 districts.

In order to analyze whether exists input surplus or output insufficiency, we carry on redundancy analysis with DEA model. The results are shown in Table 3.

According to table 3, although the synthesis efficiency of Jinan and Qingdao is lower than 1, their pure technical efficiency value is 1, and they do not have input and output redundancy, which means their production technical level have met the efficiency requirements, but their scale is big. In order to enhance synthesis efficiency, these two areas should reduce their scale to 98.6% and 96.4% of the current scale. There are 8 districts should enhance farming operational effectiveness and specialized rural labor force, 2 districts should reduce chemical fertilizer quantity, 1 district should reduce farm machinery production.

4. CONCLUSION

Firstly, the difference agriculture synthesis efficiency among 17 districts is remarkable.

In 2007, the average agriculture synthesis efficiency in 17 districts is 0.796, the standard deviation is 0.182. The highest and lowest efficiency district is Weihai and Heze in turn, whose efficiency value is 1 and 0.460 respectively. The deviation of the two districts is 0.54. In 2008 the average agriculture synthesis efficiency in 17 districts is 0.854, the standard deviation is 0.172. The highest efficiency districts are Zaozhuang, Dongying, Yantai, Tai'an as well as Weihai, whose efficiency value is 1. The lowest efficiency district is Heze, whose efficiency value is 0.467.The deviation between the highest and the lowest efficiency is 0.533. In 2009 the average agriculture synthesis efficiency in 17 districts is 0.856, the standard deviation is 0.170. The highest efficiency districts are Zaozhuang, Dongying, Yantai, Tai'an as well as Weihai, whose efficiency value is 1. The lowest efficiency district is Heze, whose efficiency value is 0.462.The deviation between the highest and the lowest efficiency is 0.538. In 2010 the average agriculture synthesis efficiency in 17 districts is 0.850, the standard deviation is 0.182. The highest efficiency districts are Zaozhuang, Dongying, Yantai, Tai'an Weihai as well as Laiwu, whose efficiency value is 1. The lowest efficiency district is Heze, whose efficiency value is 0.430.The deviation between the highest and the lowest efficiency is 0.570.

Secondly, input surplus is the main reason which causes low agriculture production efficiency.

According to agricultural production redundant variable analysis result in different areas in 2010, input surplus is the main reason which causes low agriculture production efficiency, while sown area of crops surplus and overpopulation are the two most important factors. On the one hand, it reflects farming yield rate in Shandong Province is low and grain sown area has not be made full use; on the other hand, the agriculture overpopulation result in low labor productivity.

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