Agricultural Production Efficiency of Chongqing Based on DEA

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Abstract Literatures about agricultural production efficiency are reviewed. Concept of DEA Method, as well as the definition methods of effective DEA and scale efficiency increase are introduced. According to the relevant statistical data in the years 1997 -2007 in Chongqing Municipality, efficiency of agricultural economy is calculated from the year 1997 to 2007 by DEA method and the scale efficiency is also analyzed by taking the total output of agriculture, forestry, animal husbandry and fishery industry as the output index. And the input index includes total workforce in agriculture, forestry, animal husbandry and fishery, the total sown area of crops, the total power of agricultural machinery, chemical fertilizer application, the draft animal, and the effective irrigation area. Result shows that Chongqing City became a municipality directly under the central government; its agricultural production efficiency is still low. And the sustainable development capacity of agricultural is weak in Chongqing, and the agricultural resources are not fully used. Based on this, related suggestions are put forward to improve the agricultural production efficiency of Chongqing, such as implementing an appropriate management scale of land, improving the organization degree of peasant households and the rate of industrialization management, enhancing the quality of the rural labor force, strengthening the agricultural science and technology input and extension, perfecting the construction of rural infrastructure, and improving the rate of resource utilization.

Key words Agricultural production efficiency, DEA model, Scale efficiency, China

As the agricultural growth form in China transforms from extensive to intensive, the efficiency of agricultural production has received increasing attention. Gopinath, *etc.* has made it clear that the agricultural production efficiency is an important aspect of agricultural competitiveness. As the experimental area of national urban and rural harmonious development, Chongqing City undertakes the mission to promote western rural development, the improvement of the efficiency of agricultural production has become the basic guarantee to promote the development of modern agriculture and the construction of socialist new countryside in Chongqing. Taking the C^2R model of DEA method (Data Envelopment Analysis) to calculate the efficiency of agricultural production in Chongqing during 1997 -2007 (after the city is municipalized), the author aims to provide reference for the formulation of relevant agricultural policy.

1 Literature review

There are lots of studies on agricultural production efficiency both at home and abroad, most of the studies in the past were conducted with the method of C-D production function. In recent years, with its gradual development, DEA method is widely used in the comprehensive evaluation of agricultural production efficiency. For example, Liu Can adopts the DEA method to study the relationship between the farmers' productivity and poverty in Jinzhai County of Anhui Province; Li Zhou analyzes the agricultural production efficiency of 900 counties and districts in western China through DEA method[1-8]. Some scholars use DEA-Tobit two-stage method to respectively analyze agricultural efficiency and the efficiency of county agro-innovation system and their influencing factors[9-10]; according to the input and output data of agricultural production in each areas and the Context-dependent DEA model, Zhang Yunhua divides 31 provinces, autonomous regions and municipalities of China into 6 frontiers and then analyzes the efficiency of agricultural production in each area[11]; Yang Lirong, *etc.* analyze the agricultural economic efficiency of Xiehong County in 1998 -2007 through DEA method[12]. Thus it can be seen that the application of DEA in studying the efficiency of agricultural production has gradually become mature.

2 Research method, Index selection and Data source

2.1 DEA Method DEA is a systematic analysis method proposed by the well-known operational researcher Charnes on the basis of the concept "Relative Efficiency Evaluation". It is an effective way to compare the relative efficiency and benefit of a number of the same type multi-input, multi-output decision-making units (DMU). DEA determines the efficiency frontier of production system through linear programming technique and obtains the relative efficiency and scale benefit, *etc.* of each DMU[12]. DEA model has many forms, here the author introduces C^2R model to analyze. C^2R model is a model to evaluate the technical efficiency and scale effectiveness of the departments and DMU at one time. The corresponding linear programming model of this model is:

$$\min\theta$$

$$s.t.\begin{cases}\sum_{j=1}^{n}\lambda_j X_j + S^- = \theta X_0\\ \sum_{j=1}^{n}\lambda_j T_j - S^+ = Y_0\\ \lambda_j \geqslant 0; j=1,2,\cdots,n\\ S^+ \geqslant 0, S^- \geqslant 0\end{cases}$$

Accepted: March 1, 2010 Received: March 24, 2010

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In this formula, X_j and Y_j refer respectively to the input and output elements of the departments or DMU. θ is the radial optimization amount or distance between the DMU and efficient frontier, which specially refers to the total efficiency of the agricultural economy in one year, the closer it to 1, the more effective; λ_j is the portfolio ratio of NO. j DMU in an efficient DMU reconstructed based on DMU; S^+ and S^- are slack variables used for the non-efficiency DMU to extend along the horizontal or vertical direction to the efficient frontier. Suppose that the ideal solutions of C^2R model are θ^0, λ^0, S^{+0}, S^{-0}, according to the DEA theorem: ① If $\theta^0 = 1$ and $\sum_{i=1}^{s} s_i^+ + \sum_{r=1}^{m} s_r^- = 0$, then DMU_{j0} is DEA efficiency, which means that the input cannot be reduced overall geometrically and there are no excessive input and deficient output; ② Suppose $\theta^0 = 1$ and $\sum_{i=1}^{s} s_i^+ + \sum_{r=1}^{m} s_r^- > 0$, then DMU_{j0} is only weak DEA efficiency and there do exist excessive amount of input and deficient output; ③ suppose $\theta^0 < 1$, then DMU_{j0} isn't DEA efficiency, which means, at the best state of the input and output, the current level of output can also be obtained by reducing input θ^0 geometrically; ④suppose $k = \sum \lambda_j^0 / \theta$, when $k < 1$, the scale benefit increases by degrees; $k = 1$, the scale benefit doesn't change; $k > 1$, the scale benefit decreases by degrees.

2.2 Index selection and Data source The data comes mainly from *Chongqing Statistical Yearbook*, covering the data form 1997 when Chongqing became a municipality to 2007. As the calculation method needs, the index, which is selected when Li Gucheng conducts a case study on the temporal evolution and regional distribution of the total factor productivity growth of our agriculture during transformation period in 2009, is taken for reference[13].

2.2.1 Output index. The agricultural output level is measured by the total output of agriculture, forestry, animal husbandry and fishery industry. Here adopts the total output of the generalized sense of agriculture, which refers to the monetary form of the total volume of the products in agriculture, forestry, animal husbandry and fishery industry. In this way can it be in accordance with the caliber of agricultural input statistics because the current caliber of agricultural labor force, mechanical input, draft animal and other investment all belong to generalized agricultural caliber.

2.2.2 Input index. The labor input and capital input are two most important input indexes while conducting the study of economic activity. Apart from these two factors, other relative indexes should also be taken into consideration in view that agricultural production is affected by means of production, production technology and other various factors. The author measures the investment of all resources needed in the performance of agricultural economy by six indexes the author chooses, including the total workforce in agriculture, forestry, animal husbandry and fishery, the total sown area of crops, the total power of agricultural machinery, chemical fertilizer application, the draft animal, and the effective irrigation area.

2.2.2.1 The total workforce in agriculture, forestry, animal husbandry and fishery L. It covers all labor forces engaged in agriculture, forestry, animal husbandry and fishery but excludes those engaged in industry and services.

2.2.2.2 The total sown area of crops x_1. Its value is calculated by multiplying the area of cultivated lands and the multiple cropping index.

2.2.2.3 The total power of agricultural machinery x_2. It mainly refers to the total power of the power machineries applied in agriculture, forestry, animal husbandry and fishery, including the machines used in farming, irrigation, harvest, farm transport, plant protection, animal husbandry, forestry, fishery and other agricultural machines (the internal combustion engine is calculated with the engine horsepower W, the motor is calculated with its power W); it doesn't include those power and operating machineries applied specially in industries organized by the county, town, village and group, and used for infrastructure construction, non-agricultural transport, scientific experiments, teaching and other non-agricultural production.

2.2.2.4 Draft animal x_3. It refers specially to the livestock used for farming and transportation, including cattle, horses, mules, donkeys, camels and so on. Here the number of draft animals used in agriculture among the total amount of the large livestock in Chongqing every year is used for calculation.

2.2.2.5 Chemical fertilizer application x_4. It is measured by the actual amount (pure amount) of chemical fertilizer applied for agricultural production every year, mainly including nitrogen, phosphate, potash and compound fertilizer and so on.

2.2.2.6 The effective irrigation area x_5. It is measured by the actual effective irrigation area every year, which equals to the total amount of paddy fields and irrigated lands which have been equipped with irrigation facilities and are capable of normal irrigation.

3 The evaluation of production efficiency

3.1 Analysis of total efficiency Using Lingo 8.0 software and inserting the agricultural input and output data of Chongqing during 1997 –2007 into the model, the author obtains the total efficiency and scale benefit value of agricultural economy in Chongqing every year under the hypothesis of constant returns to scale (CRS) from the perspective of investment. The results can be seen from Table 1.

As shown in Table 1, the total efficiency of agricultural economy in Chongqing is not high; there are non-DEA efficiencies in each year except in 1997 and 2007, and the θ values in four years are all below 0.9; the change of θ values shows that the total efficiency of agricultural economy in Chongqing is rather unstable and highly volatile. This indicates that the optimal efficiency has been obtained in the agricultural production practice in 1997 and 2007, in other words, the minimum input has led to the maximum output. As a result of the C^2R model, DEA efficiency contains both technology efficiency and scale efficiency, that is, the input-output points in 1997 and 2007 are on the production frontier and the scale benefit is invariant; the non-DEA efficiency in other years proves that the agricultural resources in Chongqing has not been fully utilized and the maximum agricultural output hasn't been reached, that is, in addi-

tion to 1997 and 2007, under the full use of resources, the remaining years can obtain the current same output with smaller input, or more output with same input.

3.2 Analysis of scale benefit As shown in Table 1, the DEA efficiency in two years are all at the stage of constant returns to scale, if the agricultural inputs in these two years are expanded by certain percentage, so will the outputs in these years increase by the same percentage, which shows that the agricultural inputs in these years are reasonable and have achieved the maximum scale benefit. But the scale benefit in those years with non-DEA efficiency all increase by degrees, which can be in other words that as agricultural inputs increases by certain degrees, then agricultural output will increase by larger degrees.

Table 1 The judgment results of agricultural economy scale efficiency in Chongqing from 1997 to 2007

Year	Total efficiency	Scale efficiency	Scale benefit condition
1997	1.000 0	1.000 0	invariant
1998	0.912 0	0.993 2	Increase
1999	0.866 1	0.955 2	Increase
2000	0.829 2	0.954 5	Increase
2001	0.861 7	0.872 6	Increase
2002	0.958 7	0.952 5	Increase
2003	0.861 7	0.872 6	Increase
2004	0.958 7	0.952 5	Increase
2005	0.946 8	0.961 1	Increase
2006	0.913 9	0.956 3	Increase
2007	1.000 0	1.000 0	Invariant

4 Conclusions and Discussion

According to the measurement and analysis of the agricultural input-output efficiency from 1997 to 2007 in Chongqing, the agricultural input scale in this city still needs to be improved, the overall agricultural production efficiency is not high, seen from the perspective of sustainable development, the sustainable development capability of the agriculture in Chongqing is not strong, and its agricultural resources haven't still been taken full use of.

Being a municipality can bring huge external effects for a city. Under China's economic and political system, "municipality" means great economic and political resources and the intangible impacts. As a municipality, Chongqing should take full use of these resources and speed up urban construction as well as constantly increase agricultural inputs; it should also take the lead in forming the urban and rural harmonious system in western China and truly become the growth pole in the west. According to the agricultural data in Chongqing after it was municipalized, the number of the employees in agriculture, forestry, animal husbandry and fishery saw negative growth, an average rate of −2.41%. Therefore, in order to improve the agricultural production efficiency in Chongqing, it should mainly focus on the increasing of agricultural inputs and improvement of scale efficiency so as to let the input-output point be on the production frontier.

Currently, the farmers' small-scale management and scattered distribution are one of the main obstacles restricting the agricultural scale efficiency, thus, in order to improve the scale efficiency of agricultural production, the mountainous, hills and other areas with lower scale efficiency can explore some forms of land transfer and implement an appropriate scale management of lands; the organization degree of peasant households and the rate of industrialization management can get improved through various forms of industrial organization; while speeding up the transfer of surplus labor in agriculture, the quality of rural labor force should get improved, the agricultural technology input and its extension should be enhanced and the construction of rural infrastructure should get perfected; by vigorously promoting agricultural circular economy can the efficiency of resources utilization get improved and the agricultural modernization production be realized.

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