Advances in Social Science, Education and Humanities Research, volume 500
Proceedings of the Second International Symposium on Management and Social Sciences (ISMSS 2020)

The DEA Model Analysis of Comprehensive Agricultural Efficiency in Shanxi Province of China

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ABSTRACT
Agriculture is the source of food and clothing, the foundation of survival, and the primary condition of all production. It provides grain, non-staple food, industrial raw materials, capital and export materials for other sectors of the national economy. Agriculture is the foundation of other industries, and the efficiency of agricultural production has important reference value for the development of other industries. This paper uses the DEA model to analyze the comprehensive agricultural efficiency, pure technical efficiency and scale efficiency of Shanxi Province from 2005 to 2018. It is concluded that with the improvement of agricultural mechanization and the increase in agricultural investment in recent years, the pure technology efficiency and scale efficiency of agricultural production in Shanxi Province continue to rising, reaching a technically effective state in recent years, which has further promoted the growth of comprehensive agricultural efficiency in Shanxi Province. However, there are some problems about the use of agricultural fertilizers, which need suggestions to solve.

Keywords: *Shanxi Province, Agriculture comprehensive efficiency, DEA model.*

1. INTRODUCTION

Shanxi is an inland province located on the east bank of the middle reaches of the Yellow River and on the Loess Plateau west of the North China Plain. Shanxi Province is rich in mineral resources and relied on coal resources in the early stages of development. However, as resources continue to be exploited, Shanxi Province needs to develop new industries to earn money. At the same time, agriculture is the foundation of other industries, the efficiency of agricultural production has important reference value for the development of other industries [1]. It is very important to develop agriculture industries to promote the others. The land area of Shanxi Province is 156,000 square kilometers, accounting for 1.6% of the total area of the country. In 2018, the total grain output of Shanxi Province reached 13,803952 tons, an increase of 252998 tons over the previous year, an increase of 1.8%. In order to promote the economic development of Shanxi Province, the research on agricultural production efficiency in Shanxi Province provides reference for the development of other industries. Therefore, the current research on comprehensive agricultural efficiency in Shanxi Province has very important practical significance.

Comprehensive efficiency (TE_{CRS}) refers to the efficiency of conversion of input into output. It refers to the ratio of production volume to total input volume, indicating the relationship between output volume changes and total input volume changes, to measure the effect of productivity changes on economic growth. Comprehensive agricultural efficiency is the output obtained from the input of agricultural units [2]. Comprehensive efficiency (TE_{CRS}) can be decomposed into pure technical efficiency (TE_{VRS}) and scale efficiency (SE). Pure technical efficiency refers to the degree to which the production efficiency of the technology is exerted during the stable use of the technology, and the scale efficiency refers to the impact of input growth on overall efficiency changes [3]. Based on this meaning, the efficiency referred to in this article is the Shanxi agricultural efficiency, which measures the distance between the current production points of each decision-making unit and the production frontier composed of efficient decision-making units. At present, there are many researches on agricultural efficiency, such as the research on the agricultural efficiency within the province [4-5], the research on the agricultural efficiency of some provinces in China [6], and the research on the agricultural efficiency of China from different angles [7-11]. At present, there is no research on the agricultural production efficiency of Shanxi Province from the macro-statistics. This paper uses the DEA analysis method to evaluate the comprehensive agricultural efficiency of Shanxi Province, analyzes the overall change trend of the comprehensive agricultural efficiency, pure technical efficiency and scale efficiency of Shanxi Province from 2005 to 2018. On the one hand, through the longitudinal comparison of agricultural efficiency analyzes the change trend of agricultural efficiency in Shanxi; on the other hand, the horizontal comparison of agricultural efficiency in Shanxi can draw related conclusions about the efficiency improvement plan of the technical invalid unit.

2. RESEARCH METHOD AND INDICATOR SELECTION

2.1. DEA (Data Envelopment Analysis) Model

Data Envelopment Analysis (DEA) is a new system analysis method developed by famous American operations researchers Charles, Cooper and Rhodes on the basis of the concept of “relative efficiency evaluation” [12]. DEA is a non-parametric methodology of efficiency calculation of decision making units (DMUs) which considers multiple inputs and outputs [13]. This approach does not depend on specifications like production function, weights, etc of different selected inputs and outputs. The basic idea is to determine the best production frontier of each decision-making unit in each period at first, and then compare the actual production of each decision-making unit with the best production frontier, so that the technical efficiency of each decision-making unit can be measured. There are two main types of DEA models: one is the DEA model with constant returns to scale (C^2R model), which is mainly used to measure technical efficiency including returns to scale; the other is the DEA model with variable returns to scale (C^2GS^2 model), which is used to measure pure technical efficiency [14]. The C^2R model assumes that the returns to scale of each production unit evaluated remain unchanged. But the realized in reality. So, when the actual returns to scale of production units are variable, the technical efficiency calculated by the C^2R model is actually includes the return to scale effect. In order to distinguish the pure technical efficiency and scale efficiency, this article will establish two DEA models to measure the comprehensive efficiency of agriculture: measure pure technical efficiency through C^2GS^2 model, and measure technical efficiency including scale effects through C^2R model.

2.2. Indicator Selection and Data Sources

In order to use the DEA model to evaluate the comprehensive agricultural efficiency of Shanxi Province, it is necessary to determine the input indicators and output indicators. The efficiency analysis indicators selected in this paper include 2 output indicators and 4 input indicators. The two output indicators are the total output value(Y_1)and the percapita net income of rural households (Y_2); four input indicators are rurallabor force (X_1), crop sown area (X_2), total power of agricultural machinery (X_3)and amount of agricultural fertilizers applied (X_4). This article selects the statistical data of Shanxi Province from 2005 to 2018. The data of the above indicators are from the statistical yearbook of Shanxi Province from 2006 to 2019. The original data is shown in Table 1.

Table 1. The Efficiency Analysis Indicators Selected

Year	Y1	Y2	X1	X2	X3	X4
2005	4837972.00	1563.52	637.44	3795.35	2288.70	956999.00
2006	4418484.00	1622.86	635.68	3471.30	2357.48	983000.00
2007	4983892.00	1860.38	633.92	3653.15	2440.79	1008000.00
2008	5959205.00	1986.38	637.85	3726.49	2509.90	1034042.00
2009	9087428.00	1919.76	631.62	3692.14	2655.04	1043239.00
2010	10164065.38	2028.46	632.44	3643.34	2809.17	1103663.00
2011	11634010.39	2140.83	643.43	3696.70	2927.30	1145667.00
2012	12659820.81	2334.41	640.68	3692.31	3056.09	1182795.00
2013	13720159.48	2503.60	643.85	3660.38	3183.30	1210196.00
2014	14405971.15	2482.26	656.11	3659.98	3286.20	1196137.78
2015	14249629.53	2624.36	659.89	3610.07	3351.65	1185471.70
2016	14299147.50	2729.94	662.62	3591.57	3464.73	1170718.76
2017	14187298.00	2823.96	670.71	3577.61	1376.30	1119983.82
2018	14606448.40	3075.23	672.88	3555.16	1441.09	1096107.70

Note: Assumption of constant returns to scale is rarely

3. EVALUATION RESULTS OF COMPREHENSIVE AGRICULTURAL EFFICIENCY IN SHANXI PROVINCE

By using DEAP software to measure the comprehensive agricultural efficiency of Shanxi Province from 2005 to 2018, it is easy to obtain the evaluation results of the comprehensive efficiency, pure technical efficiency and scale efficiency of each decision-making unit, as well as the efficiency improvement plan of the technical invalid decision-making unit, which is showed in Table 2 and Table 3.

3.1. The Efficiency of Each Decision-making Units

Table 2 shows the comprehensive agricultural efficiency of Shanxi Province from 2005 to 2018. It can be seen that from 2005 to 2018, only 2014, 2017, and 2018 have a comprehensive efficiency of 1, which is in the DEA effective state, which means that the technical efficiency and scale efficiency have reached the optimal factor allocation stage and the agriculture in Shanxi Province is in a state of efficient production.

Table 2. The Efficiency of Agricultural Production in Shanxi Province from 2005 to 2018

Year	TE_{CRS}	TE_{VRS}	SE	Return to scale	Is it redundant?	Is it DEA valid?	Is it in a technically effective state?
2005	0.582	1.000	0.582	irs	no	no	yes
2006	0.588	1.000	0.588	irs	no	no	yes
2007	0.658	1.000	0.658	irs	no	no	yes
2008	0.685	0.997	0.687	irs	yes	no	no
2009	0.665	1.000	0.665	irs	no	no	yes
2010	0.738	1.000	0.738	irs	no	no	yes
2011	0.826	0.992	0.833	irs	yes	no	no
2012	0.903	1.000	0.903	irs	yes	no	no
2013	0.973	1.000	0.973	irs	no	no	yes
2014	1.000	1.000	1.000	-	no	yes	yes
2015	0.988	1.000	0.988	irs	yes	no	no
2016	0.989	1.000	0.989	irs	no	no	yes
2017	1.000	1.000	1.000	-	no	yes	yes
2018	1.000	1.000	1.000	-	no	yes	yes

The technical efficiency value in 2012 and 2015 was 1, but there was input and output slack. Therefore, the agricultural production in Shanxi Province was in a weak technically effective state, indicating that the production scale for this year was appropriate and the input or output structure is unreasonable. Without reducing output (or increasing input), some inputs (or output) have reached the minimum (maximum) state and cannot be reduced (or increased), but some inputs are too large (or output are too small), you can reduce the corresponding amount according to the input or output slack.

Except for 2008 and 2011, the technical efficiency value was 1, and there was no output or input slack, indicating that the agricultural production in Shanxi Province was in a state of technically effective in these years, and the production site was at the forefront of production. Without reducing output, various inputs cannot be reduced in equal proportions, and certain inputs cannot be reduced individually.

The technical efficiency was 1 in 2012 and 2015, but there was a slack in input and output. Therefore, the agricultural production in Shanxi was in a weakly technically effective state, indicating that the scale of production was appropriate, and there were only problems with unreasonable input or output structures. Without reducing output or increasing input, some input has reached a minimum state or some output has reached a maximum state and cannot be reduced or increased. But some inputs are too large or output is too small, and the corresponding quantity can be reduced according to the quality of input or output.

The total output value of agriculture (Y_1) was slack in 2008, and the per capita net income of rural households (Y_2) in 2011, 2012, and 2015 was slack; the crop sown area (X_2) and the total power of agricultural machinery (X_3) were slack in 2008. The crop sown area (X_2) is slack in 2011. In 2012, the crop sown area (X_2) and amount of agricultural fertilizers applied (X_4) were loose. In 2015, the amount of agricultural fertilizers applied (X_4) was loose. It shows that the agricultural production in Shanxi Province has been in a state of technical ineffectiveness in recent years. In the case of constant output, the amount of input can be reduced at the same time, while the output remains the same. On this basis, it is also possible to reduce or increase the corresponding amount according to the slack of certain inputs or outputs.

3.2. Input Adjustment of Technical Invalid Decision Units

Table 3 shows the efficiency improvement plan of the technical ineffective unit in Shanxi Province. The radial adjustment value is given, which is to increase the technical efficiency to 1, and all input elements need to be reduced in the same proportion (the absolute value of the index). Therefore, the radial adjustment ratio is the difference between 1 and the technical efficiency; the horizontal adjustment value is due to the much more excessive input of some indicator than others that we need to adjust the input structure; the horizontal adjustment ratio is equal to the absolute value of the horizontal adjustment value and the original value ratio; the total adjustment ratio is the ratio of the absolute value of the sum of the horizontal adjustment value and the vertical adjustment value to the original value.

Table 3. The Efficiency Improvement Plan of Shanxi Province Technical Ineffective Unit

Year	Indicators	X1	X2	X3	X4
2008	Radial adjustment value	-1.792	-10.469	-7.051	-2904.936
	Horizontal adjustment value	0.000	-53.221	-46.669	0.000
	Horizontal adjustment ratio (%)	0.000%	2.120%	1.859%	0.000%
	Total adjustment ratio (%)	0.281%	1.709%	2.140%	0.281%
2011	Radial adjustment value	-4.919	-28.261	-22.379	-8758.425
	Horizontal adjustment value	0.000	-7.429	0.000	0.000
	Horizontal adjustment ratio (%)	0.000%	0.201%	0.000%	0.000%
	Total adjustment ratio (%)	0.764%	0.965%	0.764%	0.764%
2012	Radial adjustment value	-0.017	-0.099	-0.082	-31.709
	Horizontal adjustment value	0.000	-37.633	0.000	-5216.200
	Horizontal adjustment ratio (%)	0.000%	1.019%	0.000%	0.441%
	Total adjustment ratio (%)	0.003%	1.022%	0.003%	0.444%
2015	Radial adjustment value	-0.250	-1.368	-1.270	-449.082
	Horizontal adjustment value	0.000	0.000	0.000	-7834.031
	Horizontal adjustment ratio (%)	0.000%	0.000%	0.000%	0.661%
	Total adjustment ratio (%)	0.038%	0.038%	0.038%	0.699%

From the perspective of the radial adjustment value of each year, the lower the technical efficiency of the year, the larger the adjustment value, indicating that the various investment factors need to be reduced in the same proportion. When the technical efficiency are invalid, it is above 0.9, indicating that although the agricultural production in Shanxi Province has been in a state of technical inefficiency in recent years, the redundancy of each element investment is not serious. The year with the most investment redundancy (2011), the technical efficiency was 0.992, and the investment of each element only needs to be reduced by 0.8% at the same time.

From the perspective of the horizontal adjustment value in each year, in the years when the technology is invalid, there is an unreasonable investment structure. Among them, there are two input factors in 2008 and 2012 that are too many, while in 2011 and 2015, there is an excessive input factor. From the perspective of the adjustment ratio, the problem of irrational input structure was the most prominent in 2008. The crop sown area (X_2) should be reduced by 2.120%, and the total power of agricultural machinery (X_3) should be reduced by 1.859%. In 2011, its crop planting area (X_2) should be reduced by 0.201%. At the same time, the problem of irrational investment structure in 2013 is also prominent. The sown area of crops (X_2) and the amount of agricultural fertilizers (X_4) need to be reduced by 1.019% and 0.441% respectively. In 2015, the amount of agricultural fertilizers (X_4) used was too much, and the proportion that needed to be reduced was 0.661%.

From the perspective of the total input redundancy in each year, the factor input redundancy was the most serious in 2008, and the total power of agricultural machinery (X_3) needs to be reduced by 2.140%. In 2011, the sown area of crops (X_2) needs to be reduced by 0.965%, and the other three input factors need to be reduced by 0.764%. In 2012, the input of various factors was also more redundant, and the input factors needed to be reduced by 0.003%, 1.022%, 0.003% and 0.444% respectively. In 2015, the application of agricultural fertilizers (X_4) needs to be reduced by 0.699%, while the input.

4. CONCLUSION

Through the analysis of the pure technical efficiency, scale efficiency and comprehensive efficiency of agricultural production of Shanxi Province from 2005 to 2018, and the efficiency improvement plan of technically ineffective units, the following conclusions can be drawn:

First, from the perspective of agricultural production efficiency in Shanxi Province, during the 14 years from 2005 to 2018, most of the years were technically effective. In these years, the output cannot be reduced in proportion to the same output. There are four years of agricultural production in a state of technical inefficiency, and various inputs need to be reduced in the same proportion; and in the years when the technology is effective, 2014, 2017, and 2018 are in the DEA state, indicating that the input and output of these three years have demonstration and promotion, other years should be developed in this direction.

Second, from the perspective of the input structure of agricultural production in Shanxi Province, there is a serious surplus of agricultural fertilizer application, which not only wastes production materials, but also causes environmental pollution, which is not conducive to the sustainable development of agriculture in Shanxi Province. The second is the excessive sown area of crops, which may be related to the low land utilization rate in Shanxi Province.

Third, in terms of output indicators, the total output value of agriculture, forestry, animal husbandry, sideline and fishery was insufficient in 2008, and the per capita net income of rural households was insufficient in 2011, 2012, and 2015. Therefore, the focus of improving agricultural production efficiency should be placed on the input indicators and the per capita net income of rural households. The improvement of these types of indicators can improve the overall production efficiency of agriculture.

Generally speaking, Shanxi Province's remuneration for scale operations has continued to increase, and in recent years, agricultural production efficiency has reached 1, without output and input slack. In order to maintain the current agricultural efficiency in Shanxi Province, it is necessary to further rationally use arable land resources, optimize the structure of the agricultural industry, and optimize agricultural capital investment, and transform agricultural production from extensive to intensive. Only in this way, can the agricultural production reach the best state, laying the foundation for steady economic development.

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