Research on the Efficiency of County Agricultural Production based on DEA Model

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Abstract—Based on the perspectives of input and output, the agricultural production efficiency of Luxian county from 2015 to 2019 is calculated by using DEA model from the vertical level, and the agricultural production level of Luxian county is evaluated by projection analysis and Malmquist index, so as to calculate the agricultural production efficiency of Luxian county and provide theoretical reference for the realization of agricultural modernization development of Luxian county. The study found that the overall agricultural production efficiency of Luxian county was high in 5 years, and DEA was effective in many years. The main reason for the ineffectiveness of DEA in Luxian County in 2018 was the lack of sufficient technical input and application, resulting in insufficient resource allocation and utilization. Through projection analysis, it is found that there is redundancy between financial expenditure on agriculture, forestry and water affairs and total power investment of agricultural machinery over the years, and some input resources have not been effectively utilized. Luxian county government should strengthen the construction of modern agricultural machinery and equipment, encourage agricultural scientific and technological innovation, promote the transformation and application of achievements, and optimize the allocation of agricultural, forestry and hydropower resources.

Keywords—Agricultural production efficiency; DEA; DMU; Malmquist index

1 INTRODUCTION

Since The 19th National Congress of CPC, the country vigorously implement rural revitalization strategy and poverty crucial work, issued by the government on supporting depth of poverty alleviation implementation opinions and other documents further expounds the vision of poverty campaign and specific plan implementation, for the party committees and governments at all levels and relevant departments of the grass-roots poverty crucial work pointed out the direction. At a meeting held by the Political Bureau of the CPC Central Committee pointed out that China's poverty alleviation and development has entered a sprint period of tackling tough bones and tackling villages. In addition, we will once again put forward clear instructions and requirements on how to implement the rural revitalization strategy and the specific poverty alleviation work, how to improve the efficiency of rural agricultural production, how to win the battle against poverty to achieve the Party's centenary goal, and take important measures to achieve common prosperity for all the people.

In the study to measure the production efficiency of some decision, often use data envelope analysis (Date Envelopment Analysis, DEA) as the main research method, in the process of the

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study, the team first measure the agricultural efficiency level of luzhou, sichuan province and indicators, efficiency through the above data evaluation and ranking, finally according to the evaluation results to carry out in-depth discussion and research.

Li Yingfeng and Li Zhifeng [1] The commonly used data envelope analysis method-BCC model is selected, and the specific situation of the input and output of agricultural production in Gansu Province from 2010 to 2017 is analyzed, and concluded that there is still quite serious waste between the input of production factors and the actual output in Gansu Province, and the optimal allocation has not been reached. Therefore, it is necessary to continue to increase the investment in agricultural science and technology and to pay attention to the most reasonable use of production factors, so as to improve the agricultural production efficiency of Gansu Province. Li Middle and Wei Chi Xiaojuan [2] The DEA and Malmquist index were still used to study the agricultural production efficiency of Shandong Province from 2011 to 2016. The results showed a series of problems such as insufficient conversion of old and new growth drivers in agricultural production; Li Yonghui and Bai Lipeng [3] To study the allocation of resources in agricultural science and technology in Yunnan Province from 2001 to 2016, and choose the traditional DEA model to study its allocation efficiency, in order to make its overall high allocation efficiency, Yunnan Province has a very high investment in scientific and technological innovation resources in agricultural capital, human resources and technology investment.

According to the relevant general situation of the above research, there have been no research reports on the agricultural production efficiency under the integration mode of the three societies in Luxian County, Sichuan Province, starting from the longitudinal level. Therefore, this paper uses DEA model and the Malmquist analysis method to study the DEA-Malmquist analysis, and find the problems in agricultural production and development. The final purpose is to take corresponding measures to improve the agricultural production efficiency of Luxian County in rural poverty alleviation, promote the further implementation of the rural revitalization strategy in Sichuan province, and provide the strongest support for accelerating the agricultural and rural modernization and the economic and social development of the province.

2 DATA SOURCES AND RESEARCH METHODS

2.1 Model and method of evaluation of agricultural production efficiency

2.1.1 DEA model

Data development analysis (DEA) was summarized by transport operator Charnes et al. in the 1970s, which uses linear planning to analyze and evaluate the effectiveness of the DMU of each decision unit. Its basic idea is: first, collect the data of the DMU of each decision unit, calculate the comprehensive technical efficiency value, pure technical efficiency value and scale efficiency value, and finally accurately measure whether the DMU of each decision unit to achieve DEA is effective [4].

The numerical relationship of the three-term efficiency is as follows: comprehensive technical efficiency = pure technical efficiency and scale efficiency. The more the value approaches to 1, the higher the efficiency. If the comprehensive technical efficiency value is less than 1, the decision unit DMU is invalid as DEA; if the comprehensive technical efficiency value is equal to 1, the decision unit DMU is DEA valid [5].

The DEA model used in this paper is DEA input-oriented, based on CCR and BCC models, and conducts projection analysis to evaluate the agricultural production efficiency in Luxian County, Sichuan Province.

2.1.2 research hypothesis

SupposeThere are n decision-making units DMU, Including u types of input indicators and v types of output indicators. The m-th input number of the k-th decision-making unit is represented by X_{mk}, the s-th output number of the k-th decision variable is represented by Y_{sk}, the weight of input data is V_m and the weight of output data is U_s. Vector X_k represents the input value of the decision-making unit, vector Y_k represents the output value of the decision-making unit, and P and Q are weight value vectors to obtain:

$$X_k = (x_{1k}, x_{2k}, \dots, x_{mk})^T \quad (1)$$

$$Y_k = (y_{1k}, y_{2k}, \dots, y_{sk})^T \quad (2)$$

$$P = (p_1, p_2, \dots, p_u)^T \quad (3)$$

$$Q = (q_1, q_2, \dots, q_v)^T \quad (4)$$

Where: m=1,2, …, u; k=1,2, …, n; s=1,2, …,v_0

The efficiency evaluation index of the k-th decision unit is

$$h_k = \frac{\sum_{s=1}^{v} q_s y_{sk}}{\sum_{m=1}^{u} p_m x_{mk}}; k = 1,2, \dots, n \quad (5)$$

The comprehensive efficiency model of the k_0-th decision-making unit is expressed as

$$\begin{cases} \max = \dfrac{\sum_{s=1}^{v} p_s y_{sk_0}}{\sum_{m=1}^{u} q_m x_{mk_0}} = Q\bar{a} \\ \text{s.t. } \dfrac{\sum_{s=1}^{v} q_s y_{sk}}{\sum_{m=1}^{u} p_m x_{sk}} \le 1 \\ P \ge 0, Q \ge 0 \end{cases} \quad (6)$$

According to the observation of the above parameters, it can be known whether the k_0-th decision unit meets DEA. If the content expressed by formula (6) uses the linear plan to find the corresponding combination of certain units, and does not actually exceed the actual output of the k_0-th certain unit, then the k_0-th certain unit is considered to be the validity of DEA, on the contrary, then It belongs to the neutralization of DEA. Dong Mingtao's[6] research shows that the mathematical model of formula (6) explains the method of determining the validity of the solution: if there is an optimal value θ^*=1, the corresponding k_0-th decision unit is weak DEA effective; if there is an optimal value θ^*=1, and the optimal solution exists, that is, the input slack variable S^-=1 and the input-output variable S^+=1, then the corresponding k_0-th decision-making unit is DEA effective.

2.1.3 Data projection analysis

According to the research of Bai Jianhua et al[7], If θ= 1 of the k_0 DMU(decision making unit), the DMU is DEA effective; If $\theta < 1$ of the t-th DMU, DEA is invalid. The direction of

rectification in DEA invalid areas can be determined by projection analysis.

$$\begin{aligned} \Delta x_t &= x_t x_t^* - x_t = (\theta^t - 1)x_t - S_T^- \\ \Delta y_t &= y_t^* - y_t = S_T^+ \end{aligned} \tag{7}$$

Among them:$x_t^* = \theta\,, x_t - s_t^-$; $y_t^* = y_t + s_t^+, (x_t^*\,, y_t^*)$ is the projection on the effective front of $(x_t\,, y_t)$; s_t^- and s_t^+ represents the relaxation variables of DMU input and output respectively;Δx_t and Δy_trespectively represent the amount of input redundancy and output deficiency of the decision-making unit after quantification.

2.1.4 Analysis of the Malmquist index

The Malmquist index is a new all-round efficiency survey model for measuring the productivity of all elements of a determining unit at a dynamic viewpoint that is more comprehensive and scientific to decompose production efficiency into technology and efficiency and consider the productivity of individual elements from a static perspective. Among them, the technological changes and progress in the field of agricultural production show in the level of technological progress rate. The technological innovation and popularization in the field of agricultural production are manifested in the level of pure technical efficiency, and the popularization degree and utility level of scale production are manifested in the level of scale efficiency, which constitute the measurement indicators of the efficiency level. The analytical composition of the TFT index is

$$\mathrm{TFP} = \mathrm{TP} \times \mathrm{PTE} \times \mathrm{SE} \tag{8}$$

The principle formula is

$$M_0 = \left[\frac{D_0^{t+1}(x_{t+1},y_{t+1})}{D_0^{t+1}(x_t,y_t)} \times \frac{D_0^t(x_{t+1},y_{t+1})}{D_0^t(x_t,y_t)}\right] \tag{9}$$

$$M_0(x_t, y_t, x_{t+1}, y_{t+1}) = \frac{S_0^t(x_t\,,y_t)}{S_0^t(x_{t+1},y_{t+1})} \times \frac{D_0^t(x_{t+1},y_{t+1}/\mathrm{VRS})}{D_0^t(x_t,y_t/\mathrm{VRS})} \times \quad \left[\frac{D_0^t(x_{t+1},y_{t+1})}{D_0^{t+1}(x_{t+1},y_{t+1})} \times \frac{D_0^t(x_t,y_t)}{D_0^{t+1}(x_t,y_t)}\right] \tag{10}$$

Among them, the input - output quantities of t and t+1 in the panel data are expressed by x_t, x_{t+1}, y_t and y_{t+1} respectively; D_0^t and D_0^{t+1} represent the technical distance function under the established technical level in period t and the two time stages of t+1.

The TFP index can be continuously decomposed into a product of scale efficiency, pure technical efficiency, and technological progress rate from left to right, and the TFP index can also be interpreted as a product of integrated technical efficiency and technological progress rate. Combining the DEA model, each index means as follows. Comprehensive technical efficiency is directly related to whether the panel data can achieve DEA effect. Its scale efficiency and pure technical efficiency represent the utility level of production scale and the application level of production technology, respectively. In the case of Malmquist index analysis are greater than 1, the scale remuneration and technical efficiency level of policy decision units increased year by year, but decreased year by year. If the rate of technology progress and total factor productivity are greater than 1 in the analysis of the Malmquist index, the policy determines that the technology growth and productivity level increase year by year, but instead decrease year by year.

2.2 Selection of indicators and data sources

2.2.1 Index selection

In order to accurately determine the agricultural production efficiency of Luxian County, Sichuan Province, the efficiency evaluation system is divided into two evaluation dimensions: agricultural production input and agricultural production output. In the selection of agricultural production input indicators, three indicators are selected, including total crop sown area（X_1）, total power of agricultural machinery（X_2）and financial expenditure of agriculture, forestry and water affairs over the years（X_3）respectively, representing the basic investment, technical investment and capital investment of agricultural production in Luxian County, Sichuan Province, respectively. In the selection of agricultural production output indicators, the total output value of agriculture, forestry, animal husbandry and fishery is（Y_1）, and the per capita disposable income of rural residents（Y_2）are selected to represent the direct and indirect output of agricultural production in Luxian County, Sichuan Province, respectively. As shown in Table 1.

TABLE 1. AGRICULTURAL PRODUCTION EFFICIENCY EVALUATION INDEX SYSTEM IN LUXIAN COUNTY, SICHUAN PROVINCE

metric I	code	metricII	name
Input in agricultural production	X_1	Basic input	Total crop sown area (ha)
	X_2	Technology input	Total power of agricultural machinery (kW)
	X_3	Capital input	Financial expenditure on agriculture, forestry and water affairs over the years (10,000 yuan)
Agricultural production output	Y_1	Direct output	Total output value of agriculture, forestry, animal husbandry and fishery (ten thousand yuan)
	Y_2	Indirect output	Per capita disposable income of rural residents (Yuan)

2.2.2 Data source

Due to the cyclical characteristics of agricultural production, the input and output of agricultural production have a certain lag period, generally for about 1 year. Therefore, the input data of t year is used for agricultural production, and the output data of t+1 year is used [8]. So The input adopts the data of 2015-2019 and the output adopts the data of 2016-2020. For the availability and effectiveness of data, the data in this paper are from Luzhou statistical yearbook.

2.2.3 Statistical analysis

Using the software of DEAP Version2.1, analyze DEA model, calculate the agricultural production efficiency in Luxian County, Sichuan Province from 2015 to 2015 to 2019, calculate the total factor productivity in each period from 2015, evaluate the agricultural production efficiency; Finally, identify the constraints on agricultural development in Luxian County, and put forward corresponding suggestions and measures.

3 RESULTS AND ANALYSIS

In order to scientifically observe Luxian agricultural productivity, DEAPVersion2.1 software is used to obtain the agricultural production efficiency results from 2015-2019, as shown in Table 2.

TABLE 2. AGRICULTURAL PRODUCTIVITY VALUE OF 2015-2019 IN LUXIAN COUNTY

A particular year	Comprehensive technical efficiency	Pure technical efficiency value	Scale efficiency value	Return of scale	Is the unit DEA valid
2015	1.000	1.000	1.000	-	valid
2016	1.000	1.000	1.000	-	valid
2017	1.000	1.000	1.000	-	valid
2018	0.908	0.909	0.999	irs	of no avail
2019	1.000	1.000	1.000	-	valid

As can be seen from Table 2, in 2015 to 2019, the proportion of input and output of agricultural production was relatively appropriate, and 80% of DEA accounted for 80%, only D E A was not reached in 2018, indicating that the agricultural production efficiency in Luxian County from 2015 to 2019.Even if the D E A is in the invalid stage in 2018, the scale remuneration of all years is in the same or increasing range, indicating that the overall level of production efficiency in Luxian County is good and the resource utilization rate is expected to improve steadily.

Comprehensive technical efficiency level is jointly affected by pure technical efficiency and scale efficiency. Table 2 shows that comprehensive technical efficiency, pure technical efficiency and scale efficiency in Luxian County in 2018 were 0.908,0.909, and 0.999, respectively, which did not reach 1 level. It can be seen that there was insufficient technical investment and application in agricultural production in 2018, and insufficient resource distribution and utilization, leading to poor agricultural development in Luxian County in 2018.

In order to better analyze the input-output efficiency of the invalid years, the DEA projection analysis results of the invalid year in 2018, the input-output relaxation variables and the quantitative production adjustment amount were measured by using DEAPVersion2.1 software calculation. The final results are shown in Table 3.

TABLE 3. INVALID YEAR PROJECTION VALUES

The DEA is an invalid year	Invest in redundancy			Insufficient output	
	Financial expenditure on agriculture, forestry and water affairs over the years (10,000 yuan)	Total power of agricultural machinery (kW)	Total agricultural sown area (ha)	Total output value of agriculture, forestry, animal husbandry and fishery (10,000 yuan)	Per capita disposable income of rural residents (Yuan)
In 2018	-42280.449	-681311.185	0.000	6385.080	0.000

In the agricultural production of Luxian County in 2018, the financial expenditure of agricultural, forestry and water affairs and total agricultural machinery was redundant, and the total output value of agricultural, forestry, agriculture, animal husbandry and fishery was relaxed, which shows that Luxian County has a low utilization rate of resources in terms of financial agricultural, forestry and water affairs expenditure and total agricultural sown area, and there is a waste of resources. Under the background of the reform of supply and marketing cooperatives, the resource utilization efficiency of agricultural production in Luxian County should be the focus of the reform, and should need to focus on improvement. In order to dynamically investigate the agricultural production efficiency of Luxian County from 2015-2019, the change of total factor productivity is analyzed by using the value of DEAPA2.1. The results are shown in Table 3.

TABLE 4. AGRICULTURAL PRODUCTIVITY VALUE OF 2015-2019 IN LUXIAN COUNTY

a particular year	Comprehensive technical efficiency value	rate of technological advance	Pure technical efficiency value	Scale efficiency	Total factor production index
2015-2016	1.000	1.042	1.000	1.000	1.042
2016-2017	1.000	0.830	1.000	1.000	0.830
2017-2018	1.000	0.976	1.000	1.000	0.976
2018-2019	1.000	1.402	1.000	1.000	1.402

It can be seen from Table 4, the comprehensive technical efficiency value, pure technical efficiency value and scale efficiency value are all 1 and remain unchanged, while the technological progress rate and total factor productivity show the same trend, which shows that the technological progress rate is the key factor to promote the change of total factor productivity in Luxian County[9].The average value of total factor production index was 1.0625, with two years with more than 1 and less than 1, which shows that the change of total factor productivity in Luxian County from 2015 to 2019 showed falling and certain fluctuations, and the overall upward trend. From 2016 to 2019, the agricultural total factor production efficiency in Luxian County showed a trend of continuous growth. From 2018 to 2019, the total factor production index reached 1.402, indicating that from a dynamic perspective, the technology-led efficiency in Luxian County is constantly improved and the power is enhanced.

4 CONCLUSIONS AND SUGGESTIONS

From the vertical analysis, according to the production efficiency analysis of Luxian county from 2015 to 2019, except 2018, the average value of comprehensive technical efficiency, pure technical efficiency and scale efficiency over the years is 1, which is at a high level; Although there are slight fluctuations in the agricultural production efficiency of Luxian County, it shows an overall growth trend, which is basically consistent with the results of China's regional agricultural production efficiency studied by Liu Fengmei [10].

From the perspective of projection analysis, the insufficient investment in agricultural production technology in Luxian county leads to input redundancy and the decline of total factor output value. The slow pace of technological progress and low technical efficiency have led to insufficient utilization of production capacity, slack output of total output value of agriculture,

forestry, animal husbandry and fishery, unreasonable resource allocation, and the technical level of agricultural production has not achieved sustained and steady positive growth. This is consistent with Fang Dachun's description of Sichuan Province when studying the temporal and spatial characteristics of China's agricultural production efficiency.

From the perspective of technical input: This paper selects the total power of agricultural machinery (10000 kW) as the technical input of agricultural production in Luxian county. In the longitudinal data, the DEA of Luxian County in 2018 is invalid, and its utilization rate is very low. The redundant balance of financial expenditure on agriculture, forestry and water affairs (10000 yuan) and total power of agricultural machinery (kw) over the years is as high as 42280449 yuan and 681311.185kw, respectively. There is a waste of capital investment resources. Therefore, Increasing technology investment and optimizing the allocation of agricultural resources are of great significance to improve agricultural production efficiency.

4.1 Strengthen investment in modern agricultural machinery

The large-scale popularization and use of agricultural machinery and equipment can optimize the traditional agricultural production mode to the greatest extent, reduce the investment of physical labor, effectively improve the agricultural production efficiency, change the situation of relying on nature, and promote the development of modern agriculture. However, there are still many problems in modern agricultural mechanization, such as failure to popularize and apply according to local conditions. Therefore, Luxian county needs to use modern agricultural machinery and equipment according to local conditions.

4.2 Integrate agricultural science and technology resources and promote the transformation and application of achievements

It is concluded from the DEA model that the agricultural science and technology level of Luxian county needs to be improved. The application of agricultural science and technology level in agricultural production contributes to the improvement of agricultural production efficiency. In terms of policy, to implement the strategy of invigorating agriculture through science and technology, government departments need to increase financial support, increase investment in agricultural scientific research, and create a suitable environment for the application of scientific and technological level in the agricultural field [11]. Actively explore modern agricultural industrial cooperative production modes such as "enterprise + base + project", "scientific research institute + University + production unit + enterprise". In the application of modern agricultural advanced technology in Luxian County, we should adhere to the principle of matching technology with industry. In the new agricultural industry, we will focus on promoting the application of information technology and improving the level of mechanized planting.

4.3 Rational allocation of agricultural and forestry resources

The data analysis shows that the utilization rate of agricultural and forestry resources in Luxian county is significantly lower than the average level of Sichuan Province. It is necessary to promote the development and utilization of agricultural and forestry resources in Luxian county. On the one hand, we can develop rural land resources such as idle factories, township corners, rural barren mountains and beaches, and appropriately expand the land for agricultural production. On the other hand, further implement the land protection policy, strictly approve the land occupation in the process of urbanization, limit the transformation from agricultural land

to non-agricultural land, promote the circulation of idle rural land, and improve the land utilization rate of existing agricultural and forestry resources in rural areas.

4.4 Promote appropriate scale operation of Agriculture

In agricultural production, in order to achieve the optimal scale of agricultural production, the investment level of agricultural production needs to adapt to the scale of agricultural planting,. To promote the appropriate scale operation of agriculture, we first need to constantly improve and gradually standardize the agricultural production management system, accelerate the improvement and implementation of the rural land production collective economic circulation management system, and realize the moderation and scale of China's current agricultural and rural land management and production. Accelerating the construction of rural land production, collective operation and circulation management system, and adopting various forms of land circulation on the basis of family linked production underwriting responsibility system is an important and effective way to accelerate the realization of the current moderate scale operation of agriculture.

4.5 Rational allocation of other resources

Establish and improve the rural water management system, improve the management level of water for agricultural production, accelerate the construction of water conservancy projects and water resource allocation projects in villages and towns, strengthen the water pollution prevention and control management mechanism, and ensure the safety of agricultural water while ensuring local agricultural water use [12]. At the same time, we will strengthen the reform of the management system of rural water conservancy projects, promote the reform of water prices, establish and improve the examination and approval mechanism of competitive projects, and develop modern agriculture.

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