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Study on the Scale Efficiency of Economic Forest Products Production

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Abstract:

This paper focuses on the scale efficiency of dried fruit economic forestry production in Shandong Province. DEA model is used to explore the changes in input-output efficiency due to the scale operation of farmers' economic forests are investigated, i.e. The increase or decrease of production and the change of its input-output ratio due to the scale input of various production factors (e.g., forest land, capital, and labor) in the production and operation of farmers' economic forests, in order to test the status of scale efficiency of farmers' economic forest land production in Shandong Province. It provides some suggestions for farmers' production activities and government decision-making.

Keywords: *Economic forestry, Input-output, Scale efficiency.*

I. BACKGROUND

The optimal operational efficiency through the reasonable proportion of land and other production factors under certain technical and socio-economic conditions. Moderate scale operation should adopt the operation method that is suitable for the productivity level, input the right amount of production factors to obtain the optimal output, and make full use of the reasonable combination of production factors to obtain the best economic benefits. Adequate scale management is the rational combination of factors of production and maximization of benefits [1-3]. Scale efficiency is a comparative analysis of the changes in the input-output ratio of production caused by changes in the scale of different production operations.

II. STUDY ON SCALE EFFICIENCY OF ECONOMIC FOREST PRODUCTS MODEL AND PARAMETER EXPLANATION

2.1 DEA Model Selection and Construction

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DEA (Data Envelopment Analysis), which is data envelopment analysis, is a modeling method based on linear programming, based on the distance function approach, to carry out the comparison of decision units and units to be decided to get the relative efficiency [4].DEA model has the advantages of being able to deal with both proportional and non-proportional data, and the relevant weights are not affected by artificial advantages such as being able to handle both proportional and non-proportional data, and the relevant weights are not affected by subjective factors, so it is suitable for evaluating the relative effectiveness between decision units.

The DEA method assumes that each input is associated with one or more outputs and that some connection does exist between the inputs and outputs, but it is not necessary to determine a display expression for this relationship [5-7]. Suppose there are j Decision Making Units (Decision Making Units, DMU), denoted by DMUj, each DMU has m types of inputs and s types of outputs. The input and output vectors are denoted by Xj and Yj respectively. That is

$$X_{ij} = (\mathrm{x}_{1\mathrm{j}},\ \mathrm{x}_{2\mathrm{j}},\ \dots,\ \mathrm{x}_{\mathrm{mj}})^T, \qquad Y_{rj}=(y_{1j},\ y_{2j},\ \dots, y_{sj})^T \tag{1}$$

where, $X_{ij} > 0, Y_{rj} > 0$,i=1,2,…,m; j=1,2,…,n; r=1,2,…,s。

The BC²-DEA model to evaluate the effectiveness of the kth DMU is

$$\min\ \theta = V_D$$
$$s.t.\ \begin{cases} \sum_{j=1}^{n} \lambda_j X_j + S^- = \theta X_0 \\ \sum_{j=1}^{n} \lambda_j Y_j + S^+ = Y_0 \\ \sum_{j=1}^{n} \lambda_j = 1 \\ S^-, S^+, \lambda_j \geq 0 \end{cases} \tag{2}$$

Where, λj denotes the unit combination coefficient; θ denotes the measure of relative effectiveness of DMU, here refers to the integrated efficiency; VD,X0,Y0 are constants, s-, s+are slack variables. Under the BC2-DEA model, if θ=1,the decision unit DMUj is DEA effective, indicating that the input-output ratio reaches the optimum, if θ < 1,the decision unit DMUj is DEA ineffective, indicating that the input-output ratio does not reach the optimum, generally speaking, the larger θ indicates the better effect.

In this study, the farmer is a decision making unit DMU. It can transform the input of certain economic forest production and operation into the output of economic forest products (Chen Zhen et al., 2019), which is expressed in the data as the input and output of different dry

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fruit economic forests of farmers in different years[8-10tab. In this study, the output-dominated, multi-perspective BC²-DEA model with variable returns to scale is chosen, which can exclude the influence of scale efficiency on the measurement results.Among them, the DEA model with variable scale payoff, “irs”indicates increasing scale payoff, "drs" indicates decreasing scale payoff, and"-" indicates constant scale payoff.

2.2 Malmquist Productivity Index

The Malmquist index allows decomposition of efficiency changes and better measurement of efficiency changes for each DMU.

The expression for the Malmquist index is

$$M_0(Y_{t+1}, X_{t+1}, Y_t, X_t) = \left[\frac{d_0^t(X_{t+1}, Y_{t+1})}{d_0^t(X_t, Y_t)} \times \frac{d_0^{t+1}(X_{t+1}, Y_{t+1})}{d_0^{t+1}(X_t, Y_t)}\right]^{\frac{1}{2}} \tag{3}$$

Where, (Y_{t+1}, X_{t+1}), (Y_t, X_t) are the factor input and output vectors $t+1$ periods and t periods, $d_0^t(X_t, Y_t)$ $d_0^{t+1}(X_t, Y_t)$ respectively, in terms of the production possibility frontier in periods and t periods.and $t+1$ periods. $M_0 > 1$ the production efficiency is gradually improved, $M_0 < 1$ the production efficiency is gradually decayed, and $M_0 = 1$ the production efficiency is unchanged.

Malmquist index can also be decomposed into technical progress change index and technical efficiency change index. Technical efficiency change is mainly reflected in the improvement of factor allocation efficiency; technical change is mainly manifested in technological innovation or technology introduction thus making the improvement of technical efficiency.

$$\mathrm{I_{TFPC}} = \mathrm{I_{TEC}} \times \mathrm{I_{TC}} = \mathrm{I_{PTEC}} \times \mathrm{I_{SEC}} \times \mathrm{I_{TC}} \tag{4}$$

TFPC stands for Malmquist index, TEC refers to technical efficiency change, and TC refers to technical progress change, where technical efficiency change can be decomposed into pure technical efficiency change index (PTEC) and scale efficiency change index (SEC). Namely.

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Combined technical efficiency = pure technical efficiency×scale efficiency (5)

In this study, DEAP.XP software was used to measure and analyze the input-output efficiency of dates, chestnuts, walnuts, and ginkgoes of farmers in Shandong Province during different years by using the output-dominated1, variable scale payoff multi-ang $BC^2 - DEA$ model in DEA model (data envelopment analysis) to calculate the input-output efficiency of economic forest products production.

The study of scale efficiency of dry fruit economic forest products in Shandong province focuses on four typical dry fruit economic forests, namely, walnut, chestnut, jujube and ginkgo, to measure the scale efficiency at macro level.

III. STUDY ON MACRO-LEVEL SCALE EFFICIENCY OF ECONOMIC FOREST PRODUCTS PRODUCTION

3.1 Index Selection and Data Sources

For the measurement of scale efficiency at the macro level, the main measurement is the scale efficiency of production of economic forest products of dried fruit species at the provincial level in Shandong province [11, 12]. In the measurement of scale efficiency of dry fruit economic forest products production in Shandong province, according to the availability of indicator data, three types of data, namely, total accumulated investment completed at the beginning of the year in different tree species of dry fruit economic forest (million yuan), economic forest area (hm^2), and economic forest irrigated area (thousand hm^2), are mainly selected as input indicators. Among them, the total investment in economic forest (million yuan) represents the capital input, and the economic forest area represents the land input, due to the lack of statistical data on labor input of economic forest of different tree species and dry fruit categories, and the large error of projection. Therefore, the study chose the irrigated area of economic forest as another input for the production of economic forest products of different dried fruit species and measured the scale efficiency (Yajing Shao et al., 2020). This selection of input indicators has some rationality in the study because inputs are not only labor "inputs" but also other factors (Shuying Tian et al., 2013). The output indicators in this study were directly selected from the average annual production of jujube, walnut, chestnut, and ginkgo as output indicators. The relevant decision units are also the production and operation units of jujube, walnut, chestnut, and ginkgo. On the time scale, the starting and ending years of the relevant economic forest input-output data are different because of the difficulty of obtaining input-output statistics of different dry fruit economic forest production operations. 2005-2016 input-output statistics of dates in Shandong Province are shown in Table I; 2001-2016 input-output statistics of walnuts in Shandong Province are shown in Table II; 2001-2016 2016

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input-output statistics of chestnuts in Shandong Province are shown in Table III; input-output statistics of ginkgo in Shandong Province from 2007-2016 are shown in Table IV.

TABLE I. Input-Output Data of Dates in Shandong Province, 2005-2016

YEAR	DATE OUTPUT (T)	TOTAL CUMULATIVE INVESTMENT COMPLETED (MILLION YUAN)	ECONOMIC FOREST AREA (HM^2)	ECONOMIC FOREST IRRIGATION AREA (THOUSAND HM^2) 2
2005	283892	3067.45	807.68	2.39
2006	370277	4069.61	794.12	2.95
2007	198007	2683.58	344.65	1.76
2008	269408	3747.93	447.24	2.37
2009	236647	3143.35	387.24	2.35
2010	286034	3924.00	631.66	2.70
2011	341346	23292.39	993.02	3.14
2012	336912	45260.84	885.80	2.91
2013	308306	43667.98	1028.53	2.53
2014	282903	48047.55	978.70	2.98
2015	371400	52855.38	1105.25	3.71
2016	273378	42294.67	857.13	2.51

Source: China Forestry and Grassland Statistical Yearbook (2018).

Table II. Input-Output Data of Walnuts in Shandong Province, 2001-2016

YEAR	WALNUT OUTPUT (T)	TOTAL CUMULATIVE INVESTMENT COMPLETED	ECONOMIC FOREST AREA (HM^2)	ECONOMIC FOREST IRRIGATION AREA (THOUSAND HM^2)
2001	6253	12.83	0.01	0.03
2002	7900	15.65	0.01	0.05
2003	12391	91.35	0.09	0.10
2004	14394	167.16	0.20	0.14

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2005	20465	221.12	0.30	0.17
2006	28618	314.53	0.56	0.23
2007	32516	440.69	0.92	0.29
2008	39704	552.35	1.40	0.35
2009	48242	640.79	1.93	0.48
2010	62187	853.12	3.09	0.59
2011	73244	4997.94	20.82	0.67
2012	87911	11809.99	55.49	0.76
2013	100376	14217.10	74.85	0.82
2014	114891	19512.81	117.12	1.21
2015	219717	31268.78	338.65	2.20
2016	179901	27832.72	244.34	1.69

Source: China Forestry and Grassland Statistical Yearbook (2018).

TABLE III. Input-Output Data for Chestnuts in Shandong Province, 2001-2016

YEAR	CHESTNUT OUTPUT (T)	TOTAL CUMULATIVE INVESTMENT COMPLETED (MILLION YUAN)	ECONOMIC FORESAREA (HM^2)	ECONOMIC FORESTIRRIGATION AREA(THOUSAND HM^2)
2001	159827	330.33	1151.17	0.89
2002	172269	343.19	1120.74	1.01
2003	211298	1587.98	1508.19	1.72
2004	202207	2348.30	918.48	1.96
2005	218095	2356.51	620.49	1.84
2006	230322	2531.40	493.96	1.84
2007	221416	3000.84	385.40	1.96
2008	240618	3347.41	399.45	2.12
2009	247937	3293.31	405.72	2.47
2010	273542	3752.63	604.07	2.58
2011	279474	19070.43	813.03	2.57
2012	287746	38655.87	756.53	2.49
2013	314753	44581.13	1050.04	2.58
2014	305841	51943.29	1058.05	3.22
2015	313346	44593.49	932.48	3.13

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2016	302854	46854.94	878.85	2.85

Source:China Forestry and Grassland Statistical Yearbook (2018).

TABLE IV. Input-Output Data of Ginkgo in Shandong Province, 2007-2016

YEAR	GINKGO OUTPUT (T)	TOTAL CUMULATIVE INVESTMENT COMPLETED(MILLION YUAN)	ECONOMIC FOREST AREA (HM^2)	ECONOMIC FOREST IRRIGATION AREA(THOUSAND HM^2)
2007	3544	48.03	6.17	0.03
2008	3376	46.97	5.60	0.03
2009	3503	46.53	5.73	0.03
2010	3607	49.48	7.97	0.03
2011	4170	284.55	12.13	0.04
2012	7172	963.49	18.86	0.06
2013	9235	1308.03	30.81	0.08
2014	10078	1711.62	34.86	0.11
2015	15655	2227.92	46.59	0.16
2016	9837	1521.90	31.11	0.09

Source: China Forestry and Grassland Statistical Yearbook (2018).

3.2 Measurement Results and Evaluation

3.2.1 Results and evaluation of scale efficiency measurements of dates

Based on the above selected input-output data of economic forestry products of dried fruits in Shandong Province, the BC2-DEA model was applied to calculate the comprehensive efficiency, scale efficiency and scale payoff and their average values of inputs and outputs of jujube, walnut, chestnut and ginkgo in Shandong Province from 2005 to 2016, respectively, and the calculation results of jujube related efficiency are shown in Table V.

TABLE V. Scale Efficiency of Input and Output of Jujube in Shandong Province, 2005-2016

YEAR	COMPREHENSIVE EFFICIENCY	SCALE EFFICIENCY	COMPENSATION FOR SIZE
2005	0.836	0.836	Ir s

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2006	1	1	-
2007	0.684	0.684	irs
2008	0.968	0.968	irs
2009	0.843	0.843	irs
2010	0.704	0.912	drs
2011	0.732	0.795	drs
2012	0.723	0.796	drs
2013	0.685	0.823	drs
2014	0.486	0.639	drs
2015	0.635	0.635	drs
2016	0.505	0.685	drs
Average value	0.734	0.801	

Note: "irs" and "drs" denote increasing and decreasing returns to scale, respectively. Same as below.

From the calculation results in Table V, the comprehensive efficiency of input and output of jujube in Shandong province from 2005 to 2016 is only 1 in 2006, and the input and output of jujube is effective, which indicates that the overall input and output efficiency of jujube in Shandong province is at a low level, and the average comprehensive efficiency is 0.734; from the scale efficiency, only the scale efficiency in 2006 is 1. This is consistent with the results of the comprehensive efficiency calculation, and the average value of scale efficiency is significantly higher than the comprehensive efficiency, indicating that scale efficiency plays an important role in the comprehensive efficiency. 2010 to the present, the scale payoff of input-output of jujube in Shandong province has been in a decreasing state. Therefore, its scale efficiency is also in a decreasing trend.

In addition, horizontally, under the existing regulations and management level, it is difficult to adapt to the requirements of the market and narrow the difference between the actual scale of date output and the optimal production scale, which is also a cause of its scale inefficiency.

3.2.2 Results and evaluation of walnut scale efficiency measurements

Similarly, based on the data of the input-output indicators selected above, the combined efficiency, scale efficiency and scale payoffs of walnut inputs and outputs and their average values in Shandong Province from 2001 to 2016 were calculated as shown in Table VI.

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TABLE VI. Scale Efficiency of Walnut Inputs and Outputs in Shandong Province, 2001-2016

YEAR	COMPREHENSIVE EFFICIENCY	SCALE EFFICIENCY	COMPENSATION FOR SIZE
2001	0.821	0.821	irs
2002	1	1	-
2003	0.465	0.998	drs
2004	0.392	0.859	irs
2005	0.474	0.804	irs
2006	0.61	0.61	irs
2007	0.682	0.682	irs
2008	0.845	0.845	irs
2009	1	1	-
2010	1	1	-
2011	0.637	0.969	irs
2012	0.502	0.709	irs
2013	0.594	0.822	irs
2014	0.526	0.997	irs
2015	1	1	-
2016	0.861	0.956	irs
Average value	0.713	0.88	

From the calculation results, it can be seen that there were only four years in which the comprehensive efficiency of input-output of walnut in Shandong province was greater than 1 from 2001 to 2016, namely, 2002, 2009, 2010 and 2015, which was less than half of the total years, indicating that the overall input-output efficiency of chestnut in Shandong province was low, and the fluctuation of the comprehensive efficiency value was large, and the average comprehensive efficiency was low, only 0.713; from the scale efficiency, the years with scale efficiency of 1 are consistent with the comprehensive efficiency, and there are four of them, namely, 2002, 2009, 2010 and 2015, and the average value of scale efficiency is significantly lower than that of pure technical efficiency. Therefore, its scale efficiency is low. From the change of scale reward, the input and output of walnuts in Shandong province are constant or increasing in scale reward except for 2003, which is decreasing in scale reward, indicating that Shandong province has been expanding the production scale of walnuts since 2003.

From the cross-sectional analysis, the scale efficiency varies significantly and fluctuations are large. Therefore, stabilizing the fluctuation of scale efficiency and adjusting the structure of

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inputs and outputs are the directions of walnut production and management.

3.2.3 Results and evaluation of chestnut scale efficiency measurement

Using the BC2-DEA model, the combined efficiency, pure technical efficiency, scale efficiency and scale payoff and their average values of chestnut inputs and outputs in Shandong province calculated from 2001 to 2016 are shown in Table VII.

TABLE VII. Scale Efficiency of Chestnut Inputs and Outputs in Shandong Province, 2001-2016

YEAR	COMPREHENSIVE EFFICIENCY	SCALE EFFICIENCY	COMPENSATION FOR SIZE
2001	1	1	-
2002	1	1	-
2003	0.902	0.902	drs
2004	0.911	0.984	drs
2005	0.941	0.987	drs
2006	1	1	-
2007	0.929	0.929	irs
2008	1	1	-
2009	1	1	-
2010	0.957	0.957	drs
2011	0.92	0.953	drs
2012	0.942	0.956	drs
2013	1	1	-
2014	0.79	0.814	drs
2015	0.821	0.821	drs
2016	0.829	0.851	drs
Average value	0.934	0.947	

As can be seen from Table VII, the comprehensive efficiency of chestnut input-output in Shandong Province from 2001 to 2016 was calculated as 1 in 2001, 2002, 2006, 2008, 2009 and 2013, which means that the chestnut input-output efficiency in these years was effective. There are six of these years, which is less than half of the total years, indicating that the overall level of input-output efficiency of chestnut in Shandong province is not too high, and the average comprehensive efficiency is 0.934; in terms of scale efficiency, the years with scale efficiency of 1 are consistent with the comprehensive efficiency, and there are six of them, and

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the average value of scale efficiency is slightly higher than the comprehensive efficiency. It indicates that the change of chestnut planting scale plays a role in its efficiency change. From the change of scale payoff, the input and output of chestnut are constant or decreasing in scale payoff in all years except 2007, which is increasing in scale payoff. Therefore, narrowing the gap between the actual scale of chestnut output and the optimal production scale and increasing the scale payoff are the main directions of chestnut management in Shandong.

3.2.4 Ginkgo scale efficiency measurement results and evaluation

Similarly, based on the data of input-output indicators selected above, the overall efficiency, scale efficiency and scale payoff of ginkgo inputs and outputs in Shandong Province from 2007 to 2016 and their average values are calculated as shown in Table VIII

TABLE VIII. Scale Efficiency of Ginkgo Inputs and Outputs in Shandong Province, 2007-2016

YEAR	COMPREHENSIVE EFFICIENCY	SCALE EFFICIENCY	COMPENSATION FOR SIZE
2007	1	1	-
2008	0.973	0.973	irs
2009	1	1	-
2010	0.909	0.922	drs
2011	0.519	0.999	drs
2012	0.574	0.713	irs
2013	0.768	0.768	irs
2014	0.647	0.996	irs
2015	1	1	-
2016	0.689	0.925	irs
Average value	0.808	0.93	

From the calculation results, it can be seen that: the comprehensive efficiency of ginkgo input and output in Shandong province from 2007 to 2016 was calculated as 1 in 2007, 2009 and 2015, and there were 3 years in which ginkgo input and output were effective, which was less than half of the total years, indicating that the overall level of input and output scale efficiency of ginkgo was not too high, and the comprehensive efficiency in 2007 The average comprehensive efficiency is 0.808; from the viewpoint of scale efficiency, the years with scale efficiency of 1 are consistent with the comprehensive efficiency, and there are also 3, but the fluctuation of scale efficiency is less obvious. In terms of the change of scale payoff, there are more years in which the input and output of Ginkgo are in increasing scale payoff than in decreasing scale payoff during 2007 - 2016, but there is no definite trend of increase or decrease.

Therefore, narrowing the gap between the actual production scale of ginkgo inputs and outputs and the optimal production scale, and enhancing the resource allocation and expanding the scale of inputs and outputs of ginkgo production is the proper approach to improve the scale efficiency of ginkgo, and thus the overall efficiency.

IV. CONCLUSIONS

For the data related to economic forests in Shandong Province in this chapter, firstly, the scale efficiency situation of its macro level was analyzed by DEA method, and the scale efficiency situation of farmers' economic forests such as jujube, walnut and chestnut was analyzed, and the influence of the fine fragmentation of forest land on the scale efficiency of farmers was further studied, and the results showed that.

(1)From the DEA model results, it can be seen that the overall efficiency values of inputs and outputs of jujube, walnut, chestnut and ginkgo in Shandong province are low and not optimal, the resource allocation efficiency is not high, the scale of inputs and outputs needs to be improved, and the overall fluctuation of the overall efficiency is large, which can be smoothed out by adjusting the input-output structure.

(2)Labor input plays an important role in farmers' economic forest production, but the effect is not significant in farmers' economic forest production of jujube, walnut, chestnut, etc. In contrast, the effect of capital on the production of dates, walnuts, and chestnuts was positive and the degree of effect was more significant. In other words, the increase of economic forest production of farmers in the sample area is more caused by the increase of capital cost input, therefore, the economic forest production can be enhanced by increasing the investment.

(3)From the scale elasticity coefficients of farmers' jujube, walnut and chestnut production, their values are all greater than 1, which indicates that there is a certain economy of scale in farmers' economic forestry production in Shandong Province at present.

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