Technical Efficiency of Corn Production in Main Producing Region in China Based on DEA-Tobit

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Abstract The Panel Data of corn production in 11 provinces are analyzed, such as Jilin, Heilongjiang, Liaoning, Inner Mongolia, Hebei, Shandong, Henan, Anhui, Jiangsu, Hubei and Sichuan. Based on the CRS, VRS and Malmquist exponential models of DEA, technical efficiency of corn production is measured in main producing region by DEA-Tobit. And its influencing factors are analyzed. Result shows that corn production in main producing areas is mainly scale inefficiency and is at the stage of decreasing returns to scale. Pure technical efficiency of corn production is effective in most main producing regions. Total Factor Productivity of corn production is improved in main producing regions, because the speed of technical progress is greater than the speed of efficiency reduction. In the years 1998-2008, corn production in main producing regions is rational in structure and is not affected by the natural disasters.

Key words Main producing region, Corn production, Technical efficiency, DEA-Tobit, China

Main producing region of corn is an important engine for the production of corn in China. Sowing area of corn in China is 29 863.8 thousand hectares in the year 2008, and the that in main producing region is 22 431.3 thousand hectares, accounting for 75.1% of the total area of China. Corn output in China is 165 915 thousand tons, and that in main producing region is 129 369 thousand tons, occupying 77.97% of the total output in China. Unit yield of the national average is 5 070.1 kilograms per hectare, and that of main producing region is 5 188.5 kilograms per hectare, which is 2.34% higher than the national average. And the unit yield of corn in Jinlin Province is as high as 7 127.46 kilograms per hectare in the year 2008.

At present, the room for the improvement of corn sowing area is limited in China. We can only improve corn output by enhancing unit yield. And the effective way to improve unit yield is to enhance the technical efficiency of corn production. Therefore, it is of great significance to research on the technical efficiency of corn production in main producing region and to analyze the main factors affecting corn production, so as to increase food production and to ensure the food security in China.

1 Model establishment, index selection and data source

1.1 Model establishment Technical efficiency of major food crops is measured in main producing region by DEA-Tobit. Data Envelopment Analysis (DEA) is the most effective non-parametric method to evaluate efficiency. In recent years, it becomes popular all over the world. This research is mainly based on the CRS, VRS and Malmquist exponential models of DEA. And Tobit econometric model is designed as:

$$DEA-TE_{it}=\beta_0+\beta_1 GW_{it}+\beta_2 IRR_{it}+\beta_3 FA_{it}+\beta_4 DA_{it}+\beta_5 T_{it}+\varepsilon_{it} \quad (1)$$

where i is the ith major grain producing province, $i=1,2,\cdots,11$, $t=1,2,\cdots,10$ is the ten years from 1998 to 2008 (except the year 2001). $DEA-TE_{it}$ is the technical efficiency estimated by Malmquist exponential model in DEA under the variable returns to scale. GW is the proportion of food, IRR is irrigation rate, FA is the area of flood, DA is the area of drought, T is the time factor, and $T=1,2,\cdots,10$ means the ten years from 1998 to 2008 (except the year 2001).

1.2 Selecting evaluation indexes Unit yield is taken as the output index evaluating grain production. Amount of labor per hectare (per day) is the index measuring the input of labor force. The weight of sowed seeds per hectare (kg) is the input index of seeds. And the weight of applied chemical fertilizer per hectare (kg) is the input index of chemical fertilizer.

There are various factors affecting the technical efficiency of corn production. This paper selects grain proportion, irrigation rate, flood area, drought area and time factor as the factors affecting technical efficiency of grain production. Among them, grain proportion means the proportion of the sowing area of corn in the grain sowing area, reflecting the planting structure of grain. Index of irrigation rate is the proportion of effective irrigation area in cultivated land area, reflecting the infrastructure condition of agricultural production. Index of flood area is the proportion of crop inundated area in the damaged area by flood, reflecting the impacts of natural disaster on grain production. Index of drought area is the proportion of crop drought area in the damaged area by drought, also reflecting the impacts of natural disaster on grain production. Index of time trend variable reflects the tendency variation of technical efficiency not caused by factors. $T=1,2,\cdots,10$ means the ten years from 1998 to 2008 (except the year 2001).

1.3 Data source and processing Panel Data of corn pro-

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duction in 11 provinces area analyzed, such as Jilin, Heilongjiang, Liaoning, Inner Mongolia, Hebei, Shandong, Henan, Anhui, Jiangsu, Hubei and Sichuan, which are all the major grain producing areas. According to the related data in *National Cost-income Data of Agricultural Products*, the output per hectare, the amount of labor per hectare, the sowed seeds per hectare, and the applied chemical fertilizer per hectare are calculated[1]. Due to the lack of data, the year 2001 is eliminated. Index data affecting technical efficiency are calculated, mainly according to the *China Agricultural Statistics Yearbook*[2], *Agricultural Statistics of Recent* 60 *Years in China*[3], *Agricultural Statistics Abstract in China*[4], and *China Rural Statistical Yearbook*[5]. Since the data obtained can not be directly used to calculate irrigation rate, drought area and flood area of crops in each province, proportion of corn sowing area in the total sowing area of crop is taken as the weight, so as to obtain the irrigation rate, drought area and flood area of corn.

2 Empirical analysis

Technical efficiency of corn production in main producing regions in China from 1998 to 2008 (except the year 2001) is calculated by the method of DEA[6-9]. Considering that unit area grain yield pursues for the output maximization under a given input level, output-orientated empirical analysis is carried out by DEAP Version 2.1 software. Then, technical efficiency value of the variable returns-to-scale calculated is taken as the explained variable. According to equation (1), Tobit regression is carried out based on the Eviews 6.0 software.

2.1 Estimated result of scale efficiency of corn production VRS model is adopted in this research. And impacts of increasing returns to scale, constant returns to scale, and decreasing returns to scale on the technical efficiency of decision making unit are considered. Table 1 reports the estimation result.

In general, corn production in main producing region mostly is scale inefficiency and is at the stage of decreasing returns to scale, indicating that input should be reduced in corn production in the main producing region. In the aspect of regional level, Heilongjiang Province has been in the state of scale efficiency for ten years, which is the best. Hubei Province takes the second place, showing the decreasing returns to scale in the years 1998 and 1999. And the rest years are all in the state of scale efficiency. Jilin, Henan, Sichuan and Inner Mongolia also show the state scale efficiency in some years.

2.2 Measurement result of corn production efficiency The technical efficiency of decision making unit measured by CRS model does not exceed that measured by VRS model. This is mainly because VRS model considers the effects of the increasing returns to scale, constant returns to scale, and decreasing returns to scale on the technical efficiency of decision making unit. Technical efficiency measured by CRS model = Pure technical efficiency measured by VRS model × Scale efficiency measured by VRS model. Table 2 and 3 report the technical efficiencies measured by both CRS model and VRS model.

Table 1 Scale efficiency of corn production in main producing regions in China in the years 1998 – 2008

Year	Hebei	Inner Mongolia	Liaoning	Jilin	Heilongjiang	Jiangsu	Anhui	Shandong	Henan	Hubei	Sichuan
1998	0.993 drs	0.918 drs	0.962 drs	1.000 –	1.000 –	0.881 drs	0.799 irs	0.881 drs	0.998 irs	0.955 irs	0.949 drs
1999	0.994 irs	0.847 drs	0.916 drs	1.000 –	1.000 –	0.890 drs	0.938 irs	0.898 drs	0.975 irs	0.879 irs	0.790 drs
2000	0.917 drs	1.000 –	0.915 drs	0.875 drs	1.000 –	0.913 drs	0.963 drs	0.877 drs	0.984 drs	1.000 –	0.975 drs
2002	0.828 irs	1.000 –	0.959 drs	0.865 drs	1.000 –	0.998 drs	0.948 irs	0.902 drs	1.000 –	1.000 –	0.964 drs
2003	0.984 drs	1.000 –	0.889 drs	0.930 drs	1.000 –	0.965 drs	0.990 drs	0.954 drs	0.988 drs	1.000 –	0.986 drs
2004	0.937 drs	0.923 drs	0.865 drs	1.000 –	1.000 –	0.934 drs	0.936 drs	0.925 drs	0.976 drs	1.000 –	0.930 drs
2005	0.959 drs	0.968 drs	0.837 drs	0.960 drs	1.000 –	0.988 drs	0.994 drs	0.952 drs	0.922 irs	1.000 –	0.983 drs
2006	0.883 drs	0.916 drs	0.794 drs	0.823 drs	1.000 –	0.962 drs	0.985 drs	0.864 drs	0.957 drs	1.000 –	0.777 irs
2007	0.983 drs	1.000 –	0.927 drs	0.901 drs	1.000 –	0.974 irs	0.977 drs	0.949 drs	1.000 –	1.000 –	0.825 irs
2008	0.929 drs	0.916 drs	0.843 drs	0.899 drs	1.000 –	0.956 drs	0.981 drs	0.889 drs	0.902 drs	1.000 –	1.000 –

Note: drs means decreasing returns to scale; and irs means increasing returns to scale.

Table 2 Technical efficiency of corn production measured by CRS model in main producing regions in the years 1998 – 2008

Year	Hebei	Inner Mongolia	Liaoning	Jilin	Heilongjiang	Jiangsu	Anhui	Shandong	Henan	Hubei	Sichuan
1998	0.973	0.878	0.962	1.000	1.000	0.716	0.799	0.740	0.998	0.650	0.593
1999	0.924	0.847	0.909	1.000	1.000	0.790	0.938	0.749	0.975	0.879	0.416
2000	0.870	1.000	0.766	0.852	1.000	0.883	0.878	0.877	0.983	1.000	0.829
2002	0.828	1.000	0.959	0.852	1.000	0.963	0.840	0.746	1.000	0.935	0.853
2003	0.946	1.000	0.889	0.898	1.000	0.494	0.595	0.879	0.740	1.000	0.876
2004	0.872	0.923	0.865	1.000	1.000	0.928	0.839	0.885	0.878	1.000	0.836
2005	0.894	0.968	0.738	0.960	1.000	0.715	0.708	0.837	0.922	1.000	0.928
2006	0.841	0.916	0.736	0.823	1.000	0.822	0.871	0.817	0.875	1.000	0.777
2007	0.983	1.000	0.867	0.833	1.000	0.862	0.810	0.949	1.000	1.000	0.825
2008	0.929	0.878	0.792	0.899	1.000	0.817	0.899	0.871	0.856	1.000	1.000

Table 3 Technical efficiency of corn production measured by VRS model in main producing regions in the years 1998 – 2008

Year	Hebei	Inner Mongolia	Liao-ning	Jilin	Heilong-jiang	Jiangsu	Anhui	Shandong	Henan	Hubei	Sichuan
1998	0.980	0.957	1.000	1.000	1.000	0.812	1.000	0.840	1.000	0.680	0.624
1999	0.929	1.000	0.992	1.000	1.000	0.887	1.000	0.834	1.000	1.000	0.526
2000	0.949	1.000	0.838	0.975	1.000	0.967	0.911	1.000	0.999	1.000	0.851
2002	1.000	1.000	1.000	0.985	1.000	0.965	0.886	0.826	1.000	0.935	0.885
2003	0.961	1.000	1.000	0.965	1.000	0.511	0.601	0.922	0.750	1.000	0.888
2004	0.930	1.000	1.000	1.000	1.000	0.994	0.896	0.956	0.899	1.000	0.899
2005	0.933	1.000	0.882	1.000	1.000	0.723	0.712	0.880	1.000	1.000	0.944
2006	0.952	1.000	0.927	1.000	1.000	0.854	0.884	0.946	0.914	1.000	1.000
2007	1.000	1.000	0.935	0.924	1.000	0.885	0.830	1.000	1.000	1.000	1.000
2008	1.000	0.958	0.940	1.000	1.000	0.855	0.916	0.980	0.949	1.000	1.000

Table 2 and 3 indicate that Heilongjiang has maintained an effective DEA during the ten years, that is, scale efficiency and technical efficiency, followed by Hubei Province. This shows that the output can not be improved under the current technical level, unless the input is increased or the output is reduced. Liaoning, Jinlin, Henan and Inner Mongolia have maintained the effectiveness only in the pure technical efficiency in most of the years, indicating that the input can not be reduced according to the current output. Jiangsu Province shows effectiveness in neither scale efficiency, nor technical efficiency, indicating that even if the input is reduced, the current level of output might be maintained.

2.3 Calculation result of Total Factor Productivity (TFP) Based on the Malmquist exponential model of DEA, the Total Factor Productivity in corn production in main producing regions is calculated, as well as the changes of technical progress and efficiency, in the years 1998 – 2003, 2004 – 2008 and 1998 – 2008 (Table 4).

Table 4 Annual average change of corn TFP in main producing regions in the years 1998 – 2008

Region	The years 1998 – 2003			The years 2004 – 2008			The years 1998 – 2008		
	Total factor productivity	Technical efficiency	Technical progress	Total factor productivity	Technical efficiency	Technical progress	Total factor productivity	Technical efficiency	Technical progress
Hebei	0.991	0.993	0.998	1.022	1.016	1.006	1.015	0.995	1.020
Inner Mongolia	1.064	1.033	1.030	1.026	0.988	1.039	1.039	1.000	1.039
Liaoning	0.981	0.981	1.000	1.002	0.978	1.025	1.004	0.979	1.026
Jilin	0.951	0.973	0.977	1.003	0.974	1.030	1.001	0.988	1.013
Heilongjiang	0.983	1.000	0.983	1.023	1.000	1.023	1.018	1.000	1.018
Jiangsu	0.890	0.911	0.976	1.009	0.969	1.041	1.045	1.015	1.030
Anhui	0.946	0.929	1.018	1.037	1.017	1.019	1.042	1.013	1.029
Shandong	1.036	1.044	0.992	1.033	0.996	1.037	1.053	1.018	1.034
Henan	0.928	0.928	1.000	0.992	0.994	0.998	0.995	0.983	1.012
Hubei	1.113	1.114	1.000	1.009	1.000	1.009	1.096	1.049	1.045
Sichuan	1.087	1.103	0.986	1.078	1.046	1.031	1.096	1.060	1.034

Table 4 reports that in the years 1998 – 2008, the Total Factor Productivity in all the regions, except Henan Province, shows a positive growth. And the technical progress in all regions is positive, indicating that the speed of technical progress is greater than the speed of efficiency reduction. Among them, annual average values of Total Factor Productivity in Hubei and Sichuan are the highest, both of which are 9.6%. Shandong and Jiangsu take the second and third places, respectively, which are 5.3% and 4.5%.

In the years 1998 – 2003, Total Factor Productivity in Shandong, Hubei, Sichuan and Inner Mongolia shows a positive growth; the rest are all negative. In the years 2004 – 2008, only the Total Factor Productivity in Henan Province shows the negative growth. Growth of technical progress in the years 2004 – 2008 is faster than that in the years 1998 – 2003.

2.4 Result of Tobit quantitative analysis Based on Eviews 3.1 software, Tobit quantitative analysis is carried out to obtain the factors affecting the technical efficiency of corn production (Table 5).

Table 5 Analysis of the factors affecting the technical efficiency of corn production

Influencing factor	Coefficient	*Z* statistical quantity	*P* value
C	0.702 880***	6.435 711	0.000 0
GW	−0.001 383	−0.115 479	0.908 1
IRR	2.158 159	0.972 725	0.330 7
FA	0.342 827	0.246 391	0.805 4
TA	0.800 279	0.650 838	0.515 2
T	0.026 087	1.281 266	0.200 1

Note: *** means significance at the level of 1%.

After the adjustment of $R^2 = 0.974\ 978$, we have $R^2 = 0.973\ 520$, indicating that the fitting degree of the model is very good and the model is effective. Table 5 shows that all the 5 factors affecting the technical efficiency of corn production have not passed the significance test, showing that the assumption of the factors affecting the technical efficiency of corn production is not valid.

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4 Conclusion

From the perspective of the transportation amount of passenger and freight, the research conducts quantitative and qualitative analysis of the relationship between logistics transportation and agricultural economy. The results show that the improvement of logistics transportation conditions plays the role of promoting rural economic development prominently, and the rural economic development can also expand the demand of logistics transportation and promote the increase of logistics transportation amount. But as regards different regions and different organization forms of industrial structure, this interaction is varied. Taking Zhejiang Province as an example, the logistics transportation plays the role of promoting rural economic development prominently, but the rural economy plays the inconspicuous role of promoting logistics transportation. The conclusion has regional characteristics, and has a close relationship with the proportion of agricultural economy in national economy of Zhejiang Province.

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3 Conclusion and suggestion

3.1 Conclusion It can be concluded that corn production in main producing areas is mainly scale inefficiency and is at the stage of decreasing returns to scale. Pure technical efficiency of corn production is effective in most main producing regions. Total Factor Productivity of corn production is improved in main producing regions, because the speed of technical progress is greater than the speed of efficiency reduction. In the years 1998 – 2008, corn production in main producing regions is rational in structure and is not affected by the natural disasters.

3.2 Suggestion The main producing regions should appropriately reduce the material inputs, strengthen the adoption and promotion of new technologies and the research and development of corn seed resources, improve the infrastructure construction of corn production, and promote the further improvement of technical efficiency of corn production.

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