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The Research on Technical Efficiency and Influence Factors of Chinese Cabbage Production in China

Shuang-Yu Hu, Yu-Cong Sun, Zhi-Run Li, Jong-In Lee*
Department of Agricultural & Resource Economics, Kangwon National University

중국 배추 생산의 기술효율성과 영향요인에 관한 연구

호쌍우, 손우총, 이지윤, 이종인*
강원대학교 농업자원경제학과

Abstract This paper aims to explore the changes in the technical efficiency of Chinese cabbage production and its influencing factors. This paper uses 216 sample data from 2012 to 2019 in China's 27 provinces to construct a Trans-log production function model based on the theoretical basis of technical efficiency. The analysis results show that the Chinese cabbage's average production technical efficiency is 0.880, and there is a significant loss of technical efficiency. Furthermore, there is a big difference in the level of technical efficiency of Chinese cabbage production in various regions. The average technical efficiency from high to low is in Northeastern China, Eastern China, Northwestern China, Northern China, Central China, Southwestern China, and Southern China. The technical efficiency of Chinese cabbage in large agricultural provinces and more developed regions is generally higher. At the same time, the chemical fertilizer input and temperature positively affect the technical efficiency of Chinese cabbage production. In contrast, the disaster area harms the improvement of technical efficiency. Therefore, this paper puts forward suggestions to develop the scale of Chinese cabbage production, ensuring the quality and safety of Chinese cabbage production, and strengthening technology promotion. All this is based on the analysis results expected to promote the high-quality development of China's Chinese cabbage industry.

요 약 중국 배추 생산의 기술 효율 변동 및 그 영향요인을 탐구하기 위해 기술효율 이론에 근거하여 본 연구는 27개 성과 시의 2012~2019년 기간 내의 216개 샘플 데이터를 활용하여 초월 대수 생산함수 모델을 구축하였다. 연구 결과에 따르면 중국 배추 생산기술의 효율은 평균 0.880로, 기술 효율성에 현저한 손실이 있는 것으로 나타났다. 각 지역별 채소 생산기술 수준은 서로 큰 차이를 보이고 있으며, 이 평균기술 효율을 높은 순으로 나열하면, 동북지역, 화동지역, 서북지역, 화북지역, 화중지역, 서남지역, 화남지역의 순이다. 대규모 농업생산 성(지역)과 경제발달 지역의 배추 생산기술은 비교적 높다. 동시에 비료 투입과 기온운 배추 생산 기술의 효율성 향상에 긍정적이며, 피해 면적은 기술 효율성 향상에 부정적인 영향을 준다. 따라서, 중국 배추산업의 질적 발전을 위해, 본 연구는 데이터 분석 결과에 의거하여 배추 생산의 규모화 운영과 배추생산 품질 안전 및 기술 보급 강화 등의 측면에서 개선방안을 제시하게 된다.

Keywords : Chinese Cabbage, Technical Efficiency, Stochastic Frontier Analysis, Trans-log Production Function, Vegetable Industry

*Corresponding Author : Jong-In Lee(Kangwon National Univ.)
email: leejongin@kangwon.ac.kr
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1. Introduction

There has been increasing development of China's vegetable industry during the past decade. Vegetables have become the second-largest crop in China, second only to grain crops, and are an important industry in China's agricultural and rural economic development[1]. And the vegetable industry has played an important role in ensuring market supply, increasing farmers' income, expanding employment, and export trade[2]. As for 2019, China's vegetable planting area has reached 20.8 million hectares, and the output has reached 720 million tons. Moreover, the cultivated area of Chinese cabbage reached 2.64 million hectares, and the yield reached 114 million tons. The plant area of Chinese cabbage is still showing a trend of gradual expansion. The changes in Chinese cabbage yield and cultivated in China is as shown in Fig. 1.

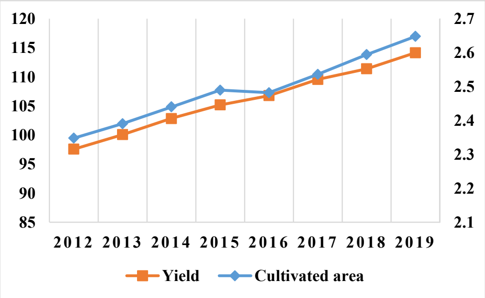

Fig. 1. Changes in Chinese cabbage yield and cultivated in China from 2012-2019.

Meantime, the consumption rate of Chinese cabbage ranks first in vegetable consumption rate in 2019. Chinese cabbage ranks first among the vegetables in China regarding planting area and has the largest storage volume among winter vegetables in the north of China. Therefore, it occupies an important position in agricultural production and has contributed to China's agricultural market[3]. With the increasing demand for vegetables in society, it will be difficult for Chinese cabbage production to achieve sustainable development simply by expanding planting areas in the future, so the only effective way to solve the problem is to improve labor productivity, resource utilization and land productivity[4]. Therefore, it is crucial to analyze the production efficiency of Chinese cabbage and find out the key factors that affect the improvement of technical efficiency. The researchers have made a good experience summary in the study of Chinese cabbage production efficiency. Yi et al. (2013) evaluated the production efficiency of the highland vegetable cultivation farms in Korea, through DEA (Data Envelopment Analysis), in order to enhance the production efficiency of highland vegetables, a size of more than 5.0ha is required, and that cost for seeds and pesticides must be reduced[5]. Jung et al. (2015) evaluated the management efficiency of the fall-cabbage farm in Korea from 2001 to 2013 and pointed the main reason for inefficiency is not the scale problem[6]. Sikora et el. (2020) assessed greenhouse gas (GHG) emissions in the cultivation of Chinese cabbage, depending on the technological variant, and the factor modifying the production technology was the use of fertilizers with a slow release of nutrients[7]. However, to be best of our knowledge, the research on the Chinese cabbage industry in China mainly focuses on the industry development status[8], cultivation and storage technology[9]. However, few studies to date have assessed and analyzed the efficiency of China cabbage production in China. Therefore, this study aims to fill this gap in the Chinese cabbage literature.

2. Literature review

The technical efficiency study has been widely used by various fields or organizations depending on the objective, context, selection of inputs and outputs, and the conduct of the study. According to the technical efficiency's initial theory and methodology, most researchers have used different techniques to estimate production boundaries, technical efficiency, and productivity. Technical efficiency (TE) is measured as the ratio between the observed output to the maximum output, under the assumption of fixed inputs, or as the ratio between the minimum input to the observed input, under fixed outputs[10]. There are two main methods to measure the level of technical efficiency, namely parametric and non-parametric approaches. Data Envelopment Analysis (DEA) is a non-parametric method, which does not need to assume the production function and the distribution of error terms. However, it cannot directly calculate the technical efficiency and ignores the particularity among samples. On the other hand, the Stochastic Frontier Analysis (SFA) is a parametric method with statistical characteristics, which can directly calculate the technical efficiency and analyze the factors affecting the technical efficiency. The two methods are often used to assess technical efficiency levels using cross-section data or panel data.

At present, the technical efficiency of vegetable production has been studied from different angles in China. Wang et al. (2014) adopted DEA and Super-efficiency DEA methods to calculate and analyze 14 vegetable varieties in 30 provinces. They found significant differences in the technical efficiency of vegetable production across the country, and the production technical efficiency levels of different vegetable varieties were also different[11]. Lv et al. (2011) calculated the annual growth rate of total factor productivity and technical progress of vegetables by the DEA-Malmquist index. The production efficiency was mainly affected by technological progress, while the annual average growth rate of technical efficiency of vegetables in China was positive[12]. Xv et al. (2010) calculated by data envelopment method that the technical efficiency of vegetable production in China fluctuated from 2003 to 2006 and continued to rise from 2007 to 2008, among which the decline of scale efficiency was the main cause of technical inefficiency[13]. Wang et al. (2013) used the three-stage DEA model to analyze the data of vegetable production of 227 households. The results showed various influencing factors that would significantly reduce farmers' technical efficiency of vegetable production[14]. Song et al. (2015) used the DEA-Tobit method based on the survey data of vegetable farmers in Shandong Province. They found that the technical efficiency of vegetable planting of farmers was low, and there were differences in vegetable technical efficiency in varieties, regions, and scales[15]. Peng et al. (2011) analyzed the technical efficiency in producing free-pollutant vegetables through the data envelopment analysis and stochastic frontier analysis. They found the technical efficiency was low, and the main reasons are the over-input of factors. Meantime, the acquisition of scientific and technological information and the establishment of stable marketing channels have significant positive effects on improving the technical efficiency of vegetables[16].

The research on the technical efficiency of vegetable production mainly adopts data envelopment analysis and seldom uses stochastic frontier analysis to calculate the technical efficiency and analyze the influencing factors. On the other hand, some studies have used the stochastic frontier analysis to calculate the technical efficiency of grain[17-19], cotton[20], soybean[21], wheat[22], and corn[23-26], and analyze the influencing factors. Based on our knowledge, none of the studies had studied the technical efficiency and influence factors in China's Chinese cabbage production in China. Generally speaking, We find that the technical efficiency and influence factors of Chinese cabbage through the model, and these findings have a targeted and practical implication for the development of China's Chinese cabbage industry.

3. Methodology and Data

3.1 Empirical method

The stochastic frontier production function is independently proposed by Aigner et al. (1977)[27] and Meeusen & Broeck (1977)[28]. Battese & Coelli (1992)[29] propose a stochastic frontier production function for (unbalanced) panel data, which has firm effects which are assumed to be distributed as truncated normal random variables, which are also permitted to vary systematically with time. The model is defined by:

$$Y_{it} = x_{it}\beta + (V_{it} - U_{it}) \tag{1}$$

Where Y_{it} represents the production for i-th firm at the t-th period of observation, x_i is a $k \times 1$ vector of input quantities of i-th firm, β is a vector of unknown parameters, the V_i are assumed to be independent and identically distributed $N(0,\sigma_v^2)$ random errors, the U_i are assumed to be independent and identically distributed non-negative truncations of $N(\mu,\sigma_u^2)$ distribution. And by the parameterization method of Battese & Corra (1977)[30], we replace the σ^2 and γ, see Eq. (2).

$$\begin{aligned} \sigma^2 &= \sigma_v^2 + \sigma_u^2 \\ \gamma &= \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2} \end{aligned} \tag{2}$$

Where σ_u^2 and σ_v^2 are the variances of the noise and inefficiency effects, respectively. The value of γ lies between 0 and 1. If it is close to zero, then deviations from the frontier can be attributed to noise, while if the value γ is close to 1, then deviations from the frontier can be attributed to technical inefficiency.

The development of the research on technical efficiency is not limited to measuring the numerical value of technical efficiency. It also attaches importance to the research on the factors that influence technical efficiency. In order to estimate inefficiency effects, Battese & Coelli (1995)[31] adapted the approach to account for panel data. They proposed a one-stage approach where the functional relationship between inefficiency effects and the firm-specific factors is directly incorporated into the maximum likelihood estimates (MLE).

$$\begin{aligned} Y_{it} &= x_{it}\beta + (V_{it} - U_{it}) \\ M_{it} &= z_{it}\delta \end{aligned} \tag{3}$$

Where U_{it} are non-negative random variables which are assumed to account for technical inefficiency in production, M_{it} is the efficiency loss function, z_{it} is a $p \times 1$ vector of variables which may influence the efficiency, δ is a $1 \times p$ vector of parameters to be estimated, W_{it} is a random error term which is assumed to be independently distributed. So we are able to estimate inefficiency effects arising from the z_{it} explanatory variables.

The technical efficiency of the i-th unit is defined by the following ratio:

$$TE_{it} = \frac{E(Y_{it}/U_{it}, x_{it})}{E(Y_{it}^{*}/U_{it} = 0, x_{it})} \tag{4}$$

Where, TE_{it} is technical efficiency of the firm for i-th firm at the t-th period of observation. In the case of a production frontier, TE_{it} will take a value between 0 and 1.

Table 1. Description of variables

Category	Variables	Unit	Mean	Std. Dev	Min	Max
Output indicator	Value of output	yuan/ha	3488.9	1153.8	1181.3	9154.3
Input indicators	Material expenses	yuan/ha	710.8	245.8	361.5	2434.6
	Labor cost	yuan/ha	1435.5	518.2	456.1	2765.5
	Land cost	yuan/ha	265.7	89.7	36.6	517.8
Influence factors	Fertilizer input	yuan/ha	235.6	100.4	68.3	790.8
	Pesticides input	yuan/ha	265.7	89.7	36.6	517.8
	Annual average temperature	℃	14.9	5.3	5.4	25.3
	Agricultural disaster area	ha	642.1	759.7	3	3541.0

Source: All China Data Compilation of Costs and Returns of Main Agricultural Products (2013-2020), China Statistical Yearbook (2013-2020)

3.2 Variable definitions

Since each administrative area (province) is treated as a decision-making unit, labor, land, and capital (material expenses) are basic and the most important inputs[32,33]. So the dependent variable is the Chinese cabbage's value of output, and the independent variables are the material expenses, land costs, and labor costs for Chinese cabbage collected from Yearbook 2013-2020. It is obviously not scientific to study the technical efficiency of vegetable production in different provinces by taking cabbage as the research object, but not differentiating the scale difference between provinces, so based on the research of XV et al.[13], this study discusses the technical efficiency difference of cabbage production in different provinces from the input and output per unit area. Moreover, according to the related literature on vegetables, the factors affecting the technical efficiency of Chinese cabbage are found out. In the process of vegetable production, the use of chemical fertilizers and pesticides play an important role in the output and quality of vegetables, and the natural environment also has an important impact on Chinese cabbage production. In the view of previous studies and the available data, and according to Zhou et al. (2017)[34], Zhang (2018)[35], Sikore et al. (2020)[7], and Tian (2015)[36], we select chemical fertilizer input, pesticides, annual average temperature and agricultural disaster area as the main variables to study whether they would influence the technical efficiency of Chinese cabbage in China. Table 1 shows some descriptive statistics of variables used in this paper.

3.3 Data source

Our sample is an unbalanced panel that covers 27 Chinese administrative areas from 2012 to 2019, with a total of 216 observations. The data is mainly drawn from All-China Data Compilation of Costs and Returns of Main Agricultural Products (2013-2020) and China Statistical Yearbook (2013-2020). The value of the output of the Chinese cabbage has been deflated for 2012 using the Chinese GDP deflator, and we use the price index of agricultural means of production with 2012 as the base year as the deflator for variables of input. To further measure the differences in the

Table 2. Regionalization of China

Regions	Provinces
Northern China	Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia
Northeast China	Liaoning, Jilin, Heilongjiang
Eastern China	Shanghai, Jiangsu, Fujian, Shandong
Central China	Jiangxi, Henan, Hubei, Hunan
Southern China	Guangdong, Guangxi, Hainan
Southwest China	Chongqing, Sichuan, Guizhou, Yunnan
Northwest China	Shaanxi, Gansu, Qinghai, Ningxia

Source: China Statistical Yearbook

technical efficiency among regions, the 27 provinces and municipalities are divided into northern China, northeast, eastern China, central China, southern China, southwest, and northwest. The regions are divided according to the China Statistical Yearbook (Table 2).

3.4 Model specification

Based on the SFA model, we estimate the model by employing a general specification as a starting point and testing for simple formulation within a formal hypothesis-testing framework. We use the transcendental logarithmic (Translog) form, the most commonly used functional form in the efficiency literature, to specify the frontier. Based on Eq. (3), the model specification is as follows:

$$\begin{aligned}\ln Y_{it} &= \beta_0 + \beta_1 M_{it} + \beta_2 L_{it} + \beta_3 S_{it} \\ &+ \beta_4 \ln M_{it}^2 + \beta_5 \ln L_{it}{}^2 + \beta_6 \ln S_{it}{}^2 \\ &+ \beta_7 \ln M_{it} \ln L_{it} + \beta_8 \ln L_{it} \ln S_{it} \\ &+ \beta_9 \ln M_{it} S_{it} + V_{it} - U_{it}\end{aligned} \quad (5)$$

Where ln(.) is the natural logarithmic form, Y represents the output value of Chinese cabbage, M represents the material and service charges of Chinese cabbage, L represents the cost of labor for the Chinese cabbage, S represents the cost of land for the Chinese cabbage. V and U are as before defined. The influence variables are as before defined. The productive efficiency of an administrative area is defined as TE and takes a value between 0-1.

The model for technical inefficiency effect is defined by:

$$M_{it} = \delta_0 + \delta_1 F_{it} + \delta_2 P_{it} + \delta_3 T_{it} + \delta_4 D_{it} \quad (6)$$

In Eq. (6), Where M_{it} represents technical inefficiency. F_{it} represents the input of fertilizer, P_{it} represents the input of pesticides, T_{it} represents the annual average temperature, D_{it} represents the average disaster area.

4. Results and Discussions

4.1 Overall results of the SFA model

Table 3 shows the estimates of parameters using the Translog production function approach. Overall, the gamma parameter (γ) obtained showed positive and significant values. This indicates that 79.3% of the compound disturbance terms come from the influence of technical inefficiency, and the stochastic frontier analysis is effective, and it proves that technical inefficiency has a significant impact on the level and change of production of the Chinese cabbage industry in China. In addition, the sigma value of squared ($\sigma^2 = \sigma_\nu^2 + \sigma_v^2$) is also significant showing that there is a province in the study not operating efficiency.

From the estimation results of the parameters, in the frontier production function, the material cost and the output value of Chinese cabbage are significantly correlated at the statistical level of 1%. Labor input and the output value of Chinese cabbage are significantly correlated at the 1% statistical level. But, the land cost is positively correlated with the output value of cabbage, but it is not significant. The estimated coefficients in the inefficient variables are of particular interest to this study. The influence coefficient of chemical fertilizer input was -0.008, which was significant at 1% level, indicating that fertilizer input could affect the technical efficiency of Chinese cabbage production. Fertilizer input is vital to agricultural production and directly affects agricultural technical efficiency. At the same time, due to the properties of vegetables, the use of pesticides also impacted the production of Chinese cabbage, but the effect was not significant. Since vegetable production in China is in the process of large-scale and professional development, continuous expansion of land input can not have a significant impact on efficiency, and fertilizer input is still an essential means to promote the output, but it also has a certain degree of influence on the ecological environment and vegetable quality[35]. Moreover, this study considers the influence of temperature on the production of Chinese cabbage, which has a significant effect on technical efficiency. The disaster area also significantly affected the efficiency of production technology, and natural disasters still have a non-negligible impact on vegetables. China has a vast territory, and the climate conditions vary significantly between the north and the south. Therefore, the development of vegetable production with local characteristics in various regions based on the principle of adopting measures to local conditions and time conditions is the main direction in the future.

Table 3. Parameter estimates of stochastic frontier model

Variable	Parameter	Coefficient	S.E.	t-ratio
Determinants of frontier				
Constant	β_0	-30.539	2.309	-13.226
$\ln x_1$	β_1	3.075***	1.163	2.644
$\ln x_2$	β_2	6.542***	1.249	5.238
$\ln x_3$	β_3	1.138	1.401	0.812
$\ln x_1 \times \ln x_1$	β_4	-0.049	0.119	-0.414
$\ln x_2 \times \ln x_2$	β_5	0.032	0.153	0.207
$\ln x_3 \times \ln x_3$	β_6	0.001	0.076	0.007
$\ln x_1 \times \ln x_2$	β_7	-0.571**	0.226	-2.526
$\ln x_2 \times \ln x_3$	β_8	-0.483**	0.194	-2.492
$\ln x_1 \times \ln x_3$	β_9	0.328*	0.188	1.745
Inefficiency model				
Constant	δ_0	-0.674	0.594	-1.135
Fertilizer	δ_1	-0.008***	0.003	-3.179
Pesticides	δ_2	-0.001	0.001	-0.653
Temperature	δ_3	-0.008*	0.005	-1.765
Disaster area	δ_4	0.001***	0.0004	2.719
σ^2		0.242***	0.061	3.940
γ		0.793***	0.132	5.195
Log-likelihood= -8.6002891***				
LR test of one-sided error=35.70974				

Note: ***, **, * indicates significance level at 1%, 5%, 10%, respectively.

4.2 Analysis of productive efficiency

The results show that, from this SFA model, it is calculated that the average productive efficiency of China's Chinese cabbage is 0.880 from 2012 to 2019, and the overall level is relatively high, but it is worth noting that if the production technology efficiency is improved, the overall level can be increased by up to 12%. In addition, the technical efficiency of Chinese cabbage production has obvious differences among different provinces. In 2019, efficiency in Heilongjiang, Shanghai, and Qinghai exceeded 0.950, concentrating around the productive frontier. However, Tianjin, Fujian, Shandong, Jiangxi, Hunan, Guangdong, Hainan, Yunnan, and Shaanxi ranked at the bottom with efficiencies less than 0.9 in 2019. In addition, efficiencies in other regions are in ranges of 0.9-0.95. The technical efficiency of Chinese cabbage production is above 0.9 in most provinces, while only three areas do not reach 0.8, indicating a large room for improvement(Fig. 2).

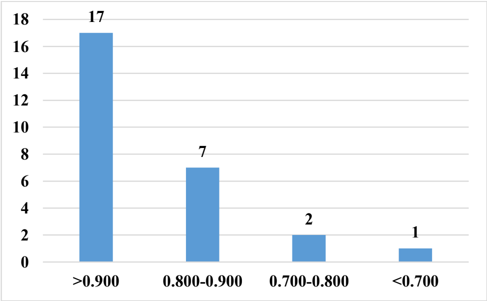

Fig. 2. Technical efficiency of Chinese cabbage production

China has experienced technical efficiency improvement of Chinese cabbage from 2012 to 2019. As shown in Fig. 3, the average production efficiency of Chinese cabbage in China changes over time from 0.888 in 2012 to 0.881 in 2019. The fluctuation of technical efficiency during this period may be that, under the background of

Table 4. The productive efficiency of Chinese cabbage from 2012 to 2019

Region	2012	2013	2014	2015	2016	2017	2018	2019	Mean
Beijing	0.930	0.909	0.952	0.947	0.930	0.950	0.948	0.916	0.935
Tianjin	0.893	0.814	0.913	0.888	0.899	0.911	0.923	0.893	0.892
Hebei	0.895	0.908	0.935	0.857	0.853	0.882	0.924	0.901	0.894
Shanxi	0.899	0.830	0.931	0.875	0.862	0.877	0.824	0.910	0.876
Inner Mongolia	0.926	0.921	0.926	0.882	0.832	0.897	0.923	0.942	0.906
Liaoning	0.861	0.816	0.944	0.938	0.928	0.937	0.929	0.934	0.911
Jilin	0.933	0.917	0.924	0.926	0.918	0.935	0.923	0.945	0.928
Heilongjiang	0.945	0.927	0.960	0.941	0.954	0.952	0.956	0.951	0.948
Shanghai	0.967	0.888	0.906	0.922	0.944	0.950	0.923	0.951	0.931
Jiangsu	0.924	0.954	0.951	0.931	0.949	0.949	0.950	0.901	0.939
Fujian	0.925	0.895	0.889	0.822	0.841	0.861	0.832	0.810	0.859
Shandong	0.903	0.883	0.880	0.906	0.819	0.881	0.837	0.846	0.869
Jiangxi	0.872	0.905	0.924	0.926	0.912	0.942	0.896	0.885	0.908
Henan	0.791	0.842	0.941	0.937	0.956	0.941	0.936	0.942	0.911
Hubei	0.952	0.942	0.848	0.875	0.927	0.932	0.937	0.936	0.919
Hunan	0.931	0.814	0.922	0.923	0.839	0.929	0.913	0.750	0.878
Guangdong	0.875	0.910	0.885	0.734	0.426	0.847	0.886	0.677	0.780
Guangxi	0.936	0.809	0.403	0.901	0.909	0.913	0.904	0.922	0.837
Hainan	0.375	0.595	0.422	0.199	0.397	0.932	0.551	0.517	0.498
Chongqing	0.854	0.930	0.932	0.933	0.877	0.941	0.944	0.939	0.919
Sichuan	0.937	0.921	0.898	0.873	0.912	0.893	0.874	0.907	0.902
Guizhou	0.944	0.887	0.892	0.947	0.880	0.872	0.912	0.912	0.906
Yunnan	0.924	0.940	0.917	0.897	0.915	0.918	0.830	0.882	0.903
Shaanxi	0.906	0.858	0.849	0.794	0.566	0.739	0.738	0.803	0.782
Gansu	0.863	0.887	0.927	0.895	0.921	0.947	0.930	0.938	0.914
Qinghai	0.884	0.910	0.950	0.808	0.899	0.914	0.924	0.954	0.905
Ningxia	0.938	0.944	0.929	0.894	0.902	0.921	0.879	0.943	0.919
Mean	0.888	0.879	0.879	0.865	0.850	0.909	0.886	0.881	0.880

the continuous growth of vegetable demand in China, vegetable production in China is mainly operated by small farmers, lacking scientific planting knowledge, and the supply fluctuates wildly. In addition, the frequent occurrence of extreme weather in recent years, including drought, flood, hail, rain, and snow across many provinces, has caused a severe impact on China's agricultural production.

From the perspective of regional division, the average technical efficiency of Northeast China is the highest, reaching 0.929, while the technical efficiency of Southern China is the lowest, only 0.705. As shown in Fig. 4, the regional difference in the efficiency is significant and ranked by descending order as follows: Northeast, Eastern China, Northwest, Northern China, Central China, Southwest, Southern China.

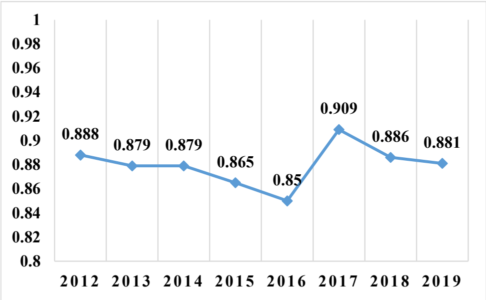

Fig. 3. The efficiency of Chinese cabbage in China, 2012-2019

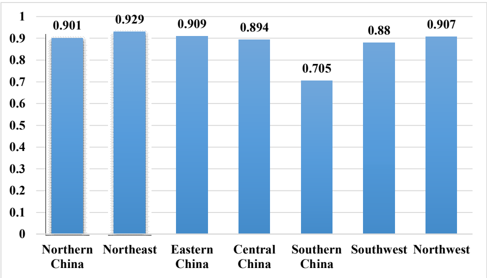

Fig. 4. Distribution of productive efficiency in different regions

Table 5. Ranking of Chinese cabbage production technical efficiency in different regions.

Region	TE	Order
Heilongjiang	0.948	1
Jiangsu	0.939	2
Beijing	0.935	3
Shanghai	0.931	4
Jilin	0.928	5
Ningxia	0.919	6
Chongqing	0.919	7
Hubei	0.919	7
Gansu	0.914	9
Henan	0.911	10
Liaoning	0.911	11
Jiangxi	0.908	12
Inner Mongolia	0.906	13
Guizhou	0.906	13
Qinghai	0.905	15
Yunnan	0.903	15
Sichuan	0.902	17
Hebei	0.894	18
Tianjin	0.892	19
Hunan	0.878	20
Shanxi	0.876	21
Shandong	0.869	22
Fujian	0.859	23
Guangxi	0.837	24
Shanxi	0.782	25
Guangdong	0.78	26
Hainan	0.498	27

As shown in Table 5, in descending order of technical efficiency, Heilongjiang, Jiangsu, Beijing, Shanghai, Jilin, Ningxia, Chongqing, Hubei, Gansu, and Henan rank in the top ten. Therefore, these regions can be roughly divided into major agricultural provinces dominated by Heilongjiang, Jilin, and Henan, and developed regions dominated by Beijing, Chongqing, and Jiangsu. The developed areas have advanced technology and management experience and many universities and research institutions to provide effective guidance for Chinese cabbage production. Meantime, because the land resource is very limited, and the vegetables are necessities, not resistant to storage and transport, to supply to protect the safety of vegetables of big cities. So the local related department importance of local vegetable production, relevant policies will be introduced to improve the production efficiency of Chinese cabbage.

5. Conclusions and suggestions

Based on the theory of technical efficiency, this analyzed the technical efficiency of Chinese cabbage production and its influencing factors by using the translog SFA model based on 216 sample data from 27 provinces from 2012-2019. The research conclusions are as follows: The average productive efficiency of China's Chinese cabbage is 0.880 from 2012 to 2019. However, there is still a significant loss of technical efficiency, and there is a big difference in technical efficiency between different regions. The inputs of the fertilizer and temperature have a positive significance on technical efficiency, the disaster area has a negative significance on technical efficiency. And the regional difference in the efficiency was significant and ranked by descending order as follows: Northeast, Eastern China, Northwest, Northern China, Central China, Southwest, Southern China. In descending order of technical efficiency, Heilongjiang, Jiangsu, Beijing, Shanghai, Jilin, Ningxia, Chongqing, Hubei, Gansu, and Henan rank in the top ten. To sum up, the study on the technical efficiency of Chinese cabbage production is of great significance to excavate the potential of Chinese cabbage production and also provides a valuable reference for the development of other vegetable production. However, due to the availability of data, this study is supported by the macro data in the statistical yearbook but lacks the intuition, accuracy, and timeliness of the microdata, which will be further supplemented and improved in future research.

Therefore, based on the above research conclusions, this study puts forward the following suggestions. (1) In vegetable production, the scale of vegetable production should be appropriately increased through land transfer or cooperative operation to promote the growth of scale efficiency and thereby improve the efficiency of production technology. And promote the promotion of cabbage production technology with the help of new agricultural business entities, carry out regular training for farmers, further promote the maturation of existing production technology, and promote the improvement of vegetable production efficiency of general growers to achieve economies of scale. (2) From the perspective of vegetable production quality and safety, increase the output and quality of cabbage through the use of new technologies, and reduce the impact of pests and diseases on vegetable production, and at the same time popularize scientific fertilization technology, improve fertilizers, and do an excellent job monitoring and early warning of natural disasters, pests and diseases, and extreme weather, and organize and promote disaster prevention and mitigation technologies for regional climate change. (3) Improve efficiency by improving management, perfecting the technology, optimizing resource allocation, and other ways. At the same time, the government needs to balance the coordinated development between different regions through macro-control policies and fully consider the endowment differences between different areas.

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Yu-Shuang Hu [Regular member]

• Jun. 2017 : Yanbian Univ., Agriculture and Forestry Economic Management, BM
• Jun. 2019 : Yanbian Univ., Rural Regional Development, MSC(Agr)
• Sept. 2019 ~ current : Kangwon Univ., Dept. of Agricultural and Resource Economics, PhD Program

〈Research Interests〉
Agriculture Circulation, Consumer Behavior

Zhi-run Li [Regular member]

• Jun. 2014 : Jilin Univ., Agriculture and Forestry Economic Management, BM
• Jun. 2019 : Jilin Univ., Rural Regional Development, MSC(Agr)
• Sept. 2019 ~ current : Kangwon Univ., Dept. of Agricultural and Resource Economics, PhD Program

〈Research Interests〉
Green Agriculture, Sustainable Agriculture

Yu-Cong Sun [Regular member]

• Jun. 2012 : JiLin Agricultural Univ., Information and Computing Science, BS
• Jun. 2018 : JiLin Univ., Agriculture and Forestry Economic Management, MM
• Sept. 2018 ~ current : Kangwon Univ., Dept. of Agricultural and Resource Economics, PhD Program

〈Research Interests〉
Livestock Economy, Consumer Behavior

Jong-In Lee [Regular member]

• Feb. 1987 : Kangwon Univ., Animal Science, BSC(Agr)
• Feb. 1993 : Kangwon Univ., Livestock Management, MM
• Aug. 1997 : Missouri Univ., Agricultural Economics, MSAE
• Dec. 2000 : Oklahoma Univ., Agricultural Economics, PhD
• Feb. 2006 ~ current : Kangwon Univ., Dept. of Agricultural and Resource Economics, Professor

〈Research Interests〉
Livestock Management, Livestock Economy, Food Consumption