The Journal of Animal & Plant Sciences, 29(5): 2019, Page: 1413-1423
ISSN: 1018-7081

BREEDING EFFICIENCY OF BEEF CATTLE IN CHINESE SUITABLE AREAS

Yong Jie Xue[1] and Jin Ling Yan[2※]
[1]College of Economics and Management, Hebei Agricultural University, Baoding, China
[※]Corresponding Author E-mail: yanjinlingchina@sina.com

ABSTRACT

Beef has been considered a semi-luxury by Chinese residents, as its price is significantly higher than other meats, like pork and chicken. Rising disposable income of residents has contributed to the growth of beef consumption in China. And the potential of beef market is enormous. Based on the panel data from 2007 to 2016, this paper uses SBM (Slacks Based Measure of Efficiency) to calculate the productive efficiency of beef cattle breeding in china, analyze each breeding area's spatial and temporal distribution characteristics, and explore the factors influencing the efficiency. The results prove that: (1)The beef cattle breeding efficiency in China was much lower than expected, there are input-output slacks in nearly all areas in different degree. (2) the net efficiency of beef cattle breeding did not show a significant upward trend, while the growth range was quite different among regions. The agricultural areas in central plains have higher efficiency and obvious annual upward trend than the northwest and northeast pastoral areas in China. (3) Beef cattle breeding model and geographical location conditions are important factors affecting the net breeding efficiency.

Keyword: China, Beef cattle breeding, SBM model, productive efficiency.

INTRODUCTION

According to the report of USDA (United States Department of Agriculture), the total estimated beef production of China was about 7.07 million tons in 2017 (US 12.11 million tons, Brazil 9.45 million tons and EU 7.83 million tons), which placed China as the fourth largest beef producing nation in the world. In addition, China's beef imports with total estimated of 1039.386 tons in 2018, second to USA, revealed it as the second largest beef importer nation in the world. However, the domestic huge demand has not led to a significant increase in the scale and total output of the Chinese beef cattle industry. Most farmers are maintaining or even reducing the scale of beef cattle breeding. China's beef breeding industry is growing slowly (Cao *et al.*, 2018) . In the research of production efficiency of beef cattle breeding industry, Chinese scholars mainly use SFA (Stochastic Frontier Analysis) and DEA (Data Envelopment Analysis) model, such as CCR model (Charnes, Cooper and Rhodes Model) and BCC model (Banker, Charnes and Cooper Model) to analyze the production function, or calculate Malmquist index, which divides TFP (Total Factor Productivity) into technical efficiency, technical progress rate, technical efficiency, pure technical efficiency and scale efficiency. Some researcher found that both TFP and growth rate of beef cattle breeding in farmers showed a fluctuating downward trend, with higher technical efficiency loss, but the overall technical efficiency level was higher, and there was a large difference in technical efficiency among different regions (Shi *et al.*, 2017;Yang and Wang, 2013).

Up to now, most scholars have used some provinces data as samples to represent the national total to measure Chinese beef cattle production efficiency from different perspectives (Zhao and Zhang, 2017). By comparing the production efficiency with other livestock and poultry farming, it is found that the productivity of beef cattle industry is higher than that of pig and lower than that of beef sheep industry (Cui *et al.*, 2014).The regional special study found that the scale efficiency of beef cattle breeding in Jilin province had a negative impact on the productivity of beef cattle breeding (Zhang *et al.*, 2010). The efficiency of labor force and fine coarse feed in Henan province was significantly improved, but the overall efficiency of breeding was not significantly improved due to the decrease in the input of piglets (Cao, 2014).Regional comparative studies have found that the technical efficiency of beef cattle breeding in Xinxiang is the highest, followed by Henan, followed by Heilongjiang, Ningxia and Shaanxi ranked last (Shi*, et al.*, 2017), but the comprehensive production efficiency of beef cattle in Xinxiang is lower than that of Henan, Shaanxi and Heilongjiang (Cui*, et al.*, 2014).The studies on the influencing factors found that cultivation density, agricultural mechanization level, disease risk and feed structure were the important influencing factors for productivity (Shi*, et al.*, 2017;Tian and Zhang, 2010;Yue, 2011;Zhang, 2011).

The influences of the improvement of production efficiency, are different on producers and consumers, which can be regulated and controlled by policies. The growth of beef cattle productivity is most closely related to labor productivity, and the direct support policy expenditure also has obvious effects(Charroin *et al.,* 2012). Both production scale and production mode will have an impact on beef cattle productivity (Bojnec and Latruffe, 2013;Dick *et al.*,

2015). Although productivity gains from higher factor productivity would reduce the price of beef, farmers would end up as net losers in the distribution (Temoso *et al.*, 2016;Veysset *et al.*, 2018). In order to avoid the decrease of farmers' enthusiasm for production, the government should transfer tax payment to farmers to offset the net welfare loss caused by price reduction, or subsidize consumers to offset the welfare loss of consumers through price maintenance policy, and redistribute welfare between consumers and farmers(Ash *et al.*, 2015;Font and Guerrero, 2014).

The existing papers, which make an important analysis of the TFP and breeding production efficiency of Chinese beef cattle industry (Bojnec and Latruffe, 2013), provides an important consult and reference for the development of the industry. However, most papers use CCR and BCC model or SFA model to analyze, whose drawback is that the efficiency values of decision units on the optimal frontier surface are all 1, especially when the DMU (Decision Making Units) samples are less than required, the efficiency values of multiple decision units cannot be analyzed. For example, the requirement of using DEA model to calculate Malmquist index is that the minimum number of DMU is the number of input indexes multiplied by the number of output indexes, and it is not less than 3 times of the total number of indexes, that is, $n \geq \{m \times q \ , \ 3 \times (m + q)\}$ (Cheng, 2014;Cooper *et al.*, 2006). In many previous studies, the number of DMU did not meet this requirement, and the calculation results may be inaccurate. In the CCR model and BCC model, input-output slack is not considered, and the inefficient DMU can only be improved in equal proportion (Cooper*, et al.*, 2006;Tone, 2001;Tone, 2010;Tone and Tsutsui, 2010). Therefore, it is impossible to propose targeted improvement measures for the slack part. Therefore, in this paper, non-radial SBM model is adopted for analysis, to take variable slack into full consideration and decompose redundant factors for targeted research; furthermore, this method can effectively avoid the situation where the efficiency value caused by the small number of DMU is 1.

MATERIALS AND METHODS

Research methods: DEA, a non-parametric technical efficiency system analysis method, is a comparative efficiency evaluation method based on multi-input and multi-output objects proposed by Charnes, A et al. in 1978 (Charnes *et al.*, 1978). After 40 years of development, traditional DEA models such as CCR and BCC have been developed into various models of non-radial SBM (such as super-efficiency SBM model, network SBM model and non-expected output SBM model), and the accuracy and accuracy of evaluation have been significantly improved. Tone proposed the SBM model in 2001, which is a non-radial DEA model that takes into account the relaxation variables (Tone, 2001). The model solves the slacks problem of efficiency evaluation, in which the distance between input and output and production frontier is incorporated into the model to decompose the relaxation variables(Cooper *et al.*, 2011).

Due to the vast size of China, the difference between natural environment and cultural environment among regions leads to the huge difference in beef cattle breeding mode, and the compensation of scale is uncertain. Therefore, we use the non-angular and non-radial SBM model to analyze the breeding efficiency without considering the compensation of scale.

We will deal with k DMUs with the input and output matrices X,and Q, respectively. We assume that the data set is positive.

$$X = (x_i) \in R^{a \times m}$$
$$Q = (q_i) \in R^{b \times n}$$
$$X > 0, \quad Q > 0$$

The production possibility set P is defined as : $P = \{(x, \ q) | x \geq X \ , \ q \geq Q \ , \mu \geq 0\}, \mu \in R^n$. where μ is a nonnegative vector.

Now, let's assume there is a certain expression DMU (x_t, q_t), as

$$x_t = X \ + s^-$$
$$q_t = Q \ - s^+$$

With $s^- \in R^m, s^+ \in R^n$, and $s^- \geq 0, \ \ s^+ \geq 0, \ \ \mu \geq 0$.

The vectors x_t and q_t indicate input and output, and the vectors s^- and s^+ indicate the input excess and output shortfall of this expression which are called slacks(Tone, 2001;Tone and Tsutsui, 2010).

We consider ρ indicates production efficiency index, which is as follows:

$$\rho = (1 - \frac{1}{a}\sum_{i-1}^{a} \frac{s_i^-}{x_{i0}})/(1 + \frac{1}{b}\sum_{j-1}^{b} \frac{s_j^+}{y_{j0}})$$

The model of SBM is as follow:

$$\text{Min}\rho = \frac{1 - \frac{1}{a}\sum_{i-1}^{a} \frac{s_i^-}{x_{i0}}}{1 + \frac{1}{b}\sum_{j-1}^{b} \frac{s_j^+}{y_{j0}}}$$
$$\text{s.t.} \ \ x_0 = X \ + s^-$$
$$y_0 = Q \ - s^+$$
$$s^-, \ \ s^+, \ \ \mu \geq 0$$

Now, we transform the model into a linear program through multiplying $t, \ \ t > 0$to the both sides of target functions and constraint variables, and the convert the denominator to a new constraint(Charnes *et al.*, 2013;Cooper*, et al.*, 2006). So, we consider $\varepsilon = t_i \ , \ \ S^- = ts^- , \ \ S^+ = ts^+ \geq 0, \ \ \delta = t_i > 0$, the new SBM model is as follows:

$$m \quad \varepsilon = 1 - \frac{1}{a}\sum_{i-1}^{a} \frac{S_i^-}{x_{i0}}$$

$$\text{Subject to } 1 = t + \frac{1}{b}\sum_{j-1}^{b}\frac{S_j^+}{y_{j0}}$$

$$t\cdot_0 = X\delta + S^-$$

$$t\cdot_0 = Y\delta - S^+$$

$$S^-,\ S^+,\ \delta \geq 0,\ t > 0$$

When and only if $S^- = S^+ = 0,\ \varepsilon = 1$, theexpression is efficient and the optimal solution can be obtained. However, when $\varepsilon < 1$, at least one of the variables S^-, S^+ is not zero, and then this DMU has efficiency slack due to input excess or output shortfall of this expression, so at this point, the improvement is necessary to achieve efficiency maximization(Ma, 2012).

Variable selection and data specification: China has a large number of beef cattle breeding areas with a wide range of layout. Since 2007, the dominant beef cattle production areas in China have shifted from "Pastoral areas Areas" to "Agricultural Areas" (Wang *et al.*, 2014). This paper takes six provinces of Hebei, Heilongjiang, Henan, Shanxi, Ningxia and Xingjian, which are advanced in beef cattle breeding and are representative of agricultural and pastoral areas, as the research object to make a regional comparative analysis on the efficiency of beef cattle breeding.

National Bureau of Statistics of China does not collect all data on the beef cattle industry, but only some representative provinces. Limited by statistical data, it is impossible for us to analyze population, and the basic rules of statistics are followed, so it is unnecessary to analyze the populations. Therefore, in order to better analyze China's beef cattle industry, the paper selected Hebei, Heilongjiang, Henan, Shanxi, Ningxia and Xingjian as samples for analysis. In 2017, The beef output of the six provinces accounted for 31.01% of China's total output, and the cattle stock accounted for 21.29% of China's total output (As is shown in Table 1). Considering the current situation of the development of China's beef cattle industry and the theme of this paper, the selected samples are typical and representative, which can explain the situation of beef cattle production in China.

The input of beef cattle breeding is the sum of the costs of the breeding process (including material and service costs, labor costs and field costs), while the labor costs, Calf costs, concentrate and roughage costs constitute the main part of the breeding costs. Therefore, the labor cost, Calf costs, concentrate and roughage costs and other costs (including the input part other than the first three indicators) were selected as the input indicators, and the total output value (including the output value of the main product and the output value of by-products) was selected as the output indicator. The input and output index system are shown in Table 2.

Table 1 The proportion of beef production and cattle stock in selected provinces in China (2017).

Index	Hebei	Heilongjiang	Henan	Shaanxi	Ningxia	Xinjiang	Total
Beef Production	8.76%	6.92%	5.52%	1.31%	1.72%	6.78%	31.01%
Cattle Breeding Stock	3.98%	5.41%	4.12%	1.67%	1.31%	4.79%	21.29%

Table 2 Input and output index system.

Index	Categories	variable declaration
Input	Calf costs	Calf costs
	Concentrate and roughage costs	concentrate costs, roughage costs
	Labor costs	Labor costs
	Other costs	• Feed processing cost, Cost of water, Fuel cost, Medical and epidemic prevention costs, Death Loss, Technical service cost, Cost of tools and materials, Cost of repair and maintenance, Depreciation of fixed assets, Insurance expense, Management fee, Financial expenses, Selling expenses，Other expenses
Output	Total output value	• Output value of main product, Output value of by-product

The data mainly come from the China Statistical Yearbook, the National Collection of Agricultural Product Cost-Benefit Data, the China Rural Statistical Room, the China Animal Husbandry Yearbook, the China Animal Husbandry and Veterinary Yearbook, the statistical yearbooks and data compilation of the relevant regions, and the national database website of the National Bureau of Statistics of China. In order to eliminate the impact of price factors, we set 2007 as the base period, and then use the annual price index of agricultural production data of corresponding provinces to reduce the input index, and use the price index of agricultural production to reduce the total output index. After the adjustment, the index data are shown in Table 3.

Table 3. The input and output of aquaculture industry in Chinese beef cattle producing areas (2007-2016) (unit: Yuan / head).

Year	DMUs	Calf costs	Concentrate and roughage costs	Labor costs	other costs	Total output value
2007	Hebei	3091.65	900.96	273.82	100.16	5179.58
	Heilongjiang	2830.61	1167.75	298.6	103.48	5651.15
	Henan	1407.13	706.25	533.7	117.29	4082.52
	Shaanxi	1445.78	808.39	496.67	42.3	4133.33
	Ningxia	984.08	984.15	207.65	79.37	4718.42
	Xinjiang	2116.81	615.15	314.98	96.7	3706.6
2008	Hebei	4407.33	1073.24	272.51	93.61	6744.99
	Heilongjiang	4036.25	1683.82	405	95.64	6893.3
	Henan	1933.1	840.85	632.88	132.31	4929.99
	Shaanxi	2023.53	839.95	557.28	58.12	5524.33
	Ningxia	1462.22	1257.91	290.03	71.17	3649.9
	Xinjiang	2509.99	816.92	276.14	107.12	4355.16
2009	Hebei	4270.57	1295.27	232.83	95.43	6703.06
	Heilongjiang	3505.8	1673.67	310	82.64	6511.87
	Henan	2084.18	1280.95	475.99	102.93	5443.06
	Shaanxi	2682.89	969.21	402.03	68.51	4865.08
	Ningxia	1472.32	1269.2	284.18	95.58	3859.06
	Xinjiang	3554.03	511.59	337.31	107.07	5047.56
2010	Hebei	4593.94	1216.85	230.67	80.82	7116.36
	Heilongjiang	3932.93	2135.41	371.69	111.9	7526.05
	Henan	2446.48	1092.06	761.37	124.1	5989.48
	Shaanxi	2796.22	1212.55	523.34	68.8	5581.78
	Ningxia	1627.63	1428.36	408.13	99.86	4579.73
	Xinjiang	3482.51	660.79	348.71	137.43	4992.86
2011	Hebei	5167.36	1457.96	294.41	74.82	8263.4
	Heilongjiang	5007.61	2609.89	428.52	112.56	8905.65
	Henan	3115.38	1234.89	851.12	100.89	7160.03
	Shaanxi	3343.33	1370.56	674.4	76.84	8221.11
	Ningxia	2007.17	1494.72	474	155.95	6438.71
	Xinjiang	3842.12	797.15	623.36	149.08	6397.58
2012	Hebei	5870.36	1612.32	441.21	80.4	10890.17
	Heilongjiang	6151.65	2998.46	557.65	106.11	11226.05
	Henan	3646.03	1325.65	1135.79	99.55	8691.61
	Shaanxi	4534.11	1470.22	950.32	78.91	10853.11
	Ningxia	3261.18	1734.15	697.86	145.83	8155.79
	Xinjiang	5570.43	1188.56	951.45	179.01	8573.66
2013	Hebei	7315.27	1611.93	558.3	86.86	13303.09
	Heilongjiang	7599.97	2976.83	630.63	108.32	12490.5
	Henan	4227.84	1403.09	1311.38	102.1	10294.05
	Shaanxi	4981	1537.93	1109.76	87.45	11902
	Ningxia	3748.87	1811.71	829.06	155.95	9375.03
	Xinjiang	8083.6	1629.36	1139.74	212.54	12396.71
2014	Hebei	8245.97	1743.54	609.9	86.29	13054.4
	Heilongjiang	6443.39	3298.94	792.29	118.95	12652.17
	Henan	4500.92	1472.13	1403.56	102.92	10925.22
	Shaanxi	4870.33	1595	1232.06	90.72	11005.89
	Ningxia	3469.46	1749.41	867.06	167.35	8517.8
	Xinjiang	6515.73	1113.46	901.17	210.19	9294.98
2015	Hebei	8104.99	1738.46	651.82	85.1	12544.28
	Heilongjiang	6415.33	3107.75	725.3	118.11	12015.37

	Henan	4598.57	1417.13	1477.16	104.09	11114.51
	Shaanxi	5038	1094.11	1308.84	91.19	10109.44
	Ningxia	3492.25	1729.01	899.4	176.19	8511.13
	Xinjiang	6582.52	1170.77	1000.61	167.69	9315.51
	Hebei	7742.89	1723.26	634.44	81.96	12620.31
	Heilongjiang	6334.33	2900.99	758.4	114.11	12088
2016	Henan	4503.36	1347.97	1519.49	104.31	10975.54
	Shaanxi	5172	1000.33	1369.31	92.36	10565.67
	Ningxia	3389.81	1650.58	936.16	177.79	8448.66
	Xinjiang	6549.93	1166.84	1118.31	176.65	9683.38

RESULTS

The empirical analysis:

Time distribution of net efficiency: Using the SBM model constructed above, we calculate the efficiency as the beef cattle net breeding efficiency. The efficiency calculated by CCR and BCC models were respectively beef cattle breeding efficiency value 1 and breeding efficiency value 2, as shown in Figure 1.

As can be seen from Figure 1, (1) Breeding efficiency in the predominant beef cattle producing areas of China from 2007to2016 is higher than the net efficiency, ignoring the influence of slacks variables. There is a large illusion in the results, which to some extent conceals the objective fact that input or output redundancy exists in the development of beef cattle breeding.(2) The average net breeding efficiency in China is 0.7032 from 2007 to 2016, which indicates that the overall level is not as high as expected. There is still much room for improvement in resource saving and production efficiency. We should consider the resource utilization and output growth of beef cattle breeding as a whole to achieve the coordination, rather than focusing solely on the growth of output value.(3)During the period from 2007 to 2016, the net efficiency of beef cattle breeding showed no obvious upward trend. It showed a downward trendfrom2007 to 2010, showed an overall rapid upward trend from 2010 to 2013, after a short adjustment in 2014 and 2015, and returned to the average level.

The change of net efficiency of beef cattle breeding comes from the influence of related industries, the law of its own development, the market demand for beef and the national industrial policy. Affected by the melamine poisoned milk powder incident in Hebei Province in 2008, Chinese milk cow farming was severely hit and transmitted to beef cattle. Beef cattle farming in China was affected, and it did not return to normal until 2010.In 2009, the Ministry of Agriculture issued the National Beef Cattle Advantage Regional Distribution Plan. Beef cattle breeding industry began to receive attention in various production areas. A series of policies to stimulate the development of the industry were issued frequently, which directly promoted the increase of investment in breeding and the rapid increase of breeding efficiency from 2010 to 2013.After 2014, China's agricultural economy has undergone structural changes, the structure of people's living needs has changed, and the efficiency of beef cattle breeding has experienced a short retreat in 2014 and 2015.In 2016, the structural reform of the supply side has become the theme of China's agricultural development. Beef has become an important part of the upgrading of people's dietary structure, which directly promotes the rapid improvement of beef cattle breeding efficiency.

Regional distribution characteristics: The general geographical dividing line between farming and pastoral areas in China is from the northeast to the southwest, i.e. the eastern foot of the Great Hinggan Mountains - the middle and upper reaches of Liaohe River - the Yinshan Mountains - the eastern margin of the Ordos Plateau (except Hetao Plain) - the Qilian Mountains (except Hexi Corridor) - the eastern margin of the Qinghai-Tibet Plateau. The southeast part of this line is an agricultural production area, and the northwest part is a pastoral area. There is a semi-agricultural and semi-pastoral transitional zone between agriculture and pastoral area, but the boundary among regions is not obvious. So, taking into account the habits of previous studies and statistical data, we use this demarcation line to determine the agricultural and pastoral areas as the research object, and no longer study the semi-agricultural and semi-pastoral areas separately. According to the geographical division, the average net breeding efficiency of Xinjiang, Ningxia and Heilongjiang provinces is taken as the net breeding efficiency of pastoral areas, and the average net breeding efficiency of Hebei, Henan and Shaanxi provinces as the net breeding efficiency of agricultural areas. According to the calculation results of SBM model, the regional distribution of net breeding efficiency in agricultural and pastoral areas of China from 2007 to 2016 is shown in Fig. 2.

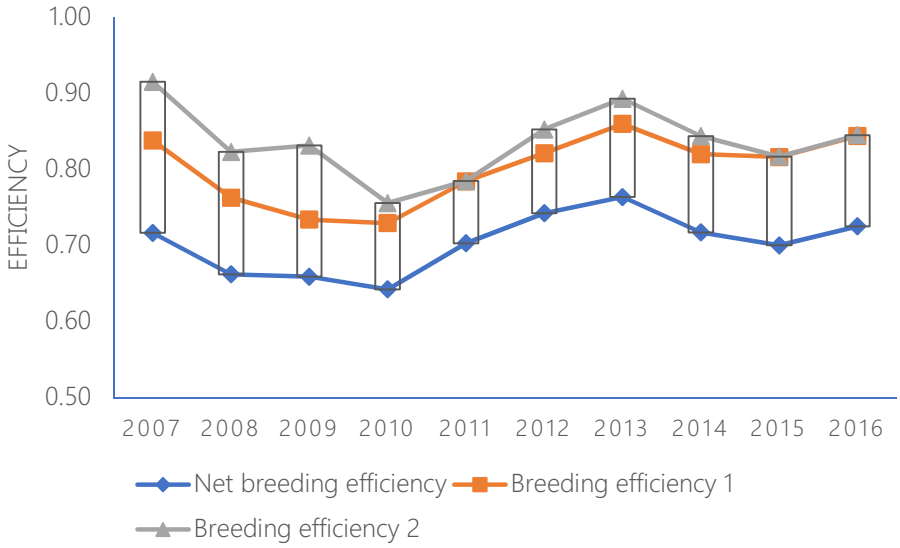

Fig. 1 Time distribution of net breeding efficiency in China（2007-2016）

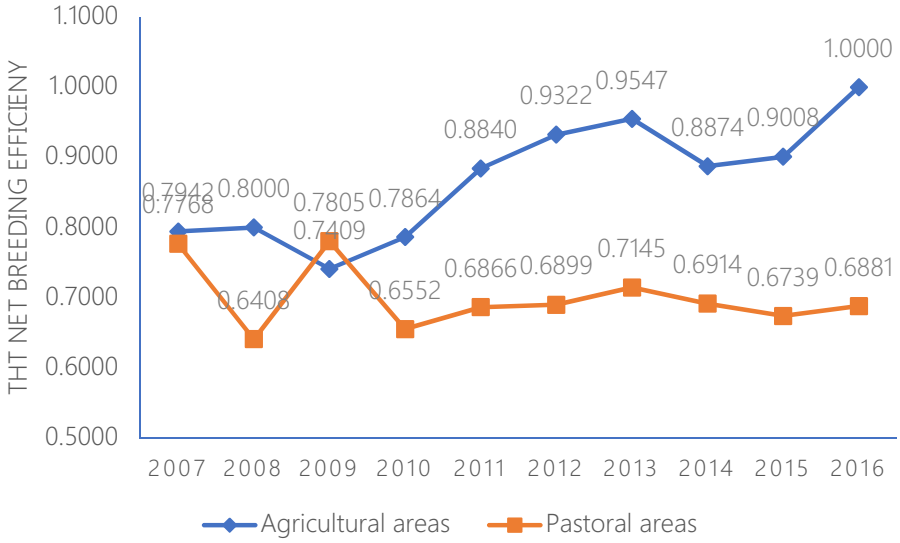

Fig. 2Temporal distribution of net breeding efficiency in agricultural and pastoral areas (2007-2016)

The average net farming efficiency (0.8680) in the farming area is much higher than that in the pastoral area (0.6998). The net farming efficiency in the pastoral area has been fluctuating around 0.7. The beef cattle farming efficiency in the farming area is fluctuating and rising rapidly, reaching and maintaining a higher level after 2013. Pastoral areas, most of which are in arid and semi-arid areas, are located in the northwest and northeast, with low population density and rich grassland resources. From the point of view of natural growth of animal husbandry, it is more important for the development of beef cattle breeding industry. From the perspective of natural growth of beef cattle, this area is more suitable for the development of animal husbandry. Agricultural area is located in the southeast, with humid climate, rich concentrate feed resources such as corn and soybean, and densely populated. Its economy is more developed than northwest and northeast. It is more suitable for beef cattle fattening. Over the past 10 years, the farming mode has been improved rapidly, breed of calf improvement, embryo transfer and other technology industries have developed rapidly, the efficiency-oriented investment supporting industries have gradually developed, and the industrial chain has been extended, which has promoted the net efficiency in recent years to continue to rise and to adjust after reaching a high level. At present, domestic calf and fattening cattle prices hang upside down, to a certain extent, affecting pastoral production, pastoral areas (Northwest and Northeast) have been in a low net breeding rate hovering within the

interval, which further affects the low operation of the national net breeding efficiency. From the perspective of regional economic development, animal husbandry is not the best strategy for backward areas, and the input of local governments in beef cattle industry will be far lower than that of high value-added industries such as manufacturing industry. However, from the perspective of Theory of Comparative Advantage, the comparative advantage of grazing and breeding with low-cost grassland resources is incomparable in the eastern region, which is also an important reason for the development of Gobi beef cattle breeding industry in the vast grassland, which is mainly to breed calves, while the fattening efficiency is low.

Inter provincial spatial temporal distribution: We use the SBM model constructed above to calculate the net efficiency, and draw the trend map of the net efficiency distribution of beef cattle in China's predominant production provinces from 2007 to 2016, as shown in Figure 3.

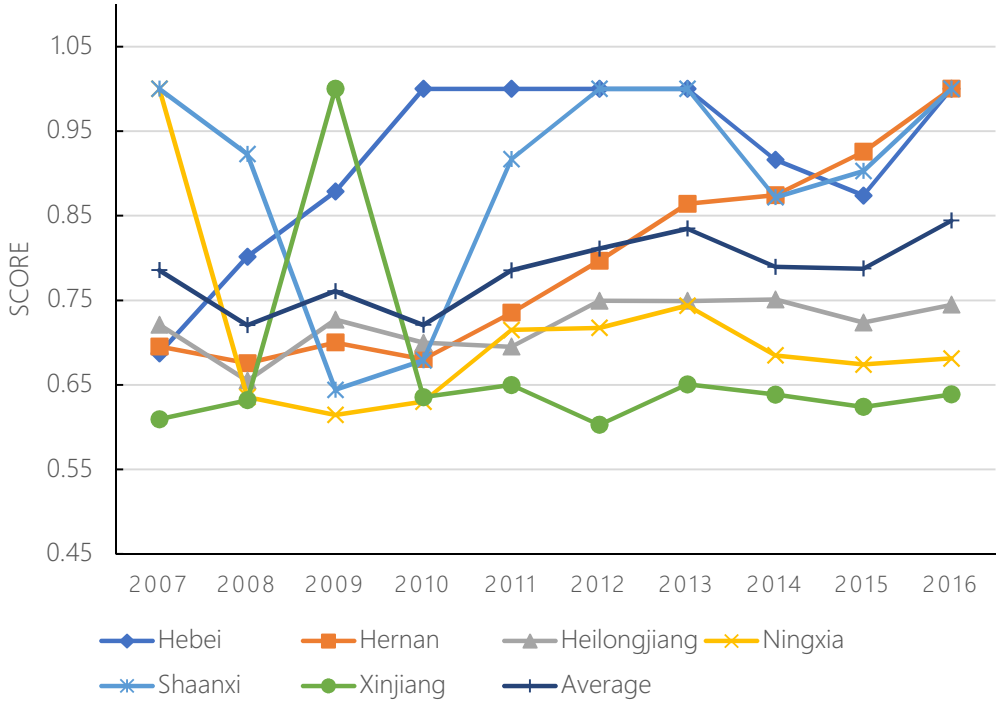

Fig.3 2007-2016 Net efficiency trend of beef cattle breeding provinces in China

As can be seen from Figure 3, the Average curve shows a volatile and slightly upward trend, especially after 2014. Average farming efficiency fluctuated around 0.75 in 2007-2010, rising steadily to 0.8346 in 2013, falling back to 0.7894 in 2014, and then accelerated to 0.8441 in the next three years. The breeding efficiency of Hebei Province rose rapidly from 2007 to 2010, and has remained at a high level (above 0.8), and has been adjusted at a high level since 2013.Henan Province fluctuated at a low level (0.68) from 2007 to 2010, maintained a high growth rate from 2010 to 2016, and achieved a high growth efficiency in 2016.The net breeding efficiency of Heilongjiang Province has been maintained at about 0.7 in the past ten years, showing a slight increase trend which is not obvious. Ningxia and Shaanxi provinces show similar trends: strong decline in 2007-2009, rising in varying degrees in 2009-2013, and declining after 2014; the difference lies in the rapid rise of Shaanxi to a high level and adjusted around this level, while Ningxia rose slowly, and fell to 0.68 after reaching the peak of 0.7437 in 2013, which has remained at that level for several years. The net breeding efficiency of Xinjiang Autonomous Region has been at a low level between 0.6 and 0.65 for many years, except for the sharp fluctuation in 2009. In a word, Hebei, Henan and Shaanxi provinces have played an important role in the change trend of the national average after 2014, which also reflects the status of beef cattle breeding in Central Plains in China, while the improvement of production efficiency in traditional beef cattle breeding pastoral areas (Xinjiang, Ningxia, Heilongjiang) is relatively slow.

Reasons for loss of beef cattle breeding efficiency

Analysis of excessive input and insufficient output: In the SBM model, when the net breeding efficiency of beef cattle does not reach 1, the DMUs has efficiency loss.

The size of S^- and S^+ can reflect the degree of efficiency loss.To facilitate analysis, redundancy is converted to redundancy: in order to obtain the input excess rate, the input slack variable is divided by the corresponding input variables; the output slack variable is divided by the total output value of beef cattle breeding, and the output shortfall rate is obtained. The input excess rate and output shortfall rate index of efficiency is shown in Table 4.

Table 4. 2007-2016 efficiency loss rate of beef cattle breeding in china.

DMU	S-(1)	S-(2)	S-(3)	S-(4)	S+(1)
Hebei	3.92%	7.82%	3.90%	13.91%*	1.37%
Heilongjiang	0.00%	49.28%*	20.05%	36.55%	1.94%
Henan	0.00%	7.33%	42.68%*	32.13%	0.00%
Shaanxi	0.00%	9.66%	20.41%*	12.35%	0.03%
Ningxia	10.86%	15.66%	39.74%*	23.51%	10.41%
Xinjiang	9.16%	5.65%	44.99%*	61.13%	4.73%
Agricultural l areas	1.31%	8.27%	22.33%*	19.46%	0.47%
Pastoral areas	6.67%	23.53%	34.93%	40.40%*	5.69%
China	3.99%	15.90%	28.63%	29.93%*	3.08%

Note: 1. The figures in the table indicate the slack rate of each index, i.e. the optimum degree of input and output, which is positively related to the loss of breeding efficiency. 2. The slack rate of China is averaged over the provinces. 3. The rate marked by* is the primary factor causing efficiency loss.

Overall, the output shortfall rate is significantly lower than the input excess rate in the same region, and the main reason for the loss of beef cattle breeding efficiency is the input excess. The output shortfall rate of each province is relatively low and the inadequate expected output is not the main reason for the loss of efficiency of beef cattle breeding in China. The excessive consumption of resources has resulted in the overall low net efficiency of beef cattle breeding in China. The provinces concentrate on the redundancy of labor input and other costs, and there is basically no redundancy in the investment of livestock. Over-investment of resources has affected the overall level of beef cattle breeding efficiency in China. Excess of investment in various regions is concentrated on labor costs and other costs, while there is basically no redundancy in Calf costs.

The slack rates in different regions are quite different. The slack exists in every element of pastoral area, which leads to serious efficiency loss. The input excess rate of other costs in Xinjiang is as high as 61.13%, the input excess rate of Concentrate and roughage costs in Heilongjiang is 49.28%, and the input excess rate of Labor costs in Ningxia is 39.74%. At the same time, there is a certain degree of output shortage in the three regions. This high input excess rate to a certain extent means that the resource utilization efficiency is low, and the factor input is not coordinated. All these results in low conversion rate of input output. The situation in agricultural l areas is better than that in pastoral areas, and the overinvestment is mainly concentrated in labor input (22.33%). There is a certain degree of overinvestment in Hebei and Shaanxi, but not serious. Henan's situation deserves attention. The Labor input excess rate is as high as 42.68% and that of Other costs is 32.13%. This is not inconsistent with the treed and the development speed of net breeding efficiency which has been analyzed in the previous part. The former describes a gradual process, and the relaxation rate discussed here represents the average of ten years, reflecting the overall situation over this period. The input excess and output shortage of Henan will be emphatically analyzed below.

Slack analysis and efficiency influence: Here we make a detailed analysis of the slack projection schemes in Henan in 2014 and 2015, using the results of slack projection from 2014 to 2016 by the SBM model. We omit the detailed process of other provinces and years, and only give the analysis results.

From 2014 to 2016 years, Henan's efficiency increased from 0.7509 to 1. According to the SBM model, the input of labor and other costs should be reduced by 30.81% and 19.48%, but in fact, the input of Calf costs increased by 2.17% and the input of Concentrate and roughage costs decreased by 3.74%. Instead of reducing the input of Labor and Other costs, it increased by 52.11% and 25.6%. Finally, the output shortage of Total output value increased by 1.73%. Therefore, there was still a loss of efficiency in 2015, which did not achieve the desired efficiency value (the actual efficiency value is 0.9256). Similar situations occurred in 2016.The SBM model projection strategy recommended a 17.57% and 12.2% reduction in Labor and Other costs, respectively. But in fact, Henan's input in labor and other costs did not decrease, but increased by 2.87% and 0.21%, and reduced the input of Calf costs to 2.07% (the same level as 2014), while reducing the input of Concentrate and roughage costs by 4.88%, which

results in a decrease of 1.25% in the Total output value. Comparing with the results of projection, it is found that the excess of Labor input and other inputs in Henan Province is obvious from 2014 to 2016, which is mainly caused by ineffective management. Henan Province's TFP has been improved by increasing input of Labor and Other costs. However, due to the inconsistency of factor input, excessive Labor input and other costs, and insufficient investment in livestock to some extent, result in loss of efficiency. Without changing the total cost Henan Province can appropriately reduce the elements of input redundancy, and increase other factors appropriately, to improve the overall level of output and efficiency.

In recent years, Hebei has significantly increased its investment in animal husbandry, and the investment in Calf costs is higher than that in other provinces. The Central Plains region is rich in soil, which is the main grain crop producing area of China, such as corn and soybean. The abundant regional advantages of feed resources, rapid economic development and inadequate grassland resources have promoted shelter-raising as the main breeding method, especially in recent years, in line with market demand, vigorously developing shelf cattle fattening project, which has played a regional advantage. Shaanxi, has advantages in both cattle source and feed, which is close to the northwest production area, but belongs to the corn production area. Therefore, Shaanxi can obtain higher breeding efficiency with relatively low input of Calf costs and Concentrate and roughage costs, under the condition of equal Labor input and other costs with other provinces. Xinjiang, Ningxia and Heilongjiang have abundant grasslands, which provide natural advantages for livestock breeding and beef cattle breeding. However, with the progress of production technology, the Northeast and Northwest superior production areas have not grasped the opportunity of national superior production area planning. They should change their development concept in time, obey the law of large-scale socialized production, change the mode of production, and give full play to their regional advantages. The state of grazing and self-supporting is an important reason for the high loss of productivity and the low level of productivity in this region.

To sum up, the characteristics of the natural environment and the socio-economic development soundings which is the basic reason for the differences in the efficiency of beef cattle breeding between regions, affect the efficiency of beef cattle breeding by influencing the breeding methods. So, the characteristics of the natural environment and the socio-economic development soundings are the fundamental reason for the difference of farming efficiency between regions. And another important conclusion that we draw from the analysis of different provinces is that the farming methods and market factors are main factors affecting the efficiency of beef cattle industry. Farming methods affect the input and output efficiency of factors, which will have a direct impact on the efficiency of farming. Market factors affect the realization process of the value of beef cattle products and the whole beef cattle industrial chain. This is another major factor contributing to the difference in the efficiency of beef cattle farming.

Table5 Projection of the slack in Henan (2014-2016).

DMU	Year	Score	S-(1)	S-(2)	S-(3)	S-(4)	S+(1)
			Projection	Projection	Projection	Projection	Projection
Henan	2014	0.7509	4500.92	1472.13	971.10	82.88	10925.22
			0.00%	0.00%	-30.81%	-19.48%	0.00%
	2015	0.9256	4598.57	1417.13	1477.16	104.09	11114.51
			0.00%	0.00%	-17.57%	-12.20%	0.00%
	2016	1	4503.36	1347.97	1519.49	104.31	10975.54
			-	-	-	-	-

DISCUSSION

Regional development methods recommendations: The farming methods and market factors are important factors affecting the efficiency of beef cattle industry. In the farming areas (such as Hebei and Henan), with the mode of free-range breeding of small farmers transferring to large-scale farming, the mode of fattening in captivity is widely adopted. In addition, the market level in this area is high and the industrial chain is perfect. However, In the pastoral areas (such as Heilongjiang, Xinjiang), free-range grazing is still adopted in the breeding mode. Although the quality of the beef produced is very high, the output efficiency is greatly affected, let alone the low industrialization level in this area. Therefore, exploring new farming modes, guiding farmers to develop and improve the direction of scale, facilities and standardization, and developing modern animal husbandry are the key points of regional development, as well as an important part of Chinese Rural Revitalization strategy.

According to the net efficiency of Chinese beef cattle breeding, it is necessary to increase and promote the scientific and technological input and innovation, promote farmers to improve the production quality and technical level, and perfect the socialized service system of beef cattle industry.

For areas with low net efficiency, such as Heilongjiang Province and Xinjiang Autonomous Region, preferential policies should be given to farmers in the beef cattle breeding process, and a perfect beef cattle breeding guarantee mechanism should also be established to promote the stable and sustainable development of the beef cattle industry in vulnerable areas. At the same time, for areas with high net efficiency such as Hebei, Henan and Shanxi, we must continue to strengthen the development of industrial science and technology, give play to the demonstration effect of advantageous regions, establish inter-regional cooperation mechanisms, and promote the common development of the national beef cattle industry.

Based on many factors affecting the net efficiency of beef cattle breeding, it is necessary to continue to optimize the scale and regionalization of beef cattle breeding, promote the development of beef cattle industry in the main producing areas, and ensure that the supporting policies are tilted to the main producing areas of beef cattle. And The main means include supporting new business entities, strengthening the capitalization level of beef cattle industry, promoting the transformation of industry management from labor-intensive to capital-intensive industries; continuing to promote agricultural mechanization, promoting the conversion of serviced cattle to beef cattle; strengthening the importance of feed structure, and appropriately reducing the dependence of beef cattle industry on concentrated feed industry; strengthening the energy level division of the main production areas, vigorously promoting the development of pasture industry in the three dominant grassland areas of northwest, southwest and northeast, and taking the lead in implementing the four-layer planting structure of "grain + grass + economy + feeding" in the main beef production areas, so as to improve the production efficiency of beef cattle industry.

Breeding system of beef cattle, standardized feeding technology system of beef cattle and the high quality feed supply system are the key points in the construction of beef cattle industry chain system. The major paths include differentiating the predominant areas of beef cattle breeding, guiding and training the main farming forces, and offering various preferential policies to attract new breeders to promote regional intensive production; optimizing the allocation of resources, adjusting the input pattern of factors and introducing advanced technology to release the productive potential of the main producing areas in order to obtain higher production potential; giving full play to the agglomeration effect of beef cattle industry, jointly promoting the technological and institutional innovation of regional beef cattle breeding, so as to make the managers specialize in cattle raising and be willing to raise cattle.

Conclusion: From the perspective of integration of beef cattle breeding industry in China, the imbalance of regional breeding efficiency is the inevitable result of the overall beef cattle industry planning in China. The conception of fattening in pastoral breeding farming areas follows David Ricardo's comparative advantage theory and is the result of the division of labor in large-scale socialized production. However, according to the important experience gained from the spread of hog plague in Africa, it is a trend to restrict the trans-regional transfer of live animals. Chinese live pigs have issued regulations to prohibit trans-provincial transfers, so we have reason to believe that this trend is likely to extend the beef cattle production, and the idea of joint production of beef cattle-breeding in pastoral areas and fattening in agricultural areas is likely to be challenged. Therefore, under the new background, exploring the development capacity building of beef cattle breeding superior areas may become a new topic for the future development of beef cattle breeding and beef industry.

Animal welfare should be given full attention. Beef cattle breeding is an industry with a very serious impact on the ecological environment. Manure treatment and the breeding environment will affect the breeding efficiency, and the manure treatment in the breeding process will affect the growth, reproduction and disease control of beef cattle. Beef cattle breeding centering on ecological environment is an important direction of future development, which is related to the sustainable development of the whole industry(Yan *et al.*, 2018).

Acknowledgments: Authors acknowledge the support from Modern Agricultural Industrial Technique System of Hebei Province: Industrial Economic Position of Innovation Team Focusing on Beef Cattle (HBCT2018130301), and Scientific Research Foundation for the PhD (Agricultural University of Hebei, No. YJ201841). We are especially grateful to the animal breeding experts, who helped us understanding the growth rules of beef cattle, and mathematical economists who gave help and support with the construction of the mathematical model.

REFERENCES

Ash, A., L Hunt, C. McDonald, J. Scanlan, L. Bell, R. Cowley, I. Watson, J. McIvor and N. MacLeod (2015). Boosting the productivity and profitability of northern Australian beef enterprises: Exploring innovation options using simulation modelling and systems analysis. Agr.

Syst. 139: 50-65.

Bojnec, Š. and L. Latruffe (2013). Farm size, agricultural subsidies and farm performance in Slovenia. Land Use Policy. 32: 207-217.

Cao, B. H., Y. J. Zhang, J. Y. Li, Z. S. Wang, A. Z. Guo, J. J. Liu and X. Luo (2018). Beef cattle industry development situation, future development trend and recommendations in 2017. Chinese J. Animal Sci. 54 (3): 138-144.

Cao, G. Q., (2014). Research on the efficiency of beef cattle breeding in henan province. MFA. thesis. Deptt. of Econ. & Manage., Univ. Agri., Jilin.

Charnes, A., W. W. Cooper, A. Y. Lewin and L. M. Seiford (2013). Data envelopment analysis: Theory, methodology, and applications. Springer Science & Business Media; New York (USA).244p.

Charnes, A., W. W. Cooper and E. Rhodes (1978). Measuring the efficiency of decision making units. Eur. J. Oper. Res. 2 (6): 429-444.

Charroin, T., P. Veysset, S. Devienne, J. Fromont, R. Palazon and M. Ferrand (2012). Labour productivity and economy in herbivore rearing: concepts, analysis and stakes INRA Prod Anim 25 (2) 193-210. 25 (2): 193-210.

Cheng, G., (2014). Date envelopment analysis: Methods and Maxdea softwave. Intellectual Property Publishing House; BeiJing (China).27p.

Çoban O, E. Laçin, N. Sabuncuoğlu and M. Genc (2013) Production and health parameters in cattle herds: A survey from Eastern Turkey. The J. Anim. Plant Sci., 23(6):1572-1577.

Cooper, W. W., L. M. Seiford and K. Tone (2006). Introduction to data envelopment analysis and its uses: with DEA-solver software and references. Springer Science & Business Media; New York (USA).377p

Cooper, W. W., L. M. Seiford and J. Zhu (2011). Handbook on Data Envelopment Analysis. 2ed edition. Springer Science & Business Media; New York(USA).121p.

Cui, M. N., M. L. Zhu, Z. Li and X. B. Wang (2014). Research of Xinjiang beef cattle Industry's total factor productivity based on DEA-Malmquist Index. Xinjiang Agr. Sci. 51 (02): 363-369.

Dick, M., M. Abreu da Silva and H. Dewes (2015). Life cycle assessment of beef cattle production in two typical grassland systems of southern Brazil. Journal of Cleaner Production. 96: 426-434.

Font, I.F.M. and Guerrero, L., (2014). Consumer preference, behavior and perception about meat and meat products: an overview. Meat. Sci. 98 (3): 361-371.

Ma, Z.X., (2012). DEA model with generalized reference set and its properties. Syst. Eng. Electron. 34 (04): 709-714.

Shi, Z. Z., M. L. Wang, X. D. Hu and C. Cui (2017). Analysis of beef cattle breeding efficiency and its influence factors in China. J. Agr. Sci. Tec. 19 (2): 1-8.

Temoso, O., R. Villano and D. J. A. S. Hadley (2016). Evaluating the productivity gap between commercial and traditional beef production systems in Botswana. 149: 30-39.

Tian, L. and Y. J. Zhang (2010). The selection of organization mode of beef cattle industrial chain and the analysis of its influencing factors are based on the investigation of 341 farmers (farms) in 14 provinces including Henan. Chinese Rural Econ., (5): 56-64.

Tone, K., (2001). A slacks-based measure of efficiency in data envelopment analysis. Eur. J. Oper. Res. 130 (3): 498-509.

Tone, K., (2010). Variations on the theme of slacks-based measure of efficiency in DEA. Eur. J. Oper. Res. 200 (3): 901-907.

Tone, K. and M. Tsutsui (2010). Dynamic DEA: A slacks-based measure approach. Omega-int. J. Manage. S. 38 (3-4): 145-156.

Veysset, P., M. Lherm, J. P. Boussemart and P. Natier (2018). Generation and distribution of productivity gains in beef cattle farming: Who are the winners and losers between 1980 and 2015? Animal. 10.1017/S1751731118002574: 1-11.

Wang, G. G., M. L. Wang and C. Yang (2014). Development stage and its Patio-Temporal Evolution of beef cattle industry in China. Econ Geogr. 34 (10): 7.

Yan, J., L. Han and Y. Xue (2018). Restoration and management of marine ecosystem in China: A sustainable perspective of indicator evaluation. Indian J. Geo-Mari. Sci. 9(47): 1787-1793.

Yang, C. and M. L. Wang (2013). Farmers' beef cattle breeding total factor productivity study based on Malmquist index. Agr. Eco. Mange. (03): 69-75+89.

Yue, H., (2011). Study on sustainalble development of beef-cattle industry in China. Ph. D. thesis. Deptt. of Econ. & Manage., Univ. Agri., Jilin.

Zhang, H., (2011). Study on beef cattle production efficiency in China. J. Anhui Agr. Sci. 31 (39): 19227-19229.

Zhang, H., Wang, Z.H. and Jiang, H.M., (2010). Production efficiency analysis of beef cattle industry in jilin province. China Cattle Sci., (04): 67-70.

Zhao, H.X. and Zhang, Y.J., (2017). Study on technical efficiency and influencing factors of beef cattle breeding in China. Chinese J. Animal Sci. 53 (04): 136-143.