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Evaluation on the competitiveness of Heilongjiang agricultural industry based on catastrophe progression method

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ABSTRACT

As a traditional agricultural province in China, the competitiveness of agricultural industrial of Heilongjiang directly affects the overall level of the industrial competitiveness of Chinese agriculture. Based on group eigenvalue method, we construct the evaluation index system, including four indicators of natural resources endowment, social conditions of agricultural production, agricultural investment, and agricultural output. We empirically evaluate the competitiveness of agricultural industry of Heilongjiang province, based on the time series data from 2007 to 2012, using mutation progression method. The results show that the model is relatively reasonable, the competitiveness of agricultural industrial of Heilongjiang has grown smoothly and steady in recent years, and it will be increased much larger. According to the final results of evaluation, we propose advisement and suggestions.

KEYWORDS

Heilongjiang province; Industrial competitiveness of agriculture; Group eigenvalue method; Catastrophe progression method; Evaluation model.

INTRODUCTION

As a traditional agricultural province in China, the competitiveness of agricultural industrial of Heilongjiang directly affects the overall level of Chinese agriculture. To the end year of 2012, the grain total output of Heilongjiang exceeded 57 million tons, increase in grain yield occupied 30% of the nationwide in the same year. The agricultural acreage of Heilongjiang is only 10% of the nation, but nearly 25% of national commodity grain is produced by Heilongjiang. The rapid development further enhances the competitiveness of Heilongjiang, however, Heilongjiang faces some problems restricting its sustainability, those are the pressures from resources, environment, and population, and the traditional extensive farming depending on satisfying resources. In the transition progress to modernized agriculture, it will be of great importance in exploring industrial competitiveness of agriculture of Heilongjiang, analyzing the constraints in the course of competitiveness improvement, that will facilitate the development harmony and sustainable.

At present, researchers paid more attention on the influence factors of industrial competitiveness of agriculture and evaluation methods, and have gained some achievements. Balmnan (2004) found fiscal subsidies could improve the level of industrial competitiveness of agriculture through empirical study on agriculture and farming industries in Germany[1]. Xiao (2009) found four key elements made effects on industrial competitiveness, which are costs, market demand, technology gap, and international trade barrier[2]. Based on the sampled data from dozens of provinces from 1993 to 1998 in Russia, Uvoarvsky (2001) studied the relationship between technical efficiency and agricultural economics growth, and results showed that technological advance made indirect effects on agricultural competitiveness by influencing total factor productivity[3]. Kevin (2000) thought that in China natural resources endowment was the key to form international market competitiveness[4]. Moreover, some scholars (Pierre, 2004; Maria Sassi, 2003; Imre Ferto, 2003; Krijn, 2007) respectively constructed the assessment indicator system on the basis of different indexes, such as trade competition, relative trade advantage, comparative strengthen, and intra-industry trade index, after evaluating industrial competitiveness of agriculture of the main agricultural countries[5-8].

From the above we learn that the present studies enrich the theory, and provide good guidance to the real practices. However, there are some deficiencies. First, there are only a few studies on the province industrial competitiveness of agriculture, especially from the perspective of horizontal and vertical comparison. Second, most of the studies are based on the methods of quantitative statics and experts rating, while there is few combing objective and subjective methods. Third, former studies overlooked a series of important factors, such as natural resources endowment and social conditions of agricultural production. Therefore, based on previous studies, we construct the evaluation index system, including four indicators of natural resources endowment, social conditions of agricultural production, agricultural investment, and agricultural output, combine the subjective method of group eigenvalue and the objective method of catastrophe progression, and take the comprehensive assessment on industrial competitiveness of agriculture of Heilongjiang province. Finally, we propose the suggestions according to the evaluation results.

THEORETICAL BASIS AND ANALYSIS

Catastrophe progression method

Catastrophe progression method originated from catastrophe theory, proposed by mathematician Renethom at the end of 1960s, which is one of the three main newly-developing theories in the field of system science. Renethom regarded mutation as the jump of the wholeness of inter-system state, with the basic characters of the continuity of running processes and the periodicity of running results. Catastrophe theory aims at showing the evolution path from one stable state to another. Because mathematic model is a good way to quantify and explain the changing progress of non-continuity from nature and social phenomenon, many content about the theory is expressed by mathematical linguistics, and a series of mathematic models are produced according to the theory. There are mainly seven types of mutation, including pinnacle mutation, swallow tail mutation, butterfly mutation, fold mutation, hyperbolic navel mutation, oval navel mutation, and parabolic navel mutation[9,10], among which the first three are the most frequent. In the operation we need to consider the primary and secondary about different control variables. Usually the main control variable is place at the front of the model, while minor control variable is behind the model. Catastrophe Progression model is used for resolving the multilevel contradiction of the evaluated.

The paper mainly analyses three model, those are pinnacle mutation, swallow tail mutation, and butterfly mutation, thus three unification models using mathematics are as follows:

(1) The unification model of pinnacle mutation

From the decomposed form of pinnacle mutation divergence equation, we get to know:

$$x_u = \sqrt{\frac{u}{-6}} \quad (1)$$

$$x_v = \sqrt[3]{\frac{v}{8}} \quad (2)$$

In equation (1), x_u represents the x value of u, x_v is the x value of v in (2).

In consideration of the simplicity of practical operation, the value range of x, u,v is usually constrained between 0 to 1 in the catastrophe progression model. If $x_u = 1$, then u=6, we hypothesize shrink u to its 1/6, and the value range is from 0 to 1, so we have:

$$u=1*6,\ x_u = \sqrt{\frac{u}{-6}} = \sqrt{u} \quad (3)$$

The principle is the same with above, we zoom out v to its 1/8, thus we get:

$$x_v = \sqrt{\frac{v}{8}} = \sqrt[3]{v} \quad (4)$$

The final mathematical expression of unification model of pinnacle mutation is:

$$x_u = \sqrt{u} \quad (5)$$

$$x_v = \sqrt[3]{v} \quad (6)$$

(2) The unification model of swallow tail mutation

According to the derivation way of unification model of pinnacle mutation, the mathematical expression of unification model of swallows tail mutation is:

$$x_w = \sqrt[4]{w} \quad (7)$$

(3) The unification model of butterfly mutation

In the same principle, we elicit the unification model of butterfly mutation as follows:

$$x_t = \sqrt[5]{t} \quad (8)$$

Based on the principle of multi-objective fuzzy decision, in the condition of various target existing, we assume that the fuzzy objects we desire are $A_1,A_2,\ldots,A_m$, therefore the ideal strategy expression is $C=A_1\cap A_2\cap\ldots\cap A_m$, and the subordinate function is $u(x)=u_{A1}(x)\Lambda u_{A2}(x)\ \Lambda\ldots\Lambda u_{Am}(x)$, in which $u_{Ai}(x)$ is the subordinate function of A_i. When we define $u_{Ai}(x)$ as the subordinate function of the whole scheme, it is the minimum value of all the subordinate function[12,13]. We suppose different scheme as $G_1,G_2,\ldots,G_n$ on the basis of various assessing scheme, and regard $u(G_i)$ as the subordinate function of G_i, according to the principle of complementation and non-complementation, we acquire the subordinate function value of overall mutation. Finally we rank the indicators' value[11,12].

Group eigenvalue method

In the most of decision-making models, the evaluation thinking is that experts make decisions subjectively depending on their specialized knowledge and experience, so such models need to integrate kinds of decision data from the experts. Because some factors are quite different, such as professional background and environment, the evaluation weight of every expert is different aiming to the same target. Group eigenvalue method is a good way to solve the gap, by weighting different weighted values and then calculating the final results.

(1) Ideal expert assumption

The operation of the model is built on a supposed ideal expert S_*, and the so-called ideal expert is the man who gets the minimum value, which is the sum of the final evaluation score vector and other experts' $(S_1,S_2,\cdots,S_m)$ included angle.

In order to gain the optimal decision of the ideal expert, we usually suppose there is one ideal S_*, who can give scientific and comprehensive data, and whose ranking values constitute the vector x^*, $x^*=(x^*_1,x^*_2,\ldots,x^*_n)^T\in E^n$. For getting the vector quantity x^*, and x^* satisfies the function $f=\sum_{i=1}^{m}(b^T x_i)^2$, we stipulate $\forall b=(b_1,b_2,\ldots,b_n)\in E_n$, meanwhile hypothesis $\|b\|=1$, then we get:

$$\max_{\substack{b\in E^n\\ \|b\|=1}}\sum_{i=1}^{m}(b^T X_i)^2=\sum_{i=1}^{m}(X_*^T Y_*)^2 \tag{9}$$

From the above, we know that x^* is the value vector of general evaluation from decision group G..

(2) Correlation theorem

Lemma

We suppose $Q\geq 0$, which is real matrix with n order, is a non-constraint matrix, and then:

(1) Q has the biggest characteristic root $\rho_{\max}$, which is a simple root.

(2) The eigenvenctor of Q correspondent to $\rho_{\max}$ is constructed on the basis of positive component, and every eigenvector just lacks one scale factor.

Therefore, it is learnt that square matrix $F=X^T X$, constituted by matrix x, conforms to all of theorem conditions above.

EVALUATION INDEX SYSTEM OF INDUSTRIAL COMPETITIVENESS OF HEILONGJIANG AGRICULTURE

The construction of the indicator system

According to the principle of scientificity and reasonability, we construct the evaluation index system of industrial competitiveness of Heilongjiang agriculture (TABLE 1), based on the research achievements of Kun and Ying (2012), Nengli (2012), Wei (2012), Hong (2012), Shuilian (2013), Yanjie (2013), Jing (2013), Liang (2012), Lingxian (2013).

TABLE 1 : Evaluation index system of industrial competitiveness of Heilongjiang agriculture

Industrial Competitiveness of Heilongjiang agriculture	Natural resources endowment A (0.164)	Per capita cultivated land A1 (0.514)
		Per capita water resource A2(0.486)
	Social conditions of agricultural production B (0.327)	Effective irrigation area B1(0.316)
		Total power of agricultural machinery B2 (0.352)
		Usage amount of chemical fertilizer B3 (0.153)
		Per capita household electricity consumption B4
	Agricultural investment C (0.214)	Fiscal expenditure of agriculture industry (hundred million yuan) C1 (0.390)
		Productive fixed assets of rural family (Yuan /person) C2(0.378)
		Per capita fixed assets of agriculture (Yuan /person) C3(0.232)
	Agricultural output D (0.295)	Per capita main agricultural output D1 (0.364)
		Total value of agricultural output (hundred million yuan)D2(0.400)
		Index of growth of Total value of agricultural output D3 (0.236)

The explanation of indicators

The index system is consisted of one target layer, four criterion layers and twelve indexes.

(1) Natural resources endowment

Natural resources is the precondition of agricultural production and development, and ecological elements, such as light, water, soil, are the significant resource condition to affect the agriculture competitiveness. Follow the principle of construction, we analyze the cultivated land and water resource of the resource endowment.

(2) Social conditions of agricultural production

With the development of the science and technology, the social conditions of agricultural production are escalating. The social condition is more and more important in the market-oriented development. Effective irrigation area mainly point to the land suitable for cultivation with abundant fresh water resource, and it can be irrigated normally by the high level irrigation engineering equipments. Total power of agricultural machinery is the sum of rated power of all the working agricultural machinery. It can be divided into four types: the power of diesel engine, power of gasoline engine, power of electromotor, and other mechanical power, such as hydraulic power, wind power, coal, and solar energy.

(3) Agricultural investment

Agricultural investment refers to three aspects including the central government and local government financial investment in agriculture, rural fixed assets investment and the status of fixed assets investment for production. Fiscal expenditure of agriculture industry (hundred million Yuan) : It is the statistics of the situation of annual national fiscal expenditure of agricultural in Heilongjiang, which is divided into the central and local governments of fiscal expenditure.

(4)Agricultural output

Agricultural output requirements is not only reflected on the quantity of agricultural products, but also reflected on the quality of agricultural products. In this paper, we measure the agricultural output in Heilongjiang Province from three aspects that are per capita main agricultural output, total value of agricultural output and index of growth of total value of agricultural output. Total value of agricultural output (hundred million Yuan) : Mainly indicates the total value of both overall products across farming, forestry, animal husbandry and fishery manifesting with the money and various kinds of support service activities for production of farming, forestry, animal husbandry and fishery. It reflects the scale and total outputs of farming, forestry, animal husbandry and fishery in a certain time period.

Index of growth of total value of agricultural output : Based on converting annual agriculture output value into a comparable price, we think of the previous as the base index and calculate it through the product conversion regulation between each chain index.

EMPIRICAL ANALYSIS ON INDUSTRIAL COMPETITIVENESS OF HEILONGJIANG AGRICULTURE

Data sample

The data of indexes are all from <Chinese Statistic Yearbook (2008-2012)>, <Chinese Agriculture Yearbook (2008-2012)>, <Rural China Yearbook (2008-2012)>, < Heilongjiang Statistic Yearbook (2008-2012)>, and websites, such as National statistics, the Ministry of Agriculture, National Development and Reform Commission, the Statistical Bureau of Heilongjiang. After a large number of mathematics operation, we gain the index values of 31 provinces in China.

Index weight

In the operating of catastrophe progression method, control variables play different roles in these mutation models, and the order of operation depend on their criticality. Therefore, we calculate the weighted value according to the marking by the experts with the method of Group eigenvalue. Take the four indicators of social conditions of agricultural production for example, according to the marking from 25 experts, and TABLE 2 is the score bar.

TABLE 2 : Scores of index weight

Expert	Index			
	A1	A2	A3	A4
S1	5	6	3	5
S2	5	6	2	2
S3	4	7	3	4
S4	5	6	4	5
S5	4	5	3	3
S6	6	6	4	5
S7	7	7	2	1
S8	5	6	3	2
S9	7	7	2	3
S10	6	7	3	4
S11	7	6	1	2
S12	6	4	2	2
S13	3	6	4	5
S14	5	6	3	2
S15	5	6	2	1
S16	6	7	3	4
S17	7	7	2	1
S18	6	6	3	2
S19	4	7	4	3
S20	6	5	1	2
S21	5	6	4	5
S22	5	4	1	2
S23	3	6	2	5
S24	7	5	2	3
S25	6	6	2	3

According to TABLE 2, we get the product of the appraisal matrix and its transposition matrix:

$$F = X * X' = \begin{matrix} 763 & 812 & 339 & 392 \\ 812 & 918 & 397 & 460 \\ 339 & 397 & 191 & 218 \\ 392 & 460 & 218 & 278 \end{matrix}$$

Based on the above, we calculate the characteristic root of F, and find out the largest eigenvalue as the result of single root, so $\rho_{\max} = 2.0549$, and its eigenvector is $B^T = (0.5977, 0.6657, 0.2902, 0.3398)$.
Finally we make a unitization on B^T, and get $B^T = (0.316, 0.352, 0.153, 0.179)$.

From the above, we know that according to the criticality, the ranking of the four indicators are total power of agricultural machinery, effective irrigation area, per capita household electricity consumption, and usage amount of chemical fertilizer.
In the same way, all the index weights are shown in TABLE 1.

From TABLE 1, we find that in the criterion layer the criticality ranking from big to small are Social conditions of agricultural production, agricultural output, Agricultural investment, natural resources endowment. Among the subordinating indexes of agricultural output, the ranking is total value of agricultural output, per capita main agricultural output, and index of growth of Total value of agricultural output.

Evaluation of industrial competitiveness of Heilongjiang agriculture

We gain the orders of the indicators by the method of Group eigenvalue, and then rank the control variables in the mutation models according to the index weight. In consideration of the limited space, we evaluate the state of industrial competitiveness of Heilongjiang agriculture, based on the data from 31 provinces in China in 2012. Meanwhile in order to avoid the difference made by the different statistic dimension among these indexes, we standardize the data with the formula (10) to the value interval [0, 1], keeping to the constraint condition of catastrophe theory.

$$\mathbf{y_{ij}} = \frac{\mathbf{x_{ij}} - \min\limits_{1\le j\le n} \mathbf{x_{ij}}}{\max\limits_{1\le j\le n} \mathbf{x_{ij}} - \min\limits_{1\le j\le n} \mathbf{x_{ij}}}, \mathbf{i = 1,2,\cdots,m; j = 1,2,\cdots,n} \tag{10}$$

In (12), i represents the amount of evaluation indexes, and j represents the amount of evaluation objects. According to the formula (10), we standardize the data, and results are shown in TABLE 3.

Based on the standardization data in TABLE 3, we calculate the level of competitiveness of Heilongjiang with the catastrophe progression method.

There are two three-level indicators in the ecological resources, which are A1 and A2 in TABLE 2. The two indicators of A1 and A2 struck the system of pinnacle mutation, and in the principle of complement, we calculate the mean of the two as the score of upper layer. Moreover, the weighted value ranking is A1 and A2, so calculate the evaluation value according to A1 first and A2 second, the specific procedure is as (11).

The system of butterfly mutation is composed by B1, B2, B3, and B4, so in the principle of complement, we calculate the mean of the four as the score of upper layer. Because the criticality value ranking is B2, B1, B4 and B3, calculate the evaluation value according to above orders. The specific procedure is as following (12).

$$X_{A1} = \sqrt{A1} = \sqrt{1} = 1, X_{A2} = \sqrt[3]{A2} = \sqrt[3]{0.0148} = 0.2463;$$
$$X_A = average(X_{A1}, X_{A2}) = 0.6232 \tag{11}$$

$$X_{B2} = \sqrt{B2} = \sqrt{0.3608} = 0.6007\ ,\ X_{B1} = \sqrt[3]{B1} = \sqrt[3]{0.9143} = 0.9706\ ,$$
$$X_{B4} = \sqrt[4]{B4} = \sqrt[4]{0.0373} = 0.4396\ ,\ X_{B3} = \sqrt[5]{B3} = \sqrt[5]{0.3463} = 0.8089$$
$$X_B = average(X_{B1}, X_{B2}, X_{B3}, X_{B4}) = 0.7049 \quad (12)$$

TABLE 3 : Standardizing data of evaluation indexes

	A1	A2	B1	B2	B3	B4	C1	C2	C3	D1	D2	D3
Beijing	0	0.0004	0.0017	0.0104	0.0128	0.0273	0.1864	0.0394	0.1308	0.0113	0.0354	0.2727
Tianjin	0.0181	0.0007	0.0276	0.037	0.0287	0.0298	0	0.1072	0.211	0.0831	0.0329	0.3068
Hebei	0.5247	0.0013	0.8797	0.8484	0.4773	0.3497	0.5246	0.1826	0.8921	0.3172	0.6671	0.3977
Shanxi	0.3297	0.0011	0.2237	0.2392	0.1668	0.0554	0.3195	0.074	0.4165	0.1944	0.1515	0.5795
Neimengu	0.5962	0.0139	0.5845	0.2574	0.2708	0.032	0.5357	0.5722	0.6529	0.8891	0.2978	0.5909
Liaoning	0.3323	0.008	0.2996	0.1962	0.2089	0.2197	0.4655	0.3734	0.6638	0.378	0.5039	0.5
Jilin	0.4572	0.0112	0.3301	0.1984	0.2969	0.0266	0.2914	0.4737	0.4147	0.768	0.3045	0.6136
Heilongjiang	1	0.0149	0.9143	0.3608	0.3463	0.0373	0.5044	0.6274	0.8391	1	0.4898	0.7045
Shanghai	0.0011	0	0	0	0.0088	0.1227	0.1791	0	0	0	0.026	0
Jiangsu	0.3908	0.0024	0.7452	0.3333	0.4798	1	1	0.0797	0.2709	0.284	0.727	0.4886
Zhejiang	0.1456	0.0182	0.2541	0.1931	0.1283	0.5125	0.4704	0.118	0.2126	0.117	0.3245	0.1477
Anhui	0.4741	0.0075	0.6763	0.4705	0.4835	0.0754	0.5045	0.2009	0.4142	0.3644	0.4612	0.5795
Fujian	0.0947	0.0285	0.1537	0.0954	0.1706	0.184	0.2192	0.1133	0.2596	0.1924	0.3691	0.4318
Jiangxi	0.2238	0.0342	0.3412	0.3646	0.2006	0.0493	0.4345	0.118	0.3772	0.3184	0.2914	0.4659
Shandong	0.628	0.001	0.9705	1	0.6937	0.2742	0.8771	0.2432	1	0.3627	1	0.4545
Henan	0.6634	0.001	1	0.8743	1	0.1705	0.6902	0.1665	0.9162	0.4152	0.8382	0.4545
Hubei	0.3822	0.0092	0.4694	0.303	0.515	0.0656	0.487	0.1302	0.5851	0.3268	0.5894	0.5795
Hunan	0.3067	0.0209	0.5027	0.4125	0.3593	0.0644	0.5309	0.0759	0.5489	0.3115	0.6114	0.2841
Guangdong	0.2241	0.013	0.3346	0.1937	0.3538	0.6998	0.6715	0.0558	0.3706	0.0973	0.5798	0.3636
Guangxi	0.3437	0.0316	0.2681	0.2505	0.3591	0.0367	0.4105	0.1673	0.4042	0.2267	0.4308	0.5909
Hainan	0.0427	0.0291	0.0115	0.0298	0.0596	0.0045	0.0347	0.1634	0.0335	0.2498	0.1231	0.6591
Chongqing	0.1728	0.0108	0.1007	0.0853	0.1339	0.0429	0.2379	0.1832	0.4097	0.2384	0.164	0.5227
Sichuan	0.4928	0.0251	0.4921	0.291	0.365	0.0914	0.8482	0.1967	0.4857	0.2782	0.679	0.4545
Guizhou	0.3667	0.0194	0.2029	0.162	0.1372	0.0316	0.3995	0.1425	0.0765	0.1871	0.1684	1
Yunnan	0.5036	0.0255	0.2954	0.2244	0.302	0.0429	0.6394	0.2972	0.2173	0.2401	0.3273	0.7386
Xizang	0.0112	1	0.0104	0.0286	0	0	0.0638	1	0.0148	0.2525	0	0.3523
Shanxi	0.3292	0.0065	0.2154	0.1818	0.3456	0.0835	0.4218	0.0929	0.5454	0.2032	0.2791	0.625
Gansu	0.3817	0.0065	0.2194	0.176	0.1282	0.0276	0.3084	0.2664	0.18	0.2591	0.1584	0.6705
Qinghai	0.0268	0.1133	0.0105	0.0262	0.0063	0.0021	0.051	0.3273	0.0714	0.1561	0.0186	0.5568
Ningxia	0.0755	0.0002	0.0584	0.0548	0.0506	0.007	0.0594	0.3372	0.0684	0.4561	0.0341	0.625
Xinjiang	0.3356	0.0285	0.765	0.1508	0.2763	0.0441	0.4048	0.6492	0.2975	0.4852	0.2756	0.7841

The system of swallow tail mutation is composed by C1, C2, and C3. Based on the principle of complement, we calculate the mean of the three as the score of upper layer. Because the criticality value ranking is C1, C2 and C3, calculate the evaluation value according to above orders. The specific procedure is as (13).

$$
\begin{aligned}
&X_{C1} = \sqrt{C1} = \sqrt{0.5044} = 0.7102\ , X_{C2} = \sqrt[3]{C2} = \sqrt[3]{0.6274} = 0.8561\ ,\\
&X_{C3} = \sqrt[4]{C2} = \sqrt[4]{0.8391} = 0.9571\\
&X_{C} = average(X_{C1}, X_{C2}, X_{C3}) = 0.8411
\end{aligned} \tag{13}
$$

$$
\begin{aligned}
&X_{D2} = \sqrt{D2} = \sqrt{0.4898} = 0.6999\ , X_{D2} = \sqrt[3]{D2} = \sqrt[3]{1} = 1\ ,\\
&X_{D3} = \sqrt[4]{D3} = \sqrt[4]{0.7045} = 0.9162\\
&X_{D} = average(X_{D1}, X_{D2}, X_{D3}) = 0.8720
\end{aligned} \tag{14}
$$

The model of swallow tail mutation system is composed by D1, D2, and D3. Based on the principle of complement, we calculate the mean of the three as the score of upper layer. Because the criticality value ranking is D2, D1 and D3, calculate the evaluation value according to above orders. The procedure is as (14).

The indicators of criterion layer, A, B, C, and D, compose the system of butterfly mutation, so in the principle of complement, we calculate the mean of the four as the score of object indicator, which is what we need, the final level of competitiveness of Heilongjiang. Because the criticality value ranking is B, D, C and A, we calculate the evaluation value according to above orders. The procedure is as (15).

According to above calculating procedure, the score of Heilongjiang is 0.9156, ranking at the higher level. The scores of the four indicators in criterion layer, A, B, C, D, respectively are 0.6232, 0.7049, 0.8411, and 0.8720. In order to analyze the level more comprehensively, we will further learn the change trend from 2007 to 2012, and compare to other provinces, from the perspective of vertical time and horizontal space.

$$
\begin{aligned}
&X_{B} = \sqrt{B} = \sqrt{0.7049} = 0.8396\ , X_{D} = \sqrt[3]{D} = \sqrt[3]{0.8720} = 0.9554\\
&X_{C} = \sqrt[4]{C} = \sqrt{0.8411} = 0.9577\ , X_{A} = \sqrt[5]{A} = \sqrt[5]{0.6232} = 0.9079\\
&r = average(X_{A}, X_{B}, X_{C}, X_{D}) = 0.9156
\end{aligned} \tag{15}
$$

Analysis of results

As it shown in TABLE 4, the evaluation value of natural resources endowment increases gradually, but changes hardly, due to its inherent feature. The value of social conditions of agricultural production rises to 0.704927 in 2012, increasing by 9.4% compared to 0.644316 in 2007, which presents that the condition was being improved in recent years, but as one of the key factors such improvement is not enough. Heilongjiang agriculture investment fluctuated greater in these years; it declined from 2007 to 2009, and then began to increase from 2009. The above phenomenon may be affected by the global economic crisis in 2007, which weakened the government investment and further hindered the asset acquisition; consequently the level of agricultural investment went down. After that, government adjusted the policy to strengthen the building of the infrastructure and stimulate consumption, so the investment on agriculture was raised between 2009 and 2012. Finally it is shown that the competitiveness is being improved gradually, but hoisting speed is slow, that is because the competitiveness of Heilongjiang are always keeping in the lead of China, so it is seem reasonable with slow speed.

TABLE 4 : Level of industrial competitiveness of Heilongjiang agriculture 2007-2012

	2007	2008	2009	2010	2011	2012
Natural resources endowment	0.598902	0.593937	0.630139	0.620606	0.610036	0.623164
Social conditions of agricultural production	0.644316	0.649621	0.662081	0.677086	0.689131	0.704927
Agricultural investment	0.796835	0.786272	0.756191	0.828461	0.841405	0.841128
Agricultural output	0.733919	0.855375	0.837239	0.856178	0.867594	0.872013
Overall level	0.888	0.8995	0.9001	0.9089	0.9119	0.9156

TABLE 5 : The evaluation values of industrial competitiveness of agriculture 2007-2012

	2007	2008	2009	2010	2011	2012
Beijing	0.648	0.6459	0.5319	0.6429	0.6355	0.6427
Tianjin	0.6867	0.6924	0.6988	0.6924	0.7004	0.6981
Hebei	0.9088	0.9066	0.9064	0.909	0.9071	0.9057
Shanxi	0.7754	0.8171	0.8201	0.8244	0.8242	0.8222
Neimengu	0.8772	0.8843	0.878	0.8856	0.8885	0.8867
Liaoning	0.862	0.8612	0.8563	0.8674	0.8691	0.8677
Jilin	0.8486	0.8612	0.8591	0.863	0.8622	0.8635
Heilongjiang	0.888	0.8995	0.9001	0.9089	0.9119	0.9156
Shanghai	0.6065	0.5252	0.5162	0.5182	0.4779	0.481
Jiangsu	0.8961	0.8953	0.8985	0.899	0.8987	0.895
Zhejiang	0.8382	0.8369	0.8343	0.8396	0.8342	0.8279
Anhui	0.8789	0.8802	0.884	0.8836	0.8811	0.8834
Fujian	0.8154	0.8129	0.8138	0.8211	0.8136	0.8169
Jiangxi	0.8419	0.8424	0.8455	0.8488	0.844	0.8498
Shandong	0.9321	0.9305	0.9302	0.9322	0.9312	0.928
Henan	0.9249	0.9264	0.9286	0.9304	0.9241	0.9204
Hubei	0.8663	0.8711	0.8719	0.8746	0.8732	0.8732
Hunan	0.8688	0.8686	0.8711	0.8742	0.872	0.8685
Guangdong	0.8581	0.8585	0.8593	0.8615	0.8599	0.8583
Guangxi	0.8502	0.8503	0.8513	0.8534	0.855	0.8558
Hainan	0.732	0.7416	0.7479	0.7408	0.7361	0.7401
Chongqing	0.8036	0.7981	0.8029	0.8051	0.8067	0.8058
Sichuan	0.8847	0.8819	0.8846	0.8865	0.8874	0.8863
Guizhou	0.8083	0.8147	0.8162	0.8194	0.8081	0.8263
Yunnan	0.8573	0.8592	0.8586	0.8588	0.8607	0.8634
Xizang	0.6887	0.6896	0.709	0.7083	0.7091	0.7076
Shanxi	0.8341	0.8346	0.8366	0.8419	0.8443	0.842
Gansu	0.8193	0.8204	0.8223	0.8247	0.8248	0.827
Qinghai	0.7252	0.7156	0.722	0.7271	0.7277	0.7297
Ningxia	0.7506	0.7414	0.7465	0.752	0.744	0.7466
Xinjiang	0.8628	0.8613	0.8616	0.8678	0.8696	0.871

Furthermore, we compare Heilongjiang to other leading provinces, such as Shandong, Henan, and Hebei, with average values of more than 0.86. Shandong and Henan rank the first two with the score above 0.92, but Henan has appeared to being down from 2010. With oblivious raising trend, Heilongjiang has ranked to the third place in 2012.

From the final ranking results, we learn that the level of different provinces is quite different in the six years. For example, Heilongjiang scored 0.888 in 2007, lower than 0.9088 of Henan, however it scored 0.9156 in 2012, higher than Henan. The above phenomenon illustrates that the development of provinces are unbalance. After equalization the value of 31 provinces, we calculate the level of competitiveness in recent years.

The ranking results are coincident with their demands of natural resource endowment, for example, the last two are Beijing and Shanghai, although with developed economics and industry, their agriculture competitiveness lag behind due to lacking of natural resources for agriculture. We also find that the constrain from the natural resource is not absolute, with well developed industry and agriculture, the example of Jiangsu province shows that although in the condition of limited land, it is also important to improve the social conditions of agricultural production and capital investment.

CONCLUSION

Based on the methods of group eigenvalue and catastrophe progression, we construct the evaluation index system of the competitiveness of agricultural industrial of Heilongjiang, including four indicators of natural resources endowment, social conditions of agricultural production, agricultural investment, and agricultural output. We empirically evaluate the competitiveness of agricultural industry of 31 provinces, and then rank their order by average values. The results show: the competitiveness of agricultural industrial of Heilongjiang has grown smoothly and steady in recent years, from the fifth in 2007 to the third place in 2012, and it will be increased much larger. Although the results are valuable, the paper is still inadequacy due to some limits from objective condition. Therefore, we will explore the following two aspects in the future. First, we may consider the factors from cities in the province; second, we can collect data with much long period of time to show the trends.

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