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Regional disparities and dynamic evolution of competitiveness of marine fish aquaculture industry – A study of China

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Abstract – China has emerged as a major player in marine fish aquaculture, contributing significantly to economic, social, and environmental development. Analyzing the competitive evolution pattern of regional marine aquaculture is critical to promote the synergistic development of this industry. The "vertical and horizontal" scatter degree method was employed to examine the dynamic evolution trend and spatial non-equilibrium of the competitiveness level of marine fish aquaculture in nine Chinese provinces and cities. Using the σ-convergence model and absolute β-convergence model, the evolution of absolute differences was characterized. The study reveals the existence of stage and regional characteristics of marine fish aquaculture in the nine provinces and cities, with an observable gradient effect. The overall difference is observed to decrease, indicating a trend towards regional synergistic development in the marine fish aquaculture industry. This finding holds practical significance and theoretical value in promoting the growth of the industry.

Keywords: Industrial competitiveness / "vertical and horizontal" scatter degree method / regional convergence / marine fish aquaculture / China

1 Introduction

China has about 3 million square kilometers of ocean land, and 18,000 kilometers of mainland coast, but large-scale mariculture began in the 1980 s, and marine fish aquaculture did not begin until the late 1990 s (Lin and Dong, 2021). China's marine fish aquaculture production grew from 638,510 tons in 1984 to 1749764 tons in 2020, and per capita consumption of marine products grew from less than 2 in 1950 to 24 kg in 2015. China's marine industry is becoming increasingly influential in the international arena (Fabinyi et al., 2017).

China's marine fish aquaculture industry (MFAI) is mainly distributed in nine coastal provinces, respectively Hebei, Liaoning, Jiangsu, Zhejiang, Shandong, Fujian, Guangdong, Guangxi, and Hainan. Since 2016, to promote the healthy development of China's seawater fish industry system, the Ministry of Agriculture and Rural Affairs (MARA) has established a national technology system for MFAI, including genetic improvement, quality and safety, nutritional quality, pond breeding, fish processing, industrial economy, and disease prevention and control functions. Given this, what is the development status of the marine fish aquaculture industry in each province of China? Does the level of competitiveness of the marine fish aquaculture industry in each region tend to be consistent?

However, there are relatively few academic studies on the competitiveness of the MFAI, mainly concerning aquaculture patterns (Lindfors and Jakobsen, 2022), consumption patterns (Zhang et al., 2021; Fabinyi et al., 2016; Thong and Solgaard, 2017), and economic benefits (Crona et al., 2020; Almeida et al., 2015). Nevertheless, some scholars have analyzed the competitiveness of fisheries from the perspective of fishery products, pointing out the importance of production factor costs in fish production and exports (Chenery, 1965); proposing the connotation of domestic resource costs (Balassa and Schydlowsky, 1972).

Research on competitiveness has been conducted mainly from two perspectives: explaining the meaning of competitiveness and evaluating the competitiveness of industries, which can be summarized into three aspects. Firstly, the competitiveness of the industry is analyzed from the perspective of strengths and weaknesses (Barney, 1995; Valentin, 2001), and the domestic demand advantage can improve the competitiveness of the industry (Neculita and Moga, 2015); secondly, it is analyzed from the perspective of resources (Wernerfelt, 1984; Omoregie, 2001; Koebel et al., 2016), such as human input (Cho, 1994), technology input (Kadarusman, 2013), management skills (Singh, 2018),

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Table 1. Evaluation index system of competitiveness of the MFAI.

Criteria level	Primary indicators	Secondary indicators	Unit
Industrial base	Industrial environment base (IE)	Marine fish aquaculture area (W1)	Hectare
		Number of fish fries (W2)	Pieces
		Number of marine motorized fishing boats (W3)	Vessel
		Number of aquatic products cold storage (W4)	Block
	Technical support base (TS)	Number of professional stations/total institutions of aquatic technology extension institutions (W5)	%
		Number of people with bachelor's degree or above / total number of fishery management personnel (W6)	%
		Number of people with bachelor's degree or above / total number of technical extension personnel (W7)	%
Industrial Output	Development potential (DP)	Marine fish production per unit aquaculture area (W8)	Tons/hectare
		The scale of the advanced aquaculture model (W9)[1]	Cubic meter
	Economic benefits (EB)	The total yield of marine fish aquaculture (W10)	Ton
		The total output value of marine fish culture (W11)	RMB
		Per capita net income of fishermen (W12)	RMB
	Penetration capacity (PC)	The total output value of aquatic distribution / total output value of fishery distribution and service industry (W13)	%

[1] The scale size of advanced aquaculture mode is the total scale of deep-water nets and factory aquaculture.

etc. Thirdly, based on the perspective of the value chain (Barney and Wright, 1998), it is considered that the value chain is the core force to improve competitiveness (Webb and Gile, 2001). From the methods of studying industrial competitiveness, competitiveness can be evaluated not only from the methods of management and economics; but also, from the methods of statistics. At present, some scholars use the DEA model (Mahajan et al., 2020), SEM model (Sarros et al., 2008), hierarchical analysis method (Singh, 2018), and other methods to evaluate industrial competitiveness.

The current literature studying the competitiveness of the marine fish aquaculture industry is relatively small and the research is not yet in-depth. The development of the marine fish culture industry itself is a dynamic process, and most of the previous studies are static data analyses. Therefore, this thesis intends to use the "vertical and horizontal" scatter degree method to compare the development level of MFAI in each province and region dynamically through two dimensions of time and space, and combine the σ-convergence test and absolute β-convergence test to analyze the development status of MFAI in each province, and analyze whether there is a convergence trend in the competitiveness level of MFAI between regions. These issues are of great practical significance for revealing the evolutionary trends of development differences between regions in the marine fish culture industry and exploring the path of coordinated development of the MFAI.

2 Materials and methods

2.1 Constructing the evaluation index system

"Green development, increase production and income, improve quality and efficiency, and enrich fishermen" is taken as the development orientation of the marine fish aquaculture industry, while increasing industrial investment and encouraging technological progress. Therefore, we constructed the evaluation index system of the competitiveness level of the marine fish culture industry from two criterion layers of industrial foundation and industrial output, based on combining the system layout and development goals of the national marine fish industry system.

A solid industrial foundation is a guarantee for the rapid development of marine fish farming. Hence, based on following the principles of scientificity, operability, and comparability, as well as referring to relevant research results, the evaluation index system of competitiveness of the MFAI is constructed, including two guideline layers of industrial foundation, and industrial output, five primary indicators such as industrial environmental foundation, technical support foundation, development potential, economic benefits, and penetration capacity, and 13 secondary indicators such as marine fish culture area and total yield of marine fish aquaculture (Tab. 1).

For sample selection, we selected Hebei, Liaoning, Jiangsu, Zhejiang, Shandong, Fujian, Guangdong, Guangxi, and Hainan for evaluation because these provinces have marine fish aquaculture industries.

2.2. Empirical methods

2.2.1 The "vertical and horizontal" scatter degree method

This study attempts to examine whether the level of competitiveness of the MFAI tends to converge between regions, over the period from 2016 to 2020. For one thing, to compare the differences in development levels between regions within a given year; for another, to reflect the development trend of a region over time. Since the subjective-objective assignment method is a static analysis method, it is not suitable for the analysis of panel data. Thus, we adopt the dynamic analysis method of "vertical and horizontal" scatter degree, and make a comprehensive evaluation of the competitiveness level of the MFAI in both "vertical" and “horizontal” latitudes, to show the differences in the competitiveness level of the MFAI in each region as far as possible. The specific calculation steps are as follows.

The “vertical and horizontal” scatter degree method is a comprehensive dynamic analysis of n identical evaluation indicators (b_1, b_2, ... b_n) of m evaluation objects (a_1, a_2, ... a_m) at a certain time (t_1, t_2, ..., t_s). According to the established index system, the initial data $\phi_{ij}(t_T)$ is obtained. (where i=1, 2, ..., m; j=1, 2, ..., n; T=1, 2, ..., s). Firstly, a set of data sets $\mu_{ij}(t_T)$ after preprocessing is required, by integrating and dimensionless form of the initial data set $\phi_{ij}(t_T)$. Then the integrated evaluation function $w_i(t_T)$ is obtained by linear weighting method.

$$w_i(t_T) = \sum_{j=1}^{n} z_j \mu_{ij}(t_T) \quad (i = 1, 2, \ldots, m; j = 1, 2, \ldots, n; T = 1, 2, \ldots, s). \tag{1}$$

In formula (1), z_j is the weighting factor. To capture the development gap between regions to a larger extent, it is necessary to use the squared deviation of $w_i(t_T)$ and the square of θ to determine.

$$\theta^2 = \sum_{T=1}^{s}\sum_{i=1}^{m}\left(w_i(t_T) - \overline{w}\right)^2. \tag{2}$$

After normalizing the data, $\overline{w} = 0$ in equation (2) and θ^2 after simplification is:

$$\theta^2 = \sum_{T=1}^{s}\sum_{i=1}^{m}\left(w_i(t_T)\right)^2 = Z^T\sum_{T=1}^{s}A_T Z = Z^T A Z. \tag{3}$$

In formula (3), $Z = (z_1, z_2, \ldots z_n)^T$ as the column vector and $A = \sum_{T=1}^{s} A_T$ is an $n \times n$ order symmetric matrix, where $A_T = \mu_T^T \mu_T$.

$$\mu_T = \begin{bmatrix} \mu_{11}(t_T) & \ldots & \mu_{1n}(t_T) \\ \vdots & \ldots & \vdots \\ \mu_{m1}(t_T) & \ldots & \mu_{mn}(t_T) \end{bmatrix}, \mathrm{T} = 1, 2 \ldots \mathrm{s}. \tag{4}$$

In order to find the maximum value of θ^2, it is transformed into a linear programming solution problem.

$$\max\ Z^T A Z$$

$$s.t\begin{cases} Z^T Z = 1. \\ Z > 0 \end{cases} \tag{5}$$

That is, when taking the eigenvector corresponding to the largest eigenvalue of A, the maximum value of θ^2 is satisfied.

The annual evaluation value of each region can be obtained by bringing the weight coefficient z_j into formula (1). The quadratic weighting can highlight the comprehensive development level of each region over some time under the influence of time factors. In this paper, we adopt the principle of “thickening the present and thinning the past” and assign increasing time weighting coefficients from 2016 to 2020, i.e., the farthest period from the present is assigned the smallest time weighting coefficient and the closest period is assigned the largest time weighting coefficient, and the sum of all time weighting coefficients is 1. The specific expressions are is as follows.

$$w_T = T / \sum_{T=1}^{s} T (T = 1, 2, \ldots s) \text{ and } \sum_{T=1}^{s} w_T = 1. \tag{6}$$

The comprehensive evaluation value y_i of the evaluation object a_i in the period $[t_I, t_s]$ is derived according to the quadratic weighting from the time weighting coefficient w_T in formula (7) and the evaluation value $w_i(t_T)$ of each region in formula (1).

$$y_i = \sum_{T=1}^{s} w_T w_i(t_T) (T = 1, 2, \ldots s). \tag{7}$$

2.2.2 σ-convergence model

If the gap between samples gradually decreases over time, it is called σ-convergence. Usually, σ-convergence can be measured by the coefficient of variation, Gini coefficient, etc. The coefficient of variation can not only reflect the overall development trend; but also examine the contribution of the differences in development levels among sample areas to the overall differences (Rezitis, 2010). So, this paper uses the coefficient of variation to measure whether there is a convergence trend in the level of competitiveness of the MFAI among the samples. If the coefficient of variation keeps getting smaller over time, it indicates that there is σ-convergence in the competitiveness level of MFAI among regions; if the coefficient of variation becomes larger, it indicates that there is no σ-convergence. The model of σ-convergence in the competitiveness level of the MFAI is:

$$\sigma_T = \sqrt{\sum_{i=1}^{m}\left[w_i(t_T) - \frac{1}{m}\sum_{i=1}^{m} w_i(t_T)\right]^2}. \tag{8}$$

2.2.3 Absolute β-convergence model

The β-convergence model is derived from the economic convergence theory, which means that the regions with lower industrial competitiveness levels at the beginning have faster growth rates than the regions with higher competitiveness levels, that is, the growth rate of industrial competitiveness level is negatively correlated with the initial industrial development level (Barro, 1992). In this paper, the absolute β-convergence model is used, which means that the competitiveness level of the MFAI in each region will converge without considering the influence of external factors. Referencing the existing studies (Xu et al., 2020; Yu et al., 2020), the absolute β-convergence model of the competitiveness level of the MFAI takes the following form:

$$\frac{lny_i(t_{T+N}) - lny_i(t_T)}{N} = \alpha + \beta lny_i(t_T) + \epsilon_{i,T}, \tag{9}$$

Table 2. Weight coefficients of each evaluation index.

Evaluation indicators	Weighting factors
Marine fish aquaculture area (W1)	0.105
Number of fish fry (W2)	0.104
Number of marine motorized fishing boats (W3)	0.099
Number of aquatic products cold storage (W4)	0.086
Number of professional stations/total institutions of aquatic technology extension institutions (W5)	0.045
Number of people with bachelor's degree or above / total number of fishery management personnel (W6)	0.047
Number of people with bachelor's degree or above / total number of technical extension personnel (W7)	0.038
Marine fish production per unit aquaculture area (W8)	0.036
The scale of the advanced aquaculture model (W9)	0.095
The total yield of marine fish aquaculture (W10)	0.106
The total output value of marine fish culture (W11)	0.099
Per capita net income of fishermen (W12)	0.041
The total output value of aquatic distribution / total output value of fishery distribution and service industry (W13)	0.098

$$y_{i(t_{T+N})} = \frac{1}{m}\sum_{i=1}^{m} w_i(t_{T+N}), \quad (10)$$

$$y_i(t_T) = \frac{1}{m}\sum_{i=1}^{m} w_i(t_T), \quad (11)$$

where, $lny_i(t_T)$ denotes the mean logarithm of the assessed value of the competitiveness level of MFAI in m provinces in year T, $lny_i(t_{T+N})$ denotes the mean logarithm of the assessed value of the competitiveness of industry in m provinces after N years, $\frac{lny_i(t_{T+N})-lny_i(t_T)}{N}$ denotes the average development rate of industry competitiveness in m provinces in N years, α denotes the constant term, β denotes the convergence coefficient, and $\epsilon_{i,T}$ denotes the error term. If $\beta < 0$ and passes the significance test, there exists absolute β-convergence in the level of industrial competitiveness, indicating that there is regional convergence in the level of competitiveness of the MFAI among provinces and cities; otherwise, there is not.

2.3 Data processing

According to the evaluation indicators selected in this study, all data were obtained from the China Fisheries Statistical Yearbook from 2017 to 2021, and individual indicator data needed to be obtained by calculating the original data, and the data of each indicator were true. Based on the constructed evaluation index system of the competitiveness level of the MFAI, the original data were collected, and due to the differences in the types and units of these data, all the original data needed to be standardized; the indicators constructed in this paper are of the same type and are all positive indicators, so there is no need to standardize the data. Therefore, all the raw data are processed by "Z-score normalization".

$$\mu_{ij}(t_T) = \frac{\varphi_{ij}(t_T) - \varphi_j(t_T)}{\gamma_j(t_T)} \quad (12)$$

where $\phi_{ij}(t_T)$ is the original data, $\phi_j(t_T)$ is the mean of the original data, $\gamma_j(t_T)$ is the standard deviation of the original data, and $\mu_{ij}(t_T)$ is the data after the normalization process.

3 Results

3.1. One time-weighted results

The annual evaluation value of each region weighted by the "vertical and horizontal" scatter degree method can analyze the development trend of the competitiveness level of MFAI in a region from 2016 to 2020 vertically, and can also compare the variability of the competitiveness level of MFAI among regions in a certain year horizontally. Based on the evaluation system of the competitiveness level of the MFAI established in this paper, the weight coefficient z_j corresponding to each indicator is obtained according to the above formula (Tab. 2), and then the evaluation value of the competitiveness level of the MFAI in each year of the nine provinces in China can be derived from the formula (1) (Tab. 3).

In general, the competitiveness level of China's MFAI presents a situation of three echelons, high, medium, and low, during the 5 yr statistical period. Fujian, Guangdong, and Shandong are the first echelon, the second echelon is Liaoning, Zhejiang, and Jiangsu, and the remaining in the third echelon (Fig. 1).

The specific developments in Fujian, Guangdong and Shandong are illustrated in Figure (a), Figure (b) and Figure (c) respectively (as shown in Figure 2). The competitiveness level of the marine fish aquaculture industry in these three regions is in the first echelon. Relative to other regions, these three areas have higher scores for each indicator. And there is also a common feature that they have the highest scores for the industrial environment base indicators, among which Fujian has the highest score and relatively excellent resource endowment of the marine fish farming industry. The scores of each indicator are stable from year to year, but the economic efficiency score of Shandong plummeted in 2020, probably due to the impact of the new crown epidemic.

The specific developments in Liaoning, Zhejiang, and Jiangsu are illustrated in Figure (d), Figure (e) and Figure (f) respectively (as shown in Figure 2). Compared with the first

Table 3. Evaluation and ranking of competitiveness level.

Year	2016		2017		2018		2019		2020	
Time weights	1/15		2/15		3/15		4/15		5/15	
Region	Score	Rank	Score	Rank	Score	Rank	Score	Rank	Score	Rank
Hebei	−0.627	9	−0.609	9	−0.592	9	−0.649	9	−0.411	7
Liaoning	0.100	4	0.015	4	−0.036	4	−0.106	5	0.215	3
Jiangsu	−0.215	6	−0.202	6	−0.190	6	−0.136	6	−0.183	6
Zhejiang	−0.085	5	−0.057	5	−0.052	5	−0.006	4	0.059	5
Fujian	0.985	1	1.037	1	1.056	1	0.984	1	0.827	1
Shandong	0.761	2	0.624	3	0.619	2	0.499	3	0.150	4
Guangdong	0.589	3	0.629	2	0.519	3	0.704	2	0.645	2
Guangxi	−0.449	8	−0.501	8	−0.455	8	−0.522	8	−0.485	9
Hainan	−0.404	7	−0.405	7	−0.285	7	−0.356	7	−0.448	8

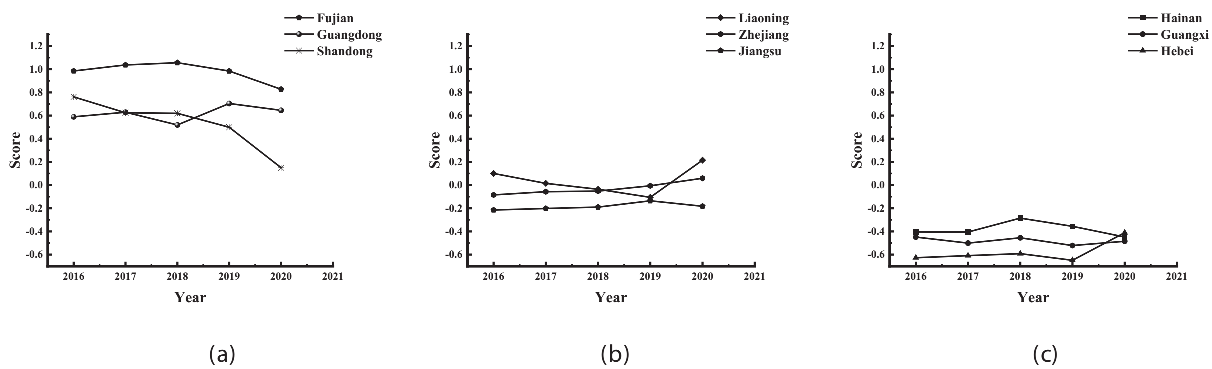

Fig. 1. Development trend of MFAI competitiveness level. (**a**) Development trend of the first echelon; (**b**) Development trend of the second echelon; (**c**) Development trend of the third echelon.

echelon regions, the scores of these three areas for each indicator are at a moderate level, and the scores fluctuate less from year to year. The economic efficiency score of Liaoning turned from negative to positive in 2020, which is breakthrough progress. Zhejiang and Jiangsu have more penetration capacity in the marine fish farming industry.

The specific developments in Hainan, Guangxi, and Hebei are illustrated in Figure (g), Figure (h) and Figure (i) respectively (as shown in Figure 2). These three regions are in the third echelon of the development level of the marine fish aquaculture industry, with unsatisfactory scores for each indicator. In contrast to the first echelon regions, the third echelon regions have the lowest industrial environment base scores and weaker resource endowment, but the technical environment index scores are higher compared to other indexes, and these regions may try to use technical means to compensate for the resource deficiency.

3.2 Secondary weighted results

To further analyze the influence of the time factor, a comprehensive evaluation of the competitiveness level of the MFAI in nine provinces and municipalities is now made by quadratic weighting. The time weight coefficients for each year are derived from equation (7) (second row of Tab. 3), and the time weight coefficients and the primary weighted evaluation values are brought into equation (8), and the resulting values are the comprehensive evaluation values for the statistical period of the sample provinces (Tab. 4).

3.3 Convergence test

The above comprehensive evaluation values show that there are still significant differences in the level of competitiveness of China's MFAI between regions. Accordingly, we use σ-convergence and the absolute β-convergence to test whether there is a regional convergence trend in the model.

3.3.1 σ-convergence test results

From the overall region, the value of the σ-convergence coefficient gradually reduced in the period of 2016–2020, indicating the existence of a regional convergence trend (as shown in Fig. 3.). Specifically, in 2016–2019 σ-coefficients showed a weak trend of decreasing, and in 2020 σ-coefficients decline more, denoting that the difference in the level of competitiveness of the marine fish farming industry in each region shows signs of reduction. By region, the σ-coefficient in the north shows a decreasing trend and there is a σ-convergence feature, indicating that the difference in the competitiveness level of the marine fish culture industry in the north is

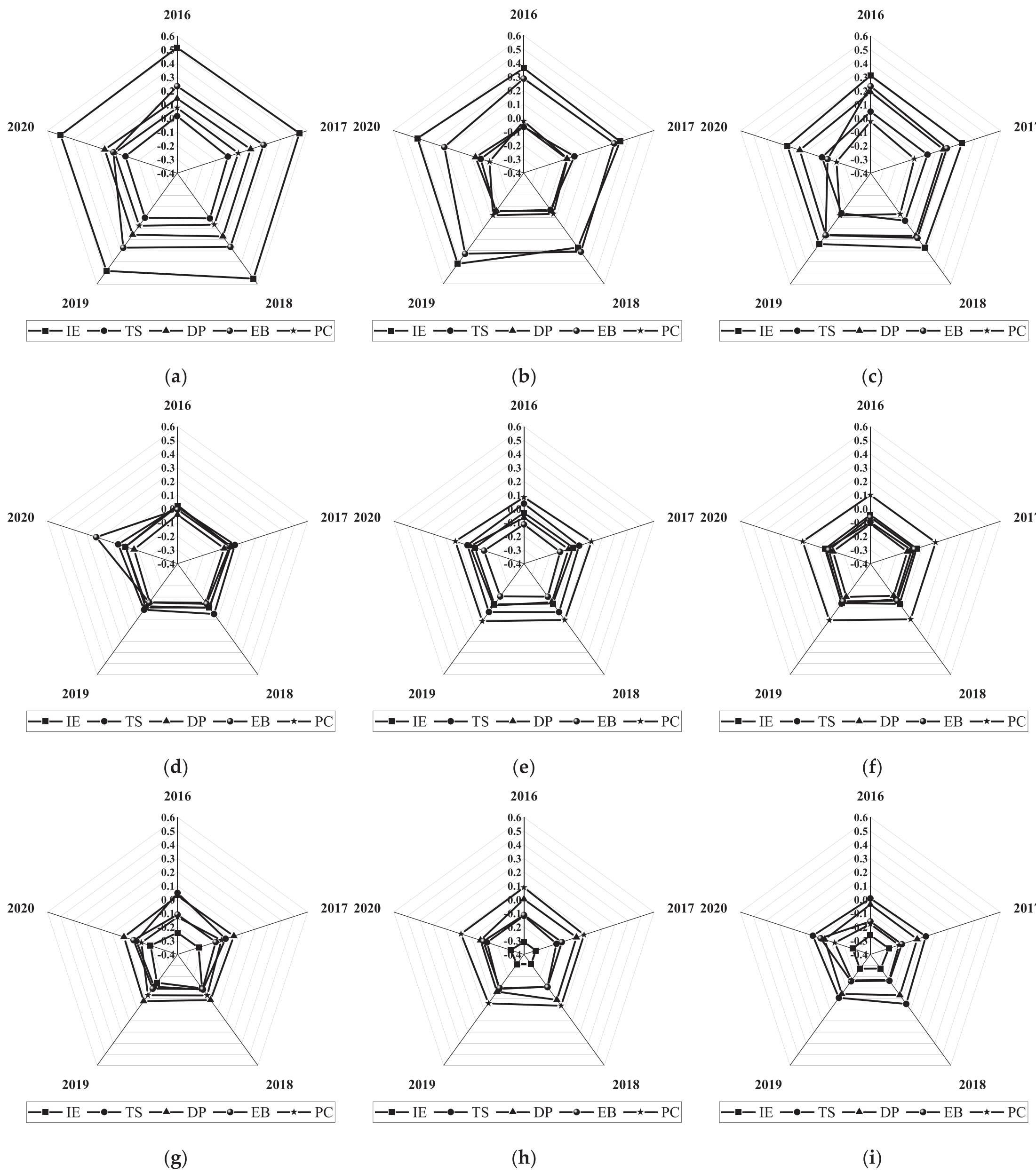

Fig. 2. Development trend of primary indicators. (a) Development trend of primary indicators in Fujian; (b) Development trend of primary indicators in Guangdong; (c) Development trend of primary indicators in Shandong; (d) Development trend of primary indicators in Liaoning; (e) Development trend of primary indicators in Zhejiang; (f) Development trend of primary indicators in Jiangsu; (g) Development trend of primary indicators in Hainan; (h) Development trend of primary indicators in Guangxi; (i) Development trend of primary indicators in Hebei.

gradually decreasing (as shown in Fig. 3). However, the changing trend of the competitiveness level of the marine fish farming industry in the southern region generally shows an "M" type characteristic and does not show obvious σ-convergence characteristics (as shown in Figure 3).

Based on the comparison between the overall region and the southern and northern regions, it can be found that the standard deviation of the competitiveness level of the marine fish culture industry in the south is greater than that of the overall region and the north. At the overall level, the difference in the competitiveness level of China's marine fish farming industry is relatively high, and by region, the difference in the competitiveness level of the marine fish farming industry in the south is the largest, and the north shows an obvious convergence trend in 2018~2020, and the difference in the competitiveness level of the marine fish aquaculture industry is gradually growing less.

3.3.2 Absolute β-convergence test results

The absolute β-convergence model was used to analyze the regional convergence characteristics, and the test results are

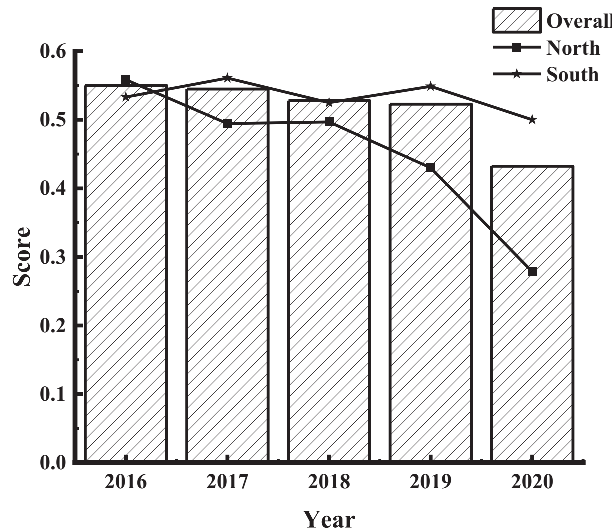

Fig. 3. The trend of σ-convergence coefficient. Note: The south includes Fujian, Guangdong, Guangxi, Hainan, Jiangsu, and Zhejiang; the north includes Hebei, Liaoning, and Shandong.

Table 4. Comprehensive evaluation value and ranking of competitiveness level.

Region	Overall score	Overall ranking	Region	Overall score	Overall ranking
Fujian	0.953	1	Jiangsu	−0.177	6
Guangdong	0.616	2	Hainan	−0.382	7
Shandong	0.441	3	Guangxi	−0.488	8
Liaoning	0.039	4	Hebei	−0.551	9
Zhejiang	−0.005	5			

Table 5. Results of absolute β-convergence test for MFAI competitiveness.

Region	β-value	Prob.	R^2	AR^2	F value
Overall	−0.8124	0.0126	0.5615	0.5067	10.2459
North	−1.0127	0.0198	0.5129	0.4520	8.4244
South	−1.0147	0.0203	0.5099	0.4487	8.3241

shown in Table 5. At the overall level, the β-value is $-0.8124<0$, and the P-value is $0.0126<0.05$, which passes the 5% significance test, indicating that the growth of the marine fish culture industry is negatively correlated with the initial marine fish industry development level, and there is absolute β-convergence for the overall marine fish culture industry development level in China, it means that there is more room for development progress in regions with lower marine fish industry development level. By region, the regression coefficients of -1.0147 and -1.0127 for the south and north respectively are less than zero and both pass the 5% significance test, suggesting that the regions with a lower level of competitiveness in the marine fish aquaculture industry are catching up with the regions with a higher level of competitiveness, and the regional marine fish aquaculture industry competitiveness levels converge toward the same level of development and eventually converge to a stable state.

4 Discussion

The level of competitiveness of China's MFAI can be divided into three echelons. Also, there is a trend of convergence in the level of industrial competitiveness among the nine provinces. The first echelon region has a higher level of industrial competitiveness. Among them, Fujian Province has always maintained first place in the statistical period, and its competitiveness level is stronger because it has a better industrial environment foundation, while its development potential and economic benefits are outstanding. Guangdong Province has a good industrial environment foundation and a large-scale advanced aquaculture model. Although the area of marine fish aquaculture is nearly twice as large as that of Fujian Province, the amount of fish fry and other industrial base inputs is not as good as that of Fujian Province. Though the industrial base of Shandong Province is better, its competitiveness level shows a decreasing trend year by year.

The industrial competitiveness of the second-echelon region is at a medium level. The industrial competitiveness level of Zhejiang Province shows a steady upward trend, with a good technical support base and strong industrial penetration ability. The investment in industrial environment foundations and advanced breeding mode in Zhejiang Province increased year by year during the statistical period, with high development potential. The total annual production of marine fish in Jiangsu Province is comparable to that of Liaoning Province, but the annual input of marine fish fry is close to three times that of Liaoning Province, while the total output value is much lower than that of Liaoning Province. The possible reason is the difference in breeding species, Liaoning Province is the main province of turbot breeding, with Huludao, Jinzhou as the representative of the factory recycling water culture model is also more mature. Although Jiangsu Province has a pufferfish aquaculture area represented by Nantong, the overall scale is not large. From the technical input, the number of professional stations of aquatic technology extension institutions in Jiangsu Province accounted for a low proportion of the total number of institutions.

The third echelon of Hainan, Guangxi, and Hebei have weaker levels of industrial competitiveness. The industrial competitiveness level of Hebei shows a fluctuating upward trend in the statistical period, while Hainan and Guangxi show a fluctuating downward trend.

5 Conclusions

This study applied the statistical evaluation of the competitiveness of China's marine fish farming industry based on the "vertical and horizontal" scatter degree method to reveal the regional differences in its industrial competitiveness, and on this foundation, the regional differences in the competitiveness of China's regional marine fish farming industry were tested for convergence using the σ-convergence and absolute β-convergence models, and the conclusions of the study are as follows.

During the period from 2016 to 2020, the competitiveness level of China's marine fish farming industry displayed an obvious "gradient effect" at three levels: high, medium, and low. The first echelon is Fujian, Guangdong, and Shandong, with a higher level of competitiveness in the marine fish culture industry; the second echelon is Liaoning, Zhejiang, and Jiangsu, with a medium level of competitiveness; the third echelon is Guangxi, Hebei, and Hainan, with a weaker level of competitiveness of marine fish culture industry.

In the period 2016–2020, there is a convergence trend in the competitiveness level of China's marine fish aquaculture industry, indicating the existence of regional synergistic development tendency in the marine fish aquaculture industry and the feasibility of jointly improving the development level.

Conflict of Interest

The authors report no declarations of interest.

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