

Measurement of the high-quality development level of China's marine economy

China's marine economy

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Abstract

Purpose – The purpose of this paper is to measure the high-quality development level of China's marine economy and analyze corresponding spatial and temporal distribution characteristic.

Design/methodology/approach – Design and optimize the index system of high-quality development level of marine economy and use entropy and TOPSIS method for comprehensive evaluation.

Findings – The research finds that from 2017 to 2019, the high-quality development tendency of China's marine economy is on the rise, but the overall level is still low. The level of each subsystem has different distribution characteristics in different provinces and cities. Guangdong, Shandong and Shanghai have a high comprehensive level. According to the comprehensive level of high-quality development of marine economy, 11 coastal provinces are divided into three types: leading, general and backward.

Research limitations/implications – This paper clarifies the temporal and spatial distribution law of high-quality development level of China's marine economy, providing basis for promoting comprehensive and coordinated improvement of coastal provinces and cities.

Originality/value – An indicator system for the high-quality development level of the marine economy has been established, including social development guarantee, marine economic foundation, marine science and technology drive and green marine sustainability.

Keywords Marine economy, High quality index system, Entropy-TOPSIS method

Paper type Research paper

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1. Introduction

General Secretary Xi Jinping has pointed out that “the ocean is a strategic place for high-quality development”. As an important part of the national economy, the gross ocean product in 2019 reached 8.9415 trillion yuan, accounting for 9% of the GDP and an increase of 6.2% over the 8.3415 trillion yuan in 2018. The contribution rate of marine economy to the growth of the national economy is as high as 6.53%. In 2012, the added value of the marine tertiary industry surpassed that of the marine secondary industry for the first time, and the marine industrial structure realized an important transformation from “second, third and first” to “third, second and first”. In 2015, the marine tertiary industry accounted for more than 50% of the gross ocean product for the first time, and the transformation and upgrading of the marine industrial structure achieved remarkable results. The reasonable growth of “quantity” of marine economic development provides the basic guarantee for the steady improvement of “quality”. High-quality development of marine economy has been a new driving force to promote high-quality development of national economy, a “blue engine” of high-quality economic development, and a top priority in the strategic construction of maritime power.

Under the background of the new era, with the land resources development intensity gradually saturated, developing the ocean and managing the ocean has become the only way to breed new economic industries, create innovative growth poles and build a new barrier for high-quality development. However, China’s marine economic development still has many problems that cannot be ignored and need to be solved urgently. It includes that traditional marine industries are too many and too excessive, emerging marine industries are facing downward pressure, the development of light and heavy marine industries is unbalanced and the marine industrial structure needs to be optimized. The development model of marine economy is mainly based on extensive and predatory development and capital driving. Offshore pollution is quite serious, the decline of biological resources has not been fundamentally improved, the governance system of marine ecological environment needs to be improved and the sustainable development of marine industry needs to be strengthened. The time fluctuation and space difference of marine labor productivity are large, the conversion rate of marine scientific and technological achievements is low and the efficiency of marine economic development needs to be improved.

The high-quality development of marine economy is of great strategic significance to the construction of maritime power and modernized economic system in China. State leaders and relevant departments at all levels attach great importance to the high-quality development of the marine economy. In October 2017, the 19th National Congress of the Communist Party of China first proposed “high-quality development” for the economy. In January 2018, the National Marine Work Conference pointed out that China should help the construction of a modernized economic system and promote the development of the marine economy to a higher quality by improving the capacity of monitoring and evaluating the operation of the marine economy, enriching the marine economic management policy tools, enhancing the capacity of driving marine innovation and speeding up the construction of marine economy demonstration zones. In March 2018, General Secretary Xi Jinping emphasized that “ocean is a strategic place for high-quality development” when he attended the review by the Shandong delegation at the first session of the 13th National People’s Congress. In August 2018, the Ministry of Natural Resources and the Industrial and Commercial Bank of China jointly issued the implementation opinions on promoting high-quality development of the marine economy, which clearly stated that priority should be given to supporting the transformation and upgrading of traditional marine industries, the cultivation and growth of emerging marine industries, the construction of major sea-related infrastructure and the green development of the marine economy and strengthening financial support for the three major marine economic circles and “the Belt and Road”

financial support for maritime cooperation. In October 2019, General Secretary Xi Jinping pointed out that the pace of innovation in marine science and technology should be accelerated, the ability to develop marine resources should be enhanced and strategic emerging marine industries should be nurtured and strengthened. We should promote maritime connectivity and practical cooperation in various fields and actively develop the “Blue Partnership”. In government work report delivered at the third session of the 13th National People’s Congress in May 2020, Premier Li Keqiang pointed out that efforts should be made to further promote the development of the Guangdong-Hong Kong-Macao Greater Bay Area, and the integrated development of the Yangtze River Delta draw up an outline for ecological protection and high-quality development of the Yellow River Basin and develop the marine economy.

Based on the above analysis, this paper will combine the new requirements and new ideas of China’s high-quality economic development in the new era with the existing problems of China’s marine economic construction, clarifies the connotation and mechanism of high-quality development of marine economy and scientifically establishes and rationally optimizes the indicator system of high-quality development of marine economy. The entropy-TOPSIS method was used to measure the high-quality development level of marine economy in 11 coastal provinces (or cities) in China from 2017 to 2019.

The contents of this paper are as follows: first, there is a comprehensive review of the current research on the high quality development level of marine economy at home and abroad. Second, it clarifies the connotation and mechanism of high-quality development of marine economy, designs the index system of high-quality development of marine economy and introduces the entropy-TOPSIS method and data sources. Finally, it measures the measurement results of each subsystem and comprehensive level of high-quality economic development in 11 coastal provinces (or cities) in China, analyzes its spatial distribution law and proposes targeted policy enlightenment.

2. Literature review

Quantity and quality are two closely related and distinctive dimensions in the process of macroeconomic development. “Quantity” emphasizes the quantitative expansion in speed and scale in the process of economic growth, while “quality” focuses on the improvement of economic development from three aspects: process, result and prospect (Ren, 2013). Pointed out in the report to the Party’s 19, China’s economy has the high-quality development stage of rapid growth stage as a period of transitional development and growth slowdown. China’s economy depends more on the quality and efficiency of economic growth than on quantity and speed (Mei and Chen, 2016); growth quantitative index such as GDP, national income is no longer the only focus, but gradually by the number of attention to focus on quality, to promote the construction of a resource-conserving and environment-friendly society (Ni *et al.*, 2014; Ghosh, 2017; Colaco *et al.*, 2020). In the new era, high-quality economic development in China is an active choice to adapt to the new normal of economic development. That is the transformation of economic growth from high-speed to medium-high speed, the optimization of economic structure to medium-high end and the transformation of economic growth driver to innovation-driven (Jin, 2018; Han, 2020). High-quality economic development is the fundamental embodiment of the five development concepts of “innovative, coordinated, green, open and share”. It is also the development that meets the people’s needs for a better life in all aspects (Chen and Chen, 2018; Zhang, 2020; Zhao *et al.*, 2020). High quality and economic development is the inevitable requirement to adapt to the changing social principal contradictions of our country. It requires the establishment of accurate product quality standards, the production of middle and high-end products, the realization of economic growth based on integrity, efficiency, balance and ecology and the promotion of regional economic development of synergy, completeness, inclusiveness and openness (Zhao *et al.*, 2019; Research Group of Economic

Research Institute of National Development and Reform Commission, 2019). Focusing on the marine field, high-quality development of marine economy is a high-efficiency, stable and sustainable development. Scientific and technological innovation should be the fundamental driving force to promote high-quality development of marine economy. And institutional innovation should be the basis to guarantee and promote high-quality development of marine economy (Han *et al.*, 2019).

With the development of marine economy high-quality research gradually transition from theory to practice analysis, single measurement indexes such as intermediate input output rate, investment efficiency, labor productivity and total factor productivity are one-sided and limited, which cannot comprehensively reveal the whole picture of high-quality development level of marine economy in a certain region (Gao *et al.*, 2018; Wu *et al.*, 2019; Sun and Song, 2019). Therefore, it has become a research focus to comprehensively evaluate the high-quality development of the marine economy by constructing index systems. These index systems have rich and diverse evaluation perspectives and measure indicators with their own characteristics. Thus, it improves the limitations of using a single index to represent the high-quality development level of the economy. Specifically, from the perspective of sustainable development of marine economy, ecological, social and economic interests should be taken into account when measuring the sustainable development ability of marine economy (Pioch *et al.*, 2011), and a sustainable evaluation system of marine economy based on three subsystems of marine economy, marine society and marine resources and environment should be built (Sun *et al.*, 2014; Bai *et al.*, 2015; Yu *et al.*, 2019; Wang *et al.*, 2020; Weijiao and Chunhui, 2020). From the perspective of green development of the marine economy, the evaluation index system of green development of the marine economy is constructed from three perspectives of economic growth, resource utilization and social development, and the green development index of the marine economy is measured to analyze the temporal and spatial differences (Wang, 2018; Liang, 2019). From the perspective of coordinated development of marine economy, it clarifies the coordinated development factors of marine economic system, land economic system, ecological environment system and marine science and technology system, constructs a multi-level index system and explores the degree and path of coordinated development of marine economy (Wang and Jiang, 2019; Di Qianbin *et al.*, 2020).

A large number of the above researches have focused on the measurement and evaluation of the high-quality development of marine economy from a certain angle, but few studies have quantified the comprehensive level of the high-quality development of marine economy through the construction of an index system. From the perspective of “quality”, the high-quality development of marine economy reveals the level of quality and quality of marine economic performance. Its core is quality, and its main body is marine economy. It focuses on the level of quality that reflects marine economic performance from the perspective of “development”. At the same time, “high” highlights new ideas and new requirements, emphasizing the advanced level of quality in the process of marine economic construction (Min and Li, 2018). Therefore, the comprehensive evaluation system for high-quality development of marine economy directly guides the work of marine economy. Thus, it not only covers multiple levels, such as long-term and medium-term, macro and micro but also includes multiple sub-evaluation systems, such as input and output. At the same time, we need to take high quality as the evaluation guide and standard. We should incorporate such issues as the coupling of sea population system, the vulnerability of marine economy, the carrying capacity of marine resources and environment, the overall planning of land and sea, the interaction between marine resources system and economic system and the efficiency of marine ecology into the high-quality evaluation system of marine economy (Liu *et al.*, 2020; Wang *et al.*, 2020; Qin and Shen, 2020; Li *et al.*, 2020).

To sum up, the high-quality development of marine economy centers on economic efficiency, marine resources and marine industry. However, the existing research focuses on

basic theoretical research, and unified research framework and evaluation system has not been formed. Therefore, the establishment of a comprehensive evaluation system for the high-quality development of marine economy, the exploration of the mechanism of innovation-driven high-quality development of marine economy and the proposal of specific implementation paths for the high-quality development of marine economy are conducive to the improvement of the overall development level of China's marine economy and are of great practical value in supporting the deepening implementation of the national strategy of maritime power.

3. Measurement of the high quality development level of China's marine economy: connotation, system and method

This chapter clarifies the connotation and characteristics of high-quality development of marine economy and identifies indicators reflecting the high-quality development of the marine economy. It uses the method of target layers constructed index system of marine economy development of high quality, expert assignment through single indexes inspection and effectiveness of screening indicators and construction of index system of marine economy development of high quality.

3.1 Connotation of high-quality development of marine economy

This paper argues that to understand the connotation of high-quality development of marine economy, it is necessary to start from the two dimensions of "quality" and "quantity" and consider the connotation of high-quality development of marine economy and the development foundation and dynamic mechanism of marine economy. High-quality development of the marine economy means that while achieving a certain "quantitative" growth, the marine economy constantly improves the comprehensive development level of the marine economy, continues to optimize the marine industry structure, rationally improves marine social welfare distribution, speeds up the balance state of marine ecological environment, steps up efforts to popularize marine culture in a step-by-step manner and effectively enhances the capacity of marine science and technology innovation drive. The goal of high-quality development of marine economy is to achieve a dynamic balance between the system of "marine economy" and the system of "marine society-marine ecology-marine culture-marine science and technology", to promote the transformation of the quality, efficiency and power of marine economic development and to promote the improvement of the quality and efficiency of marine economic development.

High-quality development of marine economy is characterized by stability, sustainability, coordination and long-term development. The high-quality development of marine economy is reflected in the transformation of development mode from extensive to intensive, the transformation of development impetus from production scale expansion to scientific and technological innovation and the transformation of resource factors to land-sea integration and efficient allocation. This is embodied in the more prominent export-oriented characteristics of marine economy, higher production efficiency of input factors of marine economy and better quality of human capital. The marine economy is more innovation-driven, and the contribution rate of marine scientific and technological progress is higher. The marine ecological environment is greener, and the capability of pollution control and environmental protection is stronger.

3.2 Total identification of high quality development index of marine economy

The design principle of index system is based on the principles of scientificity and integrity, consideration and comprehensiveness, potentiality and prospectiveness and comparability and operability. From the four aspects of social development guarantee ability, marine economy basic ability, marine science and technology driving ability and green ocean sustainable ability, 27 indicators are summarized in this paper.

The social development guarantee ability refers to the basic guarantee ability of the macro-environment of economic and social development for the high-quality development of marine economy. Specifically, it includes per capita GDP, consumer price index, natural growth rate of population, urbanization rate, social endowment insurance coverage rate of urban and rural residents, energy consumption per unit GDP and intensity of R&D expenditure input of industrial enterprises above designated size.

The basic capacity of marine economy refers to the organic unity of the difference of quantity, scale and quality of marine economy. The quantity scale of marine economy reflects the development volume and level of marine economy from the macro level. The difference of marine economy quality reflects the marine industrial structure and the importance of marine economy. Specifically, they include the proportion of GOP in GDP, the proportion of marine emerging industries' added value in GOP, the growth rate of gross ocean product, the proportion of marine tertiary industry's added value in GOP, the elasticity coefficient of marine tertiary industry's added value, marine labor productivity and foreign trade dependence.

The driving capacity of marine science and technology refers to the intensity of marine science and technology progress and innovation to generate power for the development of marine economy and enhance benefits. It includes marine science and technology progress contribution rate, marine scientific and technological achievements to realize industrialization of output per capita, marine science and technology personnel to undertake marine scientific research subject number, marine science and technology patent license number, number of marine science and technology publishing, marine professionals per capita has amount of science and technology activities and marine professional student number per capita marine education investment funds.

Green ocean sustainability refers to the ability of marine ecological environment to support the high-quality development of marine economy, so as to decouple the growth of marine economy from the overload of marine resources. It includes marine crude output intensity (unit area of marine oil production), marine fishing intensity (unit area of the ocean catches), marine disasters direct economic loss of strength (direct economic loss of marine disasters of the area of the unit area), the sea pollution discharge intensity (unit coastline length of straight row of sea pollution in sewage), environmental governance investment intensity (unit area of the environmental governance investment) and unit of marine nature reserve of pollution control projects.

3.3 Construction of high quality development index system for marine economy

In this paper, 10 experts were invited based on the Delphi method to assign 1–10 points to 27 second-level indicators under 5 first-level indicators according to the importance of indicators. The results of validity test and consistency test (Yin *et al.*, 2019) for expert assignments of a single indicator are shown in Tables 1 and 2.

According to Table 1, at the significance level of $\alpha = 0.005$, the absolute value of all test values is less than the critical value of $t_{0,005}(10-2) = 2.355$, so all expert assignments for each indicator are valid.

According to Tables 2 shows that under the level of significance level $\alpha = 0.005$, 10 indexes of the test value is greater than the critical value of 2.355, so as to eliminate the above 10 indexes. They include the consumer price index, the urbanization rate, the intensity of R&D expenditure input, marine productivity, foreign trade dependence, marine scientific and technological achievements to realize industrialization of output per capita, number of marine science and technology publishing, marine professional student number per capita marine education investment funds, marine crude output intensity and unit of marine nature reserve of pollution control projects.

Therefore, the indicator system of high-quality development of marine economy is shown in Table 3.

	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Expert 9	Expert 10
GDP per capita	1.5000	1.5000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-1.5000	-1.5000
Consumer price Index	1.2139	0.9026	0.9026	0.5914	0.5914	0.2801	-0.9649	-0.9649	-1.2761	-1.2761
Natural population growth rate	1.1212	1.1212	0.2587	0.2587	0.2587	0.2587	-0.6037	-0.6037	-2.3286	-2.3286
Urbanization rate	1.2176	1.2176	1.2176	0.9585	-0.5958	-0.5958	-0.8549	-0.8549	-0.8549	-0.8549
Social endowment insurance coverage	1.9378	1.1762	0.1762	0.1762	0.1762	0.1762	0.1762	0.1762	-1.5855	-1.5855
Energy consumption per unit of GDP	1.5855	1.5855	-0.1762	-0.1762	-0.1762	-0.1762	-0.1762	-0.1762	-0.1762	-1.9378
The intensity of R&D expenditure input	1.3393	1.0603	1.0603	0.5022	0.5022	-0.3348	-0.8929	-0.8929	-1.1719	-1.1719
GDP/GOP	1.5855	1.5855	-0.1762	-0.1762	-0.1762	-0.1762	-0.1762	-0.1762	-0.1762	-1.9378
The value of marine emerging industries /GOP	1.0279	1.0279	1.0279	-0.1142	-0.1142	-0.1142	-0.1142	-0.1142	-0.1142	-2.3984
Growth rate of gross marine product	1.1619	1.1619	0.1936	0.1936	0.1936	0.1936	0.1936	0.1936	-1.7428	-1.7428
The value of marine tertiary industry/GOP	1.5000	1.5000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-1.5000	-1.5000
Elasticity coefficient of marine tertiary industry	0.7591	0.7591	0.7591	0.0690	0.0690	0.0690	0.0690	0.0690	0.0690	0.0690
Marine productivity	1.4643	1.1931	1.1931	0.6508	-0.4339	-0.7050	-0.7050	-0.7050	-0.9762	-0.9762
Dependence on foreign trade	1.8974	0.3162	0.3162	0.3162	0.3162	0.3162	0.3162	0.3162	-1.2649	-1.2649
Contribution of marine technological	1.8974	1.8974	-0.4743	-0.4743	-0.4743	-0.4743	-0.4743	-0.4743	-0.4743	-0.4743
Marine technological achievements output	2.1118	1.1062	0.1006	0.1006	0.1006	0.1006	-0.9050	-0.9050	-0.9050	-0.9050
Undertaking marine research projects per capita	1.5855	1.5855	-0.1762	-0.1762	-0.1762	-0.1762	-0.1762	-0.1762	-0.1762	-1.9378
Ocean technology patents authorized	1.5855	1.5855	-0.1762	-0.1762	-0.1762	-0.1762	-0.1762	-0.1762	-0.1762	-1.9378
Marine technology papers published	1.3506	1.3506	1.0570	0.7634	-0.4111	-0.7047	-0.7047	-0.7047	-0.9983	-0.9983
Per capita funds for technological activities	1.9378	0.1762	0.1762	0.1762	0.1762	0.1762	0.1762	0.1762	-1.5855	-1.5855
Per capita marine education input	1.3059	1.3059	0.2176	0.2176	0.2176	0.2176	0.2176	0.2176	-0.8706	-0.8706
Intensity of offshore oil production	1.1062	1.1062	1.1062	0.1006	0.1006	0.1006	0.1006	0.1006	-0.9050	-0.9050
Intensity of marine fishing	1.5000	1.5000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-1.5000	-1.5000
Intensity of direct economic losses	1.8974	1.8974	-0.4743	-0.4743	-0.4743	-0.4743	-0.4743	-0.4743	-0.4743	-0.4743
Intensity of sewage discharge from sea pollution	2.2883	0.8581	0.8581	-0.5721	-0.5721	-0.5721	-0.5721	-0.5721	-0.5721	-0.5721
Investment in environmental governance	1.5000	1.5000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-1.5000	-1.5000
Pollution control projects	2.1118	1.1062	0.1006	0.1006	0.1006	0.1006	-0.9050	-0.9050	-0.9050	-0.9050

Table 1. Validity test of expert assignment of a single indicator

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Indicator	<i>t</i> value	Indicator	<i>t</i> value
GDP per capita	2.3094	Contribution of marine technological	1.6330
Consumer price index	5.4000	Marine technological achievements output	3.1305
Natural population growth rate	2.3333	Undertaking marine research projects per capita	1.8974
Urbanization rate	4.4980	Ocean technology patents authorized	1.8974
Social endowment insurance coverage	1.8974	Marine Technology papers published	4.9115
Energy consumption per unit of GDP	1.8974	Per capita funds for technological activities	1.8974
The intensity of R&D expenditure input	7.8779	Per capita marine education input	2.6833
GOP/GDP	1.8974	Intensity of offshore oil production	3.1305
The value of marine emerging industries/GOP	2.1320	Intensity of marine fishing	2.3094
Growth rate of gross marine product	2.1909	Intensity of direct economic losses	1.6330
The value of marine tertiary industry/GOP	2.3094	Intensity of sewage discharge from sea pollution	2.1381
Elasticity coefficient of marine tertiary industry	1.6733	Investment in environmental governance	2.3094
Marine productivity	4.7140	Pollution control projects	3.1305
Dependence on foreign trade	2.5298		

Table 2.
Consistency test of expert assignment of a single indicator

Target	Criterion	Factor	Effect
High-quality development of marine economy	Social development security capacity	GDP per capita	+
		Natural population growth rate	+
		Social endowment insurance coverage	+
	Basic marine economic capacity	Energy consumption per unit of GDP	-
		GOP/GDP	+
		The value of marine emerging industries/GOP	+
		Growth rate of gross marine product	+
		The value of marine tertiary industry/GOP	+
	Marine technology driving capability	Elasticity coefficient of marine tertiary industry	+
		Contribution of marine technological	+
		Undertaking marine research projects per capita	+
		Ocean technology patents authorized	+
	Green ocean sustainability	Per capita funds for technological activities	+
		Intensity of marine fishing	-
Intensity of direct economic losses		-	
Intensity of sewage discharge from sea pollution		-	
Investment in environmental governance		+	

Table 3.
Indicator system of high-quality development of marine economy

3.4 Evaluation of the high-quality development level of China's marine economy

In this paper, the entropy-TOPSIS method (Du *et al.*, 2014) is used to measure the development ability and comprehensive level of various indicators in the high-quality development of China's marine economy. The core idea is to use entropy method to determine the weight of each index on the basis of standardized treatment of each index, and then use TOPSIS method to conduct quantitative comparison of the high-quality development level of marine economy in different regions. The index weight value of entropy method is obtained according to the information reflected by the variation degree of each index data, which greatly reduces the interference of subjective factors when the index weights are given. By comparing the relative distance between each evaluation object and the optimal scheme the worst scheme, respectively, the TOPSIS method is characterized by strong operability and rationality of the results. Therefore, this paper adopts the entropy-TOPSIS method to carry out the comprehensive evaluation of the high-quality development level of China's marine economy, and the results are more objective and reasonable. The specific implementation steps are as follows.

First, in order to eliminate the difference between different indicators in terms of order of magnitude and dimension, the range method is used to standardize all indicators x_{ij} in the high-quality development index system of marine economy:

$$y_{ij} = \begin{cases} \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})}, & x_{ij} \text{ is a positive indicator} \\ \frac{\max(x_{ij}) - x_{ij}}{\max(x_{ij}) - \min(x_{ij})}, & x_{ij} \text{ is a negative indicator} \end{cases} \quad (2-1)$$

where, i denotes the coastal province (or city), j denotes the evaluation index and x_{ij} and y_{ij} , respectively, represent the original value and the standardized value of the evaluation index of the high quality development level of marine economy.

The second step is to calculate the information entropy E_j of each evaluation index y_{ij} in the high-quality development index system of marine economy:

$$E_j = -\frac{1}{\ln n} \sum_{i=1}^n \left[\left(\frac{y_{ij}}{\sum_{i=1}^n y_{ij}} \right) * \ln \left(\frac{y_{ij}}{\sum_{i=1}^n y_{ij}} \right) \right] \quad (2-2)$$

The third step is to calculate the weight ω_j of each rating index y_{ij} in the high-quality development index system of marine economy:

$$\omega_j = \frac{1 - E_j}{\sum_{j=1}^m (1 - E_j)} \quad (2-3)$$

The fourth step is to construct the weighted matrix of the high-quality development index system of marine economy R :

$$R = (r_{ij})_{n \times m}, \quad r_{ij} = \omega_j \times y_{ij} \quad (2-4)$$

In the fifth step, the optimal scheme Q_j^+ and the worst scheme Q_j^- are determined according to the weighted matrix R .

$$Q_j^+ = (\max r_{i1}, \max r_{i2}, \dots, \max r_{im})$$

$$Q_j^- = (\min r_{i1}, \min r_{i2}, \dots, \min r_{im}) \tag{2-5}$$

The sixth step is to calculate the Euclidean distance d_i^+ , d_i^- between each evaluation object and the optimal scheme Q_j^+ and the worst scheme Q_j^- , respectively:

$$d_i^+ = \sqrt{\sum_{j=1}^m (Q_j^+ - r_{ij})^2}$$

$$d_i^- = \sqrt{\sum_{j=1}^m (Q_j^- - r_{ij})^2} \tag{2-6}$$

The seventh step is to calculate the relative proximity between each evaluation object and the ideal scheme C_i :

$$C_i = \frac{d_i^-}{d_i^+ + d_i^-} \tag{2-7}$$

Among them, the relative proximity C_i is between 0 and 1. The larger the degree is, the better the high quality development level of marine economy in coastal provinces (or cities) is. On the contrary, the marine economy of coastal provinces (or cities) with high quality development level is worse.

4. Empirical analysis

4.1 Data sources

With regard to data sources, the four secondary indicators of social development security capacity are all from the National Bureau of Statistics. Secondary indicators related to basic marine economic capacity, driving capacity of marine science and technology and sustainable green marine capacity are obtained from Statistics Bulletin of China's Marine Economic (2017–2019), Statistics Bulletin of China's Marine Economic of each province (or city) (2017–2019) and China Maritime Disaster Bulletin (2017–2019).

4.2 China's marine economy develops at the sub-system level with high quality

Based on the high quality development index system of marine economy, it took the lead in measuring the four subsystems of high quality development of marine economy in 11 coastal provinces (or cities) in China from 2017 to 2019. The results are shown in [Tables 4–7](#).

	2019	2018	2017
China	0.5330	0.5355	0.4818
Tianjin	0.2988	0.2871	0.6652
Hebei	0.3626	0.3741	0.3663
Liaoning	0.0864	0.0828	0.0841
Shanghai	0.6101	0.6057	0.6355
Jiangsu	0.6480	0.6370	0.6606
Zhejiang	0.5654	0.5982	0.5626
Fujian	0.8700	0.8555	0.7831
Shandong	0.4980	0.5734	0.7284
Guangdong	0.7088	0.7312	0.6734
Guangxi	0.4559	0.5140	0.4212
Hainan	0.5160	0.6102	0.4698

Table 4. Measurement results of social development security capability

	2019	2018	2017	China's marine economy
China	0.4286	0.4958	0.1263	33
Tianjin	0.6328	0.6210	0.6555	
Hebei	0.1826	0.2010	0.1583	
Liaoning	0.1074	0.0746	0.3749	
Shanghai	0.6049	0.5100	0.5871	
Jiangsu	0.1220	0.0810	0.3664	
Zhejiang	0.3591	0.3123	0.5930	
Fujian	0.6369	0.5503	0.6216	
Shandong	0.7076	0.5023	0.3721	
Guangdong	0.7187	0.5073	0.4177	
Guangxi	0.1260	0.1446	0.0816	
Hainan	0.3234	0.3711	0.5543	

Table 5.
Measurement results of basic capacity of marine economy

	2019	2018	2017	
China	0.1770	0.1821	0.1774	Table 6. Measurement results of marine science and technology driving capability
Tianjin	0.3296	0.3443	0.0976	
Hebei	0.0023	0.0043	0.0009	
Liaoning	0.4827	0.4769	0.5814	
Shanghai	0.6239	0.5840	0.7205	
Jiangsu	0.2106	0.2266	0.2198	
Zhejiang	0.0894	0.0981	0.0818	
Fujian	0.0539	0.0459	0.0358	
Shandong	0.5997	0.5939	0.5749	
Guangdong	0.5702	0.6169	0.7048	
Guangxi	0.0008	0.0012	0.0019	
Hainan	0.1477	0.1466	0.0675	

	2019	2018	2017	
China	0.8544	0.8842	0.8199	Table 7. Measurement results of green marine sustainability
Tianjin	0.9526	0.9755	0.9897	
Hebei	0.1139	0.2812	0.2710	
Liaoning	0.8581	0.8858	0.9754	
Shanghai	0.9776	0.9743	0.9867	
Jiangsu	0.9445	0.9340	0.2365	
Zhejiang	0.7775	0.9666	0.9670	
Fujian	0.3807	0.1631	0.0914	
Shandong	0.8943	0.9610	0.9828	
Guangdong	0.9964	0.9981	0.3163	
Guangxi	0.9417	0.9366	0.9569	
Hainan	0.7058	0.7236	0.9604	

4.2.1 Ability to guarantee social development. According to [Table 4](#), from 2017 to 2019, the scores of social development security capability for high-quality development of China's marine economy are 0.4818, 0.5355 and 0.5330, respectively, and the average scores of more than 11 coastal provinces (or cities) in 2018 and 2019 are 0.5336 and 0.5109, respectively. Among them, the social development to ensure minimum provinces and cities of Liaoning

province, the score was 0.0841, 0.0828 and 0.0864, respectively. Fujian Province has the highest social development security capacity, which the scores are 0.7831, 0.8555 and 0.8700, respectively. Furthermore, social development support capability of Fujian Province is about roughly 9.91 times that of Liaoning Province, which shows that the social development of China's marine economy development high-quality guarantee ability exist large regional differences, different social development between the coastal provinces (or cities) co-evolution is weak.

In 2017, Fujian Province (0.7831), Shandong Province (0.7284), Guangdong Province (0.6734), Tianjin City (0.6652) and Jiangsu Province (0.6606) scored the highest in social development security ability. In 2018, Fujian Province (0.8555), Guangdong Province (0.7312), Jiangsu Province (0.6370), Hainan Province (0.6102) and Shanghai City (0.6057) were the top five provinces (or cities) in terms of social security capability.

In 2019, Fujian Province (0.8700), Guangdong Province (0.7088), Jiangsu Province (0.6480), Shanghai City (0.6101) and Zhejiang Province (0.5654) are the five provinces (or cities) with the highest score of social development security ability. Most of these provinces are located in the eastern marine economic circle and the southern marine economic circle. In addition, they have strong macroeconomic and social strength in the high-quality development of the marine economy. In the course of high-quality development of the marine economy, China has strong macroeconomic and social strength. At the same time, the input and output of factors such as productivity, labor force, social security and energy are coordinated, so they can better guarantee the high-quality development of the regional marine economy. In contrast, from 2017 to 2019, the two provinces (cities) with the lowest social security capability scores were Hebei Province and Liaoning Province, which are located in the northern ocean economic circle. Compared with the eastern and southern ocean economic circles, these two provinces have significant spatial imbalance and insufficient basic guarantee capability for high-quality development of the marine economy.

4.2.2 Basic capacity of marine economy. It can be seen from [Table 5](#) that from 2017 to 2019, the score of basic marine economy capability for high-quality development of China's marine economy is 0.1263, 0.4958 and 0.4286, respectively, which only exceeds the average level of 11 coastal provinces and cities (0.4348) in 2018. Among them, from 2017 to 2019, the provinces and cities with the lowest basic capacity of marine economy in Guangxi Province (0.0816) and Liaoning Province (0.0746, 0.1074), the provinces and cities with the highest scores of Tianjin City (0.6555, 0.6210) and Guangdong Province (0.7187), respectively. The province with the highest score is about 7.68 times that of the lowest, indicating that there are also obvious spatial differences in China's basic capacity of marine economic.

From 2017 to 2019, the five provinces (cities) with the highest score in marine economic basic ability changed from Tianjin, Fujian, Zhejiang, Shanghai and Hainan to Tianjin, Fujian, Shanghai, Guangdong and Shandong, and then to Guangdong, Shandong, Fujian, Tianjin and Shanghai. Especially, Guangdong province and Shandong Province, two big provinces with strong marine economy, gradually show their advantages, and the effect of marine economic growth control and marine industrial structure optimization is gradually obvious. But the northern marine economic circle of Liaoning Province, the eastern marine economic circle in Jiangsu Province and the southern Guangxi Province, have been in a backward position of marine economic circle. It is indicated that the marine economic development of the mechanism is not yet complete. These areas do not attach enough importance to the development of marine economy, so it is necessary to accelerate the development of local marine economy and balance the development level of the three marine economic circles.

4.2.3 Marine technology driving capability. According to [Table 6](#), from 2017 to 2019, China's marine science and technology driving ability score for high-quality development of marine economy is 0.1774, 0.1821 and 0.1770, respectively, which is always lower than the average level of 11 coastal provinces and cities. From 2017 to 2019, Guangdong, Shandong

and Shanghai are the three provinces and cities with the highest marine science and technology driving capacity, and their scores remain above 0.5. The two provinces and cities with the lowest scores were Hebei and Guangxi, respectively, and the difference in driving capacity of marine science and technology was as high as 700 times.

Guangdong, Shandong and Shanghai depend on the good foundation of marine economy and the rising marine industrial structure, through introducing talents such as policy guidance and attaches great importance to the marine professional education and marine science and technology research and development. Especially, through the establishment and development of the Guangdong-Hong Kong-Macao Greater Bay Area, China (Shanghai) Pilot-Free Trade Zone Lin-Gang Special Area, Guangdong Province and Shanghai City have absorbed international advanced technology under the concept of "openness and sharing" and strengthened the driving force of marine science and technology for the high-quality development of the marine economy. On the contrary, the driving capacity of marine science and technology in other provinces and cities urgently needs to be improved. It is worth mentioning that the driving capacity of marine science and technology in other provinces and cities urgently needs to be improved, especially in Guangxi, Hebei and other provinces with relatively backward development of marine science and technology. These areas must attach great importance to the innovation of marine science and technology and break the extensive model of marine economic development.

4.2.4 Green marine sustainability. According to [Table 7](#), from 2017 to 2019, the scores of green marine sustainability for high-quality development of China's marine economy are 0.8199, 0.8842 and 0.8544, respectively, which are always higher than the average level of 11 coastal provinces and cities. It is indicated that the green and sustainable development of marine economy in coastal provinces and cities needs to be strengthened. Among them, from 2017 to 2019, the three provinces and cities with the highest green marine sustainability have changed from Tianjin, Shanghai and Shandong to Guangdong, Tianjin and Shanghai, all with scores above 0.95. The two provinces and cities with the lowest scores were Hebei and Fujian respectively, and there was an 8-fold difference in the green marine sustainability.

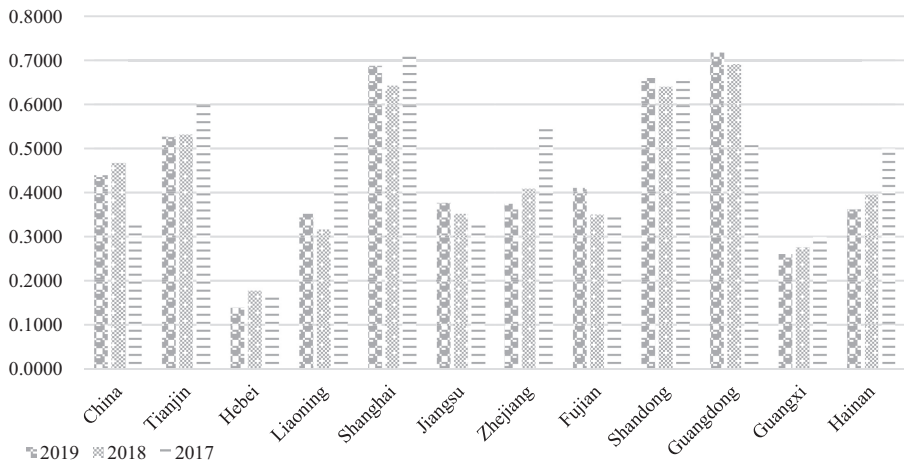
After realizing the transformation of medium-high end marine industrial structure, Tianjin, Shanghai and Guangdong have intensified efforts in marine pollution control, enhanced marine disaster resilience and post-disaster reconstruction and achieved a relatively high level of sustainable green marine development. However, the specific reasons for the high green marine sustainability score are different. Thanks to the low intensity of marine fishing and the high intensity of investment in environmental governance, Guangdong has established an orderly system to guarantee ecological civilization to the greatest extent. Tianjin City and Shanghai City rely on the lower intensity of direct economic loss of marine disasters and the intensity of sewage discharge of marine pollution sources to carry out energy conservation and emission reduction work from the source. On the contrary, due to the relatively developed marine heavy industry, pollution prevention measures and marine disaster prevention measures are not fully implemented, Hebei Province needs to further improve its green marine sustainability.

4.3 The comprehensive level of China's high-quality marine economy

From 2017 to 2019, the empirical measurement results of the comprehensive level of high-quality development of China's 11 coastal provinces (cities) are shown in [Figure 1](#). It can be found that from 2017 to 2019, the comprehensive level scores of high-quality development of China's 11 coastal provinces (cities) are within three ranges: [0.1665,0.7191], [0.1778,0.6914] and [0.1396,0.7171].

In 2017, the comprehensive score of high-quality development of China's marine economy is 0.3287, which is far lower than the average score (0.4762) of 11 coastal provinces (or cities). Hebei received the lowest score (0.1665) and Shanghai received the highest score (0.7191),

Figure 1.
Comprehensive level of
high-quality
development of China's
marine economy



indicating that the overall level of high-quality marine economic development in China in 2019 is relatively low.

In 2018, China's overall score of high-quality marine economic development was 0.4671, exceeding 11 coastal provinces (municipalities) high-quality marine economy development level of comprehensive scoring average (0.4346). The lowest score was Hebei (0.1778), while Guangdong surpassed Shanghai in the first place with a score of 0.6914. Its SD was 0.1678, indicating that China's comprehensive level of high-quality marine economic development showed an upward trend in 2018, with certain spatial differences among different coastal provinces and cities.

In 2019, China's comprehensive score for high-quality marine economic development was 0.4387, slightly lower than the comprehensive score in 2018. The mean score and SD of the overall level of high-quality development of the marine economy of the 11 coastal provinces (cities) were 0.4424 and 0.1840, respectively. The lowest score was Hebei (0.1396), while the highest score was Guangdong (0.7171), indicating that China's high-quality economic development in 2019 is inferior to that in 2018, and the spatial differences among the 11 coastal provinces (cities) have spread.

Based on the relationship between the mean score (M) and SD (SD), this paper divides the high-quality development of marine economy in 11 coastal provinces (cities) into three types: leading type (over $M + 0.5 SD$), general type (between $M - 0.5 SD$ and $M + 0.5 SD$) and laggards (below $M - 0.5 SD$).

According to Table 8, the classification results of high-quality marine economic development in 11 coastal provinces (cities) from 2017 to 2019 can be obtained (Table 9).

In 2017, the comprehensive score of high quality development of marine economy of leading provinces and cities was higher than 0.5599, including Shanghai, Shandong and

Table 8.
Division of the
three types

	2019	2018	2017
Leading	(0.5344,1.0000)	(0.5185,1.0000)	(0.5599,1.0000)
General	(0.3504,0.5344)	(0.3507,0.5185)	(0.3923,0.5599)
Laggards	(0.0000,0.3504)	(0.0000,0.3507)	(0.0000,0.3923)

Tianjin, whose comprehensive score of high-quality development of marine economy was 0.7191, 0.6608 and 0.6088, respectively.

In 2018, the comprehensive score of high quality development of marine economy of leading provinces and cities was higher than 0.5185. It is included Guangdong, Shanghai, Shandong and Tianjin, whose comprehensive score of high-quality development of marine economy was 0.6914, 0.6419, 0.6398 and 0.5313, respectively.

In 2019, the comprehensive score of high-quality development of marine economy in leading provinces and cities was higher than 0.5344. It is included Guangdong, Shanghai and Shandong, which were 0.7171, 0.6869 and 0.6591, respectively.

Guangdong province, Shandong Province, Tianjin City and Shanghai City have excellent comprehensive level of high-quality development of marine economy. In the development process of marine economy, they can not only attach importance to the improvement of quantity of marine economy growth but also the improvement of high-quality development level of marine economy, and their comprehensive performance is relatively excellent. Among them, Guangdong province has a rapid development momentum and is a "star" province with high-quality marine economy.

In 2017, the comprehensive level score of high-quality development of marine economy in general types ranged from 0.3923 to 0.5599, including Zhejiang, Liaoning, Guangdong and Hainan, while the score of laggards was lower than 0.3923, including Fujian, Jiangsu, Guangxi and Hebei.

In 2018, the comprehensive score of high-quality development of general provincial and municipal marine economy was between 0.3507 and 0.5185, including only two provinces (Zhejiang and Hainan), while the score of laggards marine economy was lower than 0.3507, including five provinces (Jiangsu, Fujian, Liaoning, Guangxi and Hebei).

In 2019, the comprehensive level score of the high-quality development of the general type of provincial and municipal marine economy was between 0.3504 and 0.5344, including five provinces and one city (Tianjin, Fujian, Jiangsu, Zhejiang, Hainan and Liaoning), while the score of the laggards was lower than 0.3504, only two provinces (Guangxi and Hebei).

Therefore, the difference between provinces and cities before the high-quality development of marine economy has been reduced, and "laggards" provinces tend to be closer to "general" and "leading" provinces. To be specific, Jiangsu and Zhejiang, two economically powerful provinces, urgently need to adjust the development concept of marine economy in the process of high-quality development and construction of marine economy and change from the pursuit of quantity to the pursuit of high-quality development, so as to truly realize healthy and sustainable high-quality development of marine economy. Liaoning and Hebei should, on the basis of the developed marine heavy industry, actively adjust and optimize the marine industrial structure, promote the balanced development of heavy and light marine industries and build a pattern of high-quality development led by marine high-tech industries. Fujian, Guangxi and Hainan should seize the opportunity of pilot free trade zones, expand ocean-related foreign trade, take the initiative to absorb domestic and

	2019	2018	2017
Leading	Guangdong, Shanghai, Shandong	Guangdong, Shanghai, Shandong, Tianjin	Guangdong, Shanghai, Tianjin
General	Tianjin, Fujian, Jiangsu, Zhejiang, Hainan, Liaoning	Zhejiang, Hainan	Zhejiang, Liaoning, Guangdong, Hainan
Laggards	Guangxi, Hebei	Jiangsu, Fujian, Liaoning, Guangxi, Hebei	Fujian, Jiangsu, Guangxi, Hebei

Table 9.
Division of provinces and cities of the three types

foreign marine technology, strengthen the capacity of marine disaster prevention and post-disaster reconstruction and accelerate the high-quality development of the marine economy.

5. Conclusions

This paper designs and optimizes the comprehensive evaluation system for the high-quality development of the marine economy. The entropy-TOPSIS method is used to measure the subsystem levels (first-level indicators) and comprehensive levels of the high-quality development of the marine economy in 11 coastal provinces (or cities) of China from 2017 to 2019, and the spatio-temporal evolution rules are analyzed. The main conclusions are as follows:

From the perspective of time, from 2017 to 2019, the comprehensive level of high-quality development of China's marine economy is on the rise, and the number of "backward" provinces and cities in 11 coastal provinces (cities) decreases, while the number of "general" and "leading" provinces and cities increases.

From the perspective of spatial dimension, different provinces and cities have different levels of high-quality development of marine economy. It is the manifestation that, Fujian, Guangdong and Jiangsu have a better social development support capability, Guangdong, Shandong and Tianjin are of the strong ability of marine economic base, Guangdong, Shandong and Shanghai are of marine science and technology driven effect significantly, and the green ocean economy development level of Tianjin, Shanghai and Guangdong is higher. On the whole, Guangdong, Shandong and Shanghai have advantages in the comprehensive level of high-quality development of marine economy.

According to the above research conclusions, in order to actively promote the overall improvement of different subsystem levels and the coordinated improvement of high-quality development level of marine economy in different provinces and cities, the following policy suggestions are proposed.

- (1) It is necessary to attach importance to the idea of high-quality development of marine economy and promote the orderly transformation of the new development concept from the pursuit of quantity to quality.

At present, the overall level of high-quality development of China's marine economy is relatively low, with the national average level less than 0.5. Most coastal provinces (cities) still develop marine economy under the concept of quantity first, resulting in unsatisfactory relative indicators of marine economy and low level of high-quality development of marine economy. Therefore, the most fundamental and crucial strategy to effectively improve the quality of China's marine economy development is to abandon the extensive and backward development model of marine economic development based only on gross domestic product. We should actively explore high-quality development paths for the marine economy in accordance with local conditions, formulate a scientific and reasonable regulation and management system for the marine economy and promote the transformation of China's marine economic development from quantity-led to quality-led.

- (2) From the perspective of the whole region, we should implement the coordinated optimization strategy of high-quality development of marine economy in various provinces and cities so as to reduce the regional gap of high-quality development level of marine economy.

The subsystem and comprehensive level of the high-quality development of China's marine economy have different scores in different provinces and cities, and the differences among provinces and regions are quite obvious. To be specific, Guangdong, Shandong and Shanghai

are in the leading position of high-quality marine economy development, while Guangxi, Hebei have a large gap with other "leading" provinces. It is not conducive to the long-term health and sustainable stability of China's marine economy. Therefore, We need to adopt a targeted strategy of coordinated regional development that optimizes the level of high-quality development of the marine economy. From the overall national level, while actively promoting the high-quality development of the marine economy in the 11 coastal provinces and cities, we should formulate policies for regional coordination and interaction. It's able to comprehensively enhance the high-quality development of marine economy in coastal provinces and cities through various means, including spatial overflow of innovative achievements, interaction and exchange of efficient allocation of resources and sharing of experience in improving market mechanisms. In the end, we need to strengthen the marine economy while strengthening the weak and work together to raise the level of high-quality development of the marine economy.

- (3) It is necessary to formulate comprehensive policies to promote high-quality development of the marine economy under an all-dimensional framework, enhance the driving effect of scientific and technological innovation and intensify opening up to the outside world and share the benefits.

The high-quality development level of marine economy is represented by multiple indicators of different subsystems, and different provinces and cities have different horizontal distribution in each subsystem of the high-quality development of marine economy. For example, although Guangdong and Shandong have a high comprehensive level of high-quality development of marine economy, Guangdong has a relatively poor performance in driving marine science and technology innovation, social development security and green marine sustainability. Therefore, it is necessary to improve the level of backward subsystems of marine economy in various provinces and cities through targeted quality improvement strategies.

The state should give priority to improving and perfecting the level of backward subsystems, adjust the structure of the marine economy, increase the proportion of strategic emerging marine industries and high-end marine service industries, deepen the system of red lines for marine ecology, ensure economical development and centralized utilization and open up the cooperation and exchange of marine industries at a deeper level. In this way, we will comprehensively promote the comprehensive and coordinated improvement of various subsystems in the high-quality development of marine economy.

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