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Evaluation and Temporal-Spatial Deconstruction for High-Quality Development of Regional Marine Economy: A Case Study of China

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The high-quality development of the marine economy has become a realistic choice to stimulate the vitality of regional economic growth and achieve the goal of building a powerful nation in the marine economy. This study constructs an evaluation index system from efficiency, coordination, innovation, sustainability, openness, and shareability to analyze the high-quality development level and temporal-spatial heterogeneity of China's regional marine economy from 2010 to 2018. Methods used in this paper are entropy, kernel density estimation, and partial spatial autocorrelation analysis. The results are shown as follows: (1) The high-quality development level of China's regional marine economy shows a slow fluctuating and upward trend, coordination, sustainability, and innovation are the primary driving forces. The ranking of the three marine economic circles in the development quality of the marine economy is Eastern> Southern>Northern, the ranking of coastal provinces is Guangdong> Shanghai> Shandong> Zhejiang> Fujian> Tianjin> Jiangsu> Liaoning> Hainan> Hebei> Guangxi. The primary driving forces for Guangdong, Shanghai, Shandong, and Zhejiang leading other coastal areas are openness, efficiency, innovation, and sustainability respectively; (2) the temporal differentiation of China's regional marine economy shows a dynamic evolution process that is obvious in the early stages, alleviating in the middle stage, and balance in the later stage; (3) the spatial zoning types and high-quality development paths of 11 coastal provinces are determined based on spatial differentiation: Shanghai and Zhejiang are high-value congregate types and named as demonstration regions, which should build global marine center cities with deepening regional cooperation and high-standard opening-up; Shandong and Guangdong are high-value discrete types and named as key engine regions, which should enhance the international competitiveness of the marine industry with scientific and technological innovation; Tianjin, Hebei, and Liaoning are low-value congregate types and named as potential zooming regions, which should improve the

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efficiency of marine resources utilization with regional cooperation; Jiangsu, Fujian, Hainan, and Guangxi are low-value discrete types and named as land-sea coordination regions, which should build a modern and characteristic marine industrial system coordinated with land and sea.

Keywords: regional marine economy, high-quality development, temporal-spatial heterogeneity, maritime power strategy, kernel density estimation, partial spatial autocorrelation analysis

1 INTRODUCTION

China's general secretary Xi Jinping points out that the ocean is a strategic location for high-quality development. Under the guidance of national strategies such as building a powerful nation in the marine economy and the 21st century maritime Silk Road, the marine economy has become an important source of the vitality and momentum for economic development in coastal areas with its important roles of fostering new dynamics, growing new industries, and leading new development (Zhao et al., 2014; Carvalho and de Moraes, 2021), as well as a strategic fulcrum to pivot China's integrated land and sea development of higher quality, and a strategic hub for building a domestic and international "Dual Circulation" development pattern. In 2019, China's GOP reached 8.9415 trillion yuan, an increase of 6.2% over 2018, and the contribution of China's marine economy to the national economy reached 9.1%. The proportion of GOP to GDP has risen steadily for three consecutive years in coastal areas of China, exceeding 17% in 2019. Affected by COVID-19, China's GOP of 2020 only reached 8.001 trillion yuan, down 5.3% from 2019. Researching the development history of China's marine economy over the past 20 years, it is found that the contribution of the marine economy to the national economy has been hovering around 9.5%, and the proportion of GOP to GDP fell from 9.6% in 2015 to 7.9% in 2020, which seems to have entered a development bottleneck. In addition, increasing marine resources and environmental constraints (Chen et al., 2020b; Xu et al., 2021), insufficient marine science and technology innovation capacity (Li et al., 2021), extensive marine development and utilization (Ostrom, 2009; Pakalniete et al., 2017), low level of land and sea integrated development (Zhao et al., 2017), and other contradictions of unbalanced or inadequate development of marine economy are becoming more and more prominent. Therefore, in the new historical orientation, promoting the quality and efficiency of marine economy, that is, high-quality development is the objective choice to build a marine economic powerful nation. Expanding the development space and optimizing the spatial layout have become the policy priorities to consolidate the marine economic development foundation and enhance the power and vitality of marine economic development. It is urgently needed to re-grasp the regional marine economic development law, especially to evaluate the high-quality development level of the marine economy in each region of China, find out the breakpoints and blockages, and provide a decision-making basis for the path optimization of high-quality development of China's regional marine economy.

Most of the existing studies focus on the high-quality development of the marine economy from connotation and evaluation. First, scholars explain the connotation of high-quality development of the marine economy from three levels: component elements, development concept, and research dimensions. (1) In terms of component elements, the high-quality development of the marine economy is the synergistic development of the five systems of marine economy, marine resources, marine environment, and marine society, which specifically manifests itself in the improvement of comprehensive marine strength and optimization of marine industrial structure, intensive use of resources, sustainability of the ecological environment, and improvement of marine social welfare distribution (Han et al., 2019; Ding, 2020a); (2) in terms of development concept, the high-quality development of the marine economy is the organic unity of innovation, coordination, green, openness, and shareability (Lu et al., 2019; Liu et al., 2020; Yu and Xing, 2021); (3) in terms of research dimensions, the connotation of high-quality development of marine economy can be interpreted at three levels of macro, meso, and micro. From the macroscopic point of view, it is the comprehensive and balanced development of the marine economy. From the mesoscopic point of view, it is the adjustment and optimization of the marine industrial structure. From the microscopic point of view, it is the continuous improvement of input-output efficiency and economic efficiency of marine factors (An, 2018). Therefore, high-quality development of the marine economy should be efficient, stable, and sustainable, as well as coordinated, long-term, and comprehensive, with significant multi-system, multi-level, and multi-dimensional characteristics (Li et al.,2018).

Second, when it comes to the evaluation of the marine economic development quality, the existing studies are mainly divided into two categories: one is the comprehensive evaluation, and the other is the unidimensional evaluation which includes the evaluation of sustainability, efficiency, and coordination of regional marine economic development. (1) In terms of comprehensive evaluation, Li et al. (2020) constructed an evaluation index system based on comprehensive strength of the marine economy, marine industrial structure, marine social welfare, and marine ecological environment, and put forward that the focus of the marine development policy has changed from the pursuit of growth speed to growth quality. The coastal areas of the Yangtze River Delta continue to be the hotspots of high-quality development, the Bohai rim and Pan Pearl River Delta areas feature a mixture of cold and hot spots; Wang et al. (2015) constructed an evaluation index system covering five dimensions of economic scale, industrial structure, industrial efficiency, scientific and technological support and development potential, using the variable fuzzy identification model to measure the high-quality development level of the marine economy in China's coastal areas, and analyze

its dynamic evolution based on kernel density estimation. Lu et al. (2019) constructed an evaluation index system of the five new development concepts of innovation, coordination, green, openness, and shareability, using the entropy method to conclude that Shanghai, Guangdong Province, and Jiangsu Province are in the forefront, while Guangxi Zhuang Autonomous Region and Hebei Province are relatively lagging. Yu and Xing (2021) also constructed an evaluation index system based on the five new development concepts, and put forward that the quality of China's marine economic growth was increasing from 2004-2016, which was high in the middle coastal regions and low in the southern and northern coastal regions, with improvements gradually spreading from the middle to the northern and southern regions; Ding et al. (2021) constructed the "2+3+5" evaluation index system of high-quality development level of marine economy based on the five new development concepts and three major systems of marine economy, resource environment, and society. They conclude that the high-quality development level of China's marine economy has steadily increased in both the system object and the dimension of new development concepts and presents evolution trends of the stratified development of the economic system, the intensive development of resources and the environment system, and the gradual strengthening of marine support for the social system. (2) In terms of evaluating the sustainability of regional marine economic development, Yuan et al. (2014) constructed an evaluation index system based on the input-output perspective, using the PCA and DEA models to measure the sustainable development level of Tianjin's marine economy and its vertical evolution pattern; Li et al. (2015) constructed a sustainable development index system including four dimensions of regional development, marine economy, marine resources and environment, and marine talents and technology, using the gray correlation and hierarchical analysis to measure the sustainable development level of Shanghai's marine economy; Sun et al. (2016) constructed an evaluation index system of pressure, sensitivity, and coping capacity, using the data envelope analysis method (WSBM) and kernel density estimation to analyze the dynamic evolution of vulnerability of the marine economy; Yan et al. (2022) put forward that technological innovation driving has gradually replaced the resource-invested growth model. The sustainability of China's regional marine economy shows a stratified trend, with obvious differences between different areas. (3) In terms of evaluating the development efficiency of the regional marine economy, scholars use the ratio of inputs and outputs in the production process to assess the development efficiency of the marine economy. They use total factor productivity, selecting marine capital, sea-related labor force, marine resources, and environmental governance indicators as input factors (Ren, 2021), and adapting models to measure the growth of different regional marine economy and the input-output relationship between various production factors, such as CCR (Hu and Yu, 2018) and super-efficient DEA (Ding et al., 2018), to evaluate the development efficiency of regional marine economics. (4) In terms of evaluating the coordination of regional marine economic development, most of the existing studies focus on the evaluation of benign association between various factors of regional marine economy, including the evaluation of the coordination of the marine economic, resource, and environmental system (Sun and Wang, 2012; Lin and Chen, 2020), and the evaluation of the coordination of the marine economic system and the marine science and technology factors (Shao et al., 2021).

In summary, the existing research results present the following characteristics: First, most of the relevant results study marine economic development and its influencing factors from the temporal dimension, but have not yet evaluated the high-quality development of the marine economy from the perspective of spatial expansion or optimal layout; second, the research areas are mostly at the level of China's coastal regions as a whole or a single province, and the research contents are mostly the evaluation of marine economic development quality. There are a few spatial comparative studies on the high-quality development of the marine economy in different regions of China. Compared with the existing literature, the marginal contributions of this paper are as follows:① Based on the multiple strategies such as building new development patterns, domestic and international "dual circulation" and coordinated regional economic development, a comprehensive index system is constructed from six dimensions of efficiency, coordination, innovation, sustainability, openness, and shareability, and a comparative analysis of the high-quality development of China's regional marine economy is conducted at three levels: China's coastal regions as a whole, the three major marine economic circles, and the 11 coastal provinces (cities and districts).② Explore the spatial heterogeneity of the high-quality development of the marine economy of 11 coastal provinces (cities and districts) by partial spatial autocorrelation analysis, classify the spatial subdivisions types, and formulate the paths of high-quality development of the marine economy, to help improve the quality and efficiency of China's marine economy.

In view of the above discussion, the purposes of this paper are to comprehensively measure the high-quality development level of China's regional marine economy in 11 coastal provinces (cities and districts) and analyze its temporal-spatial heterogeneity. First, we construct a comprehensive index system from six dimensions of efficiency, coordination, innovation, sustainability, openness and shareability, and use the entropy method to evaluate the high-quality development level of the regional marine economy at three aspects: China's coastal regions as a whole, the three major marine economic circles, and the coastal provinces (cities and districts); second, we explore the temporal and spatial heterogeneity of high-quality development of the marine economy in 11 coastal provinces (cities and districts) by kernel density estimation (Ding et al., 2020b) and partial spatial autocorrelation analysis; third, we classify the spatial zoning types of 11 coastal provinces (cities and districts) and formulate the paths of high-quality development of the marine economy, in order to provide theoretical guidance for improving the quality and efficiency of regional marine economy in coastal regions of China. The remainder of this paper is organized as follows. Section 2 describes the methodology used in this study. Section 3 analyzes the era connotation and reality representation of high-quality development of the marine economy. Section 4 contains the evaluation of high-quality development level of China's regional marine economy. Section 5 contains the temporal-spatial heterogeneity deconstruction of high-quality

development level of the marine economy in 11 coastal provinces (cities and districts). Section 6 presents the conclusion.

2 METHOD AND DATA

2.1 Method

2.1.1 Entropy Method

This paper chooses the entropy method to carry out the calculation of index weights and comprehensive scores, which is a relatively good objective assignment method with fewer restrictions, and is suitable for the comprehensive evaluation of multiple indicators in multiple regions (Sun X. et al., 2021). The calculation steps are as follows.

(1) Standardization of indicators

The initial sample set is constructed:{ X_{hij} |h=1,2,⋯n;i=1,2,⋯r; j=1,2,⋯m } ,where X_{hij} denotes the value of the evaluation index j of the region i in the year h, h, r,and m represent the number of years, the number of sample regions, and the number of evaluation indexes, respectively. The evaluation indicators are standardized using the normalization method, and a +0.0001 leveling proces[1].

$$X_{hij} = \frac{x_{hij} - \min x_{hij}}{\max x_{hij} - \min x_{hij}}$$

(2) Same metrics for indicators

Calculate the proportion of the evaluation indicator j of the region i to the whole evaluation indicator j.

$$P_{ij} = \frac{X_{ij}}{\sum_{i=1}^{r} X_{ij}}$$

(3) Indicator entropy value

Calculate the entropy value of indicator **j.**

$$E_j = -k \cdot \sum_{i=1}^{r} P_{ij} \cdot \ln\left(P_{ij}\right)$$

$$k = \frac{1}{\ln(nr)}$$

(4) Indicator weights

Calculate the weight of indicator **j.**

$$W_j = \frac{1 - E_j}{m - \sum_{j=1}^{m} E_j}$$

(5) Comprehensive evaluation scores

Calculate the comprehensive scores of region i in year h.

$$S_{hi} = \sum_{j=1}^{m} W_j \cdot X_{hij}$$

2.1.2 Kernel Density Estimation

The kernel density estimation is used in probability theory to estimate the unknown density function and belongs to one of the nonparametric test methods. The kernel density estimation formula is as follows.

$$fh'(x) = \frac{1}{nh} \cdot \sum_{i=1}^{r} K \cdot \left(\frac{x - x_i}{h}\right)$$

K is the Gaussian kernel function, $h = 0.9SN^{-0.8}$, and S is the standard deviation.

2.1.3 Partial Spatial Autocorrelation Analysis

The partial spatial autocorrelation analysis is based on the spatial data of geographic variables, in order to analyse and test the correlation between its neighboring locations, and is used to reveal the spatial dependence and spatial heterogeneity characteristics of the variable data (Sun H. P. et al., 2021). The calculation steps are as follows.

(1) Standardizing the high-quality development scores of the regional marine economy

Calculate the standardized value Z_i of the high-quality development score of the marine economy in region i

$$Z_i = \frac{(S_i - \bar{S})}{\sqrt{\frac{1}{r} \cdot \sum_{i=1}^{r} (S_i - \bar{S})^2}}$$

(2) Calculating the local spatial autocorrelation coefficients

Calculate the local spatial autocorrelation coefficient LMI_i for the region i (a positive number shows a positive correlation, and a negative number shows a negative correlation).

$$LMI_i = Z_i \cdot \sum_{j=1}^{n} W_{ij} \cdot Z_j$$

W_{ij} is the spatial weight coefficient, and this paper uses the adjacency criterion to determine the value of W_{ij}, if region **i** and region **j** are adjacent, the $W_{ij} = 1$, vice versa $W_{ij} = 0$, and the diagonal element of the spatial weight coefficient matrix is 0 ($W_{ii} = 0$).

2.2 Data Source

In this paper, 11 provinces (cities and regions) along the coast of China (Liaoning Province, Hebei Province, Tianjin, Shandong Province, Jiangsu Province, Shanghai, Zhejiang Province, Fujian Province, Guangdong Province, Guangxi Zhuang Autonomous Region, and Hainan Province) are selected as research objects and divided into the Northern Marine Economic Circle (Liaoning, Hebei, Tianjin, and Shandong), the Eastern Marine Economic Circle (Jiangsu, Shanghai, and Zhejiang), and the Southern Marine Economic Circle (Fujian, Guangdong, Hainan, and Guangxi). Considering data availability, 2010-2018 is selected as the study time interval. Vector map data are obtained from the National Basic Geographic Information Centre, and social statistics are obtained from the China Marine Statistical Yearbook (2011-2017), the China Marine Economic Statistical Yearbook (2018-2019), and the China Financial Yearbook (2011-2019). Due to the change of statistical calibre, a small amount of missing data in 2016-2019 is made up by the regression fitting method.

[1]To solve the problem of zero inability to calculate the entropy value after data normalization.

3 ERA CONNOTATION AND EVALUATION INDEX OF HIGH-QUALITY DEVELOPMENT OF MARINE ECONOMY

3.1 Era Connotation

Based on the general connotation of high-quality economic development (Liu Y. et al., 2021; Wang, 2020; Jiang et al., 2021), combined with the complexity, dynamism, and multifunctionality of the marine economy, in line with the requirements of multiple strategies such as building new development patterns, building a powerful nation in the marine economy, and coordinated regional economic development, according to the new development concept of "innovation, coordination, green, openness and shareability", this paper believes that the connotation of high-quality development of the marine economy is an economic form that is based on the sustainable development and utilization of marine resources and led by technological innovation, industry modeling, and model change, relies on the efficient and coordinated development of the modern marine industry with the open development of land and marine economy as an extension, uses digital and intelligence technology, modern management methods to promote the innovative development of coastal economy and society and the formation of strong international competitiveness. This economic form requires a good relationship between government and market, efficiency and fairness in the process of high-quality development, and a good relationship between sea and land, domestic and international.

Xi Jinping's strategic thought of maritime power provides fundamental guidelines for the theoretical vision of high-quality development of China's regional marine economy in the new period. The high-quality development of the regional marine economy needs to focus on the long-term sustainable development of the marine and regional economy, and the inter-generational fair distribution of marine resources in the temporal dimension, on the optimization and integration of the layout between marine and adjacent land economy and the shareability of welfare between the marine economy and social development in the spatial dimension. Therefore, the vision of high-quality development of the regional marine economy is to adhere to innovation-driven, green development and high-level open development, promote the protection and development of marine resources in an integrated manner, continuously cultivate and strengthen the special marine industries, optimize the spatial layout of the marine economy, and strive to form a new pattern of interactive and coordinated development of land and sea elements, industries and space, and the integration and shared development of port, industry, city, and sea.

3.2 Evaluation Index

This paper argues that the high-quality development of the marine economy should include the following contents: efficient development of the marine economy, coordinated development of the marine industry, innovation-driven development, sustainable development and utilization of marine resources, high-level open development of the marine economy, and integrated and shared development of port, industry, city, and sea. Based on the overlapping requirements of new development concepts and multiple strategies such as building a new development pattern and a powerful nation in the marine economy, considering the multidimensional nature of marine economic development and combining with the foundation of previous scholars' research, this paper constructs an evaluation index system of high-quality development of regional marine economy from six dimensions of efficiency, coordination, innovation, sustainability, openness, and shareability (**Table 1**).

3.2.1 Efficiency

Efficient growth of the marine economy is an essential requirement for high-quality development, which requires an accurate grasp of the potential growth rate of the marine economy, as well as the relatively effective economic production efficiency. This paper selects five secondary indicators to measure the efficiency of regional marine economy based on the growth rate of marine output value, contribution rate to GDP, and production efficiency perspectives (Wu, 2014; Chen et al., 2020a).

3.2.2 Coordination

The coordinated development of the marine industry is an endogenous feature of high-quality development, pushing the transformation and upgrading the marine industry structure, and promoting the structural growth of the marine industry in the middle and high end will provide a strong impetus for marine economic development. This paper selects six secondary indicators to measure the coordination of marine industry structure based on the perspectives of rationalization and advancement of marine industry structure (Wang L. L. et al., 2021; Wang B. et al., 2021).

3.2.3 Innovation

Marine science and technology innovation is the first driving force leading high-quality development, scientific and technological self-reliance, and self-improvement are important strategic supports for the development of the marine economy. Innovation helps cost intensification and production efficiency, which in turn drive the transformation and upgrading of the marine industry, the transformation of marine economic development patterns, and shapes new advantages of high-quality development comprehensively. This paper selects six secondary indicators to measure the innovation of marine science and technology based on the perspectives of innovation resources and innovation performance of the marine economy (Liu P. D. et al., 2021; Li et al., 2016; Yang et al., 2021).

3.2.4 Sustainability

The sustainable development of marine resources and environment are the universal forms of high-quality development and adhering to "ecological priority and green development" is the realization path to drive the green transformation of the marine economy and the synergistic high-quality development of ecology and economy. This paper selects six secondary indicators to measure the sustainability of marine resources and environment based on the perspectives of ecological protection and environmental governance (Liu, 2017; Marshak and Link, 2021).

TABLE 1 | Evaluation index system for the high-quality development level of the regional marine economy.

Objective	Sub-dimension	Guideline layer	Indicator layer	Explanation of indicators and sources	Weight
High-quality development index of regional marine economy	Marine economy efficiency A1	GOP	Regional GOP growth rate B1	Sequential growth rate	0.0260
			Regional GOP contribution rate B2	Regional GOP/Regional GDP	0.0295
		Production efficiency	Sea productivity B3	Regional GOP/Total marine areas	0.0395
			Labor productivity B4	Regional GOP/Total regional population	0.0299
			Capital productivity B5	Regional GOP/Total investment in fixed assets	0.0308
	Marine industry coordination A2	Rationalization	Regional marine secondary industry output value ratio B6	Regional marine secondary industry output value/Total regional marine industry output value	0.0272
			Regional marine tertiary industry output value ratio B7	Regional marine tertiary industry output value/ Total regional marine industry output value	0.0273
			Regional major marine industry value-added ratio B8	Value-added of regional major marine industries/Gross value-added of regional marine industries	0.0281
		Advancement	Regional marine secondary industry growth elasticity coefficient B9	Regional marine secondary industry output growth rate/Growth rate of regional GOP	0.0259
			Regional marine tertiary sector growth elasticity coefficient B10	Regional marine tertiary industry output growth rate/Growth rate of regional GOP	0.0259
			Marine industry structure advanced index B11	Regional marine tertiary industry value-added/ Regional marine secondary industry value-added	0.0261
	Marine science and technology innovation A3	Innovative resources	Regional marine scientific research investment B12	Total funding income of regional marine research institutions	0.0297
			Number of regional marine scientific research institutions B13	Obtained from the China Marine Statistical Yearbook and the China Marine Economic Statistical Yearbook	0.0281
			Educational level of regional marine science and technology personnel B14	Proportion of scientific and technical personnel with master's degree or above	0.0273
			Title level of regional marine science and technology personnel B15	Proportion of scientific and technical personnel with senior title or above	0.0268
		Innovation performance	Number of regional marine science and technology achievements B16	Total regional marine science and technology patents, publications, and topics	0.0303
			Application rate of regional marine science and technology results B17	The number of regional marine results application topics/Total number of regional marine topics	0.0287
	Marine resources and environmental sustainability A4	Ecological protection	Regional marine biodiversity Index B18	Total regional phytoplankton, microzooplankton, and benthic organisms	0.0271
			Number of regional marine protected areas B19	Total number of national and local protected areas	0.0320
			Regional marine ecological monitoring area B20	Obtained from the China Marine Statistical Yearbook and the China Marine Economic Statistical Yearbook	0.0303
			Number of regional marine observation stations B21	Total number of marine stations, tide gauge stations, weather stations, and seismic stations	0.0269
		Environmental governance	Regional comprehensive utilization rate of industrial solid waste B22	Regional comprehensive utilization of industrial solid waste/total regional industrial solid waste	0.0278
			Number of regional marine pollution control projects B23	Number of regional completed pollution control projects in current year	0.0301
	Marine economy openness A5	Port openness	Coastal port cargo throughput B24	Obtained from the China Marine Statistical Yearbook and the China Marine Economic Statistical Yearbook	0.0295
			Coastal port passenger throughput B25	Obtained from the China Marine Statistical Yearbook and the China Marine Economic Statistical Yearbook	0.0327
			Coastal port container throughput B26	Number of international standard containers	0.0313
			Number of berths for port production B27	The total number of production berths in ports above designated scale	0.0319

(Continued)

TABLE 1 | Continued

Objective	Sub-dimension	Guideline layer	Indicator layer	Explanation of indicators and sources	Weight
		Port city openness	Number of inbound tourists received B28	Total number of inbound tourists received by major coastal cities	0.0372
			Total regional export-import volume ratio B29	Total regional imports and exports in coastal areas/Regional GDP	0.0300
	Marine economy shareability A6	Income benefits	Per capita disposable income of urban residents B30	Obtained from the China Marine Statistical Yearbook and the China Marine Economic Statistical Yearbook	0.0304
			Per capita disposable income of rural residents B31	Obtained from the China Marine Statistical Yearbook and the China Marine Economic Statistical Yearbook	0.0293
		People's livelihood improvement	Percentage of financial education expenditure B32	Local financial expenditure on education/Total local general budget expenditure	0.0275
			Percentage of financial health care expenditure B33	Local financial health care expenditure/Total local general budget expenditure	0.0284
			Percentage of financial social security and employment expenditure B34	Local financial social security and employment expenditure/Total local general budget expenditure	0.0303

3.2.5 Openness

The open development of the marine economy is the only route that must be passed to promote high-quality development. With the help of high-level opening to the outside world, China can form a domestic and international "dual-circulation" development pattern of marine economy, and build a global community of interests and destiny of the marine economy, to help the high-quality development of port, industry, city, and sea. This paper selects six secondary indicators to measure the openness of the marine economy based on the perspectives of port opening and port city opening (Sun et al., 2019; Wang, 2021).

3.2.6 Shareability

Shared development of the regional marine economy is the fundamental purpose of high-quality development. Continuous and obvious improvement of people's livelihoods, enabling people to share the fruits of marine economic development and helping achieve common prosperity are the proper meanings of high-quality development of the marine economy. This paper selects five secondary indicators to measure the openness of marine economy based on the perspectives of income welfare and livelihood improvement (Zheng and Ge, 2020; Zhang and Li, 2021).

4 EVALUATION OF HIGH-QUALITY DEVELOPMENT LEVEL OF THE REGIONAL MARINE ECONOMY

4.1 Evaluation Index Weights

Using the entropy method, based on the panel data of 11 coastal provinces (cities and regions) from 2010 to 2018, the index weights of the high-quality development of the marine economy are obtained (**Table 1**).The indicator weights of the six sub-dimensions are as follows: 0.1556 for the efficiency of the marine economy, 0.1606 for the coordination of the marine industry, 0.1710 for the innovation of marine science and technology, 0.1742 for the sustainability of marine resources and environment, 0.1926 for the openness of the marine economy, and 0.1460 for the shareability of the marine economy. Therefore, according to the importance of sub-dimensions to the high-quality development of regional marine economy, the six sub-dimensions are ranked as openness>sustainability> innovation>coordination>efficiency>shareability.

4.2 Overall Evaluation

This paper measures and evaluates the high-quality development level of the marine economy in China's coastal regions as a whole, the three major marine economic circles, and the 11 coastal provinces (cities and districts) (**Table 2**). Due to the small values obtained from the entropy method, this paper expands the values by 100 times overall to make the comparison between the values more intuitive when evaluating the high-quality development level of regional marine economy.

4.2.1 Overall Evaluation of China's Coastal Regions and the Three Major Marine Economic Circles

China's marine economy has shown a fluctuating upward development trend, with the comprehensive score of high-quality development rising from 39 in 2010 to 42 in 2015, and then slightly declining to 40 in 2018. Among them, the comprehensive score of the Eastern Marine Economic Circle has fluctuated upward, rising from 45 in 2010 to 49 in 2016, and then decreasing to 45 in 2018; the comprehensive score of the Southern Marine Economic Circle has been stable in fluctuation at 39; the comprehensive score of the Northern Marine Economic Circle has fluctuated upward, rising from 35 in 2010 to 39 in 2016, and then decreasing to 37 in 2018. Therefore, the high-quality development level of the three major marine economic circles is ranked as follows: Eastern Marine Economic Circle>coastal overall average value>Southern Marine Economic Circle>Northern Marine Economic Circle. The high-quality development level of Southern and Northern

TABLE 2 | Comprehensive scores of the high-quality development level of the regional marine economy.

TimeRegions		2010	2011	2012	2013	2014	2015	2016	2017	2018	Average value	Ranking
Coastal regions as a whole		39.05	39.98	39.88	41.45	40.94	41.93	41.74	39.13	39.99	40.45	
Three ocean economic circles	Northern Ocean Economic Circle	34.60	36.84	36.42	38.50	38.63	37.49	39.41	36.28	37.37	37.28	3
	Eastern Ocean Economic Circle	45.40	47.95	47.65	47.26	46.77	48.32	49.34	45.19	45.49	47.04	1
	Southern Ocean Economic Circle	38.74	37.13	37.52	40.04	38.87	41.59	38.38	37.43	38.48	38.69	2
11 coastal provinces (cities and districts)	Tianjin	38.65	39.63	39.34	42.17	42.53	39.85	35.79	35.35	38.41	39.08	6
	Hebei Province	23.99	27.77	26.08	27.90	26.70	23.84	27.78	25.68	29.15	26.54	10
	Liaoning Province	31.29	33.84	29.82	34.46	36.23	36.70	41.43	34.89	31.91	34.51	8
	Shanghai	57.34	57.50	58.44	57.72	55.87	57.98	59.95	55.25	53.97	57.11	2
	Jiangsu Province	35.28	39.90	38.16	37.80	37.02	38.34	40.33	37.53	38.65	38.11	7
	Zhejiang Province	43.57	46.46	46.34	46.25	47.43	48.65	47.74	42.80	43.86	45.90	4
	Fujian Province	37.52	38.64	37.90	41.08	40.60	45.27	39.37	42.90	45.11	40.93	5
	Shandong Province	44.47	46.09	50.45	49.45	49.08	49.56	52.66	49.19	50.01	49.00	3
	Guangdong Province	61.23	61.79	63.59	63.88	64.17	64.74	64.65	61.48	61.70	63.03	1
	Guangxi Zhuang Autonomous Region	23.81	19.19	21.02	23.94	20.63	25.94	20.78	17.60	20.89	21.53	11
	Hainan Province	32.41	28.89	27.59	31.26	30.07	30.40	28.70	27.73	26.21	29.25	9

Marine Economic Circles is very close, the gaps between the Eastern and the Southern, and the Eastern and the Northern marine economic circles are obvious and stable.

4.2.2 Overall Evaluation of 11 Coastal Provinces

The comprehensive scores of high-quality development level of the marine economy in each province are ranked as follows: Guangdong Province>Shanghai>Shandong Province>Zhejiang Province> Fujian Province>Overall average level>Tianjin>Jiangsu Province>Liaoning Province>Hainan Province>Hebei Province>Guangxi Zhuang Autonomous Region. Guangdong Province and Shanghai are in the first echelon of marine economic development quality, the comprehensive scores of which are between 53-65 each year; Shandong, Zhejiang, and Fujian Provinces are in the second echelon of marine economic development quality, the comprehensive scores of which are between 37-53 each year; Tianjin, Jiangsu, and Liaoning Provinces are in the third echelon of marine economic development quality, the comprehensive scores of which are between 29-43 each year; Guangxi Zhuang Autonomous Region, Hainan and Hebei Provinces are in the fourth echelon of marine economic development quality, the comprehensive scores of which are between 17-33 each year. In terms of the evolution of comprehensive scores (**Figure 1**), the high-quality development level of the marine economy in the 11 coastal provinces (cities and districts) has been fluctuating upward. The comprehensive scores of Fujian and Shandong Provinces present the fastest growth rates, the comprehensive scores of Jiangsu, Liaoning, and Hebei Provinces maintain moderate growth rates, the comprehensive scores of Tianjin, Guangdong, and Zhejiang Provinces are in low growth rates, and the comprehensive scores of Shanghai, Guangxi Zhuang Autonomous Region, and Hainan Province are in the slowest growth rates or even negative. Therefore, the 11 coastal provinces (cities and districts) can be divided into the following four categories according to the absolute values and growth rates of comprehensive scores of regional marine economic high-quality development level: (1) Leading type: Guangdong and Shandong Provinces; (2) advanced type: Shanghai, Zhejiang, and Fujian Provinces; (3) medium type: Tianjin, Jiangsu, and Liaoning Provinces; (4) catching-up type: Guangxi Zhuang Autonomous Region, Hainan and Hebei Provinces.

4.3 Sub-Dimensions Evaluation

The scores of the six sub-dimensions of high-quality development level of the marine economy in China's coastal regions as a whole, the three major marine economic circles (**Table 3**), and the 11 coastal provinces (cities and districts) are calculated. According to the contribution rates of the six sub-dimension scores to comprehensive scores, the core driving factors of the high-quality development of the marine economy in each region are analyzed (**Figure 2**).

4.3.1 Sub-Dimensions Evaluation of China's Coastal Regions

The importance of coordination, sustainability, and innovation dimensions to the high-quality development of China's regional marine economy are ranked in the top three, the average scores of which are 8.20, 7.71, and 7.70, respectively. The contribution of shareability and openness dimensions to the high-quality development of China's regional marine economy are second to the preceding three dimensions, the average scores of which are 5.99 and 5.72. And the role of efficiency dimension is the weakest, the average score of which is 5.13. Therefore, coordination, sustainability, and innovation dimensions become the three powerful boosters of the overall high-quality development of China's regional marine economy. At the same time, the scores of efficiency, coordination, and sustainability dimensions fluctuate upward year by year, while the scores of innovation, openness, and shareability dimensions are stable in fluctuation year by year.

4.3.2 Sub-Dimensions Evaluation of the Three Major Marine Economic Circles

(1) The Eastern Marine Economic Circle is outstanding in terms of marine economic high-quality development. Its four sub-dimensions of efficiency, innovation, sustainability, and shareability all rank first among the three major marine economic circles, while the score of openness dimension is slightly lower than

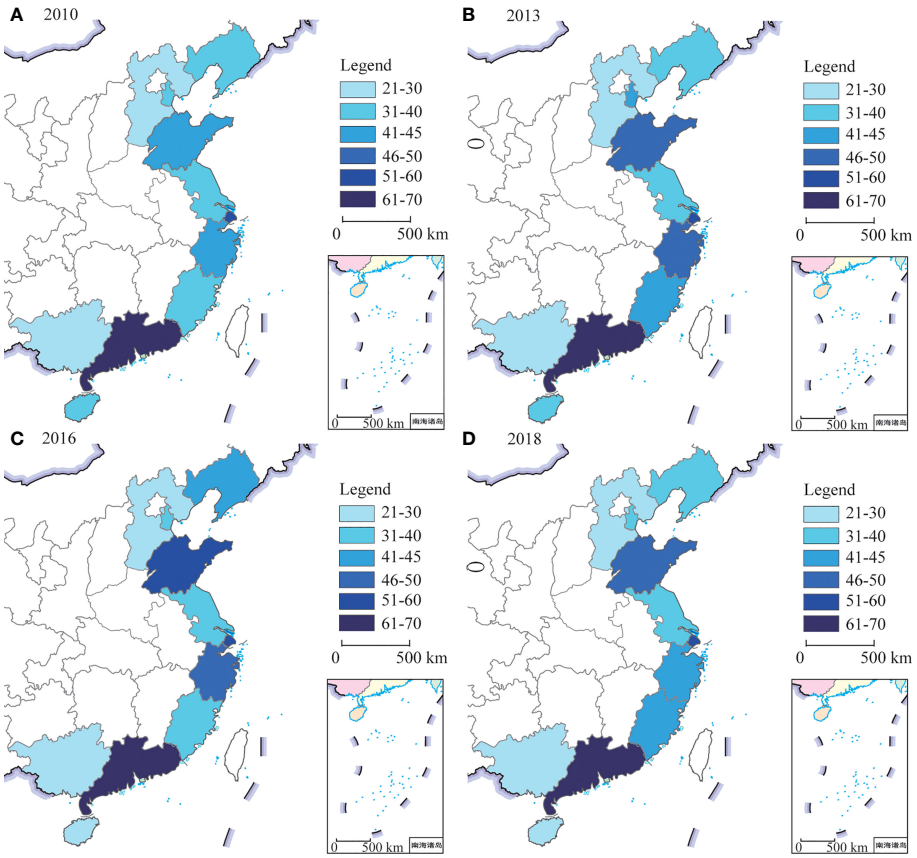

FIGURE 1 | Developing trend of the high-quality development comprehensive scores of the marine economy in 11 coastal provinces (cities and districts). **(A–D)** Display the high-quality development comprehensive scores of the marine economy in 11 coastal provinces in 2010, 2013, 2016, and 2018 respectively.

that of the Southern Marine Economic Circle, and only the score of coordination dimension is at the bottom. Among them, the average scores of efficiency, innovation, and sustainability dimensions are 6.41, 9.48, and 10.02, respectively, which are much higher than those of the Southern and Northern Marine Economic Circles. Therefore, the advantages of the Eastern Marine Economic Circle lie in efficiency, sustainability, and innovation dimensions, the weakness lies in the coordination dimension. At the same time, combined with the contribution rates of sub-dimension scores to comprehensive scores, the core drivers of the high-quality development of the Eastern Marine Economic Circle are sustainability and innovation.

(2) The Southern Ocean Economic Circle ranks second in terms of marine economic high-quality development. Its openness dimension score ranks first among the three ocean economic circles, while its efficiency, coordination, and sustainability dimension scores are in the middle, and its innovation and shareability dimension scores are at the bottom. Therefore, the strengths of the Southern Ocean Economic Circle lie in openness, coordination, and sustainability, while its weaknesses lie in innovation and shareability. At the same time, combined with the contribution rates of sub-dimension scores to comprehensive scores, the core drivers of the high-quality development of the Southern Ocean Economic Circle are openness, coordination, and sustainability.

(3) The Northern Marine Economic Circle is slightly lower than the Southern Marine Economic Circle in terms of high-quality development of the marine economy. Its coordination dimension score ranks first among the three marine economic circles, while its innovation and shareability dimension scores are in the middle, and its efficiency, sustainability, and openness dimension scores are at the bottom. Among them, the scores of openness and sustainability are much lower than those of the Eastern and Southern Marine Economic Circles. Therefore, the advantages of the Northern Marine Economic Circle are coordination and innovation, and the disadvantages are efficiency, sustainability, and openness. At the same time, when combining the contribution rates of sub-dimension scores to comprehensive scores, the core drivers of high-quality development of the Northern Marine Economic Circle are coordination and innovation.

4.3.3 Sub-Dimensions Evaluation of 11 Coastal Provinces

Comparing the average scores of the six sub-dimensions from 2010 to 2018(**Figure 3**), the high-quality development of Guangdong's marine economy ranks first, benefiting from its extremely strong openness, and its sustainability and innovation are significantly higher than the average of coastal regions. The high-quality development of Shanghai's marine economy ranks second,

TABLE 3 | Sub-dimension scores of the high-quality development level of marine economy in China's coastal regions and the three ocean economic circles.

Region	Project	Sub-dimension scores of the high-quality development level											
		2010	2011	2012	2013	2014	2015	2016	2017	2018	Average value	Internal ranking	External ranking
Coastal region as a whole	A1 (Efficiency)	4.60	4. 97	4.74	4. 65	5. 18	5. 64	6. 16	4. 39	5.86	5. 13	6	
	A2 (Coordination)	7.44	8. 01	8.23	8. 91	8. 20	8. 84	8. 57	7. 92	7.65	8. 20	1	
	A3 (Innovative)	7.69	8. 14	7.72	7. 68	7. 90	7. 97	7. 63	7. 09	7.47	7. 70	3	
	A4 (Sustainability)	7.29	7. 28	7.18	7. 95	7. 70	8. 04	8. 11	8. 23	7.63	7. 71	2	
	A5(Openness)	5.77	5. 83	5.86	5. 80	5. 73	5. 64	5. 64	5. 64	5.60	5. 72	5	
	A6 (Shareability)	6.27	5. 76	6.14	6. 46	6. 23	5. 80	5. 63	5. 85	5.77	5. 99	4	
Northern Ocean Economic Circle	A1 (Efficiency)	4.14	4. 98	3.93	4. 10	4. 88	4. 49	5. 35	3. 34	4.62	4. 43	5	3
	A2 (Coordination)	7.63	7. 89	8.63	9. 60	9. 26	8. 63	9. 01	8. 67	8.69	8. 67	1	1
	A3 (Innovative)	8.09	8. 47	7.97	8. 14	8. 03	8. 40	8. 45	7. 41	7.80	8. 08	2	2
	A4 (Sustainability)	4.66	5. 69	5.65	6. 14	6. 38	6. 05	7. 16	7. 16	6.60	6. 17	3	3
	A5(Openness)	4.13	4. 18	4.34	4. 42	4. 39	4. 20	4. 22	4. 25	4.23	4. 26	6	3
	A6 (Shareability)	5.94	5. 63	5.89	6. 09	5. 69	5. 72	5. 23	5. 45	5.43	5. 68	4	2
Eastern Ocean Economic Circle	A1 (Efficiency)	6.30	6. 33	6.19	5. 36	5. 78	7. 06	8. 02	5. 52	7.13	6. 41	6	1
	A2 (Coordination)	6.85	7. 77	8.22	7. 86	7. 25	8. 45	8. 39	6. 81	6.94	7. 62	3	3
	A3 (Innovative)	9.34	10.26	9.80	9. 58	10.10	9. 33	9. 66	8. 63	8.63	9. 48	2	1
	A4 (Sustainability)	9.00	10.04	9.59	10.28	9. 95	10.55	10.10	10.81	9.83	10. 02	1	1
	A5(Openness)	6.82	6. 82	6.64	6. 38	6. 33	6. 34	6. 28	6. 31	6.29	6. 47	5	2
	A6 (Shareability)	7.09	6. 74	7.21	7. 79	7. 35	6. 60	6. 90	7. 11	6.67	7. 05	4	1
Southern Ocean Economic Circle	A1 (Efficiency)	3.78	3. 95	4.46	4. 67	5. 03	5. 74	5. 58	4. 61	6.16	4. 89	6	2
	A2 (Coordination)	7.68	8. 30	7.84	9. 00	7. 85	9. 35	8. 25	8. 01	7.15	8. 16	1	2
	A3 (Innovative)	6.04	6. 22	5.93	5. 78	6. 13	6. 52	5. 29	5. 62	6.28	5. 98	4	3
	A4 (Sustainability)	8.62	6. 79	6.90	8. 02	7. 32	8. 15	7. 58	7. 38	7.01	7. 53	2	2
	A5(Openness)	6.64	6. 73	6.80	6. 73	6. 62	6. 55	6. 58	6. 51	6.44	6. 62	3	1
	A6 (Shareability)	5.98	5. 14	5.60	5. 83	5. 92	5. 28	5. 09	5. 29	5.44	5. 51	5	3

benefiting from its extremely high efficiency, and its innovation, sustainability, and openness are higher than the average of coastal regions. The innovation and sustainability of Shandong's marine economy are more outstanding. The sustainability, openness, and shareability of Zhejiang's marine economy are more prominent. The sustainability of Fujian's marine economy is better, but its innovation is too low. The efficiency of Tianjin's marine economy is more prominent, but its openness and sustainability are too low, The innovation and sustainability of Jiangsu's marine economy are higher than the average of coastal regions, but its openness and efficiency are too low. Liaoning's marine economy has better innovation and coordination, but its efficiency and sustainability are too low. Hainan's marine economy has better coordination, but its innovation, openness, and sustainability are too low. Hebei and Guangxi's marine economies have better coordination, but their efficiency, innovation, sustainability, and openness are too low. Therefore, the primary drivers for Guangdong, Shanghai, Shandong, and Zhejiang Provinces ahead of other coastal regions in the high-quality development of marine economy are openness, efficiency, innovation, and sustainability, respectively.

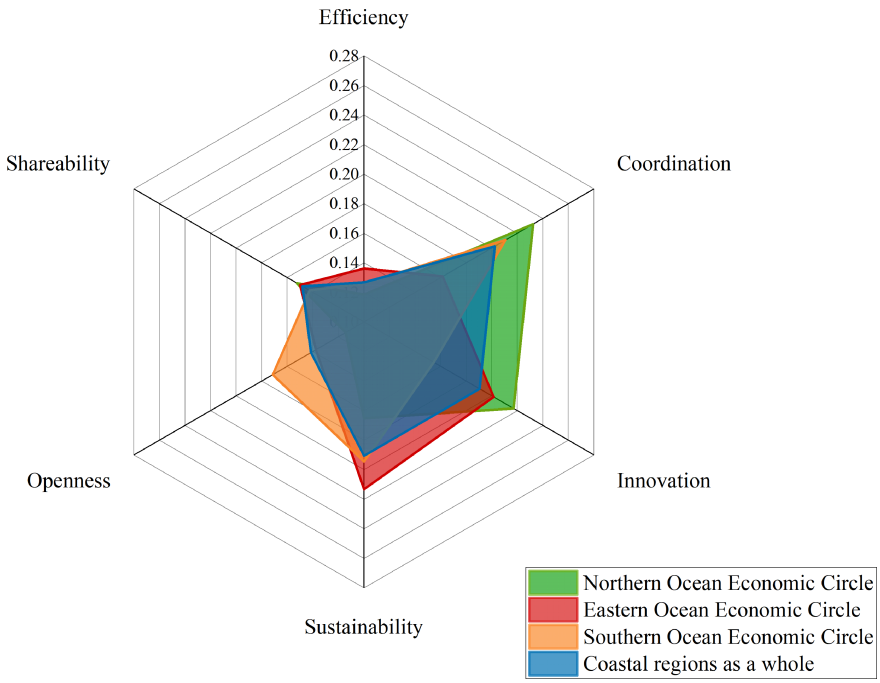

FIGURE 2 | Average contribution rates of the sub-dimension scores to comprehensive scores of China's coastal regions and the three ocean economic circles from 2010-2018.

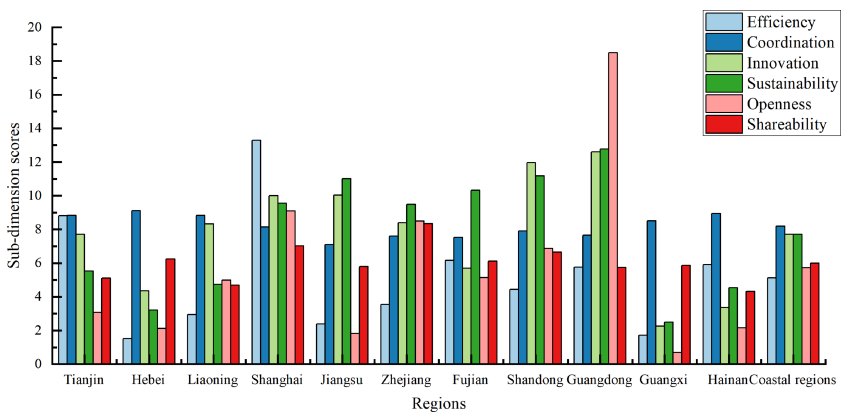

FIGURE 3 | Average scores of the six sub-dimensions of the marine economy in 11 coastal provinces (cities and districts) from 2010-2018.

5 TEMPORAL-SPATIAL HETEROGENEITY DECONSTRUCTION OF HIGH-QUALITY DEVELOPMENT OF MARINE ECONOMY IN 11 COASTAL PROVINCES

5.1 Temporal Heterogeneity

This paper applies the kernel density estimation to measure the dynamic evolution pattern of the high-quality development of the marine economy in 11 coastal provinces (cities and districts). The representative years (2010, 2014, and 2018) are selected to calculate the kernel density of the high-quality development of marine economy in 11 coastal provinces (cities and districts). The kernel density diagram is shown in **Figure 4**, and the results are as follows.

(1) According to the overall distribution, the kernel density curves show an overall slow moving trend to the right over time, and the maximum probability values have increased slightly from 38 in 2010 to 39 in 2014, and have stabilized at this level

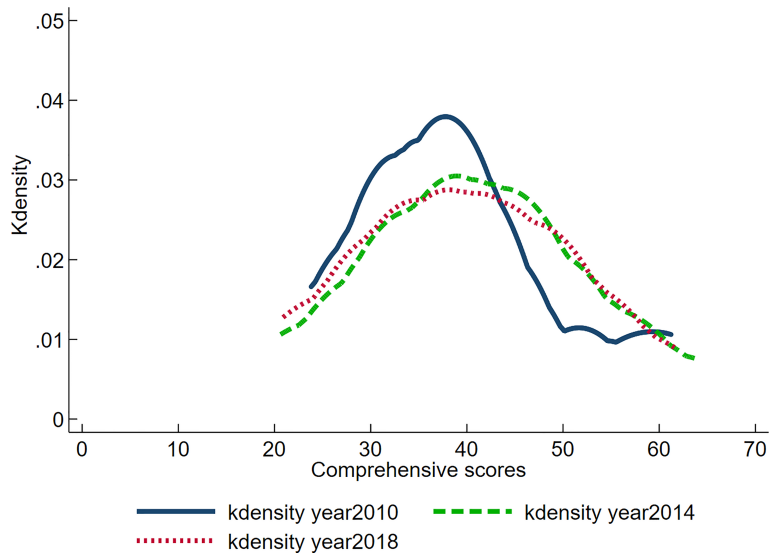

FIGURE 4 | The kernel density curves of the high-quality development level of the marine economy in 11 coastal provinces (cities and districts).

from 2014 to 2018.At the same time, the tail of the kernel density curves extended to the right in 2014, indicating that the maximum values of the regional marine economy's high quality development level showed a rising trend. The overall high-quality development level of the marine economy in 11 coastal provinces (cities and districts) shows a slowly fluctuating growth. (2) According to the distribution shape, the kernel density curves show a more obvious skewed distribution, with a double-peaked skewed distribution in 2010 and a single-peaked skewed distribution in 2014 and 2018. From 2010 to 2014, the first peak decreased rapidly and the second peak disappeared, the kernel density curves have changed from "spiky peak" to "broad peak", which indicates that the polarization of the high-quality development level of the marine economy in the 11 coastal provinces (cities and districts) has been alleviated and the distribution tends to be balanced. From 2014 to 2018, the peak has decreased further, and the characteristics of "broad peak" have become more significant, indicating that the balanced development of the marine economy in 11 coastal provinces (cities and districts) has been further deepened. Therefore, the high-quality development level of the marine economy in the 11 coastal provinces (cities and districts) shows a dynamic evolution process that the differentiation is obvious in the early stage, alleviates in the middle stage, and tends to be balanced in the later stage. The reason is that Guangdong Province, which ranks first in the high-quality development level of the marine economy in 11 coastal provinces (cities and districts), and Shanghai which ranks second, both have low growth rates and even present decreasing trends. But Fujian Province, which is in the middle of the 11 coastal provinces (cities and districts) according to high-quality development level of the marine economy, has a leading growth rate. Liaoning and Hebei Provinces, which are at the back of the 11 coastal provinces (cities and districts) according to high-quality development level of marine economy, both have moderate growth rates. Therefore, thanks to the effective catch-up of the middle and lower ranked provinces according to the high-quality development level of the regional marine economy, as well as the stable marine economic development of the top ranked provinces, the polarization degree of the high-quality development level of 11 coastal provinces (cities and districts) has been alleviated year by year.

5.2 Spatial Heterogeneity and Policy Recommendation

In view of the significant spatial differences in the high-quality development level of the marine economy in 11 coastal provinces (cities and districts), this paper uses the local spatial autocorrelation analysis to carry out spatial heterogeneity analysis. By adopting the comprehensive scores of the regional marine economic high-quality development level from 2010 to 2018, this paper calculates the standardized value (Z) of the comprehensive scores of the regional marine economic high-quality development level, and the local spatial autocorrelation coefficient (LMI) of 11 coastal provinces (cities and districts). The spatial distribution differences of 11 coastal provinces (cities and districts) are analyzed according to the positive or negative level of Z and LMI, the spatial zoning types and its policy recommendations are determined accordingly (**Figure 5**).

5.2.1 Demonstration Regions

The provinces (cities and districts) with high-value congregate types (H-H:Z>0 and LMI>0) are classified as demonstration regions, including Shanghai and Zhejiang Province which concentrates in the Yangtze River Delta region. Shanghai and Zhejiang Provinces have high levels of development quality in the marine economy and are surrounded by regions with high

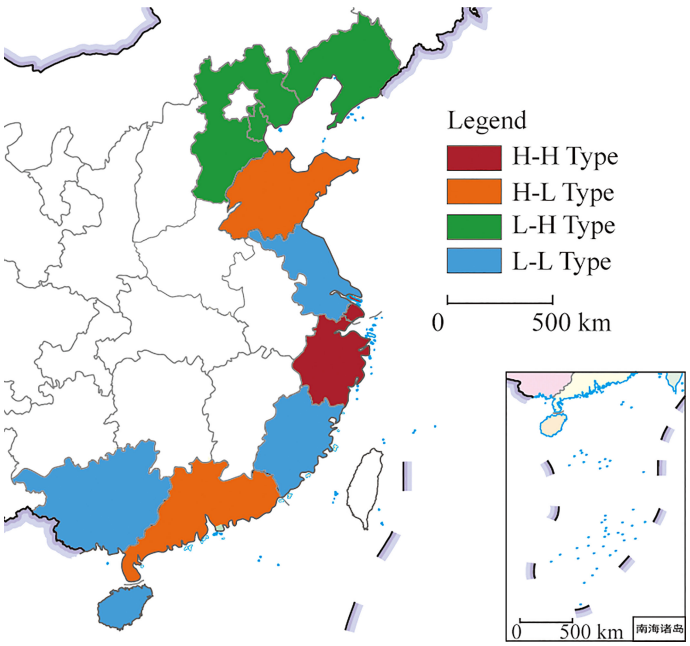

FIGURE 5 | Space partition of the high-quality development level of the marine economy in 11 coastal provinces (cities and districts).

levels of development quality in the marine economy. Therefore, they have strong positive spatial correlations with neighboring regions and show a spatial pattern of high-value congregate type. According to the previous measurement results, Shanghai's marine economy presents extremely high efficiency and ranks second among the 11 coastal provinces (cities and regions) in terms of marine economic high-quality development level. Zhejiang's marine economy presents outstanding openness, sustainability, and shareability, and ranks fourth among the 11 coastal provinces (cities and regions). Therefore, Shanghai and Zhejiang Provinces should be regarded as core areas of high-quality development of the regional marine economy and release the potential of efficient development and open development of marine economy.

When it comes to the policy recommendations and specific realization routes, the demonstration regions should seize the important period of strategic opportunity that China is vigorously implementing the high-standard opening-up, the "Belt and Road Initiative" and Domestic and International "Dual Circulation" development strategy, build global marine center cities on the basis of deepening regional cooperation and high-standard opening-up. The specific realization routes are as follows: (1) First, Shanghai and Zhejiang Provinces should constantly deepen maritime cooperation and establish blue economy partnerships with neighboring countries, strengthen cooperation in basic scientific research and the introduction of advanced talents and technologies actively integrate into the construction of the "Belt and Road Initiative" with its advantages to build a maritime community with a shared future. (2) Second, relying on the strong domestic market, Shanghai and Zhejiang Provinces should smooth the production, distribution, circulation, and consumption of marine products, connect domestic and foreign trade regulation, promote high-level two-way investment with reasonable fiscal expenditure level and deficit fiscal policy to promote the Domestic and International "Dual Circulation" development of the marine economy.

5.2.2 Key Engine Regions

The provinces (cities and districts) with high-value discrete types (H-L:Z>0 and LMI<0) are classified as key engine regions, including Shandong and Guangdong Provinces located in the Northern and Southern Marine Economic Circles, respectively. Shandong and Guangdong Provinces have a high level of development quality in the marine economy, but their neighboring regions have low levels of development quality in the marine economy, which makes them have strong negative spatial correlations and present a spatial pattern of high-value discrete type. According to the previous measurement results, Shandong's marine economy ranks third among the 11 coastal provinces (cities and regions) in terms of marine economic high-quality development level, and the innovation and sustainability of its marine economy are significantly higher than the average level of coastal regions; Guangdong's marine economy ranks first among the 11 coastal provinces (cities and regions), and the openness of its marine economy is extremely remarkable. The innovation and sustainability of its marine economy are significantly higher than the average level of coastal regions. Therefore, Shandong and Guangdong Provinces should focus on the development of the marine economy and act as the leading forces in the high-quality development of China's regional marine economy.

When it comes to the policy recommendations and specific realization routes, guided by the strategies of building a powerful nation of science and technology, green economy, and high-standard opening-up, the key engine regions should enhance the international competitiveness of the marine industry with scientific and technological innovation. The specific realization routes are as follows: (1) First, Guangdong Province should be developed into a key engine region for opening-up. Relying on the construction of the "two corridors and two points" architecture system of the Guangdong-Hong Kong-Macao Greater Bay Area and the construction of Shenzhen as a global marine center city, Guangdong Province should build an open and interconnected trade pattern, support and cultivate a number of internationally competitive leading sea-related enterprises and brands, and enhance the vitality of Guangdong's modern marine industry development. (2) Second, Shandong Province should be developed into a key engine region for innovative development. It should research and develop key core technologies in the field of marine emerging industries, and build a highland of marine science and technology innovation with international influence. At the same time, Shandong Province should activate the industrial chain by the innovation chain, promote its marine industry to grow in advanced directions. Specifically, Shandong Province should vigorously develop the marine tourism and culture industry, ocean industry, and other competitive industries by taking full use of Shandong's rich coastal tourism resources and transportation resources and pave the way for its marine industry to enhance its international competitiveness.

5.2.3 Potential Zooming Regions

The provinces (cities and districts) with low-value congregate types (L-H:Z<0 and LMI>0) are classified as potential zooming regions, including Tianjin, Hebei, and Liaoning Provinces, which are concentrated in the Bohai Rim region. These three provinces have low levels of marine economic development quality and strong positive spatial correlations with neighboring regions, which makes them show a spatial pattern of low-value congregate type. According to the previous measurement results, Tianjin's marine economy ranks sixth among the 11 coastal provinces (cities and districts), the efficiency of its marine economy is higher than the average level of coastal regions, but its openness and sustainability are too low; Liaoning's marine economy ranks eighth among the 11 coastal provinces (cities and districts), and the innovation and coordination of its marine economy are higher than the average level of coastal regions, but its efficiency and sustainability are too low; Hebei's marine economy ranks tenth among the 11 coastal provinces (cities and districts), which is more backward. Therefore, Tianjin, and Hebei and Liaoning Provinces should deepen their cooperation to maximize the positive effect of spatial accumulation on enhancing the high-quality development of the regional marine economy.

The root causes of the low levels of high-quality development of marine economy in potential zooming regions lie in the low efficiency and sustainability of the marine economy development. Considering the strong positive spatial correlation in the marine economy, Tianjin, Hebei, and Liaoning Provinces should improve the efficiency of marine resources utilization with regional cooperation. The specific realization routes are as follows: (1) First, these three provinces should strengthen inter-regional cooperation and promote coordinated development among regions, focus on building a northern shipping center, construct inter-regional connectivity and realize the sharing of economic strength, infrastructure, marine science and technology, and human resources. (2) Second, these three provinces should pursue ecological optimization and green development, step up efforts to control the red line of marine ecology, jointly prevent and control the marine pollution, and restore the marine ecological environment. At the same time, the development space of green marine industries such as seawater resource utilization, seawater desalination, modern green fishery, and ocean wind power industry should be expanded to improve the utilization efficiency of marine resources and sustainability of the marine environment.

5.2.4 Land-Sea Coordination Regions

The provinces (cities and districts) with low-value discrete types (L-L:Z<0 and LMI<0) are classified as land-sea coordination regions, including Guangxi Zhuang Autonomous Region, Jiangsu, and Fujian and Hainan Provinces. The regional marine economy of the four provinces has a low level of high-quality development and strong negative spatial correlations with neighboring regions, which makes them show a spatial pattern of low-value discrete type. Fujian's marine economy ranks fifth among the 11 coastal provinces (cities and districts), the sustainability of its marine economy is higher than the average level of coastal regions, but its innovation is too low; Jiangsu's marine economy ranks seventh among the 11 coastal provinces (cities and districts), the innovation and sustainability of its marine economy are higher than the average level of coastal regions, but its openness and efficiency are too low; Hainan's marine economy ranks ninth among the 11 coastal provinces (cities and districts), the coordination of its marine economy is higher than the average level of coastal regions, but its innovation, sustainability, and openness are too low. The level of high-quality development of Guangxi's marine economy ranks in last place and has no advantages. Therefore, these four provinces are the disadvantaged areas of high-quality development of the marine economy and should focus on finding strategic breakthroughs.

Considering that the common advantages of marine economic development in Guangxi Zhuang Autonomous Region, Jiangsu, Fujian, and Hainan Provinces lie in the better coordination of marine industries, the land-sea coordination regions should build modern and characteristic marine industrial systems coordinated with land and sea, thus promoting the interactive development of land and sea industries and the realization of land-sea economic integration linkage development situation. The specific realization routes are as follows: (1) First, these four provinces should build modern marine industrial systems by accelerating the development of marine engineering equipment, marine power, seawater desalination, large-scale utilization of marine energy, marine biomedicine, and marine cultural tourism that meet the new needs of the people and the market. In terms of marine traditional industries, promoting the deep integration of big data, digital technology, and artificial intelligence with them and vigorously promoting the development of the marine industry

structure to the direction of high added value and high efficiency are effective channels. Moreover, institutional innovation can be used to improve the marine economic development environment, such as establishing positive and negative lists of industrial development according to local characteristics of marine industries, and making functional industrial policies targeted at weak links. (2) Second, governments should formulate the overall development plan of land economy and marine economy from the perspective of land-sea integrated development. Through unified planning, joint development, industrial chain connection, and comprehensive management of coastal zone, marine and land resources can be rationally allocated, and the coordination between the sea area and the coastal land area can be realized to improve the comprehensive benefits of marine economy and land economy.

6 CONCLUSION

This paper constructs a comprehensive evaluation index system based on six dimensions of efficiency, coordination, innovation, sustainability, openness and shareability, uses the entropy method in evaluating the high-quality development level of regional marine economy from three levels of China's coastal regions as a whole, the three major marine economic circles, and 11 coastal provinces (cities and districts). Then, this paper adapts the kernel density estimation and partial spatial autocorrelation analysis methods in analyzing the temporal-spatial heterogeneity of 11 coastal provinces (cities and districts). The main conclusions are as follows.

First of all, according to the evaluation results, we can conclude that: (1) Coastal regions overall perspective: the high-quality development level of China's marine economy is fluctuating upward, coordination, sustainability, and innovation are strong boosters of high-quality development; (2) three major marine economic circles perspective: the ranking of high-quality development level of the marine economy is the Eastern Marine Economic Circle>overall average value>Southern Marine Economic Circle>Northern Marine Economic Circle. The high-quality development level of the Southern and Northern Marine Economic Circles is very close, the gaps between the Eastern and Southern, and the Eastern and Northern Marine Economic Circles are more obvious and maintain a stable development trend. The core driving forces for high-quality development of the Eastern Marine Economic Circle are sustainability and innovation, the core driving forces of the Southern Marine Economic Circle are openness, coordination, and sustainability, and the core driving forces of the Northern Marine Economic Circle are coordination and innovation. (3) At the perspective of 11 coastal provinces (cities and districts): the ranking of high-quality development level of the regional marine economy is Guangdong Province>Shanghai>Shandong Province>Zhejiang Province>Fujian Province>overall average value>Tianjin>Jiangsu Province> Liaoning Province>Hainan Province>Hebei Province>Guangxi Zhuang Autonomous Region. Among them, Fujian and Shandong Provinces are growing faster, while Shanghai, Hainan Province, and Guangxi Zhuang Autonomous Region are growing slowly. The primary drivers for Guangdong, Shanghai, Shandong, and Zhejiang Provinces ahead of other coastal regions in the high-quality development of the marine economy are openness, efficiency, innovation, and sustainability, respectively. Therefore, the 11 coastal provinces (cities and regions) are classified into the following four categories: ①Leading type: Guangdong and Shandong Provinces; ②advanced type: Shanghai, Zhejiang, and Fujian Provinces; ③ medium type: Tianjin, Jiangsu, and Liaoning Provinces; ④ catching-up type: Guangxi Zhuang Autonomous Region, and Hainan and Hebei Provinces.

Second, according to the analysis of temporal and spatial heterogeneity, we can conclude that: (1) At the perspective of temporal heterogeneity, the high-quality development level of marine economy in 11 coastal provinces (cities and districts) shows a dynamic evolution process that the differentiation is obvious in the early stage, alleviates in the middle stage, and tends to be balanced in the later stage. (2) At the perspective of spatial heterogeneity, based on the differences in spatial distribution of high-quality development level of regional marine economy, the spatial zoning types and high-quality development paths of 11 coastal provinces are determined as follows: ① Demonstration regions (high-value congregate type) includes Shanghai and Zhejiang Province, which should build global marine center cities with deepening regional cooperation and high-standard opening-up. ② Key engine regions (high-value discrete type) include Shandong and Guangdong Provinces, which should enhance the international competitiveness of the marine industry with scientific and technological innovation. ③ Potential zooming regions (low-value congregate type) includes Tianjin, Hebei, and Liaoning Provinces, which should improve the efficiency of marine resources utilization with regional cooperation. ④ Land-sea coordination regions (low-value discrete type) includes Guangxi Zhuang Autonomous Region, Jiangsu, and Fujian and Hainan Provinces, which should build modern and characteristic marine industrial systems coordinated with land and sea.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found here: The datasets analyzed for this study can be found in the National Bureau of Statistics of China. http://www.stats.gov.cn.

AUTHOR CONTRIBUTIONS

DA: Conceptualization, methodology, software, data curation, validation, writing-original draft. CSL: Formal analysis, writing-review and editing. LY: Writing-review and editing, supervision, project administration. All authors contributed to the article and approved the submitted version.

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