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Evaluation and Countermeasures of High-Quality Development of China's Marine Economy Based on PSO-SVM

Sheng Gao [1], Huihui Sun [1,2,*], Jingyi Wang [1] and Wei Liu [1]

[1] School of Government Audit, Nanjing Audit University, Nanjing 211815, China
[2] College of Forestry, Fujian Agriculture and Forestry University, Fuzhou 350002, China
* Correspondence: 320277@nau.edu.cn

Abstract: An accurate grasp of the high-quality development of the marine economy is important for the timely adjustment of marine policies and the promotion of sustainable development of the ocean. Based on the latest development philosophy, this paper constructed the evaluation index system of high-quality development of marine economy from five dimensions including innovation, coordination, green, openness, and sharing. The particle swarm optimization (PSO) algorithm and support vector machine (SVM) model based on the entropy weight composite index were employed to evaluate the high-quality development of China's marine economy from 2006 to 2017. The spatial and temporal distribution characteristics and dynamic evolution mechanism were revealed. The random forest model was applied to analyze the main driving factors of high-quality development of the marine economy. It was found that: (1) The high-quality development level of marine economy in Guangdong, Shandong, Jiangsu, Zhejiang, and Shanghai has always been in the forefront. The growth rate of high-quality development level of marine economy in Guangdong and Shandong was 53.69% and 37.69%, respectively. The growth rates of Fujian and Hainan were 43.46% and 33.68%, respectively. Jiangsu and Zhejiang accounted for 33.30% and 24.47%, respectively. (2) The regulation methods of the main driving factors were examined. It was necessary to adhere to innovative development and improve the marine scientific research, education, management, and service industry, in addition by optimizing and adjusting the marine industrial infrastructure and spatial layout. It is also critical to strengthen the comprehensive prevention and control of land and sea pollution and implement the total emission control of pollutants into the sea. (3) Finally, the pathway for high-quality development of marine economy was analyzed and future directions were proposed.

Keywords: marine economy; high-quality development; new development concept; driving factors; improvement path

Citation: Gao, S.; Sun, H.; Wang, J.; Liu, W. Evaluation and Countermeasures of High-Quality Development of China's Marine Economy Based on PSO-SVM. *Sustainability* **2022**, *14*, 10749. https://doi.org/10.3390/su141710749

Academic Editor: Vincenzo Torretta

Received: 19 July 2022
Accepted: 24 August 2022
Published: 29 August 2022

1. Introduction

China's coastline is one of the regions with the fastest economic development, the largest total economic scale, and the most economic vitality and greatest development potential. Meanwhile, it also has a relatively high degree of exploitation of marine resources and a highly concentrated area of pollutant discharge. If we randomly pursue high growth of marine economy, it will accelerate the depletion of marine resources and the deterioration of marine environment. At present, China's marine economy has shifted from a high-speed growth stage to a high-quality development stage. It is in a key period, with the focus on transforming the mode of development, optimizing the economic structure, and transforming the driving forces of growth. At the same time, it is also facing the problems of careless marine economic growth, increased pressure of transformation, low efficiency of marine resources utilization, and aggravated marine environmental pollution. China's 14th five-year plan clearly pointed out that it is necessary to develop the marine economy and speed up the construction of a marine power. Therefore, we need to pay attention to the economic quality, resource allocation, and environmental optimization in the process of ocean economic development.

The fundamental purpose of the high-quality development of marine economy is to improve the quality of life, and the fundamental connotation is the new development concept. In terms of the perspectives, the previous research on marine economic development mainly focus on the marine economic efficiency [1], marine economic benefits [2–4], green development of marine economy [5,6], green total factor productivity of marine economy [7], economic energy of marine ecosystem [8], marine industrial productivity [9], regional differences of marine economy [10], spatial–temporal coordination of marine economic development [11], and the high-quality of marine economic growth [12–15], etc. Zhao et al. [16] analyzed the research dimension, development path, and guarantee mechanism of high-quality development of marine economy from the aspects of connotation, significance, and evaluation. Ding et al. [17] summarized the evaluation and practice of high-quality economic development from three aspects: connotation, index, and path [18]. In terms of the evaluation index system, the previous research mainly includes a sustainable development indicator system [19], green economy measurement index system [20], PSR (pressure–state–response) [21], DPSIR (driving force–pressure–state–impact–response) [22], DPSER (driver–pressure–state–exposure–response) [23], DPSEEA (driving force–pressure–state–exposure–effect–response) [24], SENCE (social–economic–natural composite ecosystem framework system) [25], and the index system of five development concepts [26–28], etc. In terms of the evaluation methods, the previous research methods mainly include the grey correlation method [29], principal component analysis [30], linear weighted model [31,32], entropy method [3,5], entropy correction G2 weighting [33], TOPSIS model [34,35], the modified gravity model and social network analysis method [35], PVAR model [36,37], analytic hierarchy process [38], the center gravity model [39], the fuzzy identification model, VAR model [40], the quadrant diagram classification and identification method [41], the multi-indicator evaluation models such as panel, threshold, and Bayesian [42], set pair analysis, kernel density estimation model, standard deviation ellipse and GMM model [43], the coupling coordination degree model [44], and entropy, and mean standard deviation classification methods [45], etc.

Compared with the previous research, the innovation of this paper is based on the new development concept, with innovation as the driving force, coordination as the requirement, green as the mode, opening as the path, and sharing as the goal. The evaluation index system for the high-quality development of the marine economy was selected and constructed from six aspects: economic vitality, structural optimization, openness, social livelihood, green development, and innovation driven. It reflects the overall situation of marine economic development and the relationship between various internal parts. In terms of research methods, PSO-SVM model based on the entropy weight composite index was used for the first time to reveal the spatiotemporal evolution mechanism of high-quality development of China's marine economy. The driving factors, control methods, optimization paths, and specific countermeasures were analyzed.

2. Data Sources

In recent years, the marine economy of China has followed a trend of total contraction and structural optimization, and has then become a new growth point of the national economy. From the perspective of the total marine economy, the gross marine product in 2018 was CNY 8.3 trillion, an increase of 6.7% over the previous year. In 2019, it was CNY 8.9 trillion, an increase of 6.2% over the previous year, accounting for 17.1% of the gross coastal product. In 2020, affected by the COVID-19 pandemic and the complex international environment, the gross marine product was CNY 8 trillion, which decreased by 5.3% over the previous year, accounting for 14.9% of the gross coastal product. In 2021, the gross marine product was CNY 903.85 billion, an increase of 8.3% over the previous year, accounting for 15.0% of the gross coastal product. From the perspective of marine economic structure, the added value of the primary, secondary, and tertiary marine industries accounted, respectively, for 4.4%, 37%, and 58.6% of the gross marine product in 2018; 4.2%, 35.8%, and 60.0% in 2019; 4.9%, 33.4%, and 61.7% in 2020; 5.0%, 33.4%, and 61.6% in 2021 (Figure 1). The structure and spatial layout of the marine economy had been optimized, and the modern marine industry system had been accelerating. In short, China's marine economy had shifted from the high-speed growth stage to the high-quality development stage. The development mode of the marine economy had changed from scale and speed to intensive growth by quality and efficiency. Marine economic growth momentum has been changing from traditional factor-driven to technology innovation-driven.

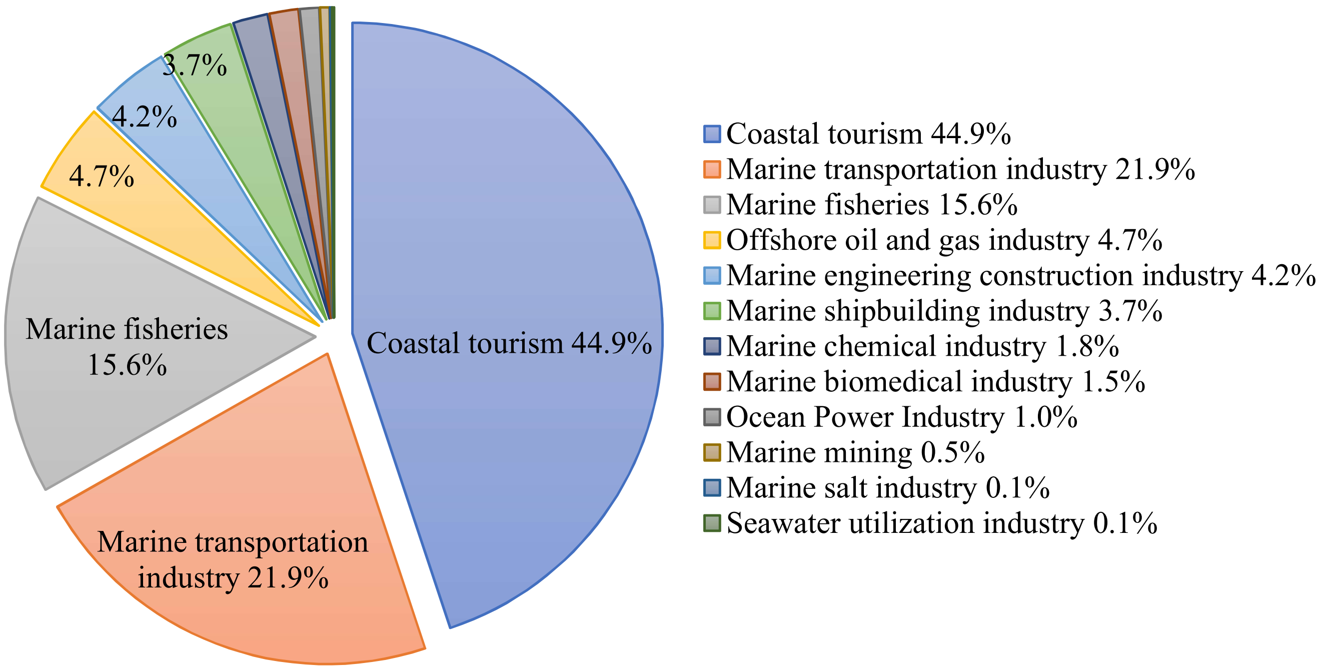

Figure 1. Proportion of output value of China's major marine industries in 2021.

The research data mainly comes from marine statistical yearbook of China, fishery statistical yearbook of China, and the port yearbook of China, the China environmental database, ocean database of China, regional economy database of China, Chinese city database, and urban and rural construction database of China in the EPS data platform.

2.1. Evaluation Index System of Marine Economic Growth Quality

The high-quality development of the marine economy is mainly reflected in the green development of the marine economy, the progress of coastal society, the efficient utilization of marine resources, and a good marine ecological environment. The economy–society–resources–environment system has achieved dynamic balance, and the comprehensive strength of the ocean has been significantly improved. Therefore, the evaluation index system of high-quality development of marine economy is a composite system. The indicator screening must conform to the principles of scientificity, integrity, operability and practicability, hierarchy, dynamics, and stability. This paper constructed an evaluation index system from six aspects: economic vitality, structural optimization, openness, social livelihood, green development, and innovation drive. The range standard method was used to calculate the standardized value and entropy weight (Table 1).

Table 1. Evaluation index system of high-quality development of the marine economy.

Six Aspects	Sort	Coastal Area Indicators	Entropy Weight
Economic vitality in coastal areas	×1	GDP of coastal areas (CNY 100 million)	0.0186
	×2	Growth rate of GDP in coastal areas (%)	0.0021
	×3	Gross marine product (CNY 100 million)	0.0228
	×4	GDP of major marine industries in coastal areas (CNY 100 million)	0.0198
	×5	Gross product value of marine scientific research, education, management, and service industry (CNY 100 million)	0.0379
	×6	Gross product value of marine-related industries (CNY 100 million)	0.0214
Structural optimization in coastal areas	×7	Proportion of marine gross product to coastal area gross product (%)	0.0176
	×8	Proportion of marine primary industry in total marine production (%)	0.0254
	×9	Proportion of marine secondary industry output value in total marine production (%)	0.0072
	×10	Proportion of marine tertiary industry output value in total marine production (%)	0.0068
	×11	Proportion of major marine industries in the added value of marine and related industries (%)	0.0084
	×12	Proportion of marine scientific research, education, and management services in the added value of marine and related industries (%)	0.0135
Openness level in coastal areas	×13	Total import and export of goods (USD 1 million)	0.0337
	×14	Port cargo throughput (10,000 tons)	0.0180
	×15	Port passenger throughput (10,000 people)	0.0395
	×16	Ocean freight volume (10,000 tons)	0.0222
	×17	Cargo Turnover Volume (10,000 tons)	0.0306
	×18	Port standard container throughput (10,000 TEUs)	0.0317
Social livelihood in coastal areas	×19	Per capita disposable income of urban residents (CNY)	0.0132
	×20	Per capita disposable income of rural residents (CNY)	0.0141
	×21	Number of Employed Persons (10,000 people)	0.0238
	×22	Number of health institutions (number)	0.0263
	×23	General public budget expenditure (CNY 10,000)	0.0996
	×24	Fixed asset investment of the whole society (CNY 100 million)	0.0205
Green development in coastal areas	×25	Area of marine nature reserves (km^2)	0.1159
	×26	Total wetland area (1000 hm^2)	0.0175
	×27	Water resources per capita (m^3/person)	0.0366
	×28	Water consumption per capita (m^3/person)	0.0186
	×29	Comprehensive utilization of general industrial solid waste (tons)	0.0765
	×30	Total wastewater discharge (10,000 tons)	0.0168
Innovation drive in coastal areas	×31	Number of employees in marine scientific research institutions (person)	0.0180
	×32	Total revenue of marine scientific research institutions (CNY 10,000)	0.0460
	×33	Number of marine scientific research institutions (number)	0.0159
	×34	Number of scientific and technological projects in marine scientific research institutions (items)	0.0293
	×35	Marine scientific research institutions publish scientific papers (articles)	0.0242
	×36	Number of colleges and universities (number)	0.0098

2.2. Methods

2.2.1. PSO Algorithm and SVM Model

The SVM model can be used for supervised learning in classification and regression analysis. The goal of building the model is to establish a hyperplane that can classify the data sample points clearly. The hyperplane refers to the straight line fitting the data. The data points closest to the fitting line on both sides of the hyperplane are called support vectors [46]. Figure 2 shows the principle of SVM. $y = \omega x + \mathrm{b}$ is the regression function. ε is the maximum acceptable deviation between the fitting value of the regression function and the actual value. The shaded part in the figure represents the hyperplane. The points on the dotted lines on both sides are support vectors. Then, $\frac{2}{\|\omega\|}$ is called the interval, which represents the sum of the distances of two heterogeneous support vectors to the hyperplane.

The ultimate goal of the model is to find the hyperplane with the maximum interval for which the objective function $\|\omega\|^2$ is of minimum size. In order to eliminate the influence of noise on data, this paper introduced a relaxation factor ξ and penalty factor cost, so the objective function of SVM is as follows:

$$\min\frac{1}{2}\|\omega\|^2 + C\sum_{i=1}^{n}\xi(i) \tag{1}$$

where $\|\omega\|^2$ refers to the objective function, $\xi(i)$ is the relaxation factor, and C is the penalty factor.

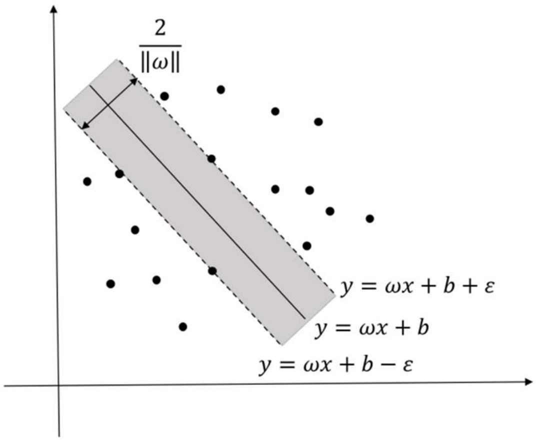

Figure 2. Schematic diagram of SVM.

The relaxation factor is the fault tolerance rate set for the model to ignore the special points affected by noise. The penalty factor is the tolerance of special points. The smaller the penalty factor, the smaller the tolerance, and the better the fitting degree of the sample. If the penalty factor is too large, the sample will be more strict, and errors are not allowed, and the model is easy to overfit. If the penalty factor is too large or too small, the generalization ability of the model will become poor, and the expected goal will not be achieved. In fact, the regression model is not always linear but more nonlinear, so we introduce the radial basis function as the kernel function of the SVM model. The formula of radial basis kernel function is:

$$K(\vec{x}, \vec{x}_i) = exp(-\frac{\left\|\vec{x} - \vec{x}_i\right\|}{2\sigma^2}) \ = exp(-gamma \times \left\|\vec{x} - \vec{x}_i\right\|) \tag{2}$$

$$gamma = \frac{1}{2\sigma^2} \tag{3}$$

The practical meaning of *gamma* is the width of the radial kernel function, which is a similar radius to the nonlinear function. The larger the similarity radius, the greater accuracy of the kernel function and the better the fitting effect. However, if the *gamma* value is too large, the overfitting phenomenon will also occur.

In order to establish an SVM model with a good fitting effect, it is necessary to find the best penalty factor and *gamma* value. In this paper, we use the PSO algorithm to iterate the optimal solution. PSO algorithm is a random search algorithm based on group cooperation [47]. The speed and position update formula is as follows:

$$v_{i+1} = v_i + c_1 \times rand \times (pbest_i - x_i) \times c_2 \times rand \times (gbest_i - x_i) \tag{4}$$

$$x_{i+1} = v_i + x_i \tag{5}$$

where v_i and v_{i+1} designate the speed of the particle and the speed of the next particle, *rand* is a random number between 0 and 1, x_i and x_{i+1} refer to the current position of the particle and the position of the particle after the next movement, c_1 and c_2 denote the learning factor, which is usually equal to 2, and $pbest_i$ and $gbest_i$ refer to the initial optimal position of the particle and the global optimal position of the particle swarm, respectively. The current global optimal solution and the updated optimal solution are being substituted into the SVM model respectively; we regard the difference between the two as the fitness change of particle swarm. When the change in particle swarm fitness is less than the set threshold, the iteration will exit. Finally, we calculate the root-mean-square error between the predicted value and the actual value to judge the fitting effect of the model.

2.2.2. Random Forest Model

Assuming that the random forest is composed of K trees, we used the bootstrap method to conduct random sampling of n samples. As a result, each tree selects n new samples from N original samples randomly to form an automatic sample set. In a sample set, a sample may be selected many times. Finally, K automatic sample sets are generated after the above steps are repeated K times. Each automatic sample set is classified to form k decision trees, namely a random forest [48,49]. The specific process is shown in Figure 3.

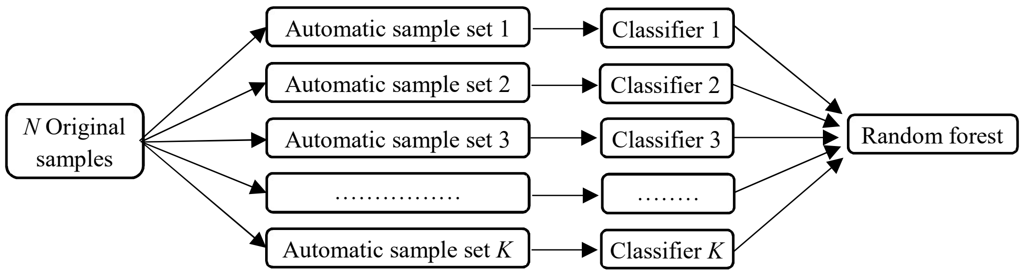

Figure 3. Flow chart of random forest model construction.

The decision tree is trained from N samples by sampling with replacement. The unselected sample data is called out of bag (OOB). Although OOB does not participate in the construction of a decision tree, it can be used to evaluate the performance of a decision tree. At first, we calculate the prediction error rate of the model, which is called out-of-bag error. Out-of-bag error of each decision tree is recorded as $errOOB_1$. Then we calculate the out-of-bag error again after adding noise interference to each feature of the sample, which is recorded as $errOOB_2$. If random noise is added, namely after introducing uncontrollable factors, and out of bag error increases sharply, it will prove that this feature has a significant impact on the prediction results of the model. In other words, the degree of importance of the feature is very high. Thus, we can conclude the importance of feature X in the following equation:

$$X_{importance} = \sum_{i=1}^{k} \frac{errOOB_{i2} - errOOB_{i1}}{N} \tag{6}$$

where $errOOB_1$ denotes out of bag error of each decision tree, $errOOB_2$ refers to out of bag error after adding noise interference, $X_{importance}$ is the importance of factor X, and N is the number of samples.

3. Analysis of the Results

3.1. High-Quality Development Level of Marine Economy

The entropy weight was calculated based on the normalized value of the range of each index. The linear weighted sum method [19] was used to calculate the comprehensive index of entropy weight of the high-quality development of the marine economy in various provinces of China as the Y. Based on the standardized value of the *Z-score* of each index, the PSO-SVM model was used. PSO-SVM is two swarm intelligence optimization algorithms.

PSO is mainly used to solve optimization problems. SVM is mainly used to solve the problems of pattern recognition and regression prediction. The ratio of the number of samples in the training set and the test set was set as 7:3. When the penalty factor was 3.96 and the *gamma* value was 0.07, it was the best SVM model after PSO. In addition to PSO, this paper used the trial and error method to find the best penalty factor and *gamma* value, and adjusted the parameters of SVM. First, the range of penalty factors was set from 10 to 10,000, and the range of *gamma* value was from 10^{-6} to 10^{-1}. Then 10-fold cross validation was used to calculate the error deviation of each parameter combination. Finally, the parameter combination with the smallest error was selected. It was found that when the penalty factor was 10,000 and the *gamma* value was 10^{-5}, the performance of the model was better compared to the calculation results when the training set (Figure 4) and the test set (Figure 5) of the PSO algorithm and the adjusted SVM model were both 7:3. It was found that the predicted value of the adjusted SVM model was a little larger than that of the PSO model, and the effect was better.

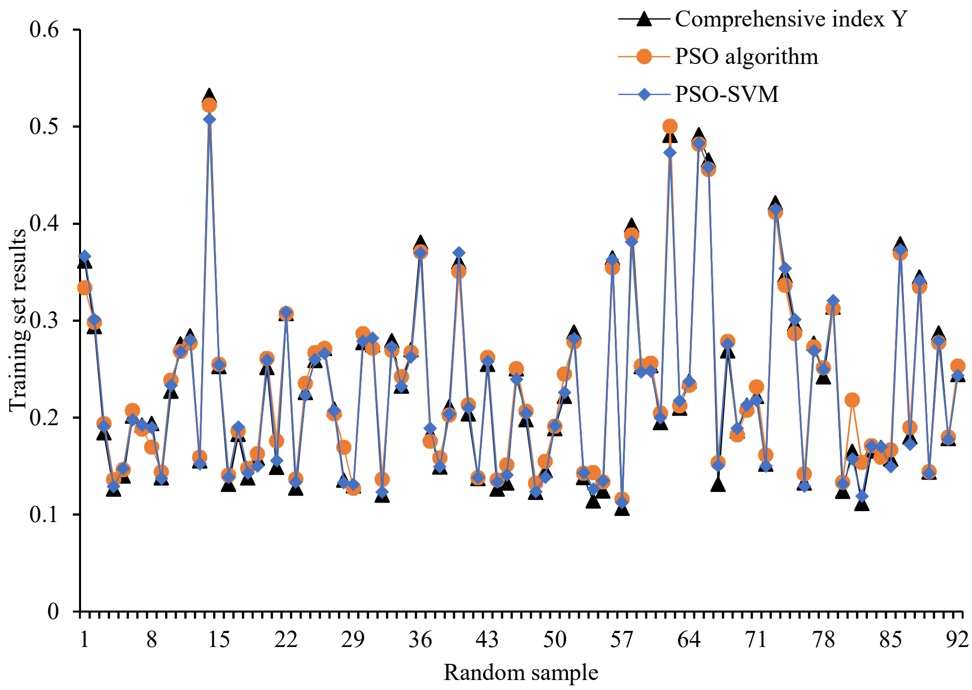

Figure 4. Comparison of results with a 70% training set.

Compared with the comprehensive index of entropy weight of high-quality development of China's marine economy, it was found that the prediction result of the support machine vector model based on the particle swarm optimization algorithm was better (Figure 6). Among them, the high-quality development level of marine economy of Guangdong and Shandong in all the evaluation years was ranked first and second, belonging to the first echelon. Jiangsu, Zhejiang, and Shanghai followed closely, ranking third, fourth, and fifth in all evaluation years, belonging to the second echelon. Fujian and Liaoning ranked sixth or seventh in all evaluation years, belonging to the third echelon. Hebei, Guangxi, Hainan, and Tianjin belong to the fourth echelon.

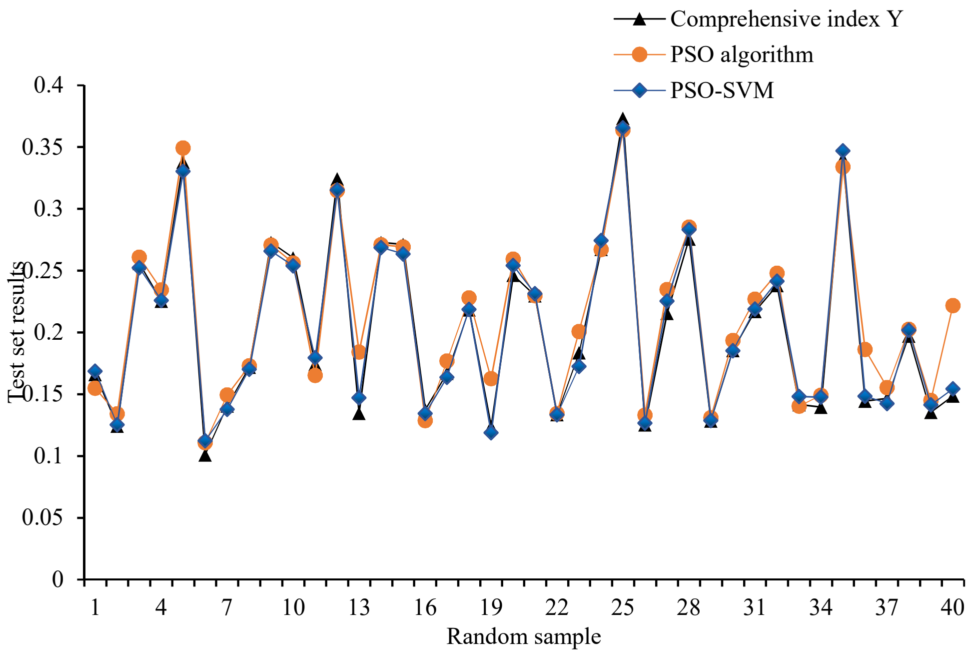

Figure 5. Comparison of results with a 30% test set.

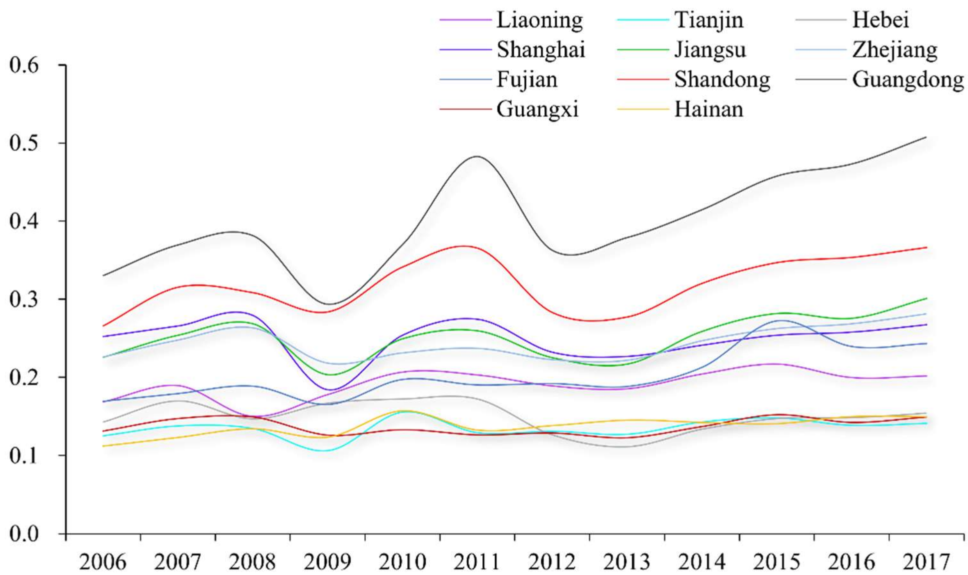

Figure 6. High-quality development of marine economy based on PSO-SVM.

3.2. Temporal and Spatial Evolution of High-Quality Development of Marine Economy

GIS visualization method was used to analyze spatiotemporal heterogeneity and reveal spatiotemporal distribution characteristics and dynamic evolution mechanisms. A spatial pattern map of the high-quality development level of the marine economy in China's coastal provinces in 2006, 2012, and 2017 was drawn (Figure 7). It was found that the high-quality development level of the marine economy at Guangdong and Shandong has always been at the forefront, followed by Jiangsu, Zhejiang, and Shanghai.

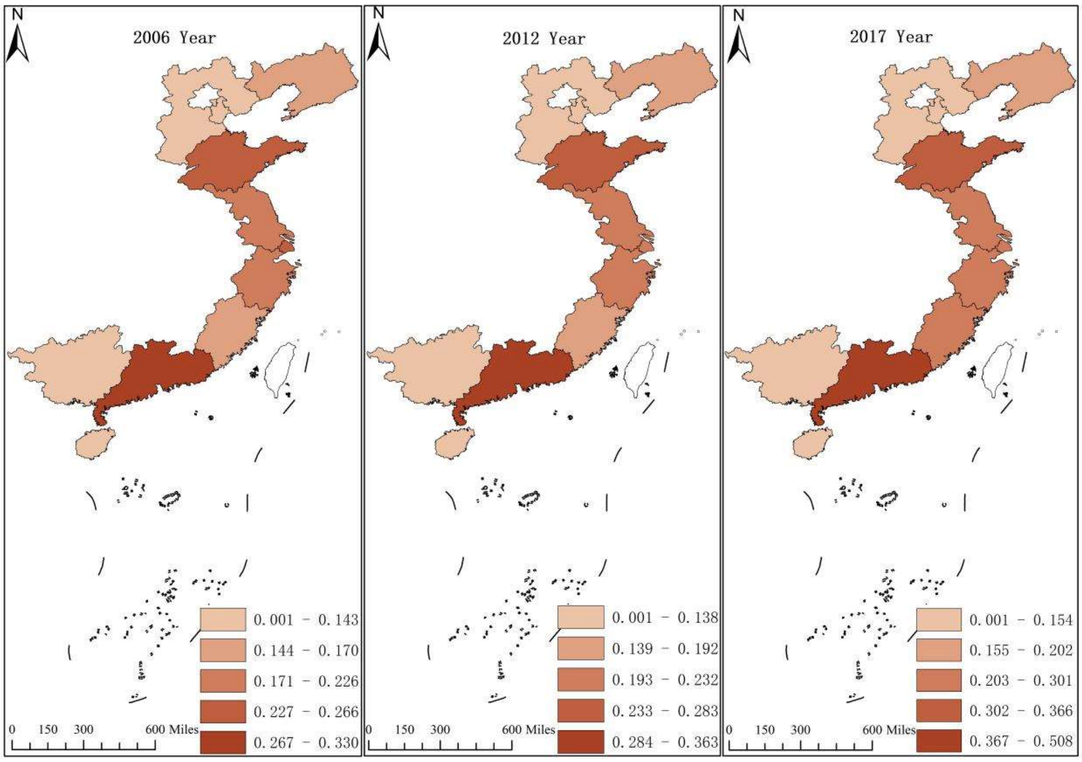

Figure 7. Temporal and spatial evolution characteristics of high-quality development of marine economy.

Regarding to level of high-quality development of the marine economy in 2017 relative to 2006 and 2012, Guangdong improved by 53.69% and 39.98%, respectively; Fujian improved by 43.46% and 26.62%, respectively; Shandong improved by 37.69% and 29.29%, respectively; Jiangsu improved by 33.3% and 33.6%, respectively; Zhejiang improved by 24.47% and 26.25%, respectively; Hebei improved by 8.07% and 22.22%, respectively; Guangxi improved by 13.57% and 15.95%, respectively; Shanghai increased by 6.03% and 15.25%, respectively, and the improvement was especially obvious since 2012. In addition, Hainan improved by 33.68% and 8.49%, respectively, Liaoning increased by 19.75% and 6.76%, respectively, and Tianjin has improved by 12.70% and 7.70%, respectively (Table 2).

Table 2. Growth rate of high-quality development level of marine economy in 2017 compared with 2006 and 2012.

Province	2017/2006	Sort	2017/2012	Sort
Guangdong	53.69%	1	39.98%	1
Jiangsu	33.30%	5	33.60%	2
Shandong	37.69%	3	29.29%	3
Fujian	43.46%	2	26.62%	4
Zhejiang	24.47%	6	26.25%	5
Hebei	8.07%	10	22.22%	6
Guangxi	13.57%	8	15.95%	7
Shanghai	6.03%	11	15.25%	8
Hainan	33.68%	4	8.49%	9
Tianjin	12.70%	9	7.70%	10
Liaoning	19.75%	7	6.76%	11

3.3. Driving Factors and Regulation Methods of High-Quality Development of Marine Economy

The random forest model was used to analyze the key drivers of the high-quality development of China's marine economy (Table 3). It was found that the gross product value of marine scientific research, education, management, and service industry (×5), marine scientific research institutions publish scientific papers (×35), total import and export of goods (×13), proportion of major marine industries in the added value of marine and related industries (×11), total wastewater discharge (×30), and number of scientific and technological projects in marine scientific research institutions (×34) were the main driving factors for the high-quality development of China's marine economy (Figure 8).

Table 3. Driving factors for high-quality development of marine economy.

Factors	Importance	Sort	Factors	Importance	Sort
×5	0.1719	1	×21	0.0094	19
×35	0.1704	2	×23	0.0085	20
×13	0.1121	3	×36	0.0079	21
×11	0.1003	4	×4	0.0076	22
×30	0.0884	5	×12	0.0075	23
×34	0.0487	6	×28	0.0058	24
×33	0.0347	7	×29	0.0055	25
×26	0.0291	8	×8	0.0052	26
×15	0.0289	9	×7	0.0052	27
×18	0.0234	10	×31	0.0048	28
×3	0.0229	11	×22	0.0046	29
×6	0.0201	12	×27	0.0039	30
×16	0.0178	13	×9	0.0027	31
×1	0.0140	14	×20	0.0025	32
×14	0.0113	15	×19	0.0025	33
×32	0.0099	16	×10	0.0025	34
×25	0.0097	17	×2	0.0020	35
×17	0.0095	18	×24	0.0014	36

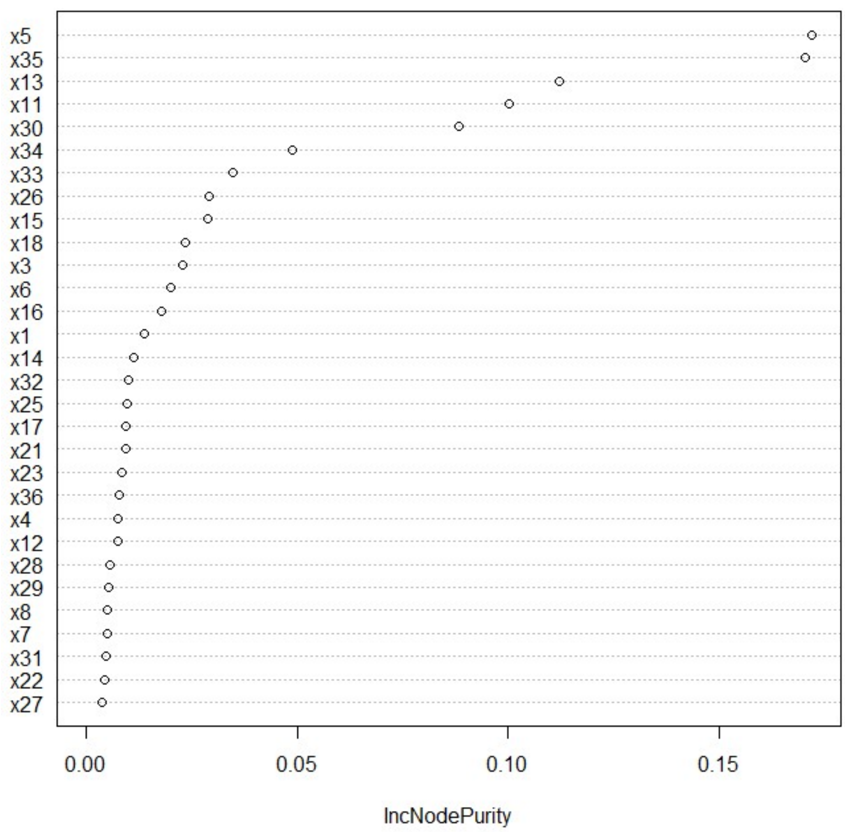

Figure 8. Importance ranking of drivers.

3.4. Regulation Methods of Main Driving Factors

In order to further improve the high-quality development level of the marine economy, this paper discussed the optimization and regulation methods of the main driving factors in the past. First, in order to improve ×5, ×35, and ×34, it is necessary to adhere to the innovation of marine science and technology and develop the marine scientific research, education, management, and service industry; develop marine education and strengthen the cultivation of marine talents; increase investment in R&D and build a carrier for technological innovation; and cultivate marine high-tech industries and improve the transformation rate of technological achievements. Second, in order to increase ×13 and ×11, it is necessary to optimize and adjust the structure and spatial layout of marine industry and promote the diversification of marine industry; cultivate strategic emerging marine industries and modern marine service industries; promote the upgrading of marine industry; take advantage of coordinated development of coastal areas; enhance industrial linkage; and promote the agglomeration of marine industries. Third, in order to regulate ×30 and reduce the total amount of major pollutants in the ocean, it is necessary to strengthen the comprehensive prevention and control of ocean and land pollution; establish and improve the total amount control system of pollutants discharged into the sea; and reduce the discharge rate of pollutants.

4. Discussion

The monitoring and evaluation of the high-quality development of the marine economy are helpful to accurately grasp the overall operation level and dynamic trends. It provides a decision-making reference for the rational selection of the index system screening and marine economic development types in different regions. It is helpful to make rational adjustments to marine economic policies and promote the sustainable development of marine economy society resources environment [9].

In order to test whether the selection ratio of the training set and test set had an impact on the model results, we adjusted the ratio of the training set to test set as 1:1, and built two models again. It was found that the penalty factor of the best model of PSO was 10,000, and the *gamma* value was 10^{-5}. The penalty factor of the adjusted SVM model was 5.29, and the *gamma* value was 0.04. The SVM model with adjusted parameters was still better than the PSO model. *MSE* was the mean square error within the group. *MSR* was the mean square error of the row factor, indicating the influence of inter-group factors. It was found that the *MSR* of the original data and the parameter-adjusted SVM model was 0.0000104, less than 0.0001, indicating that the network training was complete (Table 4).

Table 4. Analysis of variance.

Source of Difference	SS	df	MS	F	*p*-Value
MSR of index *Y* and PSO	0.0018	1	0.0018	0.2451	0.6209
MSE of index *Y* and PSO	1.9484	262	0.0074		
MSR of index *Y* and PSO-SVM	0.0000	1	1.040×10^{-5}	0.0014	0.9707
MSE of index *Y* and PSO-SVM	2.0123	262	0.0077		

The main problems at present are that the theory of high-quality development of the marine economy is imperfect, the measurement method and index system are not unified, and the threshold standard is not yet determined [14]. Previous research has mainly discussed the vulnerability, coupling coordination, mutual coercion, and sustainability of the marine economic system, but has not paid attention to the interaction mechanism among subsystems [50]. On the one hand, it is impossible to conduct a comparative analysis of different regions and time periods. The research scale mainly focuses on the time evolution of a certain region, which lacks the multiscale analysis of the spatial–temporal sequence, and ignores the dynamic evolution and driving analysis of the spatial–temporal patterns [51].

On the other hand, it focuses on the construction of the framework, mainly introducing the economic model into the field of marine resources and environmental economics [52]. Building on previous research, this paper proposed the following research framework: dynamic evolution characteristics, driving factor analysis, regulation method discussion, optimization path. For the first time, two intelligent algorithms (the PSO-SVM model) based on the entropy weight composite index were applied to evaluate the high-quality development of the marine economy. The research revealed the spatial–temporal distribution characteristics, dynamic evolution mechanism, driving mechanism, and optimization path of the high-quality development of China's marine economy from 2006 to 2017 (Figure 9). The future research focuses mainly include an in-depth discussion on the connotation, theoretical framework, accounting methods, and constraints of high-quality development of marine economy [53]. There is a need to establish a unified evaluation index system to improve the accuracy and credibility of the model, and attention should be paid to the coupling and coordination of the marine economic composite system.

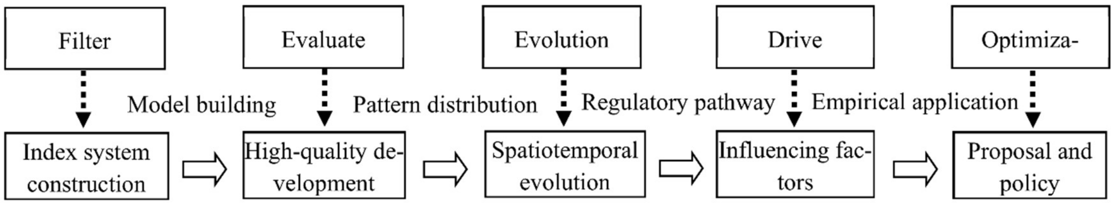

Figure 9. The main research steps.

Based on the dynamic evolution characteristics, main influencing factors, and control methods of high-quality development level of marine economy, the path to promote the high-quality development of the marine economy is discussed from the following six aspects. First, enhancing economic vitality. There is a need to optimize the assessment and evaluation of marine economic development and improve the overall management mechanism of the marine economy. There is also a need to formulate plans for strategic emerging industries and strengthen fiscal, tax, and financial preferential policies and industrial support policies. Second, promoting structural optimization. There is a need to deepen the supply side structural reform in the marine field, and optimize the structure and spatial layout of the marine industry. There is also a need to cultivate modern marine industry and improve the level and scale of marine industry agglomeration. Third, improving the openness level. There is a need to adhere to land and sea coordination and coordinated development, and to deepen international cooperation related to the sea. There is also a need to promote the coordinated development of the coastal economic belt and the four bay areas. Fourth, improving social livelihood. There is a need to strengthen the construction of infrastructure and supporting systems, build a comprehensive service platform for marine economic development, and improve comprehensive marine management and control service capacity. There is also a need to establish a dynamic and long-term mechanism for the assessment, feedback, and adjustment of marine comprehensive governance capacity. Fifth, promoting green development. There is a need to optimize the allocation of marine resources, improve utilization efficiency, and alleviate the contradiction between the supply and demand of marine resources and the marine economy. There is also a need to protect the marine ecological environment and strengthen the construction of marine protected areas and the regulation and restoration of coastlines. These actions should strengthen the comprehensive prevention and control of land and sea pollution and establish and improve the total amount control system for pollutants discharged into the sea. There is also a need to improve the marine environment monitoring, early warning, disaster prevention, and mitigation system, risk source and risk prevention, and control system of environmental sensitive points. Sixth, strengthening the innovation drive. There is a need to formulate a plan for revitalizing the sea through science and technology, and promote the transformation of the new and old driving forces of the sea. There is also a need to increase investment in research and development, strengthen the training of marine talents, enhance the innovation ability of marine science and technology, and develop new advantages for the marine high-tech industry.

5. Conclusions

Based on a new development concept, this paper has screened and established an index system for the evaluation of the high-quality development of the marine economy. The spatiotemporal distribution, dynamic evolution mechanism, main driving factors, and regulation methods of high-quality marine economic development in China's coastal provinces from 2006 to 2017 have been revealed. The path to promote high-quality development and the countermeasure suggestion have been put forward.

First, it was found that Guangdong and Shandong have the highest level of high-quality development of marine economy during 2006–2017, belonging to the first tier. Shanghai, Jiangsu, and Zhejiang followed closely, belonging to the second tier. Fujian and Liaoning belong to the third tier. The remaining provinces, Hebei, Guangxi, Hainan, and Tianjin, belong to the fourth tier. In 2017, the ranking (from high to low) was: Guangdong, Shandong, Jiangsu, Zhejiang, Shanghai, Fujian, Liaoning, Hebei, Hainan, Guangxi, and Tianjin.

Second, the high-quality development level of the marine economy in China's coastal provinces grew rapidly from 2006 to 2017. Guangdong, Fujian, Shandong, Hainan, and Jiangsu increased by 53.69%, 43.46%, 37.69%, 33.68%, and 33.3%, respectively. Zhejiang, Liaoning, and Tianjin increased by 24.47%, 19.75%, and 12.70%, respectively.

Third, based on the main driving factors for the high-quality development of China's marine economy, the main regulation methods are to accelerate scientific and technological innovation, improve the marine scientific research, education, management, and service industry, and optimize and adjust the marine industrial structure and spatial layout. There is a need to strengthen the comprehensive prevention and control of ocean and land pollution and implement the total emission control of pollutants into the ocean.

Fourth, the main suggestions include: promoting the development of the marine economy from quantitative to efficient and enhancing economic vitality; promoting the marine industrial structure from simplification to diversification and realizing structural optimization; promoting the overall management of the oceans from segmented to collaborative and improving the level of openness and the people's livelihood; promoting the development of marine resources from extensive to intensive, and promoting the marine environmental protection from extension to connotation, and realizing green development; and promoting marine scientific and technological innovation from primary to high-end, and realizing transformation and upgrading.

Author Contributions: S.G. proposed the research framework and drafted the paper. H.S. worked on the analysis and interpretation of results. J.W. was responsible for model construction and data processing. W.L. performed extensive editing of the English language and further revisions. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the China Association for Science and Technology Think Tank Youth Talent Plan (20220615ZZ07110286), and the Jiangsu University Philosophy and Social Science research project (2022SJYB0342).

Informed Consent Statement: All authors have read and agreed to the published version of the manuscript.

Acknowledgments: The authors are very grateful to the anonymous reviewers for reading our manuscript and for providing suggestions.

Conflicts of Interest: The authors declare no conflict of interest.

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