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Research Article

Correlation Modeling between Ocean Spatial Distribution and Economic Sustainability

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The ocean is the second most vital space for human production and life, and it is a backbone of the ecosystem of the earth. There is a strong correlation between the ocean's spatial distribution and environment; similarly, there is a strong correlation between spatial distribution and economic sustainability. This study proposes a strategy for analyzing the relationship between marine spatial layout and economic sustainability based on a correlation combination weighting model. The essential conditions of marine industry development are examined utilizing soft computing methodologies to analyze important theories of marine industry layout. The entropy method is used to compute the weight of the marine economic evaluation index. By maximizing the difference, we can get the upper and lower boundaries of the weight of the marine industry development combination. To study the association between ocean spatial arrangement and economic sustainability, the correlation assessment results are obtained using the combination weighting model. The correlation analysis results of the experimental data are used to determine the appropriate spatial layout of the marine industry, which has some practical implications for the long-term development of the marine industry layout economy and the coordination and interaction of land-sea systems.

1. Introduction

The ocean is abundant in biological and mineral resources, making it essential for addressing resource scarcity, population density, and environmental deterioration. Under the backdrop of China's energetically implementing policy of becoming a maritime power, the marine economy will stand out in national economic and social development. The notion of the marine economy was first proposed in the 1990s. Still, it has yet to achieve a uniform understanding and definition after more than 20 years of evolution and development [1]. On the definition of maritime economy, there are two widely held scholarly viewpoints. The marine economy encompasses all types of marine economic activities, with marine resources serving as the development object and marine space serving as the activity location. Another academic definition of the marine economy is "input and output, demand and supply of products, general term for economic activity relating to marine resources, marine space, and marine environmental conditions" [2]. This point of view thoroughly displays the supply side's demand characteristics in the process of marine economic development [3]. Although the two representative views have different emphases, they are essentially interlinked. To commence with, the marine economy encompasses not only the primary marine industrial activity but also economic activities directly tied to the marine industry. Second, because the marine economy is essentially a way of studying land-sea coordination, its research subject consists of both marine and land-based sea-related economic activity.

The fabric is furnishing and setting; the bureau refers to the grid to accomplish things and results, which are referred to as layout collectively [4]. Similarly, the combination of marine industrial or economic activity in space is referred to as a marine industry layout. According to the general industrial distribution theory and principle, the marine industry is mainly distributed and dynamically combined; that is, the coastal zone and each sea area are set as the Distribution Bureau, and the rational utilization of various marine resources is made to achieve a win-win situation between regional economic and ecological benefits [5].

The distribution of marine industry refers to the distribution and combination of marine industry departments in space and region. The layout space for the marine sector is not solely made up of water but also includes some land. It is called a supratidal zone geographically [6]. The expansion of the above tidal zone makes the research industry layout stay in the sea area and study the internal resource and environment conditions of the coastal area to determine the coordination and division of marine industry in each region [5]. The significance of rational planning of marine industry layout is mainly reflected in two aspects:

(1) Improving Productivity. It refers to the distribution of marine industry in terms of distribution of productivity in space [7]. The difference in the bearing capacity of resources and environment requires the unbalanced distribution of productivity in marine space [8]. By coordinating the reasonable distribution of productivity, the most effective utilization and maximum production capacity of marine resources can be achieved, and the sustainable development of marine resources and the environment can be realized.

(2) To Realize the Unification of Economic and Social Benefits [9]. As an important part of the national economic system, the marine industry plays an important role in national economic development planning. The state carries out the overall layout and planning of the marine industry, realizes interest coordination between regions and industrial departments, and meets the social needs of each region. It also realizes the effective utilization of marine resources based on the marine resource endowment and economic development status of each region [10]. The main contribution of the proposed research work is as follows:

   (i) Based on the analysis of the spatial characteristics and heterogeneity of marine industry, this study studies the association between ocean spatial arrangement and economic sustainability.
   (ii) The correlation assessment results for the marine industry are obtained using the combination weighting model.
   (iii) A study on coordinated development of marine and land economy through the complementary advantages of resources between coastal and inland areas is focused.
   (iv) The correlation modeling method between marine spatial layout and economic sustainability is developed to have a certain exploration significance for the development of marine industrial layout theory.
   (v) Integration of land and sea economy in the coastal areas is carried out, which provides a broad space for the theoretical and empirical research of this study.

The rest of the study is structured as follows: in Section 2, the current research work is discussed. In Section 3, the proposed model for correlation modeling between ocean spatial distribution and economic sustainability is elaborated. In Section 4, the results are explained. The last section concludes the correlation modeling method research work to analyze the theoretical and empirical impact on spatial distribution and economic sustainability.

2. Related Works

Previous studies mainly focus on the following three levels: trans, provincial, and municipal. The principles and foundations of the marine industry's structure at all levels, as well as the major body of decision-making behavior and conflicts of interests, are all different [11]. The cross-provincial marine industry layout involves many provinces and cities. The similarity of marine resources is high, and the phenomenon of repeated construction of marine industry is serious. As a result, the central government is frequently the focus of macro-decision-making. The contradiction to be solved is the conflicts of interest between regions, based on each provincial administrative unit's economic strength and development demands. The provincial marine industry layout mainly considers the coordinated development between coastal cities and inland cities in the province, mainly solves the imbalance of economic development between inland cities and coastal cities through marine industry layout, and maximizes the social benefits of coastal resources [12]. The layout of the marine industry at the municipal level involves all districts and counties of a city, with small areas and uneven distribution of marine resources. The layout of the marine industry solves the problem of unbalanced development of the urban economic industry in coastal areas [13]. Marine resources have the characteristics of integrity, mobility, and multi-suitability. The only reasonable marine industrial layout can make the overall function of marine resources play an effective role. In other words, Yantai's resource carrying capacity reflects the degree of comprehensive development of resources, which is not only a simple sum of the benefits of marine resources development [14]. Therefore, the reasonable layout of the marine industry needs to connect the social and economic basis of each county and city based on resource endowment, which is a systematic and complex project.

2.1. A Theoretical Study on the Layout of Marine Industry. The evolution process can be divided into four stages: ignorance, formation, deepening, and new development. The first stage is the ignorance of industrial layout theory [15]. From the beginning of the 18th century to the middle of the twentieth century, with the beginning and end of the first industrial revolution marked by the invention of the steam engine, the second industrial revolution marked by the widespread use of electric power, and the third industrial revolution marked by the invention of the electronic computer, not only the demand for industrial layout arose but also the great development of geography and economics was accelerated. It developed a number of famous location theories, including Du Neng's agricultural location theory and Weber's industrial location theory, which has set the groundwork for the development of marine industrial layout theory.

The second stage is forming the marine industry layout theory [16]. In the 1930s, with the publication of the idea of seaport location, which was compiled by the German scholar Gotz, the view of the marine industrial layout was formally separated from the general theory of industrial layout and became an independent theoretical system. Gotz points out that if a port can meet the lowest transportation cost of goods from inland hinterland to another overseas port, then the port's location is the best. This theory takes the relationship between port and hinterland as the breakthrough point and provides important enlightenment for future generations to study the economic development of port areas [17]. However, because the port location theory ignores natural conditions and hinterland economic capacity as contributing variables, the theory's applicability is severely limited.

In the third stage, the theory of marine industry layout is deepened. In the late 1950s, Edgar Hoover, the representative of the cost school, further proposed the location theory of transfer point based on port location theory. In the book "location of economic activities," he pointed out that the transportation cost of ports or other transfer points is mainly composed of terminal and line operating costs. Specific conditions determine the former, and the latter is calculated by the distance function [18]. The theory of location of transfer point makes up for the shortage of seaport location theory. Many scholars have made remarkable achievements in applying the theory of location of transfer points to optimize the regional marine industry.

The fourth stage is the new development of the marine industry layout theory. Since the 1960s, more and more experts and scholars have focused on the field of marine industrial layout, such as the bird "arbitrary port" model, Taaffe model, and Rimmer model, which fills the gap in the research field of single port spatial structure and port system space and promotes the continuous updating and improvement of marine industry layout theory.

Foreign scholars' research on the marine economy mainly focuses on the comprehensive management of coastal zone, the impact of the marine economy on the national economy, and the layout of the port industry. They pay attention to the comprehensive development and management of coastal zone, especially ports, from the aspects of regional nature, environment, economy, society, and resources to improve the efficiency of coastal zone development and utilization and the level of sustainable development. However, there is a lack of research on realizing the coordinated development of marine and land economy through the complementary advantages of resources between coastal and inland areas. More attention is paid to the marine economy's contribution to the national economy and the protection of the ecological environment in coastal areas, and less attention is paid to the relationship between the integration of marine and land economy and the layout of the marine industry.

The domestic academic circles pay attention to the marine economy for a short time, the existing specialized research results are relatively few, and the accumulation of basic theory is still weak. Compared with foreign scholars focusing on the integrated coastal management and port layout, domestic scholars pay more attention to the integration of land and sea economy, the evolution of marine industrial layout, and the layout evaluation system [19]. In terms of theoretical research, scholars have established a system of land-sea economic integration based on the relevant regional and industrial economics theories and explored the evolution law of marine industrial layout [20]. In the aspect of empirical analysis, scholars make quantitative analysis on the correlation of marine and land industries using the methods of grey correlation analysis, input-output method, and coupling model. From many perspectives, the construct evaluation index system of marine industry layout establishes the groundwork for quantitative study on integrating marine and land economies and marine industry layout. However, the existing relevant research still separates the two issues of land-sea economic integration and marine industrial layout. It lacks systematic research on the internal relationship and interaction mechanism between them, especially the lack of research on land-sea industrial agglomeration, land-sea spatial connection, land-sea resource convection, factor sharing, infrastructure interconnection, and land-sea economic integration. It is difficult to effectively guide the practice of the integration of land and sea economy in the coastal areas, which provides a broad space for the theoretical and empirical research of this study.

3. Proposed Model

3.1. Correlation Modeling between Ocean Spatial Distribution and Economic Sustainability

3.1.1. Evaluation Index Weight of Marine Economy Based on Entropy Method. In information theory, the smaller the information entropy of an index value, the lower the degree of information disorder is. The greater the information utility value, the greater the index's weight is and vice versa. The calculation steps of the entropy method are as follows.

Using the extreme value method, the original data of marine economic indicators are standardized, and the standardized index value is recorded as X_{ij} as follows:

$$X_{ij} = \frac{x_{ij} - x_{\min}}{x_{\max} - x_{\min}}. \quad (1)$$

Negative index processing is done as follows:

$$X_{ij} = \frac{x_{\min} - x_{ij}}{x_{\max} - x_{\min}}. \quad (2)$$

Calculation of the proportion y_{ij} of the index value of the i city and county under the j index is calculated as follows:

$$y_{ij} = \frac{x'_{ij}}{\sum_{i=1}^{n} x'_{ij}}. \quad (3)$$

The index information entropy e_j and information utility d_j are calculated as follows:

$$e_j = -K\sum_{i=1}^{n} y_{ij}\ln\, y_{ij}, K = \ln(n), d_j = 1 - e_j. \tag{4}$$

The weight of evaluation index W_j is calculated as follows:

$$W_j = \frac{d_j}{\sum_{j=1}^{m} d_j}\,(m = 1, 2, \ldots, j). \tag{5}$$

Through the comprehensive evaluation index Z, the score of marine economy evaluation index is calculated as follows:

$$Z = \sum_{j=1}^{m} W_j X_{ij}. \tag{6}$$

3.1.2. Weighting Method of Maximum Difference. The objective function is the maximum differentiation of the evaluation results. The optimization model is established based on the reasonable value range of the index weight as the constraint condition. The subjective and objective weighting method is used to solve the combined weight of the evaluation indexes. The calculation steps of the method are as follows:

(1) Determination of Reasonable Interval of Attribute Weight hypothesis $\delta_j = \theta_j^+ - \theta_j^-$. Then the combined weight of the jth attribute lies between the interval of θ_j^-, θ_j^+]. θ_j^+ is the upper bound of the combined weight of the jth attribute and θ_j^- is the lower bound of the combined weight of the jth attribute, which are given in the following equations, respectively.

$$\theta_j^+ = \max\{\alpha_{1j}, \alpha_{2j}, \ldots, \alpha_{nj}\}, \tag{7}$$

$$\theta_j^- = \min\{\alpha_{1j}, \alpha_{2j}, \ldots, \alpha_{nj}\}. \tag{8}$$

3.1.3. Combined Weighting Model of Correlation between Marine Spatial Distribution and Economic Sustainability. The objective function is to effectively distinguish the evaluated objects, and the maximum variance of the evaluated object score under the combined weight is considered as the objective function. The calculation method is as follows.

The positive and negative attribute values of ocean spatial layout are standardized and are calculated using the following equations:

$$x_{ij} = \frac{v_{ij} - \min\limits_{1\le i\le k}(v_{ij})}{\max\limits_{1\le i\le k}(v_{ij}) - \min\limits_{1\le i\le k}(v_{ij})}. \tag{9}$$

$$x_{ij} = \frac{\max\limits_{1\le i\le k}(v_{ij}) - v_{ij}}{\max\limits_{1\le i\le k}(v_{ij}) - \min\limits_{1\le i\le k}(v_{ij})}. \tag{10}$$

$$s^2 = \frac{1}{k-1}\sum_{i=1}^{k}(\theta x_1 - \theta\overline{x})^2 = \frac{1}{k-1}\sum_{i=1}^{k}\theta H\theta^T, \tag{11}$$

where X is the standardized matrix of m indexes and k evaluation objects of marine spatial layout, Z is the comprehensive evaluation result of correlation between marine spatial layout and economic sustainability, and s^2 is the variance of comprehensive evaluation result. The reasonable interval of attribute and the sum of attribute weights is equal to one as a constraint condition. The objective function is the maximum variance of the score of the evaluation object under the combination weight, and the constraint condition is the reasonable interval of attributes and the sum of attribute weights is given as follows: $\max 1/k - 1\sum_{i=1}^{k}\theta H\theta^T$,

$$s.t\left\{\sum_{i=1}^{m}\theta_i, \theta_i^- \le \theta_i \le \theta_j^+.\right. \tag{12}$$

The NRCA model is used to determine the marine spatial layout and economic sustainability and is given as follows:

$$NRCA = \frac{X_j^i}{X} - \frac{X_j X^i}{XX}, \tag{13}$$

where X_j^i is the score of basic conditions for marine industry development of i city and county j, and X_i is the score of all the basic conditions of marine industry development in i city and county; X_j is the total score of the basic conditions for the development of marine industry in a place, and X is the total score of the correlation between the spatial layout of all the oceans and the economic sustainability in a place.

4. Result and Analysis

4.1. Modeling and Analysis of the Correlation between Marine Spatial Distribution and Economic Sustainability

4.1.1. Characteristics of Total Scale of Marine Industry. In recent years, with the implementation of China's maritime power strategy and the strategy of local maritime provinces (cities), the marine economic development of the Beibu Gulf region has made steady progress. In 2012, the total output value of the marine industry in the Beibu Gulf region was only 275.7 billion yuan, which increased to 397.06 billion yuan in 2016, with an average annual growth rate of 9.55%, which is 0.19 percentage points higher than the average annual growth rate of GDP in the same period. From 2015 to 2020, the proportion of the marine economy in regional GDP has no significant growth, and the proportion remains between 34% and 35% throughout the year. Table 1 shows the total scale of the marine industry.

From the perspective of development speed, the total output value of the marine industry in Beibu Gulf shows fluctuating growth. From 2012 to 2013, the growth rate soared, and the total output value of the marine industry increased the most. In 2014, the growth rate fell to the bottom and rebounded completely and then rebounded for

Table 1: Total scale of marine industry.

Particular year	Total output value (RMB 100 million)						
	2014	2015	2016	2017	2018	2019	2020
Total output value of marine industry	2968	3213	3353	3752	3976	4216	4532
Gross regional product	7853	8213	8321	8432	8564	8765	8964
Growth rate (%)							
Growth rate of total output value of marine industry	9.2%	12.3%	6.3%	8.2%	9.2%	9.5%	9.8%
GDP growth rate	12.1%	10.5%	10.2%	6.3%	7.9%	8.2%	8.9%

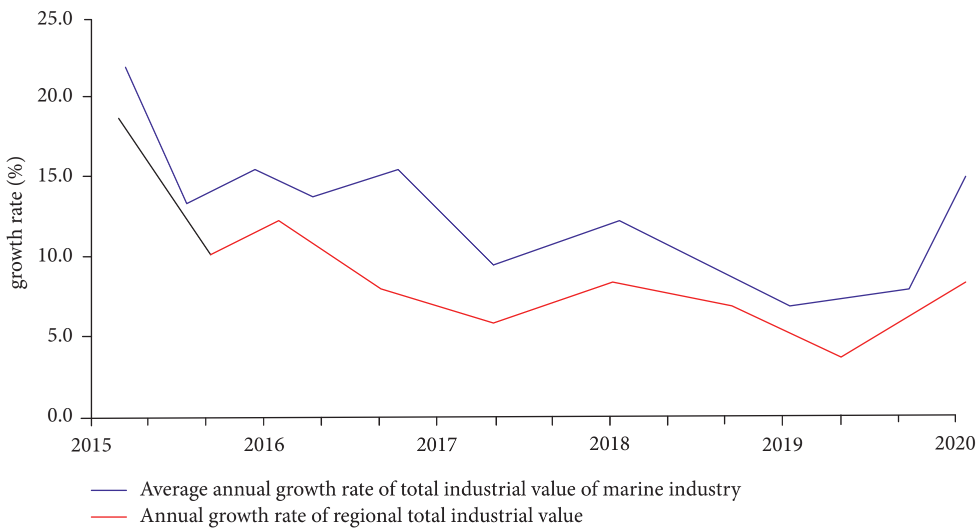

Figure 1: Average annual growth rate of total marine industrial output value and regional GDP in Beibu Gulf from 2015 to 2020.

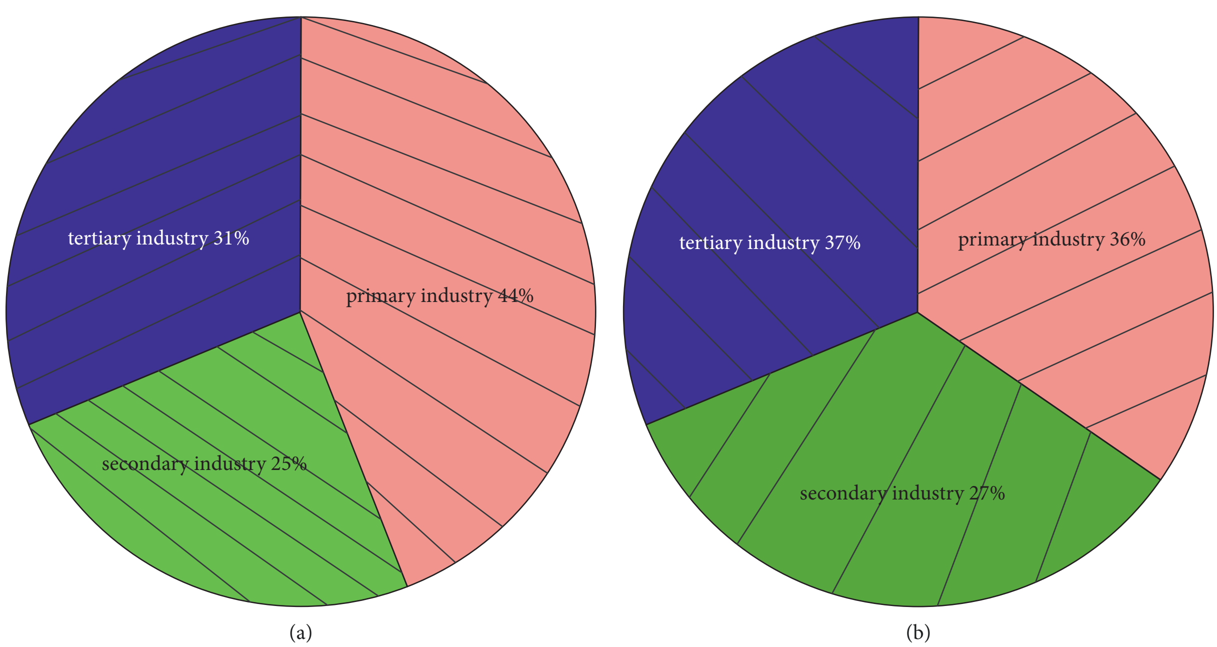

Figure 2: Comparison of three marine industrial structures in Beibu Gulf between 2015 and 2020.

three consecutive years. Due to the downward pressure of the economy and the structural adjustment of the supply side, after 2015, the total output value of the marine industry is in tune with the GDP development. The growth rate is controlled at 6%–9%, and the growth rate of the total output value of the marine industry is 1–1.7% higher than that of the GDP in the same period. Generally, the marine industry in Beibu Gulf is stable and far-reaching.

4.1.2. Regional Difference Characteristics of Marine Industry Scale. From 2015 to 2020, the marine economy of cities and counties in Beibu Gulf has made steady progress, and the regional industrial gap has gradually decreased. In terms of growth rate, the annual average growth rates of marine industry gross output value and regional GDP in Beibu Gulf show positive growth. Except that the annual average growth rates of marine industry gross output value in 2017 and 2019 gradually fall down, which is lower than that of other regions, the annual average growth rates of other marine industry gross output values are 1–8 percentage points higher than that of regional GDP in the same period, and the development momentum is strong. Figure 1 shows a line plot of average annual growth rate of total marine industrial output value and regional GDP in Beibu Gulf from 2015 to 2020.

Between 2015 and 2020, cities with considerable marine economic power accounted for approximately 60% of the whole marine industry output value in Beibu Gulf, accounting for half of the marine economy. In other years, the marine economy lags behind, with the marine sector's total output value accounting for less than 10% of overall output, making a minor contribution to the marine economy of the Beibu Gulf.

4.1.3. The Characteristics of Marine Tertiary Industry Structure. Based on 11 major marine industries including marine fishery, marine salt industry, marine mining, marine oil and gas, marine chemical industry, seawater utilization, marine biomedicine, marine engineering construction, marine shipbuilding, marine transportation, and coastal tourism, the proportion structure of three marine industries in Beibu Gulf area is calculated. The proportion structure of Beibu Gulf's three maritime industries has been modified from 44 : 25 : 31 in 2015 to 36 : 27 : 37 in 2020. It can be seen from Figure 2 that the proportion of primary industry in the study area is decreased, while the proportion of secondary and tertiary industries has steadily increased, and the marine industrial structure in Beibu Gulf is constantly optimized and adjusted.

(a) Comparison of the three marine industrial structures in 2015

(b) Comparison of the three marine industrial structures in 2020

5. Conclusion

The ocean is rich in biological and mineral resources, which are the key to suffice for the purpose of resource requirements by human beings. The Beibu Gulf has prominent geographical advantages and rich marine resources. Under the backdrop of China's aggressively pursuing its plan of becoming a maritime power, the marine economy will stand out in national economic and social development. However, the overall level of basic conditions for the growth of the marine industry in the Beibu Gulf is low, the marine industry structure is unsound, and the degree of development of the marine industry in different cities and countries is unequal. Based on the modeling analysis, this study proposed the correlation modeling method between marine spatial layout and economic sustainability. To have a certain exploration significance for the development of marine industrial layout theory, this study is studying the correlation between marine life and economic sustainability. It has some practical implications for the long-term development of the marine industrial layout economy and the coordination and interaction of land and sea systems. It is also strengthening the international collaboration. During the investigation, it was observed that the annual growth rate of total marine industrial structures in Beibu Gulf is exactly linked to regional GDP. Between 2015 and 2020, three marine industrial structures in Beibu Gulf are compared. The proportion of primary industry in the Beibu Gulf area has steadily declined, while the proportion of secondary and tertiary industries has steadily increased. The environment of the marine industrial structure in the Beibu Gulf is continually getting impacted and affecting adversely the wetlands around it. In the future, a comparison of the entire country's GDP with the maritime sector can be made, and artificial intelligence and machine learning techniques can be employed to help the marine industry flourish by studying the factors affecting marine environment.

Data Availability

All the data pertaining to this article are available in the article.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this study.

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