Comprehensive Evaluation and Coupling Coordination Degree Analysis of Marine Science and Technology and Economy in 11 Coastal Provinces and Cities

Zhiyong Huang

School of Economic and Management, Wuyi University, Guangdong, China
**Corresponding author. Email: 643264315@qq.com*

ABSTRACT
In this paper, by constructing the evaluation system of Marine science and technology innovation and Marine economy, the Entropy-TOPSIS method was used to measure the Marine science and technology innovation capacity and economic level of 11 coastal provinces and cities in China, and then the coupling coordination degree model was used to estimate the synergistic development of the two systems. The results show that the scientific and technological innovation ability of provinces and cities presents a pyramid distribution of "wide at the bottom and narrow at the top", while the economic level presents an inverted triangle distribution of "wide at the top and narrow at the bottom". The scientific and technological economic systems of provinces and cities are highly coupled, but the coordination degree is not ideal, and there is obvious spatial heterogeneity, and the regional radiation driving ability is limited. Finally, based on the analysis results, it is suggested that the national strategic deployment should be further strengthened, each province should clarify its own Marine development orientation, optimize the allocation of resources, enhance the synergistic effect between systems, and expand the radiation range of strong ocean city.

Keywords: *Entropy-TOPSIS method, Coupled coordination degree model, Collaborative development.*

1. INTRODUCTION

In the 21st century, ocean plays an increasingly important role as a space for global competition and for major countries to gain strategic advantages, and ocean strategy has become the top-level strategic deployment of many countries. Since China's reform and opening up, especially since the implementation of the strategy of becoming a Marine power was put forward at the 18th National Congress of the Communist Party of China, China's Marine science and technology and comprehensive Marine economic strength have achieved rapid development with the continuous increase of Marine industry input and output and continuous optimization of Marine industry. There are also abundant studies on the comprehensive evaluation of Marine economy and science and technology and the relationship between them. From the investigation object, from the perspective of different areas in the comprehensive level of Marine science and technology and economic, the research is mainly concentrated in the coastal 11 provinces and cities, such as NingLing panel vector autoregressive model is used to calculate the 11 provinces and cities along the coast of China in 2007-2017 Marine science and technology innovation, Marine dynamic relationship between total factor productivity and the development of the Marine economy, Du Jun, Wu Fan et al., PVAR model and threshold model respectively explored the impact and mechanism of Marine scientific and technological innovation on Marine economic growth [1-2]. Secondly, important coastal economic belts, such as pan-Pearl River Delta [3], Yangtze River Delta [4], Bohai Rim [5], Guangdong-Hong Kong-Macao Greater Bay Area [6], have their own unique strategic positioning. They play different but very important roles and are the focus of scholars' research. The third is the study of coastal provinces, including Guangdong [7], Shandong [8], Liaoning [9] and other large maritime provinces. From the perspective of research methods, Marine science and technology and economic index system are mostly constructed, and qualitative comprehensive evaluation or regression method is selected to comprehensively evaluate the strength of the system or the relationship between the systems. For example, by constructing Marine science and technology innovation evaluation system, Entropy-topsis method was used to measure the regional characteristics of Marine science and technology innovation capability of 36 sea-related cities in China [10]. Based on the "new development concept", Liu Bo et al. constructed the high-quality development system of Marine economy in Jiangsu province from the five dimensions of "innovation, coordination, green, openness and sharing", and used the linear weighted model to measure the high-quality development level of Marine economy [11].

Indeed, the research on the ocean has been quite rich both in terms of research objects and methods. The

research objects have gradually expanded from single cities and provinces to economic circles and the whole country. The research methods also include comprehensive evaluation, data regression, spatial metrology and so on, forming a solid theoretical basis. However, a general review of various literature studies shows that the comprehensive evaluation of 11 coastal provinces and cities mostly revolves around a single system of science and technology or economy, and there is a lack of literature on the simultaneous comprehensive evaluation of the two systems. Therefore, this paper carries out a comprehensive calculation of the science and technology and economic system respectively through an intuitive method, analyses the coupling relationship, and then intuitively expresses its space-time evolution relationship. The purpose is to reveal the coordinated development of science and technology and economy in China's ocean provinces in recent years, and contribute to the study of ocean economy.

2. RESEARCH METHOD AND INDEX SELECTION AND CONSTRUCTION

2.1. Entropy-topsis

Entropy TOPSIS method is a comprehensive index evaluation method combining entropy method with approximately ideal solution ranking method (TOPSIS). The basic principle is as follows: firstly, the entropy weight method is used to determine the weight of each evaluation index, and then the weight is multiplied by the standardized value of the index to construct a weighting matrix. Finally, the relative progress of each evaluation object is calculated according to the relative distance between each evaluation object and the optimal solution and the worst solution, so as to judge the merits and disadvantages of the evaluation object [12]. The calculation steps are as follows:

(1) Construct the judgment matrix.

$$X = \left(x_{ij}\right)_{m\times n} (i = 1,2,\dots,m; j = 1,2,\dots,n) \quad (1)$$

In the formula: the actual value of the j-th evaluation index in the i-th coastal province.

(2) All the indicators are normalized

$$x_{ij}^{1} = \frac{x_{ij}}{x_{max}} \quad (2)$$

x_{ij}^{1} is the maximum value of all evaluation indexes

(3) Computational information entropy

$$H_j = -k\sum_{i=1}^{m} P_{ij} \times lnp_{ij}$$
$$P_{ij} = \frac{x_{ij}}{\sum_{j=1}^{m} x_{ij}}; k = \frac{1}{ln\, m} \quad (3)$$

H_j is information entropy, P_{ij} is characteristic specific gravity.

(4) Define weights

$$W_i = \frac{1-H_j}{\sum_{j=1}^{n}(1-H_j)} \quad (4)$$

(5) Calculate the weighted matrix

$$R = (r_{ij})_{m\times n};\ r_{ij} = w_j \times x_{ij} \quad (5)$$

(6) Calculate the optimal and the worst solution

$$S_j^{+} = \max(r_{1j}, r_{2j}, \dots, r_{mj});\ S_j^{-} = \min(r_{1j}, r_{2j}, \dots, r_{mj}) \quad (6)$$

(7) Calculate the Euclidean distance between each coastal city I and the optimal solution and the worst solution

$$sep_i^{+} = \sqrt{\sum_{j=1}^{n}(s_j^{+} - r_{ij})^2} \quad (7)$$

$$sep_i^{-} = \sqrt{\sum_{j=1}^{n}(s_j^{-} - r_{ij})^2} \quad (8)$$

(8) Calculate the relative closeness degree, that is, the comprehensive index of each coastal province

$$C_i = \frac{sep_i^{-}}{sep_i^{+} + sep_i^{-}}$$

The closer C_i gets to 1, the better

2.2. Coupling coordination degree model

In this study, Marine science and technology and regional economic system are regarded as two coupling systems, and the coupling coordination degree model is used to measure the coupling coordination degree of the two systems. After the weight is determined by formula (4), their contribution degree is calculated by linear weighting method, and then the coupling degree of C and Coupling coordination degree D are further calculated. Referring to the classification standards of relevant coupling degree and coupling coordination degree and combining with actual research characteristics, the coupling degree and coupling coordination degree are divided into four development stages, and the specific classification is shown in Table 1 below.

Table 1. Classification criteria of coupling coordination degree

The coupling of C		Coupling coordination degree D			
Value range	In phase	Value range	In phase	Value range	In phase
0<C≤0.2	Low level coupling phase	0<D≤0.125	Severe disorder	0.5<D≤0.625	Primary coordination
0.2<C≤0.4	Antagonism phase	0.125<D≤0.25	Mild disorder	0.625<D≤0.75	Good coordination

Table 1. cont					
0.4<C≤0.6	Running-in stage	0.25<D≤0.375	Moderate disorder	0.75<D≤0.875	Moderate coordination
0.6<C≤1	High level coupling phase	0.375<D≤0.5	Barely coordinated	0.875<D≤1	Excellent coordination

2.3. Index system construction

About Marine innovation ability and the research achievements of Marine economy has been quite rich, and constitute the scientific index system, this article summarizes related literature index set, on the basis of following the scientific nature of the index selection, the principle of objectivity, comprehensiveness, availability, first under the two subsystems respectively set up multiple dimensions, and then the corresponding indicators, based on the dimension The subsystem of ocean innovation capability and ocean economy is constructed, as shown in Table 2. The data used in this paper are from the China Marine Statistical Yearbook from 2008 to 2019 and the Marine Environmental Quality Bulletin of coastal provinces over the years.

Table 2. Indicator system of Marine science and technology and economic system and relevant weights

The subsystem	The dimension	code	The evaluation index	unit
Marine science and technology	Investment in science and technology	X11	Professional and technical personnel	people
		X12	Proportion of senior titles of professional Marine researchers	%
		X13	Marine science and Technology institute government investment	One thousand yuan
		X14	Number of projects in Marine research institutions	item
	The output of science and technology	X21	Number of Marine science and technology papers published	pcs
		X22	Number of patents granted for sea-related inventions	pcs
		X23	Publications in Marine science and technology	pcs
		X24	Income from Marine scientific research institutions	Ten thousand yuan
	Science and technology environment	X31	Number of Marine scientific research institutions	pcs
		X32	Density of Marine research institutions	Units per square kilometer
		X33	Number of personnel in Marine research institutions	people
The Marine economy	Economic strength	X41	Marine GDP	One hundred million yuan
		X42	The proportion of Marine GDP in regional GDP	%

		Table 2. cont		
		X43	Per capita Marine GDP	Ten thousand yuan
		X44	Added value of Marine industry	One hundred million yuan
	The economic structure	X51	Proportion of secondary industry in Marine economy	%
		X52	Proportion of tertiary industry in Marine economy	%
		X53	Marine scientific research, education, management and service industry	%
	Economic benefits	X61	Marine economic growth rate	%
		X62	Marine labor productivity	%
		X63	Marine Industry competitiveness Index	%

3. ENTROPY-WEIGHT TOPSIS ANALYSIS

The Entropy-TOPSIS method is used to comprehensively evaluate the Marine innovation capability system and Marine economic system of 11 coastal provinces (or municipalities directly under the Central Government) in Mainland China. Due to the length, the final detailed score results of the comprehensive evaluation of the two systems will not be described. As can be seen from Figure 1, the overall Marine science and technology innovation capacity in coastal areas presents a "pyramid" structure, with the majority of provinces (municipalities directly under the Central Government) with low level of Marine science and technology. Specifically, the regions with important economic development strategic positions, such as the municipalities directly under the Central Government, the Yangtze River Economic Belt and the Pearl River Economic Belt, rank the top in Marine scientific and technological innovation capacity. They not only have a good Marine scientific and technological innovation environment, but also have a first-mover advantage in terms of innovation input and output. Ranking the first Shanghai and the latter has a big gap, the latter is hard to emulate its. Shandong has a stable score of 0.3. Guangdong has always maintained a continuous upward trend, from low to high. Although some regions have a good performance in Marine innovation, some regions have a large space for improvement, and there is strong heterogeneity in regional scientific and technological innovation capacity. Among them, Fujian, Guangxi and Hainan have insufficient innovation capacity and small innovation scale, and there is an obvious gap between input-output and developed provinces and cities.

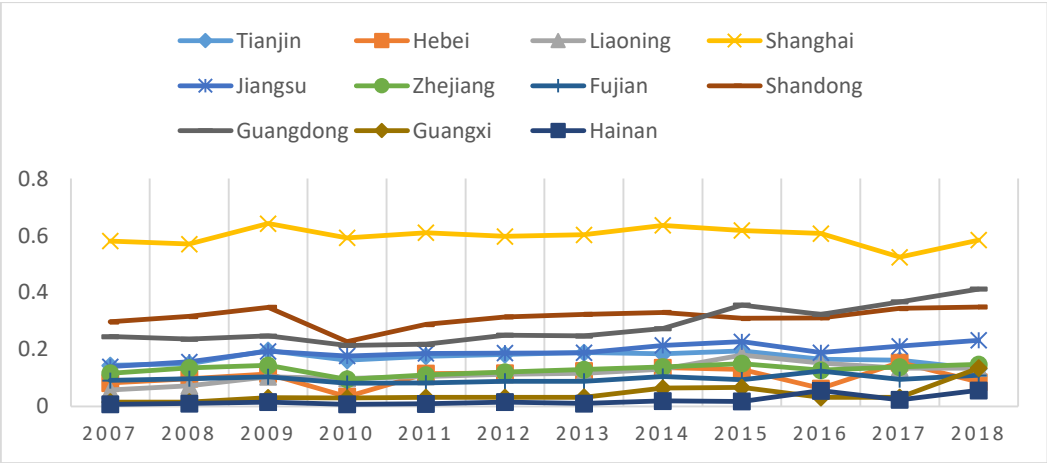

Figure 1 Change trend of comprehensive measure of Marine economy in coastal areas from 2007 to 2018

By the figure 2 shows, coastal Marine economic strength assessment score "nabla" structure, in most of the scores are greater than 0.3, and Marine economic strength and its ability to innovate number does not

match the situation, part of the innovation ability of the provinces, its economic strength is at the top, one of the most obvious is the two provinces, Fujian and Hainan The backward innovation ability matches the good economic strength, which also fully reflects its efficient technological innovation transformation ability. Guangdong and Shanghai performed well, with scores of more than 0.5, leading other regions. The Marine GDP of the two regions continues to lead the country, and the proportion of Marine GDP in regional GDP is high, indicating that Marine industry has made outstanding contributions to the economic development of the region. Hebei and Guangxi are in the inferior position in Marine economic strength, which may also be the Marine innovation ability hindering their Marine economic development. As can be seen from Figure 2, the economic strength of each region has improved in different degrees during the statistical period, and the growth rate is gradually obvious, among which Guangdong, Shandong and Fujian have the most obvious improvement. This phenomenon shows that, on the one hand, the economic impact brought by the 2008 financial crisis slowly subsided and the economy gradually recovered; On the other hand, the goal of building China into a maritime power proposed at the 18th National Congress of the Communist Party of China in 2012 is becoming increasingly effective, and the development and utilization of oceans are gradually improving.

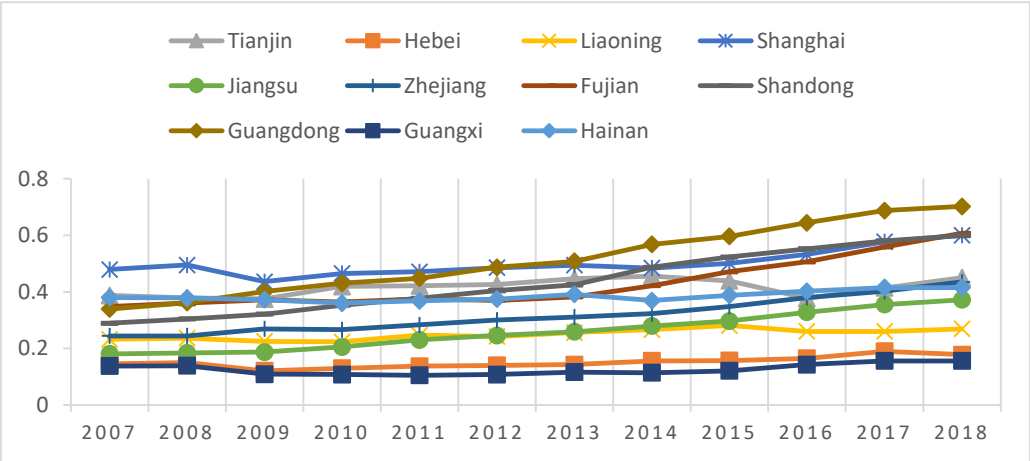

Figure 2 Change trend of comprehensive measure of Marine economy in coastal areas from 2007 to 2018

4. COUPLING COORDINATION ANALYSIS

4.1. Coupling degree analysis

The empirical results show that, except Hainan, most of the coupling degree is greater than 0.9, and some of the coupling degree is 1. The study period belongs to the high coupling stage, and Hainan province has a low coupling degree in the early stage. From 2007 to 2015, it was in the antagonistic stage, but it can be seen that the coupling degree has been improving. In 2014, it entered the running-in stage, and in 2016, it entered the high-level coupling stage. Except Hainan, the coupling degree of other provinces and cities is at a very high level, indicating that the coastal provinces and cities have good coupling, mutual influence and close relationship.

4.2. Coupling coordination degree analysis

Table 3 shows the calculation results of the coupling coordination degree between science and technology and economic system of 11 coastal provinces and cities from 2007 to 2018. In the early stage of statistics, the coupling coordination degree is generally not ideal, and 6 provinces and cities are on the verge of disorder or have entered the disorder state. Among them, Hebei, Guangxi, Hainan have moderate above disorders. Tianjin, Jiangsu, Zhejiang and Fujian's performances are general, and always keep in barely coordinated edge. On the whole, although many provinces and cities have different degrees of imbalance, the overall improvement has been made. In 2018, there was a qualitative leap in coordination compared with 2007. In 2007, only Shanghai achieved good coordination, and Shandong and Guangdong entered the good coordination level together during the 12 years. The continuous improvement of the coordination degree between Marine science and technology and economic system indicates that the development of Marine undertakings in China has been improved in both quantity and quality, and has gradually stepped into the stage of high-quality development from the previous "extensive" development. Former Marine economic development is given priority to with the traditional Marine industry, such as Marine fisheries, provide more rigid demand characteristics of the product, there is no better scientific and efficient development and utilization of ocean, science and technology and economy showed two

independent systems, failed to make good use of science and technology power to release the productive forces, science and technology - economy in a low stage of coupling.

Table 3. Coupling coordination degree of science and technology and economic system in 11 coastal provinces and cities from 2007 to 2018

	Tianjin	Hebei	Liaoning	Shanghai	Jiangsu	Zhejiang	Fujian	Shandong	Guangdong	Guangxi	Hainan
2007	4	3	3	6	4	4	4	5	5	1	2
2008	4	3	3	6	4	4	4	5	5	1	2
2009	5	2	4	6	4	4	4	5	5	1	3
2010	5	2	4	6	4	4	4	5	5	1	2
2011	5	3	4	6	4	4	4	5	5	1	2
2012	5	3	4	6	4	4	4	7	7	1	3
2013	5	3	4	6	4	4	4	7	7	1	2
2014	5	3	4	6	4	4	4	7	7	2	3
2015	5	3	4	6	4	4	4	7	6	2	3
2016	4	3	4	8	4	4	4	7	6	2	4
2017	4	4	4	6	5	4	4	6	6	2	3
2018	4	4	4	6	5	5	5	6	6	3	4

Annotation：1.Severe disorder 2.Mild disorder 3.Moderate disorder 4.Barely coordinated 5.Primary coordination 6.Good coordination 7.Moderate coordination 8.Excellent coordination

5. CONCLUSIONS

Based on the comprehensive measurement of ocean innovation capacity and economic strength of 11 coastal provinces and cities by Entropy-TOPSIS, the coupling coordination degree model is used to analyze the coupling coordination degree of ocean science technology and economic system in coastal areas, and the following conclusions are drawn.

In the comprehensive assessment of science and technology and economy, the Marine science and technology and economic strength of provinces and cities are uneven, but they almost match each other. Generally, regions with strong Marine economic strength have strong scientific and technological performance, and with the improvement of Marine strategic position, the Marine science and technology and economic strength of provinces and cities are also slowly improving. The disparity of regional Marine science and technology and economy is closely related to local Marine resource ownership, resource input, resource attraction and industrial allocation. At the same time, the strategic positioning of Marine economy is inconsistent among provinces and cities, and the local attraction of high-end technical talents and scientific research institutions is inconsistent. The Pearl River Delta in Guangdong, the Yangtze River Delta in Jiangsu and Shanghai, as well as Shandong are all highly attractive regions for talents. The strong economic foundation and geographical advantages also make it easier to attract scientific research institutions to settle down. In addition, due to the reasons of national strategic deployment, the government supports different provinces and cities. Jiangsu, Shanghai, Guangdong and Shandong can receive more scientific research funding from the government, while Hainan, Guangxi and Liaoning are at a disadvantage in terms of funding. All provinces and cities, especially the backward areas, can actively mobilize resources according to their own strategic planning needs, and strive to improve the attractiveness of their own resources, so as to gather more high-quality resources.

System coupling coordination degree. From the perspective of system coupling degree, the coupling degree of all regions is quite high, except Hainan which has a low coupling degree in the early stage, which further shows that science and technology and economy are closely combined and inseparable. The dual system cannot become an independent individual, but must develop cooperatively. From the point of coupling coordination degree, regional performance is not very ideal, many cities showed low system coordination and even not harmonious, but in the years, the regional coupling coordination degree has a different degree of increase, although there are still part of the city by 2018 with low coordination degree, but if without the disorder, it also shows that the system is running in technology and economy. The coupling coordination between science and technology and economy system is a long-term system engineering with problems, which need to be adjusted and improved continuously.

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