RESEARCH ON THE COORDINATED DEVELOPMENT OF MARINE SCIENCE AND TECHNOLOGY AND MARINE ECONOMY IN THE BOHAI RIM REGION

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Abstract. *Based on the theory of coupling coordination degree, through establishing the marine science and technology indicators evaluation system and the marine economic development indicators evaluation system, the article analyzed the coupling coordinated development of marine science and technology and marine economy of Bohai Rim Region via the public data of the year of 2012-2016. The result showed that the coupling degree of Shandong, Liaoning and Tianjin is better than that of Hebei Province. The coordinated development degree of marine science and technology and marine economy of Shandong Province is the best, while the result of Hebei Province is poor. And at the last, this article gave some suggestions on the development of marine economy and marine science and technology to the Bohai Rim Region based on the analysis results.*
Keywords: Coordinated development, Marine science and technology, Marine economy, Coupling theory

1. **Introduction.** The resources of ocean are important for the future development. Since 2000, marine economy has developed rapidly in China. In 2018, China's gross ocean product (GOP) has accounted for 9.3% of China's gross domestic product (GDP). With the publication and implementation of the 13th Five-Plan for National Marine Economic Development (China) and the National Plan for Promoting the Sea by Science and Technology (China), the relationship between marine economy and marine science and technology will become more and more closer.

With the development of marine economy, scholars in various countries began to analyze the mechanism of the coordinated development between the technological innovation and marine economy. Some scholars studied the relationship between technological innovation and the optimization of marine industry by establishing indicator system or via the econometric model, to find out the influence factors in the adjustment of marine industry, and analyze its mechanism [1,2]. The research on the relationship between technological innovation and economic growth mainly relies on the econometric model with the theory of economic growth theory, such as Solow model, data envelopment analysis (DEA), and production function, to measure the contribution rate of marine science and technology or the input-output efficiency of scientific and technological elements [3-5]. The research on the coordinated development of marine economy mainly focuses on measuring the degree of coordinated development, the influencing factors and coordination mechanism, and researching the development policies and measures. In the research, the establishment of quantitative evaluation model and indicator system has become the basis of scholars' researches. Scholars in China focus on establishing indicator system. The research methods are mainly based on entropy method [6-9], and they prefer empirical research on the

coordinated development of marine economy, while other scholars mainly focus on the comprehensive index of sustainable development of marine economy [10-12].

For the coupling coordination degree of marine economy, in China, most of articles' focus is mainly on the whole country or a certain province; at present, regional cooperation is becoming the choice of local economic development, so the research of marine economy about the region is necessary. This article takes the Bohai Rim Region as an example to calculate the coupling coordination degree. And the Bohai Rim Region is important for North of China to develop marine economy, to do research about coupling coordination on Bohai Rim Region is significant for the development of marine economy, and we hope we can give some suggestions on the development of marine economy.

2. Methods.

2.1. Evaluation indicator system.
The strength of input on marine science and technology decides the quality of output on marine science and technology. In some way, the transformation and utilization of output on marine science and technology has promoted marine economic efficiency, improved the marine industrial structure, and provided technical support for marine economic development. The development of marine economy decides the strength of investment in innovation of marine science and technology, and it is the most direct security of material basis for the development of marine science and technology. Besides, the development of marine science and technology has a positive effect on the protection of marine ecosystems and the improvement of the utilization of marine resources. To summarize, the relationship between marine economy and marine science and technology is close and complex.

According to the current situation of marine economic development of four provinces (Tianjin city is municipality directly under the Central Government) in the Bohai Rim Region, combined with the existing achievements and data of marine science and technology, this paper constructed the following evaluation indicator system of marine science and technology and marine economic development evaluation indicator system.

TABLE 1. The indicator system of marine science and technology

Marine science and technology	The investment in science and technology	The number of research institutions on marine science and technology T_1
		The number of scientific research practitioners T_2
		The investment of science and technology T_3
		The number of research projects on marine science and technology T_4
	Output of science and technology	The proportion of added value of scientific research management service industry T_5
		The number of the papers about marine science published T_6
		The number of publications (book) about marine science T_7
		The number of patent authorizations T_8

2.2. Evaluation model of coupling coordination degree.
To calculate the coupling degree, we need to calculate the efficiency coefficient of each index first. The efficiency coefficient represents the contribution degree of the index variable to the system. And the range of contribution degree is $[0, 1]$; the closer the value of the efficiency coefficient is to

TABLE 2. The indicator system of marine economic development

Development of marine economy	Economic scale	GOP in provinces E_1
		GOP/GDP in provinces E_2
		The number of employed persons for marine economy E_3
	Industrial structure	The proportion of output value of the marine secondary industry to the GOP E_4
		The proportion of output value of the marine tertiary industry to the GOP E_5
	Environmental protection	Wastewater discharge in coastal zone E_6
		The number of completed pollution projects in the year E_7

1, the higher the contribution degree is. The calculation formula of efficiency coefficient is:

$$u_{ij} = \begin{cases} (x_{ij} - L_{ij})/(Y_{ij} - L_{ij}) & \text{Positive indicators } (i = 1, 2, \ldots, n) \\ (Y_{ij} - x_{ij})/(Y_{ij} - L_{ij}) & \text{Contrary indicators } (j = 1, 2, \ldots, m) \end{cases} \quad (1)$$

$$u_i = \sum_{j=1}^{m} w_{ij} u_{ij} \quad (2)$$

u_i: the synthetic order parameters of the subsystem i, u_{ij}: the efficiency coefficient of indicator j in subsystem i, x_{ij}: the data of the indicator, L_{ij}: the minimum value of the indicator, Y_{ij}: the max value of the indicator, w_{ij}: weight of the indicator.

According to the contribution degree of each subsystem calculated, the synchronization between marine science and technology and marine economic development can be calculated. Based on the ratio R of u_1/u_2, when $R > 1.1$, we think that the development of marine science and technology is ahead of that of marine economy. When $R < 0.9$, we think that the development of marine economy is faster than that of marine science and technology. When R is in the range of $[0.9, 1.1]$, we think that is the synchronous development [13].

With the development of management science, the concept of coupling degree has become a common method to study the interaction of multi-systems. In this paper, only two systems are involved, and the calculation formula of coupling degree is as follows:

$$C = 2\left\{ (u_1 \cdot u_2)/(u_1 + u_2)^2 \right\}^{1/2} \quad (3)$$

Coupling coordination degree can better evaluate the coordination degree of interaction and coupling between systems. The calculation formula is as follows:

$$T = \lambda_1 u_1 + \lambda_2 u_2 \quad (4)$$

$$D = \sqrt{CT} \quad (5)$$

In Formulae (4) and (5), D is the degree of coupling coordination, T is the comprehensive coordination index of two subsystems, λ is the undetermined coefficient. After reviewing [14,15], this paper defined it as follows: $\lambda_1 = \lambda_2 = 0.5$, and the specific classification of coupling coordination degree D is shown in Table 3.

2.3. **Weight determining.** Coefficient of variation (CV) method is an objective weighting method, which directly uses the information contained in the index data to calculate the weighting. If the internal difference of the index data is greater, the greater the differentiation degree of the index, the greater the weight allocated to it. We can get the

TABLE 3. Coordination level

D	Coordination level	D	Coordination level
0-0.1	Extreme imbalance	0.5-0.6	Basic coordination
0.1-0.2	Serious imbalance	0.6-0.7	Primary coordination
0.2-0.3	Intermediate imbalance	0.7-0.8	Intermediate coordination
0.3-0.4	Primary imbalance	0.8-0.9	Well coordination
0.4-0.5	Basic imbalance	0.9-1	Wonderful coordination

weight w_j by this way.

$$v_j = \frac{\sigma_j}{\overline{x_j}} \qquad (6)$$

$$\sigma_j = \sqrt{\frac{1}{n}\sum_{j=1}^{n}(x_j - \overline{x_j})^2} \qquad (7)$$

$$w_j = \frac{v_j}{\sum_{j=1}^{n} v_j} \qquad (8)$$

where, v_j is the coefficient of variation of the indicator j, and σ_j is standard deviation of the indicator j.

3. Main Results.

3.1. **Data illustration.** The object of study in this paper is the Bohai Rim (Tianjin, Hebei, Liaoning and Shandong). Based on the availability of getting data, the data for 2012-2016 used in this paper are from the *China Ocean Statistics Yearbook* and *The Economic Statistics Bulletins* of various cities. According to the weight determination method, combined with data, the calculation value of weight is shown in Tables 4 and 5.

TABLE 4. The weight of marine science and technology indicators

Indicator	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8
Weight	0.0839	0.1014	0.1390	0.1584	0.0991	0.1308	0.0978	0.1896

TABLE 5. The weight of marine economic development indicators

Indicator	E_1	E_2	E_3	E_4	E_5	E_6	E_7
Weight	0.1655	0.1201	0.1422	0.0497	0.0370	0.1680	0.3175

According to the method, the results of the coupling coordination degree of the Bohai Rim Region are obtained step by step.

3.2. **Result and analysis.** Based on the calculation results, between 2012 and 2016, the development of marine economy in Hebei Province is better than marine science and technology; the development of marine science and technology in Liaoning Province and Shandong Province are ahead of marine economy in 2012-2016.

According to the result, between 2012 and 2016, the development of marine economy in Hebei Province is faster than marine science and technology, and both Liaoning and Shandong Provinces are in the state of marine science and technology advanced development. While Tianjin had achieved the synchronous development in 2015 and 2016, but it is unstable. And the development of marine science and technology in the Bohai Rim Region is not balanced. Shandong and Liaoning Provinces are superior to other regions

TABLE 6. The result of synergistic development

	2012	2013	2014	2015	2016
Tianjin	0.79	0.85	0.81	0.91	0.90
Hebei	0.45	0.45	0.42	0.43	0.33
Liaoning	1.52	1.28	1.55	2.24	1.20
Shandong	1.92	1.99	1.76	1.81	1.57

on the scientific research and industrial development. And Hebei Province is developed slowly in marine economy and marine science and technology.

According to the result of coupling degree, the result of Tianjin is better, Hebei Province is slightly insufficient, also the gap between the four provinces is not obvious. And according to the results of the coupling coordination degree, we can find that the result of Shandong is the best in Bohai Rim Region, had reached intermediate coordination stage in 2012-2016. Tianjin and Liaoning Provinces have reached the stage of basic coordination, Tianjin had reached primary coordination between 2013 and 2015. Hebei Province has been in a state of imbalance development. We also found something in 2016 about the result, the coupling coordination degree of the four provinces has declined. Considering the implementation of the 13th Five-Year Plan in 2016 and the deepening of the reform, the change of the policy environment may have an impact on the development of marine economy and marine science and technology.

TABLE 7. The result of coupling degree

	2012	2013	2014	2015	2016
Tianjin	0.9935	0.9966	0.9942	0.9990	0.9986
Hebei	0.9255	0.9263	0.9130	0.9188	0.8645
Liaoning	0.9784	0.9923	0.9765	0.9238	0.9960
Shandong	0.9493	0.9439	0.9614	0.9576	0.9753

TABLE 8. The result of coupling coordination degree

	2012	2013	2014	2015	2016
Tianjin	0.5847	0.6113	0.6124	0.6248	0.5888
Hebei	0.3753	0.3868	0.4141	0.3952	0.3650
Liaoning	0.5030	0.5384	0.5811	0.6507	0.5779
Shandong	0.7403	0.7560	0.7987	0.8137	0.7881

4. **Suggestions.** The planning of the marine economic development should be practicable and actively integrated to the national development strategy. Liaoning Province should actively use its own marine resources and integrate to the Northeast Revival Strategy to drive regional economic development with port shipping, shipbuilding and seaside tourism. Hebei and Tianjin Provinces should actively cooperate to find a balance in coordinated development for the Beijing-Tianjin-Hebei, optimize the allocation of marine resources and promote the innovation and development of marine science and technology. Basis in the existing development, Shandong Province should actively implement policies at all levels and promote the construction on the Blue Economy Zone in Shandong Province. Deepening reform, driving the shift of economic growth mode by scientific and technological innovation, and eliminating backward production facilities are necessary to us. We should promote the financial supply-side structural reform, provide

precise financial services, bring into play to the advantages of the entity economy and build a modern marine industry system.

To establish incentive mechanism in technological innovation and optimize innovative atmosphere of science and technology, Liaoning, Shandong and Tianjin Provinces in the Bohai region have a solid foundation of scientific research, and there are a lot of ocean universities and scientific institutions. In the future development, we should actively take advantage of this advantage, combine with the regional superior industries such as shipbuilding, desalination, and utilization, and establish wholesome mechanism of marine science and technology innovation, in order to ensure the development of marine science and technology innovation. We should promote and build a support platform of diversified ocean finance and ensure the duplication of investment. At the same time, it is necessary for us to encourage the transformation of scientific and technological innovation results, expand investment in scientific and technological innovation, improve the utilization of scientific and technological results, encourage innovation entrepreneurship of scientific researchers, and guide innovative results to transfer into productive use.

Speeding up the talent team construction of marine science and technology and encouraging regional cooperation are important things for us. Marine science and technology talents are obviously gathered and the distribution of scientific and technological talents around Bohai region is unreasonable in Shandong Province. We should embroider on major oceanographic colleges and scientific institutions and promote the construction of high-quality marine talents team in the Bohai region, and create an innovation platform for science and technology. It is one of the most important tasks for us to actively promote the flow of talents and scientific and technological cooperation, drive the rational distribution of talents and closely integrate marine scientific research with industrial development at the same time, build a platform which includes government-enterprises-education-research, and train marine scientific research talents with solid theory and strong practical ability.

5. **Conclusions.** Through the analysis of the coordinated development of marine science and technology and marine economy, it is concluded that the coordinated development of marine science and marine technology and marine economy in Shandong Province is better than others, while Hebei Province is relatively backward, and Shandong has reached well coordination development in 2015. Overall, in Bohai Rim Region there exists polarization phenomenon in the development of marine science and technology and marine economy; in order to take the development of the Bohai Rim Region more coordinated, in the future, we should pay attention to strengthening cooperation.

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