Original Research Article

Research on the Influence of Foreign Direct Investment on the Efficiency of China's Marine Green Economy under the Target of "Double Carbon"

ABSTRACT

Aims: It is of great significance to China to realize the green and sustainable development of Marine economy in the process of continuously and steadily promoting the practice of reaching carbon peak and carbon neutrality. In recent years, the measure of Marine green economy efficiency has attracted wide attention from academic circles.

Methodology: Under the dual perspective of environmental constraints and government governance, this paper will, based on the panel data of 11 coastal provinces in China from 2004 to 2019, use the ultra-efficiency SBM model to measure the efficiency of Marine green economy in 11 coastal provinces in China, and conduct a static effect analysis. At the same time, the traditional DEA model is adopted to calculate the Marine economic efficiency without considering the unexpected output and resource input, and the two calculation results are compared and analyzed.

Conclusion: (1) the overall efficiency level of Marine green economy in China is not high; (2) the undesired output has obvious influence on the efficiency value of Marine green economy, and the resource and environmental constraints will cause a certain degree of resource loss; (3) due to the economic development level and regional differences in different provinces, some provinces improve the Marine economic efficiency by sacrificing the environment. Finally, based on the above conclusions, targeted suggestions are put forward for the development of China's Marine economy to develop the Marine economy and accelerate the construction of a maritime power.

Keywords: double carbon; Marine green economy efficiency; countermeasures

1. INTRODUCTION

1.1 Research Background

With the rapid economic development and the rapid progress of science and technology, the number of Marine resources available to use continues to increase. Some developed countries have already taken the ocean as a key area to maintain their strategic advantages and enhance their comprehensive national strength. The United Nations Convention on the Law of the Sea has also strongly promoted the participation of countries around the world in the "blue land enclosure movement", the jurisdiction of coastal states have expanded, and countries have accelerated the implementation of the Marine resources development strategy. Nobel Prize winner in physics George Smutt once pointed out at the China-Europe Blue Industry Cooperation Forum that the global blue economy is currently worth about 1.3 trillion euros and is expected to be close to 3 trillion euros by 2030. It can be seen that human understanding and utilization of Marine resources are constantly expanding in depth.

China is a big Marine economy. The 20th report of the CPC points out "develop Marine economy, protect the Marine ecological environment, and accelerate the construction of maritime power"; the report of the 19th National Congress of the CPC puts forward "adhere to the strategy of land and sea coordination, accelerate the construction of maritime power"; the national "14th Five-Year Plan" emphasizes "adhere to the land and sea coordination, sea harmony, win-win cooperation, promote Marine ecological protection, the development of maritime power and maritime rights and interests, and accelerate the construction of maritime power".

Since the 21st century, China's Marine economy has developed rapidly. Since 2000, the overall strength of China's Marine economy has increased significantly, and the Marine economy has maintained a trend of steady development. The gross Marine product increased from 951.84 billion yuan in 2001 to 8001 billion yuan in 2020, with an average annual growth rate of 11.86%. The proportion of the gross coastal product has increased from 8.7% to 14.9%. Marine economy has become an important engine for national economic and social development in coastal areas. The Marine economic structure has been continuously optimized, and the proportion of the three Marine industrial structure has changed from 6.8 44.0 49.2 to 4.9 33.4 61.7. The Marine tertiary industry, mainly Marine transportation, coastal tourism and Marine scientific research, education and management service industry, has achieved rapid development.

However, in the process of Marine economic development, the problems of Marine environmental pollution, low efficiency of Marine development and utilization, and low level of Marine science and technology innovation still exist. With the rapid development of the Marine economy, the problems of resource consumption and environmental pollution are still prominent. Under the new normal, in order to " improve the quality and efficiency of the Marine economy and realize green, healthy and sustainable development, the Chinese government has continuously increased investment in Marine environmental governance and strengthened the protection of the Marine ecological environment. Under the constraints of Marine resources and environment, optimizing the Marine industrial structure, improving the quality of Marine economy, improving the efficiency of Marine economy and realizing the high-quality sustainable development of Marine economy are the foothold for the long-term development of China's Marine undertakings.

1.2 Study significance

The rapid development of the Marine economy has led to endless problems such as excessive Marine fishing, rapid intensification of Marine pollution and continuous deterioration of the Marine environment, which have seriously damaged the Marine ecosystem. To this end, the coastal countries in the world began to abandon the traditional extensive Marine economy development mode, take the green, low-carbon and environmental protection issues of Marine economy as the focus of development, and seek effective ways to improve the utilization efficiency of Marine resources. In terms of the current situation of China's Marine economy, in addition to resource and environmental problems, regional imbalance is becoming increasingly prominent, and the development potential of Marine economy needs to be further explored. In his report to the 19th CPC National Congress, General Secretary pointed out that "pollution prevention and control and environmental control are an important juncture that China needs to cross from a stage of rapid growth to a stage of high-quality development." and "Accelerate the building of a maritime power and continue to ensure the protection of the Marine ecological environment."As an important guarantee for the coordinated development of Marine economy and ecological environment, the green development of Marine economy, how to maximize the output efficiency of production factors of Marine industry under the premise of not destroying the resources and environment, is an important issue to be solved in China's coastal areas under the background of high-quality development. Therefore, to re-examine the green development of Marine industry from the perspective of efficiency, analyze the efficiency evolution characteristics of green Marine economy from the perspective of time and space, and grasp the law of convergence are the key to reverse the traditional development situation of "high input and low output" in coastal areas and improve the quality of Marine economy development.

1.3 Literature review

As the main index to measure the quality of Marine economy development, the connotation of Marine economy efficiency also experiences the evolution from simple to complex. The calculation of economic efficiency traditionally only considers the input and expected output of typical production factors such as capital and labor, but in the context of vigorously developing green economy, it is of great significance for the calculation of economic efficiency to consider resource and environmental constraints and undesired output.

For the study of Marine economic efficiency, the previous literature mainly focused on the Marine green economic efficiency of a certain industry or a certain region. Cheng Na (2016) has measured the economic efficiency of China's three Marine industries respectively, and designed the system innovation mechanism of Marine industry according to the characteristics of various Marine industries and the property right structure of different enterprises, so as to improve the overall efficiency level of Marine economy【1】; Sun Qizhi (2020) applied SBM model to calculate the entropy efficiency of Marine economy system in 17 coastal cities in the Bohai Rim region in 16 years, and finally analyzed the evolution law

and mechanism of the entropy change process and toughness of Marine economy system【2】; Liao Kaicheng (2022) takes the innovation ecological environment as the input and the innovation ecological main body as the output, adopts SE-SBM DEA, model and Malmquist-Luenberger index to measure the dynamic operation efficiency of the innovation ecosystem in China's eight comprehensive economic zones from 2007 to 2018, and empirically tests the regional difference decomposition and formation mechanism of the dynamic operation efficiency of the innovation ecosystem【3】. Some scholars are no longer limited to industrial or regional restrictions, To study China's overall efficiency of the Marine economy, At the same time, considering the important impact of resource and environmental constraints on the development of the Marine economy, For example, Yuan Qingmin et al. (2016) adopted the SBM measurement method from the perspective of resource and environment constraints, To calculate the Marine economic efficiency of 11 coastal provinces, regions and municipalities from 2001 to 2011, And compare it with the marine economic efficiency based on traditional DEA methods, Between 2001-2006, The Marine economic efficiency measured by SBM is lower than that of the DEA method; while in 2006-2011, The Marine economic efficiency measured by SBM is higher than the efficiency level of DEA method. This shows that the impact of resource and environmental constraints on the Marine economy after 2006 has a positive impact【4】. Based on the SBM model considering the undesired output, Zhao Lin et al. (2016) studied 11 coastal provinces and cities for measuring the Marine economic efficiency from 2001-2012 and showed that the Marine economic efficiency without the unexpected output is significantly higher than that of the unexpected output, considering the unexpected output has obvious influence on the economic efficiency measurement and is more consistent with the reality situation; the Chinese Marine economic efficiency level of considering or without the unexpected output, and the Marine economic efficiency needs to be improved【5】. Gei et al. (2018) incorporated Marine environment and Marine economic growth into a production process, and measured the Marine green economic efficiency using the SFA model【6】; Zhao Xin et al. (2018) constructed the "Marine resources and environmental loss index", and calculated the Marine green economic efficiency by using the SBM-DEA model considering the undesired output【7】. However, for the measure of unexpected output, different scholars have different choices, such asZhao Lin (2016)【5】, Zhu Jingmin (2019)【8】And Game (2018)【6】The efficiency of Marine green economy is measured with the inflow of industrial wastewater as the unexpected output. Ji Yujun (2016) uses the "three wastes" discharge index as the unexpected output, and the GML model is used to reflect the efficiency of Marine green economy【9】; Guan Hongjun et al. (2019) arranged the wastewater treatment project as environmental treatment input and discharged industrial wastewater into massive quantities as undesired output, measured the green and traditional total factor productivity of Marine economy with DEA-Malmquist index, and compared it from the perspectives of time and space【10】。

The existing research has affirmed the research significance of Marine green economic efficiency. This paper will, on the basis of previous research, based on the coastal provincial level data, using the unexpected output efficiency SBM model and traditional DEA model, select industrial waste discharge as a measure of industrial solid waste output, measure the efficiency of Chinese coastal provinces to explore the overall level of China's Marine economy and provincial gap, at the same time, through the comparative study of environment and resource constraints on the efficiency of Marine green economy.

2 Measurement of Marine green economic efficiency

2.1 Study Methods

Data envelope analysis (DEA), proposed by Charnes, Cooper and Rhodes, is based on the relative effectiveness of decision units (DMU) based on multi-index input and output evaluation, which is widely used in related studies on production efficiency. However, the traditional DEA model is based on the Angle and radial direction, which means that the input orientation or the output orientation should be determined before the efficiency measurement, and the production efficiency cannot be accurately evaluated from multiple angles. Therefore, Tone proposed the SBM super-efficiency model in 2001, which is a non-Angle and non-radial measurement model based on relaxation variables, which can not only solve the problem of relaxation variables, but also enable all decision units to achieve complete ranking and analyze the changes in efficiency. Therefore, this paper adopts the SBM ultra-efficiency model based on the non-expected output and the input-output type to calculate the Marine green economic efficiency in 11 coastal provinces (municipalities and autonomous regions).

Taking each coastal province and city as a decision unit, each decision unit contains three input and output vectors: input, expected output and undesired output, The SBM ultraefficiency model assumes that the production system has n decision units, and the specific calculation formula for each decision is:

$$\min\ p^{*}=\frac{1+\frac{1}{m}\sum_{m=1}^{M}s_{m}^{x}/x_{jm}^{t}}{1-\frac{1}{l+h}\left(\sum_{l=1}^{L}s_{l}^{y}/y_{jl}^{t}+\sum_{h=1}^{H}s_{h}^{b}/b_{jh}^{t}\right)}$$

$$s.t.=\begin{cases} x_{jm}^{t} \geq \sum_{j=1, j\neq 0}^{n} \lambda_j^t x_{jm}^t + s_m^x \\ y_{jl}^{t} \geq \sum_{j=1, j\neq k}^{n} \lambda_j^t y_{jl}^t - s_l^y \\ b_{jh}^{t} \geq \sum_{j=1, j\neq k}^{n} \lambda_j^t b_{jh}^t + s_h^b \\ \lambda_j^t \geq 0, s_m^s \geq 0, s_l^y \geq 0, \ j=1,...,n \end{cases} \quad (1)$$

P * is the Marine green economic efficiency, j is the decision unit, t is time,,, is input, expected output and unexpected output value respectively; m, l, h respectively indicates the number of elements;,, is the relaxation of input and output; is the weight vector. When P * 1, the decision unit is effective, and when P * <1, the decision unit is inefficient, there is a need for improvement in the input and output.

2.2 Evaluation indicators and data description

Marine economy is a kind of resource-dependent economy. The investment of Marine resources such as capital, labor and seaports plays an irreplaceable role in the development of Marine economy. The efficiency of the Marine economy is a scientific evaluation of the efficiency of the input-output systems. From the perspective of input, the input index is composed of capital elements, human elements and resource elements, including the expected output and undesired output from the perspective of output. Input and output together constitute the calculation index system of China's Marine green economy efficiency calculation (Table 1).

Table 1 Efficiency index system of Marine green economy

Indicator category	Level 1 indicators	Secondary indicators	Index interpretation
Input index: put into	capital	Capital stock of Marine economy (100 million yuan)	Reflect the Marine economy capital input
	labour force	Maritime employment number (10,000 people)	Reflect the Marine economy labor force input
	resource	Wharf berths for port production	Reflect the resource input of the Marine transport industry
		Travel agency number	Reflect the investment of Marine tourism resources
		sea water breeding area	Reflect the Marine aquaculture resources input
output-input ratio	Expect output	Marine GDP GOP (RMB 100 million)	Reflect the total output value of the Marine economy
	Undesired output	Marine industrial wastewater is discharged directly into massive amounts (10,000 tons)	Reflecting the environmental costs of the Marine economy
		Total discharge of Marine industrial solid waste (10,000 tons)	Reflecting the environmental costs of the Marine economy

According to the classical economic theory, it reflects the input elements in the production process of Marine economy from the perspectives of capital, labor and resources. Among them, in terms of capital input, the capital stock of Marine economy is selected as the index of capital input. Since there is no data related to Marine fixed asset investment at present, this paper draws on the research of Zhang Jun (2004) and uses the base period of 2000 to calculate the capital stock of coastal provinces and cities【11】 $K_t = K_{t-1} - \delta K_{t-1} + I_t / P_t \; K_t \; K_{t-1} \; I_t \; \delta$. First, calculate the capital stock of each coastal province. The formula is, the amount of capital of the current period, the amount of capital of the previous period, the amount of investment of the current period (current price), and the depreciation rate of capital, using the

depreciation rate of 9.6%. Then, the ratio of Marine GDP to GDP is adopted to obtain the Marine capital stock of coastal provinces and cities. In terms of labor input, the number of employed is used as the index of labor input, and the statistical caliber of employed changes around 2006. To avoid calculation error, this paper treats missing data. For resource input, resource input is divided into three aspects: port production berth, number of travel agencies and mariculture area, and calculated by entropy method.

Output index: in the process of Marine production, while obtaining economic output value, the environmental pollution and ecological damage can not be ignored. Therefore, in addition to the desired output, coupled with the undesired output of environmental pollution. In terms of expected output, drawing on the previous research results and considering the availability of data, the Marine gross domestic product (GOP) is selected as the expected output index and converted at the constant price in 2000; in terms of unexpected output, considering the impact of land pollutants on Marine ecology, the total amount of industrial wastewater discharge and solid waste production in coastal areas are selected as the undesired output index.

Statistics from 11 provinces (municipalities, autonomous regions) including Liaoning, Hebei, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Guangdong, Guangxi, Fujian and Hainan from 2004 to 2019. The original data are from the 2005-2020 China Marine Economy Statistical Yearbook, China Statistical Yearbook, China Marine Economy Statistical Bulletin, and the statistical yearbooks of various provinces and cities. The specific data characteristics of the input-output indicators are shown in Table 2:

Table 2 Descriptive statistics of Marine green economy efficiency indicators

Indicator category	put into					output-input ratio	
Level 1 indicators	capital	labour force	resource			Expect output	Undesired output
Secondary indicators	Capital stock of Marine economy (100 million yuan)	Maritime employment number (10,000 people)	Number of berths for the port production wharf	Travel agency number	Mariculture area (ha)	Marine GDP (RMB 100 million)	Industrial waste water is directly discharged into massive amounts (ten thousand tons)
mean	11064.61	295.17	382.04	1118	176686.24	3252.45	22014.52
median	7375.92	208.4	212.5	1053	111902	2721.19	8806
crest value	60867.19	868.5	1335	3281	942050	12811.75	150443.1
least value	135.35	58	30	143	6	108.71	368
standard deviation	11635.59	203.83	385.54	665.51	213060.82	2787.83	29986.98

2.3 Calculation results of China's Marine green economy efficiency

According to the above SBM measurement method considering the unexpected output, the Marine green economic efficiency of 11 coastal provinces (municipalities and autonomous regions) in China from 2004 to 2019 was calculated by using MaxDEA Ultra8.0 software. In order to compare with the traditional efficiency model that ignores resource and environmental constraints, this paper uses the traditional DEA method to calculate the Marine economic efficiency value without considering the resource input and undesired output. Due to the different economic and technical conditions of coastal provinces, regions and municipalities, the production technical constraints with variable scale remuneration are selected. The specific calculation results are shown in Table 3 and Table 4.

Table 3 Value of China from 2004-2018 based on SBM method

a particular year	Liaoning	Hebei	Tianjin	Shandong	Jiangsu	Shanghai	Zhejiang	Fujian	Guangdong	Guangxi	Hainan	average
2004	0.674	0.553	1.000	0.609	0.572	1.000	0.541	1.000	0.771	0.412	0.736	0.715
2005	0.594	0.509	1.000	0.515	0.499	1.000	0.499	0.872	1.000	0.458	0.597	0.686
2006	0.489	0.589	0.661	0.468	0.476	1.000	0.378	1.000	1.000	0.475	0.571	0.646
2007	0.423	0.586	0.641	0.467	0.502	1.000	0.381	0.853	1.000	0.391	0.596	0.622
2008	0.431	0.609	1.000	0.584	0.591	1.000	0.433	0.709	1.000	0.399	0.727	0.680
2009	0.439	0.472	1.000	0.651	0.707	1.000	0.492	0.728	1.000	0.419	0.623	0.685
2010	0.375	0.434	1.000	0.596	0.666	1.000	0.451	0.629	1.000	0.375	0.529	0.641
2011	0.386	0.442	1.000	0.600	0.678	1.000	0.454	0.624	1.000	0.349	0.509	0.640
2012	0.344	0.432	1.000	0.744	0.669	1.000	0.435	0.560	0.685	0.348	0.492	0.609
2013	0.326	0.424	1.000	0.575	0.644	1.000	0.418	0.550	0.664	0.351	0.461	0.583
2014	0.329	0.467	1.000	0.626	0.703	1.000	0.415	0.597	0.708	0.367	0.412	0.602
2015	0.296	0.459	1.000	0.642	0.701	1.000	0.411	0.625	0.693	0.361	0.369	0.596
2016	0.330	0.408	1.000	0.634	0.682	1.000	0.405	0.622	0.676	0.350	0.440	0.595
2017	0.318	0.425	1.000	0.558	0.612	1.000	0.381	0.619	0.644	0.359	0.366	0.571
2018	0.396	0.460	1.000	0.574	0.549	1.000	0.379	0.458	1.000	0.299	0.283	0.582
2019	0.572	0.507	1.000	0.572	0.623	1.000	0.482	0.554	1.000	0.336	0.353	0.636

Table 4 China Marine Green Economic Efficiency from 2004-2018 by traditional DEA method

a particular year	Liaoning	Hebei	Tianjin	Shandong	Jiangsu	Shanghai	Zhejiang	Fujian	Guangdong	Guangxi	Hainan	average
2004	0.939	0.746	1.000	0.749	0.732	1.000	0.758	1.000	0.859	0.785	0.981	0.868
2005	0.852	0.766	1.000	0.746	0.727	1.000	0.745	0.987	1.000	0.843	0.931	0.872
2006	0.827	0.945	0.959	0.789	0.839	1.000	0.681	1.000	1.000	0.777	0.947	0.888

2007	0.758	0.921	0.890	0.768	0.833	1.000	0.696	0.972	1.000	0.719	0.972	0.866
2008	0.675	0.758	1.000	0.731	0.779	1.000	0.675	0.943	1.000	0.644	0.994	0.836
2009	0.624	0.639	1.000	0.727	0.759	1.000	0.688	0.926	1.000	0.597	0.903	0.806
2010	0.558	0.573	1.000	0.656	0.699	1.000	0.674	0.820	1.000	0.552	0.736	0.752
2011	0.522	0.529	1.000	0.644	0.696	1.000	0.662	0.757	1.000	0.518	0.686	0.729
2012	0.463	0.503	1.000	0.823	0.714	1.000	0.617	0.669	0.982	0.475	0.675	0.720
2013	0.412	0.518	1.000	0.596	0.699	1.000	0.564	0.645	0.917	0.423	0.626	0.673
2014	0.380	0.639	1.000	0.656	0.807	1.000	0.518	0.673	0.851	0.431	0.556	0.683
2015	0.369	0.644	1.000	0.690	0.821	1.000	0.479	0.675	0.793	0.423	0.534	0.675
2016	0.376	0.569	1.000	0.741	0.819	1.000	0.448	0.679	0.769	0.411	0.544	0.669
2017	0.405	0.612	1.000	0.648	0.743	1.000	0.429	0.671	0.735	0.418	0.479	0.649
2018	0.743	0.718	1.000	0.782	0.784	1.000	0.638	0.586	1.000	0.433	0.472	0.741
2019	0.778	0.706	1.000	0.809	0.885	1.000	0.719	0.763	1.000	0.477	0.581	0.793

According to Ma Zhanxin, set efficiency value ρ =1 is the highest efficiency; 0.8 ρ <1 is good efficiency; 0.6 ρ <0.8 is moderate efficiency; ρ <0.6 is invalid efficiency. The results presented in Table 3 show that, Shanghai and Tianjin have the best coordination between the resources and environment of coastal provinces, regions and municipalities, The average environmental efficiency of its Marine economic development is 1 and 0.956, respectively, This shows that the Marine economy of these two provinces was at the forefront of production between 2004 and 2019, Can reasonably control the pollution emission level of the Marine environment; In addition to 2004,2012-2017, The average efficiency of the Marine green economy is also 1, Are all at the forefront of production, The average efficiency of Marine economic development from 2004 to 2019 was 0.865, Good efficiency; The efficiency of Fujian and Jiangsu is relatively moderate, Its values were all above 0.6, There is still some room for improvement. However, the Marine economic environmental efficiency of Liaoning, Hebei, Shandong, Zhejiang, Guangxi and Hainan is low, with an average annual value of only about 0.4 and 0.5, which is a big gap with other provinces and cities.

According to the results of Table 3 and Table 24, we can see that resource and environmental constraints affect Marine economic efficiency in coastal provinces, regions and municipalities. It has little influence on Shanghai, Guangdong and Tianjin with developed Marine economy; in other coastal provinces after considering the resource environment constraints, the development of Marine economy in these provinces has caused relatively high pressure on Marine resources and environment, which promotes the development of provincial economy at the expense of environmental conditions.

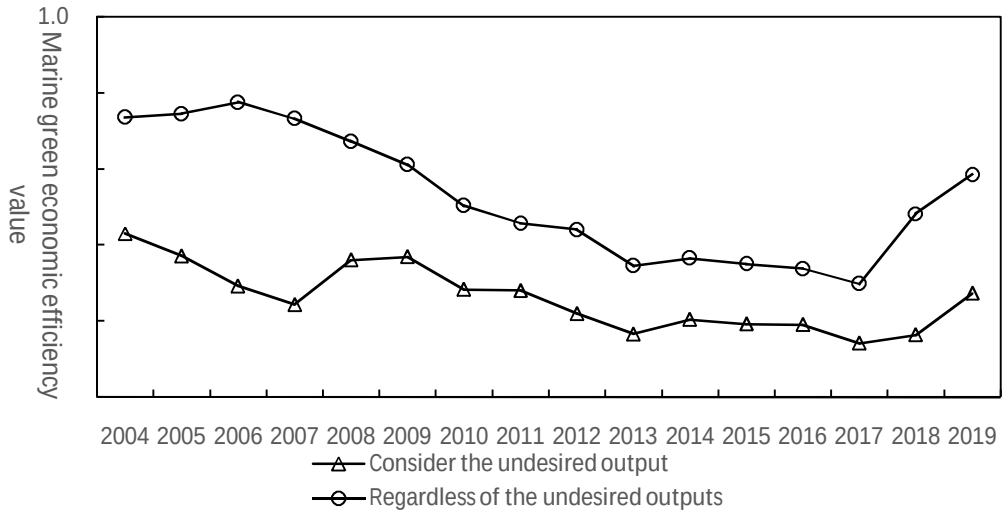


Figure 1: Efficiency change trend of Marine green economy in China from 2004 to 2019

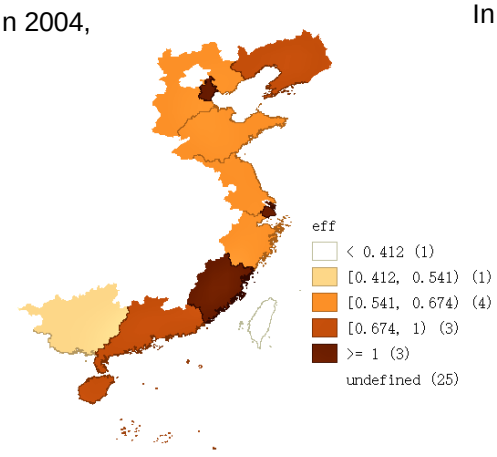
Judging from the results presented in Figure Figure 1, Between 2004-2019, The efficiency value of Marine green economy in China's coastal provinces shows the overall trend of declining first and then increasing, The marine green economic efficiency value when considering undesirable output is significantly lower than that without considering unexpected output; and after 2007, Considering that the gap in Marine economic efficiency between resource and environmental constraints and ignoring resource and environmental constraints is narrowing year by year, This case illustrates, In the early stage of Marine economic development, States neglect the protection of marine resources and the environment, Therefore, resource waste and environmental pollution have caused a certain degree of resource waste. In 2007, as an inflection point, the country began to formally implement energy conservation and emission reduction work, and the efficiency of resources and environment has been improved, thus effectively improving the environmental efficiency level of Marine economic development.

3. Evolution analysis of the spatial and temporal pattern of Marine economic efficiency

3.1 Spatial pattern of Marine economy

According to the Marine economic efficiency in China's coastal provinces from 2004 to 2019, the natural breakpoint method is used to divide the efficiency values into 5 grades: low efficiency (<0.0.412), low efficiency (0.4121~0.541), relatively high efficiency (0.541~0.674), high efficiency (0.674~1) and highest efficiency (1), and select the efficiency values in 2004,2009,2014 and 2019 to draw the efficiency chart of Marine economy in coastal areas (Figure 2).

In 2004,



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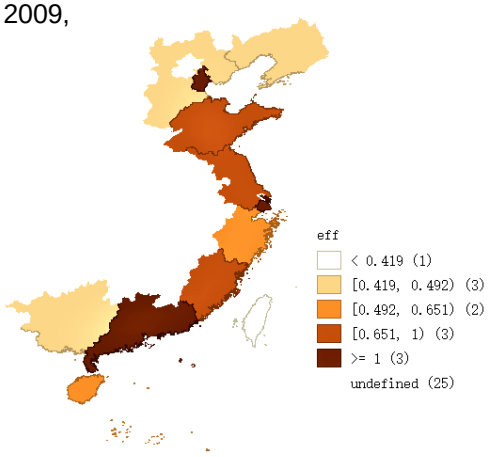

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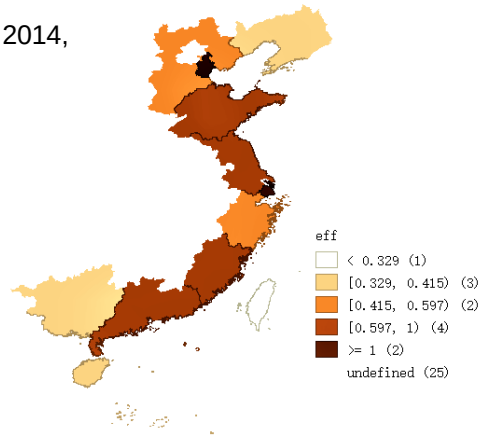

In 2019,

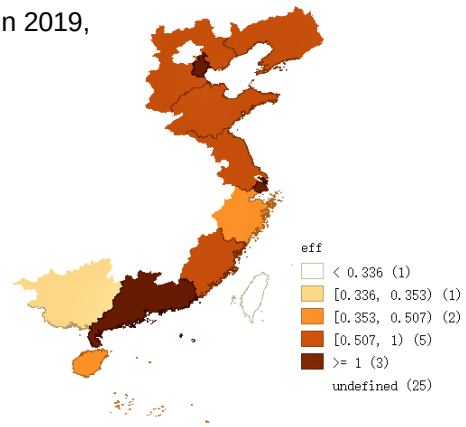

Figure 2: Spatial pattern of China's Marine economy efficiency

By analyzing the four-year cross-sectional data and the spatial pattern of Marine economic efficiency, At the end of the 2004 Plan (2001-2015), Among the 11 coastal provinces and autonomous regions, Tianjin, Shanghai and Fujian have the most efficient and fully effective Marine green economy, The efficiency values were all set at 1, Suggest that the Marine economic level of these three provinces is higher than that of other provinces, Liaoning (0.674) and Guangdong (0.771) provinces have a relatively high level and effective Marine economic efficiency, While other provinces are at ineffective levels, The spatial pattern has the economic characteristics of high efficiency in the north and south and low efficiency in the middle; In 2009, At the end of the 11th Five-Year Plan (2006-2010), In contrast to that seen in 2004, The efficiency of China's Marine economy shows an overall downward trend, The Marine economic efficiency value of Tianjin, Shanghai and Guangdong is 1, Fully efficient and the most efficient, In Fujian Province (0.728), the highest efficiency to high efficiency, Except for Shandong (0.651), Jiangsu (0.707), Fujian (0.728) and Hainan (0.623), which are at the effective level, All the other provinces are invalid, And the efficiency difference between provinces is small, There is a low-level equilibrium pattern in space; By 2014, At the end of the 12th Five-Year Plan (2011-2015), Increasing the number of provinces with effective Marine efficiency, Tianjin and Shanghai are the most efficient, The efficiency value of 1, Shandong (0.626), Jiangsu (0.703) and Guangdong (0.708) are all effective and high efficiency, The spatial tripole pattern has begun to take shape; At the end of the 13th Five-Year Plan of 2019 (2016-2020), The Marine economic efficiency value of Tianjin, Shanghai and Guangdong is 1, The highest efficiency, next, Jiangsu Province (0.623) has efficient and high efficiency, The spatial pattern has evolved from the characteristics of high Marine economic efficiency in the north and low in the middle in 2004 to a three-pole pattern around Tianjin in the north, Shanghai in the central part and Guangdong in the south, This characteristic is consistent with China's three major coastal Marine economic circle.

3.2 Characteristics of temporal changes of Marine economic efficiency

By analyzing the changing trend of Marine green economy efficiency in China from 2004 to 20190 (Figure 1), it can be seen that the overall level of China's Marine economy efficiency is not high, and it shows the time series characteristics of first decline and then rise. With the evolution of time, it has obvious stage characteristics. The efficiency value in 2004 was 0.715, which was a moderate efficiency level; decreased to 0.622 in 2007 for three consecutive years from 2004 to 2007, and in 2009 to 0.685, the highest value of the study period; in 2009, to 0.583, thus the efficiency of Marine green economy decreased in 2004-2013; after 2013, the efficiency showed a steady increase, but the increase rate was slow. Since 2013, the first efficiency (0.602) in 2014, and the second efficiency (0.636) in 2019, it can be predicted that the Marine economic efficiency began to change from medium efficiency to good efficiency. It can be seen that the Marine economic efficiency is in a slow growth stage from 2013-2019.

The efficiency of China's Marine green economy presents the above time and stage characteristics, mainly for the following reasons:

During the tenth Five-year Plan period of 2001-2005, China was in the early stage of the development of Marine economy. The state strongly supported the development of Marine resources and promoted the rapid development of Marine economy, thus ignoring the quality, efficiency and environmental problems of development. During the 11th Five-Year Plan period, 2006-2010, Is a critical period for the development of the Marine industry, To the orderly development of Marine resources, To protect the Marine ecological environment, However, due to the poor foundation of the Marine economy, Weak ability to protect the oceans, Low levels of public services and innovation, Without the measures to protect the oceans to work well in the short term, therefore, From 2004 to 2013, the efficiency of China's Marine green economy has not been effectively improved, But there is a trend of downward fluctuations; During the 12th Five-Year Plan

period of 2011-2015, The overall strength of the Marine economy has been significantly improved, The Marine industry layout is more reasonable, The Marine ecological environment has been continuously improved, Increasing the capacity for sustainable Marine development, therefore, The efficiency of the Marine economy began to grow steadily and slowly; After 2016, In particular, the 19th National Congress of the Communist Party of China proposed "accelerating the building of a maritime power." Put forward an urgent requirement for the construction of Marine economy, The efficiency of Marine economy began to improve.

3.3 Regional change characteristics of Marine economic efficiency

According to the Marine green economic efficiency in China in 2004-2019 calculated by the ultra-efficiency SBM model, and according to the formula of standard deviation and coefficient of variation of Marine economic efficiency in China's coastal provinces in 2004-2019 (Figure 3).

The standard deviation can reflect the absolute differences between the regions. By analyzing the standard deviation of the Marine economic efficiency in China from 2004 to 2019, It can be seen that the absolute difference in Marine economic efficiency between China's coastal provinces presents a relatively stable situation, The smallest absolute difference in 2004 (0.197), The largest absolute difference in 2018 (0.269), It is not difficult to conclude that, Although the absolute difference was stable at around 0.2,0.3 in most years, But in recent years began to show a slow expansion trend; The coefficient of variation is used to reflect the relative differences in the regions, As can be seen from Figure Figure 3, The relative difference in Marine economic efficiency in China's coastal provinces from 2004 to 2019 is a process of fluctuating rise, The lowest relative difference in 2004 (0.276), The ative differences widened each year in 2004-2007, In 2007-2009, it again experienced a phase of shrinking year by year, Starting in 2009, After nine years of relative growth, To 0.464 in 2018, Again again to 0.374 in 2019, It can be seen that the relative difference of Marine economic efficiency in coastal provinces from 2004 to 2019 is fluctuating, But the overall trend of expansion; Combining the standard deviation and the coefficient of variation, The regional gap of China's Marine economy has a widening trend. On the one hand, as the country increasing the importance of Marine economy development, coastal provinces successively according to the national strategy to formulate corresponding measures and planning, to promote the Marine economy development in the province, but because the coastal provinces level of economic development, as well as the technical level, capital investment, resource endowment condition, so the provinces in the process of Marine development will appear more obvious gap. On the other hand, in the process of the continuous spread of the Marine economy, the first developed regions will transfer the high energy consumption and high pollution sectors of their Marine industry to the later areas, which will lower the Marine green economic efficiency of the later areas, so that the difference between the first areas and the later areas will gradually expand.

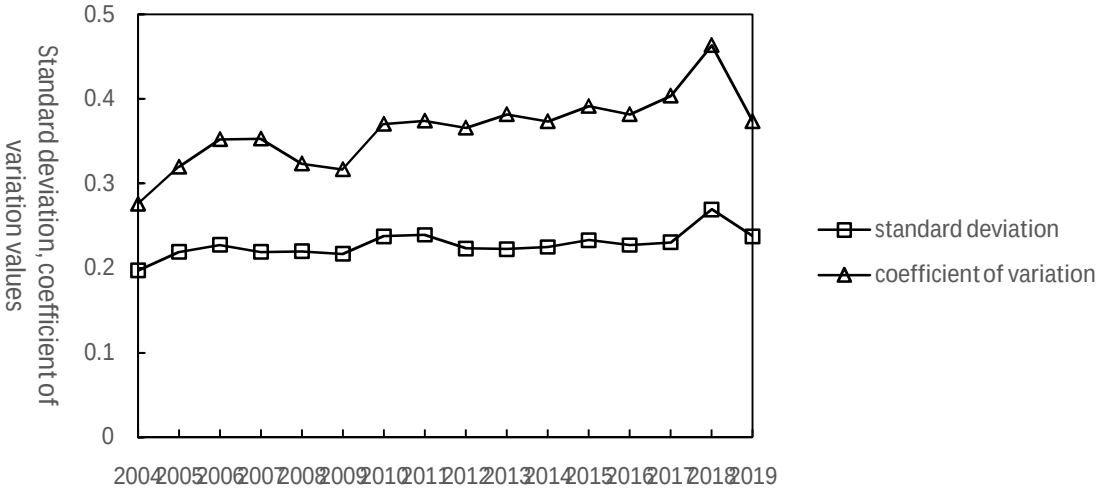

Figure 3: Standard deviation and coefficient of variation of China's Marine economic efficiency

3.4 Evolution type of interprovincial Marine economy efficiency

In terms of the change of Marine economic efficiency in coastal provinces, the changes of each province since 2004 have its own characteristics. Therefore, according to the change trend of the provinces, the evolution of Marine green economic efficiency in 11 provinces in China is divided into the following four types, namely stable type, rising type, fluctuating type and decreasing type. The specific evolution types of each province are shown in Figure 4,5,6 and 7.

In the stable areas including Tianjin and Shanghai, the efficiency of Marine green economy in the two provinces remained stable during the study period. Among them, the efficiency of Tianjin remained fully effective in all the other years, and the

efficiency of Shanghai has been maintained at the highest level, with the efficiency value of 1. at the same time, As can be seen from Figure 4, The Marine economic efficiency of Tianjin and Shanghai is not only stable, And it belongs to the high level of stable region; The Marine economic efficiency of Jiangsu and Zhejiang provinces is slowly rising, The two provinces show varying degrees of upward trend, But the rise was varied, among, Jiangsu's Marine economic efficiency is at a medium level, Efficiency fluctuates between 0.6-0.7, The Marine economic efficiency in Zhejiang province is lower than 0.6 in most years, The efficiency is invalid; The evolution of Marine economic efficiency in Hebei, Shandong and Guangdong provinces, Except for a few years, the Marine economic efficiency in Guangdong province is at the highest level, However, large fluctuated during the study period, Therefore, it belongs to the high-level fluctuation type, The Marine economic efficiency of Hebei and Shandong provinces fluctuated between 0.4 and 0.8 between 2004 and 2019, Therefore, it belongs to the low-level fluctuation type; The declining areas include Liaoning, Fujian, Guangxi and Hainan, The Marine economic efficiency of the four provinces showed an overall trend of declining year by year during the research period, From 0.674 (Liaoning), 1.000 (Fujian), 0.412 (Guangxi) and 0.736 (Hainan) in 2004 to 0.572,0.572,0.353 and 0.353 in 2019, Liaoning, Fujian and Hainan have all changed from full effective efficiency to ineffective efficiency, Guangxi is still in ineffective efficiency.

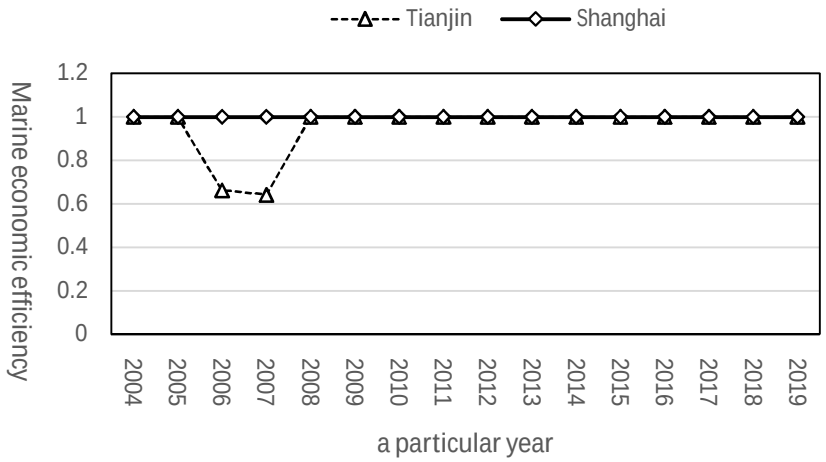

Figure 4: Evolution of efficiency of Interprovincial Marine economy in China- -stationary type

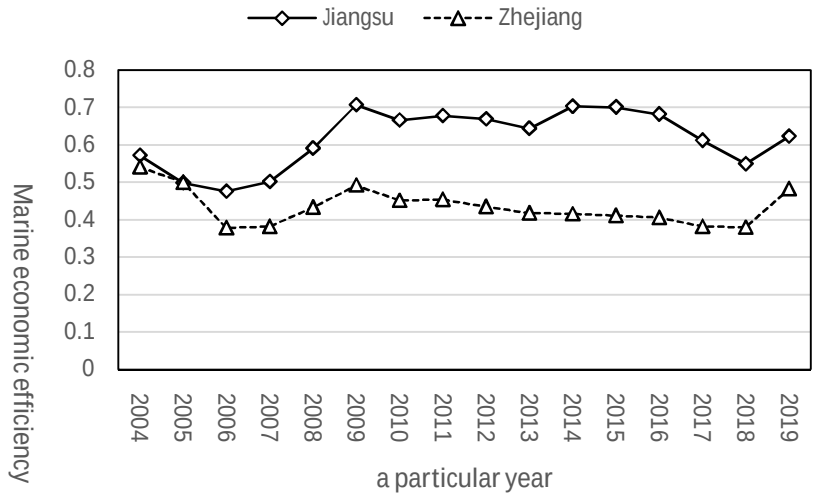

Figure 5: Evolution of efficiency of Interprovincial Marine economy in China- -rising type

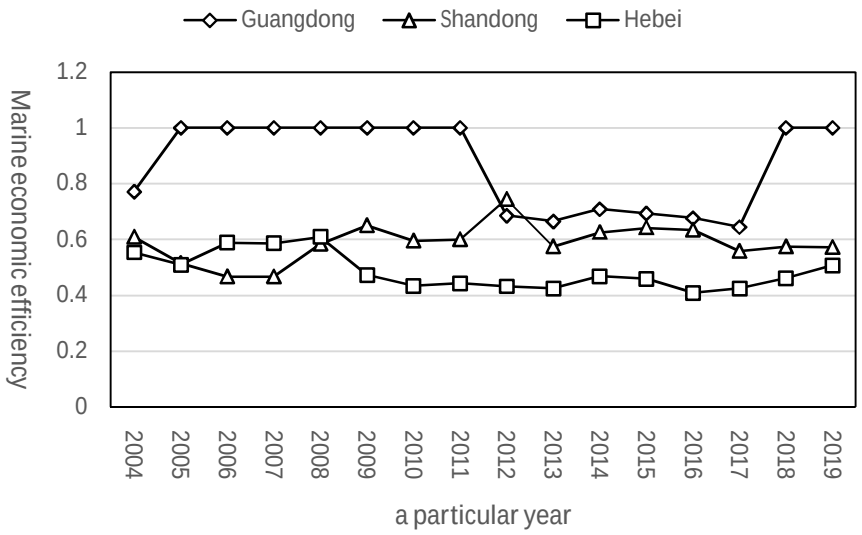

Figure 6: Evolution of efficiency of China's provincial Marine economy- -fluctuation type

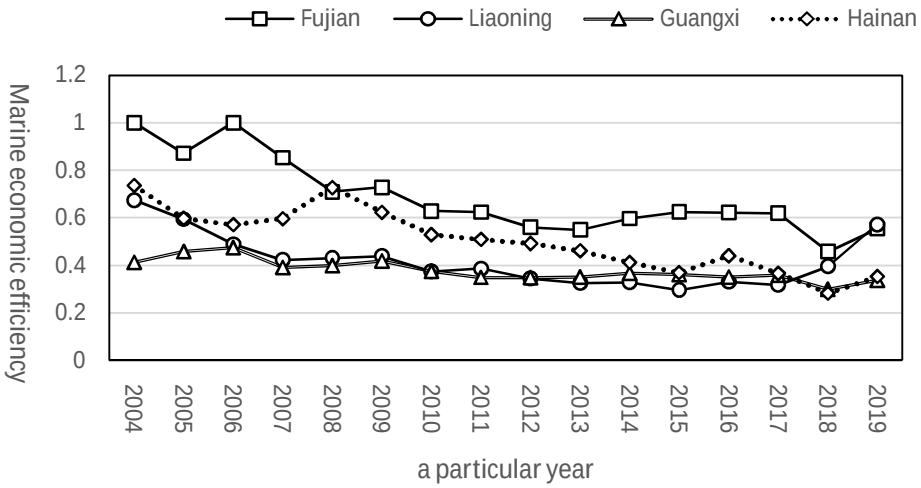

Figure 7: Evolution of China's interprovincial Marine economy efficiency- -declining type

The evolution of the coastal provinces, The reasons are: (1) in terms of stable areas, Tianjin and Shanghai have a high level of economic development, Are located in the core area of the coastal economic belt, The Marine economic foundation is relatively good, Marine strategic emerging industries are developing rapidly, In particular, the high level of Marine environmental protection technology, At the same time, the two provinces and cities can attach great importance to the effective development of Marine resources and the protection of the Marine environment, At the forefront of other coastal provinces in transforming the development mode of the Marine economy, for instance, In 2019, Shanghai proposed a key development direction based on the field of Marine economy, Docking with the construction of the "five centers", To implement the "three major tasks", Strengthening the restoration of the Marine ecological environment, Marine public services, Marine cultural exchange. In the same year, Tianjin issued a new policy to plan "building a global Marine center city" to promote the leapfrog development of Marine economy. Therefore, Tianjin and Shanghai have a high level of Marine intensification and good overall economic and environmental benefits, so their Marine economic efficiency remains at a stable high level.(2) in terms of rising region, Zhejiang and Jiangsu have certain Marine economic foundation, but the main Marine industry sector for Marine fisheries, Marine transportation, Marine shipbuilding and other traditional industries, Marine strategic emerging technology industry development lags behind the Yangtze river delta region, so the two provinces of Marine economic efficiency has been in medium efficiency level, but in recent years the provincial government issued relevant policies to promote the healthy development of Marine economy, so since 2018 two provinces of Marine green economic efficiency has rising obvious trend. According to the 14th Five-Year Plan of Jiangsu Province, the total output value of Marine economy in Jiangsu Province will reach 1.1 trillion yuan, accounting for more

than 8% of the regional GDP, and build a national leading Marine industry innovation highland and a pilot zone for green development of Marine economy. Zhejiang province focuses on Marine "Internet +", on Marine life and health, and builds a research and development center for Marine new materials. The Marine economy of Jiangsu and Zhejiang provinces has profound development potential.(3) In terms of fluctuating regions, Although Guangdong has a higher level of economic development than Shandong and Hebei, And Guangdong province has obvious shoreline advantages, Total length of 4,114 km, With 1,963 sea islands, But every year, typhoons visit Guangdong, From 1949-2019, A total of 194 typhoons have landed in Guangdong, And there are sometimes ship oil leakage and chemical leakage occurred, Therefore, Guangdong's Marine economic efficiency occasionally fluctuates; Shandong and Hebei have less efficient Marine economies, As far as Hebei is concerned, In 2019, the Marine economic output value was 218.6 billion yuan, Only 6.2% of the province's total output value, Well below the average in the coastal provinces, At the same time, with the continuous transformation of the Marine economic development mode, Implementation of measures such as energy conservation and emission reduction, To improve the Marine economic efficiency of the two provinces, However, due to the relatively low proportion of emerging Marine industries, Marine aquaculture and shipbuilding industry are still the pillar industries, Higher levels of pollution introduced into the sea, Therefore, the efficiency of the Marine economy in the two provinces fluctuates trend.(4) in terms of declining region, Fujian, Liaoning, Guangxi, Hainan four provinces at the beginning of the Marine economy development, developing Marine chemical industry, offshore oil, lingang heavy chemical industry, Marine economy starting area to its high pollution, high emissions industry to the region, the four provinces of Marine technology level is not high, Marine production, the production process intensive, clean low level, extensive production mode, so Marine economic efficiency will be reduced.

4 Conclusion, and suggestions

The improvement of the efficiency of Marine green economy is an important expression and result of the high-quality development of Marine economy, which is of great significance to promoting the implementation of the high-quality development strategy of Marine economy. This paper is based on panel data from 11 coastal provinces from 2004 to 2019, Ultra-efficiency SBM model is used to measure the Marine green economic efficiency and traditional DEA model, The results show that: (1) among the 11 coastal provinces, Marine green economy efficiency is in the medium or high level, Its general distribution pattern is consistent with the current bohai Rim, Yangtze River Delta and Pearl River Delta economic circle; (2) Affected by the regional economic development level and regional differences, The result difference of Marine green economic efficiency between the north and south provinces is large; (3) The efficiency value without considering the unexpected output is significantly higher than that without considering the unexpected output, Undesired output has a clear impact on the efficiency of the Marine green economy, Resource constraints and environmental pollution will cause a certain degree of efficiency loss;

The results show that the coastal areas of Marine green economic efficiency needs to further improve, "development of Marine economy, protect Marine ecological environment, speed up the construction of Marine power", "carry out green development concept", "explore ecological priority" and other national strategy, is now and even a long period of Marine economy development scientific guidance. In the context of the new normal of the Marine economy, to achieve the simultaneous development of the Marine economy and ecological environment protection, we must adhere to the innovation-driven high-quality development of the Marine economy. The following suggestions will be made here:

(1) In the macro-Marine economic management level. National, provincial and local governments should give full play to their role in macro-control and governance, and formulate and improve the overall plans and policies for green Marine development. The specific approach is as follows, We will improve the linkage mechanism between regional Marine resources development and Marine management, Integrating the concept of ecological protection into the development model of Marine green economy, Give full play to the function of Marine regional collaborative innovation development; From the current situation of the resources in the coastal provinces, To draw the red line for Marine ecological protection, Strictly define the intensity and timing of Marine development, Improve the input-output efficiency of the coastline and the sea area, With a scientific Marine resource management system, To promote green development of the Marine economy and improve the environment, Maintaining the ecological security of the ocean; in addition, To strengthen the legislative awareness of Marine ecology, Improving Marine laws and regulations, We will improve the planning system for Marine economic development, With the high-level legal system to ensure the green and high-quality development of the Marine economy.

(2)In the regional Marine economic development level. We should encourage the three major Marine economic circles around the Bohai Rim, the Yangtze River Delta and the Pearl River Delta to help each other and reduce the differences in the efficiency of Marine green economy among regions. Promote the flow and transfer of high level areas of Marine green economy to the middle and low level areas, so as to expand the scale of Marine industry in the area of middle and low level; take the opportunity to give full play to the leading role of the region of Marine green economy to participate in the domestic and foreign scientific and technological cooperation, develop Marine emerging industries and high-tech industries, effectively improve the Marine ecological environment, strengthen the exchanges and cooperation with

neighboring Marine provinces, and play the "chess game" of green and high-quality development of regional Marine economy.

(3) Optimization and coordination of the Marine industry. We should rationally locate the key direction of the development of Marine economy in each province, actively promote the construction of Marine carrier, scientifically, determine the development sequence of Marine industry, develop the emerging strategic industries with low resource consumption and high technology content, build the modern Marine system through the optimization and upgrading of Marine industrial structure, and improve the green economic efficiency; take modern Marine industry as the development orientation, strengthen the supporting role of science and technology in the Marine secondary industry, firmly grasp the scale and level of Marine tertiary industry, not only focus on the increase of the proportion.

(4) In improving the level of Marine technical support level. It is necessary to actively create a good environment for Marine science and technology innovation, improve the allocation ability of Marine green economic resources, guide new Marine science and technology innovation subjects, introduce new management system, encourage universities, scientific research institutions and enterprises to establish industry-university-research independent innovation teams, and build regional technical cooperation platform; local governments should formulate differentiated scientific and technological innovation policies. For areas with low Marine science and technology level, such as Guangxi and Hainan, they can focus on the transformation and application of scientific and technological achievements and use preferential policies to attract high and new Marine technologies. For Shandong, Jiangsu, Zhejiang and other regions with high innovation level, we should fully tap the potential of scientific and technological resources, focus on emerging Marine industries, break breakthroughs in key Marine core technologies, and effectively give play to the role of science and technology in promoting the high-quality development of Marine economy.

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