__Original Research Article__

Influence of FDI on China's green marine economy

ABSTRACT

The party's 20th report points out that the protection of Marine resources, the development of Marine economy, the construction of a maritime power. FDI is highly concentrated in China's coastal areas and accompanied by space spillover, which affects the development speed and quality of Marine economy. Does FDI improve the efficiency of China's Marine green economy? Based on the panel data of 11 coastal provinces and cities in China from 2004 to 2020, the "efficiency evaluation system of Marine green economy" is constructed from the dual perspective of environmental constraints and resource conservation, considering the unexpected output and measuring the efficiency of Marine green economy with the ultra-efficiency SBM model. Then, under the geographical weight and economic geographical weight, the FDI spatial index is constructed to study its influence on the efficiency of Marine green economy.The results show that FDI space can improve the efficiency of Marine green economy in China. FDI has a negative effect on the efficiency of Marine green economy, but after considering the spatial factors, the FDI spatial index has a positive promotion effect on the improvement of the efficiency value, and the promotion effect is more significant under the weight of economic geography and space.

Keywords: Marine green economic efficiency; FDI; economic geographic weight

1. INTRODUCTION

1.1 Background

Most of China's foreign investment is concentrated in coastal areas, where the marine economy is active, and a large amount of foreign capital inflows will inevitably have a major impact on China's marine economic development. China is a big country in marine economy. Report to the 20th CPC National Congress pointed out that "developing marine economy, protecting marine ecological environment and accelerating the construction of a maritime power"; In the report of the 19th National Congress of the Communist Party of China, it is proposed to "adhere to the strategy of land and sea planning and accelerate the construction of a maritime power". Since the 21st century, China's marine economy has developed rapidly. Since 2000, the overall strength of China's marine economy has improved significantly, and the marine economy has maintained a steady development trend. The gross marine production increased from 951.84 billion yuan in 2001 to 8.001 billion yuan in 2020, with an average annual growth rate of 11.86%. The marine economy has become an important engine of national economic and social development in coastal areas. See Figure 1 for the total marine production and its proportion in GDP from 2011 to 2022. The marine economic structure has been continuously optimized, and the marine tertiary industry, which is mainly composed of marine transportation, coastal tourism and marine scientific research, education and management services, has achieved rapid development. However, problems such as marine environmental pollution, low efficiency of marine development and utilization, and low level of marine scientific and technological innovation still exist in the process of marine economic development. With the rapid development of marine economy, the problems of resource consumption and environmental pollution are still outstanding. In order to promote the marine economy to "improve quality and efficiency" and achieve green, healthy and sustainable development, the Chinese government has continuously increased investment in marine environmental governance and strengthened the protection of marine ecological environment. “Under the constraints of marine resources and environment, it is the foothold to realize the long-term development of China's marine industry to optimize the marine industrial structure, improve the quality and efficiency of marine economy and realize the high-quality sustainable development of marine economy” [14].

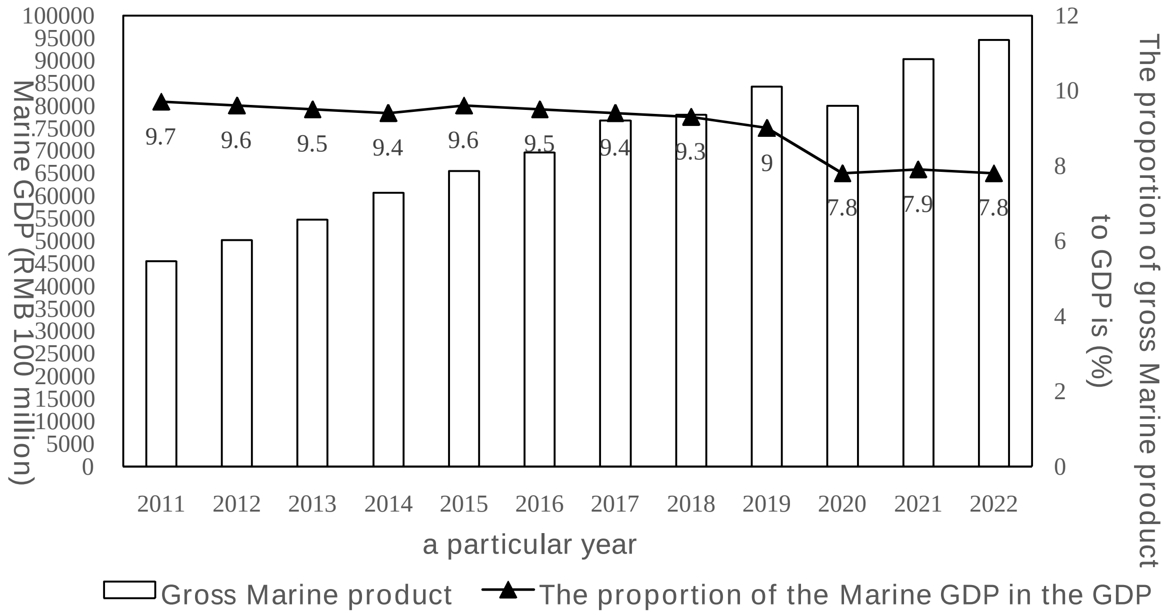

Figure1 Total Marine GDP and its proportion to GDP in 2011-2022

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 have begun to abandon the traditional extensive Marine economic development mode, take the green, low-carbon and environmental protection issues of the Marine economy as the focus of development, and seek an effective way to improve the utilization efficiency of Marine resources” [14]. 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 Xi Jinping pointed out that "pollution prevention and control and environmental governance 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, on 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” [14]. 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

Foreign direct investment (FDI) is a package of capital, technology and management experience, and it is an important source of direct capital investment and indirect knowledge spillover. Foreign R&D investment is an important way to produce knowledge spillover and promote the technological progress of host country enterprises. The research of Hollenstein & Berger (2015)[6] found that R&D investment of multinational corporations contributes to the improvement of innovation performance of domestic enterprises in the host country; Barrio etal. (2005)[1] divided the influence of FDI on independent innovation into negative competitive effect and positive external effect. Because the competition effect is mainly produced at the beginning and the external effect is mainly produced at the later stage, the spillover effect has a "U" curve on the innovation ability of enterprises; Yan Bing (2006) [9] found that the spillover effects of foreign-funded enterprises within and between industries are not significant. Xing Fei (2009) [8] and others made a systematic GMM estimation based on the panel data of 36 industries in China from 1999 to 2004, and found that the technology spillover effect of FDI was not significant in either short-term or long-term.

The research on the efficiency of marine economy under open economy needs to fully consider the influence of FDI on the structure and efficiency of marine economy. With regard to FDI and marine economic efficiency, most studies only take FDI as an influencing factor for simple demonstration, and there is no unified answer to the influence of FDI on marine economic efficiency. Zou Wei (2017)[12] and others used the Bootstrap-DEA model and found that FDI has a significant negative effect on the efficiency of marine green economy. Zhao Xin (2018)[13] constructed the "comprehensive index of environmental governance investment" from the dual perspectives of environmental constraints and government governance, and then constructed the spatial index of FDI under the geographical and economic geographical weights to study its impact on the efficiency of marine green economy. It was found that the spatial spillover effect of FDI was more significant under the economic geographical weight. Ding Lili (2017)[4] and others believe that FDI has an insignificant negative effect on the comprehensive efficiency of the marine economy; Zhao Xin (2018)[13] and others found that FDI has a significant negative effect on marine economic efficiency, but it has a positive spatial spillover; Di Ganbin(2022) [3] use SBM and Malmquist models to affirm the positive effect of FDI on marine economic efficiency, but it is not significant.

Some scholars use most DEA and its extended models to evaluate the efficiency. Gaimei (2016)[5] used SFA model, kernel density estimation, coefficient of variation, Gini coefficient, α convergence, β convergence and other methods to analyze the spatial and temporal differences and dynamics of green marine economic efficiency in China's coastal areas, and then analyzed the influencing factors of green marine economic efficiency through the construction of Tobit model; Cheng Wai (2021)[2] used the super-efficiency SBM model and Malmquist index model to measure the static and dynamic marine green economic efficiency, and used the panel threshold model to explore the "human capital threshold" effect of FDI on marine green economic efficiency. Zhao Xin (2018)[13] and others measure the efficiency of marine green economy by using the network RAM model of virtual production frontier, and then construct the spatial index of FDI to study its influence on the efficiency of marine green economy under the weight of geographical space and economic geographical space.

Generally speaking, there are not many research documents about the efficiency of FDI on marine green economy, and there is no unified research conclusion, and there are few studies on the spatial spillover effect of FDI. Therefore, the research starting point of this paper is novel, and the model construction is appropriate and has high research value.

2 CALCULATION OF MARINE ECONOMIC EFFICIENCY

2.1 Model Selection

“The traditional DEA model is based on the Angle and radial direction, which means that the input orientation or output orientation need to 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)” [14].

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

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

$$s.t.=\begin{cases} x_{jm}^{t}\geq\sum_{j=1,\,j\neq0}^{n}\lambda_{j}^{t}x_{jm}^{t}+s_{m}^{x} \\ y_{jl}^{t}\geq\sum_{j=1,\,j\neq k}^{n}\lambda_{j}^{t}y_{jl}^{t}-s_{l}^{y} \\ b_{jh}^{t}\geq\sum_{j=1,\,j\neq k}^{n}\lambda_{j}^{t}b_{jh}^{t}+s_{h}^{b} \\ \lambda_{j}^{t}\geq0,s_{m}^{s}\geq0,s_{l}^{y}\geq0,\ j=1,\dots,n \end{cases}$$

Where ρ^* is the efficiency of ocean green economy, j is the decision unit, t is the time, x_j^t y_j^t b_j^t s_m^x s_l^y s_h^b λ The input, expected output and undesired output value; m, l and h respectively represent the number of elements;, is the relaxation of input and output; is the weight vector. When ρ^*= 1, the decision unit is effective, when ρ^* <1, the decision unit is inefficient, there is a need for improvement in the input and output.

2.2 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" [14]. Input and output together constitute the calculation index system of China's Marine green economy efficiency (Table 1)

Table1 Efficiency index system of Marine green economy

Indicator category	Level 1 indicators	Secondary indicators	Index interpretation
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	Marine industrial wastewater is	Reflecting the

output	discharged directly into massive amounts (10,000 tons)	environmental costs of the Marine economy

Investment index: In terms of capital input, the capital stock of Marine economy is selected as the capital input index. Based on the study of Zhang Jun (2004). In 2000 as the base period, the number of Marine employment changes around 2006, to deal with the missing data in the port berth, the number of travel agencies and the mariculture area, and the entropy method.

Output index: "undesired output in addition to environmental pollution. In terms of expected output, drawing on the previous research results and considering the availability of data, the total Marine gross product (GOP) is selected as the expected output index and converted at the constant price in 2000; and in terms of undesired output, considering the impact of land pollutants on Marine ecology, the total discharge of industrial wastewater from coastal areas is selected as the undesired output index" [14].

Statistics from 11 provinces, including Liaoning, Hebei, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Guangdong, Guangxi, Fujian and Hainan from 2004 to 2020. The original data are from China Marine Statistical Yearbook, 2005-2021, China Energy Statistical Yearbook, China Energy Statistical Yearbook, China Statistical Yearbook, China Marine Economy Statistical Bulletin, as well as the statistical yearbooks of various provinces and cities.

The specific data characteristics of the input-output indicators are shown in Table 2 .

Table 2 Data characteristics of the input-output indicators

Indicator category			mean	crest value	least value	median	standard deviation
Investment index	capital	Capital stock of the Marine economy (100 million)	12043.63	60867.19	135.35	7555.16	12575.64
	labour force	The number of employed persons involved in the sea (thousands of people)	296.76	868.5	58	209.8	204.58
	resource	Number of berths for port production wharf (one)	385.77	1335	30	216.33	386.08
		Number of travel agencies (NA)	1160.72	3390	143	1082	707.44
		sea water breeding area (hectare)	176964	942050	6	111404	213128
Output indicators	Expect output	Gross Marine product (100 million)	3368.05	12811.75	108.71	2788.25	2841.78
	Undesired output	Industrial waste water is directly discharged into a massive amount (ten thousand tons)	786.73	3968	10	536	809.40

2.3 Results Analysis

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 2020 was calculated by using Max-DEA Ultra8.0 software. Results are presented in Table 3.

Table3 China 2004-2020 based on SBM method

year	Liaoning	Hebei	Tianjin	Shandong	Jiangsu	Shanghai	Zhejiang	Fujian	Guangdon	Guangxi	Hainan
2004	0.674	0.553	1.000	0.609	0.572	1.000	0.541	1.000	0.771	0.412	0.736
2005	0.594	0.509	1.000	0.515	0.499	1.000	0.499	0.872	1.000	0.458	0.597
2006	0.489	0.589	0.661	0.468	0.476	1.000	0.378	1.000	1.000	0.475	0.571
2007	0.423	0.586	0.641	0.467	0.502	1.000	0.381	0.853	1.000	0.391	0.596
2008	0.431	0.609	1.000	0.584	0.591	1.000	0.433	0.709	1.000	0.399	0.727
2009	0.439	0.472	1.000	0.651	0.707	1.000	0.492	0.728	1.000	0.419	0.623
2010	0.375	0.434	1.000	0.596	0.666	1.000	0.451	0.629	1.000	0.375	0.529
2011	0.386	0.442	1.000	0.600	0.678	1.000	0.454	0.624	1.000	0.349	0.509
2012	0.344	0.432	1.000	0.744	0.669	1.000	0.435	0.560	0.685	0.348	0.492
2013	0.326	0.424	1.000	0.575	0.644	1.000	0.418	0.550	0.664	0.351	0.461
2014	0.329	0.467	1.000	0.626	0.703	1.000	0.415	0.597	0.708	0.367	0.412
2015	0.296	0.459	1.000	0.642	0.701	1.000	0.411	0.625	0.693	0.361	0.369
2016	0.330	0.408	1.000	0.634	0.682	1.000	0.405	0.622	0.676	0.350	0.440
2017	0.318	0.425	1.000	0.558	0.612	1.000	0.381	0.619	0.644	0.359	0.366
2018	0.396	0.460	1.000	0.574	0.549	1.000	0.379	0.458	1.000	0.299	0.283
2019	0.572	0.507	1.000	0.572	0.623	1.000	0.482	0.554	1.000	0.336	0.353
2020	0.429	0.464	1.000	0.568	0.595	1.000	0.414	0.544	0.881	0.331	0.334

According to Ma Zhanxin, set efficiency value $\rho = 1$ is the highest efficiency; $0.8 \leq \rho < 1$ is good efficiency; $0.6 \leq \rho < 0.8$ is moderate efficiency; $\rho < 0.6$ 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 2020, Can reasonably control the pollution emission level of the Marine environment; In addition to 2004 and 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 2020 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.

3 MECHANISM ANALYSIS OF FDI INFIUENCE ON MARINE GREEN ECONOMY EFFICIENCY

Along with the large inflow of FDI, there are also advanced technology and management experience into the coastal areas, namely the spillover effect of FDI. The efficiency of Marine green economy comprehensively reflects the development status of Marine economy in China's coastal provinces by ecology and economy from the perspective of input and output. Both from the perspective of economic development and environmental governance, FDI has a certain impact on the efficiency of the development of Marine green economy. The influence mechanism is shown in the figure below, which is mainly reflected in the following three effects.

(1) Scale effect.
The large inflow of foreign direct investment will improve the economic benefits of China's coastal provinces, and then promote their economic development. However, the large scale of FDI may lead to excessive consumption of resources and environmental pollution, resulting in "diseconomies of scale". The improvement of economic development level means that more social wealth should be allocated to conserve Marine resources and control Marine pollution. In this way, the Marine economy may be improved to a certain extent. So, the scale effect of the FDI is uncertain.

(2) Technical effect.
The inflow of foreign direct investment is accompanied by the inflow of related technologies. With the diffusion of technology in the coastal areas, the production process and production process are improved, which can improve the environmental governance capacity and resource conservation and pollution control. Meanwhile, the technical effect of FDI will bring space overflow, that is to say, the advanced technology brought by attracting foreign investment will be learned and absorbed by the neighboring areas, greatly accelerating the diffusion of technology and having a positive impact on the improvement of Marine environment, thus improving the efficiency of Marine green economy in coastal areas.

(3) Industrial structure effect.
The inflow of foreign direct investment will also bring about the adjustment of industrial structure, and the industries that cause serious damage and pollution to the environment will transfer to the coastal areas of China, thus bringing excessive consumption of resources and environmental pollution to the coastal provinces, and ultimately reducing the green development of the Marine economy, namely the "pollution paradise (pollution haven)" hypothesis.

4 AN EMPRICAL STUDY OF FDI ON THE EFFICIENCY OF MARINE GREEN ECOMOMY

4.1 Model Setting

4.1.1 Benchmark Model Construction

In order to explore the action path of FDI on the efficiency of marine green economy, this paper first constructs a benchmark model of the factors affecting the efficiency of marine green economy in China, which is set as follows:

$$MGEE_{\mathrm{it}} = \alpha_0 + \alpha_1 FDI_{it} + \alpha_2 STRU_{it} + \lambda Z + \mu_i + \upsilon_t + \varepsilon_{\mathrm{it}} \quad (1)$$

In the (1) formula, subscripts i and t represent the i-th province and the t-th year respectively, and MGEE is the explained variable, representing the marine green economic efficiency of 11 coastal provinces and cities in China. FDI is the core explanatory variable, indicating the foreign direct investment attracted by a coastal province and city, and STRU is the regulating variable, indicating the marine industrial structure of a coastal province and city. Z is the set of control variables, and λ is the estimation coefficient of control variables.

(2) In order to investigate whether FDI has a moderating effect on the efficiency of marine green economy, it is necessary to add the interaction between FDI and STRU in formula (1), and the expansion model is as follows:

$$MGEE_{it} = \alpha_0 + \alpha_1 FDI_{it} + \alpha_2 STRU_{it} + \alpha_3 FDI_{it} \times STRU_{it} + \lambda Z + \mu_i + \nu_t + \varepsilon_{it} \quad (2)$$

4.1.2 Construction of Spatial Econometric Model

The 11 coastal provinces and cities in China are not only related to each other because of marine resources, but also geographically related because of their common proximity to the sea. In addition, due to the close social and economic activities, it is inevitable that there is spatial correlation among coastal provinces and cities. Therefore, when studying the influencing factors of FDI on marine economic efficiency, spatial correlation must be taken into account, otherwise there may be estimation bias. The spatial econometric model introduces the relationship between regions, and the original linear regression model is revised through the construction of spatial weight matrix. In this paper, spatial lag model (SLM), spatial error model (SEM) and spatial Dobbin model (SDM) are selected, and the models are set as follows:

$$MGEE_{it} = \alpha_0 + \alpha_1 FDI_{it} + \alpha_2 STRU_{it} + \alpha_3 FDI_{it} \times STRU_{it} + \rho_1 WMGEE_{it}$$
$$+\rho_2 WFDI_{it} + \lambda Z + \mu_i + \nu_t + \varepsilon_{it} \qquad (3)$$

$$MGEE_{it} = \alpha_0 + \alpha_1 FDI_{it} + \alpha_2 STRU_{it} + \alpha_3 FDI_{it} \times STRU_{it} + \lambda Z + \mu_i + \nu_t + \omega_{it}$$
$$\omega_{it} = \lambda W \omega_{it} + \varepsilon_{it} \qquad (4)$$

$$MGEE_{it} = \alpha_0 + \alpha_1 FDI_{it} + \alpha_2 STRU_{it} + \alpha_3 FDI_{it} \times STRU_{it} + \rho_1 WMGEE_{it}$$
$$+\lambda Z + \mu_i + \nu_t + \varepsilon_{it} \qquad (5)$$

(5) Formula ρ is the spatial lag coefficient, ρ_1 is the regression coefficient of the spatial lag term of marine green economic efficiency, ρ_2 is the regression coefficient of the spatial lag term of FDI, and W represents the spatial weight matrix.

Before the spatial auto correlation test, it is necessary to set the spatial weight matrix. The construction of spatial weight matrix can reflect the spatial correlation degree of the studied economic variables to some extent. Considering geographical factors, this paper takes geographical distance as the spatial weight matrix, and the formula is as follows:

$$D_{ij} = \begin{cases} 0\ (i = j) \\ \frac{1}{d^2} (i \neq j) \end{cases} \qquad (6)$$

4.2 Selection of Indicators and Data Description

4.2.1 Selection of Indicators

Based on the data of FDI and its spatial indicators in China's coastal provinces and cities from 2004 to 2020, this paper explores its impact on China's marine green economic efficiency. The explained variable is marine green economic efficiency (MGEE). The core explanatory variable is foreign direct investment (FDI), the regulating variable is marine industrial structure (STRU), and the control variables include marine economic scale (GOP), regional economic development level (PGDP), marine technology level (TI) and environmental regulation intensity (ENV).

(1) Explained variable: marine green economic efficiency (MGEE). In this paper, the static efficiency value calculated by super-efficiency SBM considering unexpected output is expressed.

(2) The core explanatory variable: foreign direct investment (FDI). In order to avoid multiple collinearity problem between variables and eliminate the influence of time trend, foreign direct investment is expressed by the proportion of foreign direct investment in GDP of provinces and cities in that year, that is, FDI/GDP. The data comes from the Statistical Yearbook of China from 2005 to 2021.

(3) Adjustment variable: marine industrial structure (STRU), which is expressed by the proportion of the total output value of marine tertiary industry in GOP. The data comes from China Statistical Yearbook of Marine Economy from 2005 to 2021.

(4) Control variables: □ the scale of marine economy (GOP), which is expressed by the proportion of marine GDP to GDP, that is, GOP/GDP. The data comes from China Statistical Yearbook of Marine Economy from 2005 to 2021. □ Regional economic development level (PGDP), expressed by per capital GDP. The data comes from China Statistical Yearbook from 2005 to 2021. □ The level of marine technology (TI) is expressed by the number of personnel engaged in scientific and technological activities in marine research and development institutions. The data comes from China Statistical Yearbook of Marine Economy from 2005 to 2021. □ The environmental regulation intensity (ENV) of each province and city is measured by the reciprocal of sulfur dioxide emissions per unit GDP. The greater the value, the greater the environmental regulation intensity. In order to eliminate heteroscedasticity, this paper deals with two variables: regional economic development level (PGDP) and marine technology level (TI) logarithmically.

Table 4 Factors affecting Marine economic efficiency

variable		meaning	explain
explained variable	MGEE	Marine green and economic efficiency	Marine green economic efficiency value
core explanatory variables	FDI	foreign direct investment	The proportion of foreign direct investment in GDP(%)
regulated variable	STRU	Marine industrial structure	Gross output value of marine tertiary industry accounts for the proportion of GOP (%)
controlled variable	GOP	Scale of Marine economy	Proportion of marine GDP to GDP (%)
	PGDP	Regional economic development level	Per capital GDP (yuan)
	TI	Marine technical level	Number of personnel engaged in scientific and technological activities in marine research and development institutions (persons)
	ENV	Intensity of environmental regulation	Percentage of industrial governance investment in industrial added value over the years (%)

4.2.2 Data Description

The above data are from the 2005-2021 China Marine Economy Statistical Yearbook, Marine Economy Statistical Bulletin, China Statistical Yearbook, statistical Yearbook of various provinces and cities, etc. Variable implications and descriptive statistics are shown in Table 5.

Table 5 Implications of variables and descriptive statistics

variable		meaning	sample capacity	mean	standard deviation	least value	crest value
explained variable	MGEE	Marine green and economic efficiency	187	0.628	0.233	0.283	00629
explanatory variable	FDI	foreign direct investment	187	0.221	0.499	0.015	6.791
regulated variable	STRU	Marine industrial structure	187	0.508	0.086	0.313	0.712
controlled variable	GOP	Scale of Marine economy	187	0.178	0.092	0.024	0.391

Ln PGDP	Regional economic development level	187	10.521	10.187	8.695	12.100
Ln TI	Marine technical level	187	7.541	7.251	3.466	8.871
ENV	Intensity of environmental regulation	187	1.183	0.646	0.527	5.244

4.3 Empirical Results and Analysis

4.3.1 Benchmark Regression Test (OLS)

(1) Hausman Test

Hausmann test is generally used to judge whether the model adopts random effect model or fixed effect model. The statistics of Hausmann test are:

$$\left(\hat{\beta}_{FE}-\hat{\beta}_{RE}\right)'\left[\widehat{Var(\hat{\beta}_{FE})}-\widehat{Var(\hat{\beta}_{RE})}\right]^{-1}\left(\hat{\beta}_{FE}-\hat{\beta}_{RE}\right)\xrightarrow{d}\chi^{3}(K)$$

Among them, K is the dimension of $\hat{\beta}_{FE}$, that is, the number of explanatory variables that change with time contained in X_{it}. If the statistic is greater than the critical value, the original hypothesis is rejected, indicating that the model should adopt fixed effect instead of random effect. According to the output result of Stata, the p value is 0.0000, which obviously rejects the original hypothesis, so this paper adopts the fixed effect model.

(2) Benchmark Regression Analysis

In this paper, we use Stata17.0 to perform OLS benchmark regression on the samples, and the regression results are shown in Table 6..

Table 6 Results of the base regression

VARIABLE	(1)	(2)	(3)	(4)	(5)	(6)	(7)
FDI	0.860*** (0.268)	0.753*** (0.218)	0.840*** (0.269)	0.432*** (0.125)	0.698*** (0.213)	0.568*** (0.163)	0.885*** (0.273)
STRU		5.693*** (1.34)	4.304* (2.459)	3.227*** (0.884)	3.084* (1.793)	2.196* (1.207)	4.025*** (1.121)
FDI*STRU			5.693*** (1.599)	4.304* (2.502)	3.227*** (0.941)	3.084* (1.783)	2.196* 1.234)
GOP				3.866*** (1.117)	2.741* (1.498)	3.110** (1.532)	2.119*** (0.528)
LN PGDP					4.662** (2.139)	3.102** (1.385)	4.235** (1.802)
LN TI						-3.787 (3.351)	-2.829 (2.816)
ENV							6.626*** (1.911)
CONS	1.181*** (0.342)	36.62** (15.583)	78.38** (33.21)	125.6*** (33.55)	92.56*** (24.71)	104.6*** (28.54)	120.6*** (27.38)

N	187	187	187	187	187	187	187
R^2	0.149	0.173	0.197	0.201	0.255	0.341	0.346

*Note: 1) Document standard error is included in parentheses; 2) *, * * and * * * indicate that t values are significant at 10%, 5% and 1% respectively, the same below*

From column (1) to column (7), the adjustment variables, the interaction between FDI and adjustment variables, and the control variables are added in turn for regression. It can be seen that the parameter estimation values of the coefficient of foreign direct investment are positive before and after the adjustment variables and control variables are added in turn, and the significance test at the level of 1% verifies that the increase of foreign direct investment will promote the efficiency of marine green economy to a certain extent, which is also in line with the hypothesis of "pollution halo". That is, with the influx of international capital, it will bring advanced technology and management experience, marine resources development technology and marine pollution treatment technology to China's coastal provinces and cities. Through the adjustment of the industrial structure of enterprises, the technology will be transferred to domestic enterprises. At the same time, the marine industry with high energy consumption, high pollution and high emission will gradually lose its competitiveness and eventually be eliminated by the market. The fierce market competition will make enterprises move closer to advanced marine governance technology, and their own marine environmental protection technology will be continuously improved, thus promoting the development of marine green economy.

As far as regulating variables are concerned, the coefficient of marine industrial structure (STRU) is significantly positive, which shows that industrial structure has a positive effect on the development of marine green economic efficiency. As the output value of marine tertiary industry accounts for a higher proportion of the total marine output value, the traditional backward industries with high pollution and high energy consumption are gradually eliminated, which makes the marine industrial structure gradually move towards advanced level, thus reducing the pollution of marine environment and finally promoting the improvement of marine green economic efficiency. The coefficient of interaction between FDI and marine industrial structure (STRU) is significantly positive, which shows that there is an industrial structure transmission mechanism of FDI to marine green economic efficiency, that is, with the inflow of international capital, the marine industrial structure is further upgraded, and then the efficiency of marine green economy is improved.

As far as control variables are concerned, the estimated value of the parameters of the marine economic scale (GOP) is significantly positive, indicating that the larger the marine economic scale, the higher the efficiency of marine green economy, which is mainly due to the existence of scale effect. The larger the scale, the lower the cost of environmental protection investment such as sewage treatment system, which is more conducive to the green and sustainable development model. The coefficient of regional economic development level (Ln PGDP) is significantly positive, which shows that regional economic development has a significant role in improving the efficiency of marine green economy. With the development of regional economy, the efficiency of marine green economy will gradually increase. The coefficient of environmental regulation intensity (ENV) is significantly positive, indicating that the greater the intensity of environmental regulation, the more conducive to improving the efficiency of marine green economy. With the further strengthening of environmental control, in the process of market competition, some enterprises with high pollution and high energy consumption will be banned, shut down or forced to transform, while clean enterprises with low pollution will win in the market competition. At the same time, in order to stabilize their market position, they will continue to increase research and development and investment on high-efficiency, low-energy consumption and pollution-free production technologies and products, thus improving the efficiency of marine green economy.

4.3.2 Spatial Effect Analysis

(1) Spatial auto correlation test

Global spatial auto correlation analysis can measure the overall spatial correlation and spatial difference between regions, mostly by constructing the global Moran's index (Moran's I). In this paper, Moran's I is used to verify the global spatial correlation of marine green economic efficiency in 11 coastal provinces (cities) in China, and the specific formula is as follows:

$$\text{Moran's I}=\frac{\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}(x_i-\bar{x})(x_j-\bar{x})}{s^2\sum_{i=1}^{n}\sum_{j=1}^{n} w_{ij}}$$

In the above formula, W_{ij} represents the spatial weight matrix. In this part, the geographical adjacency matrix (0-1 matrix), Y_i is used to represent the marine green economic efficiency values of coastal provinces and cities in China, S^2 is the variance of the marine green economic efficiency values of coastal provinces and cities in China, $\overline{Y}$ is the annual average of provinces and cities, and n represents the number of research objects, here referring to 11 coastal provinces and cities. Moran's I can be used to explain whether there is spatial correlation between variables in different regions and the size of correlation. The numerical range of Moran's I is [-1,1]. When Moran's I is in the range of [-1,0], it shows that the research object has negative spatial correlation; When Moran's I is between [0,1], it indicates that there is a positive spatial correlation; When Moran's I is equal to 0, it shows that there is no spatial correlation in the efficiency of marine green economy. Moran's I of foreign direct investment and marine green economic efficiency based on economic distance matrix is shown in Table 7 below. It can be seen that there is a spatial correlation between foreign direct investment and marine green economic efficiency at a significant level of 1%, and the spatial econometric model can be used for further analysis.

Table 7 The Global Moran Index of Foreign Direct Investment and the Efficiency of Marine Green Economy

VARIABLE	2004	2005	2006	2007	2008	2009	2010	2011
FDI	0.408***	0.347***	0.296***	0.495***	0.275***	0.257***	0.365***	0.326***
MGEE	0.585***	0.508***	0.598***	0.570***	0.610***	0.577***	0.408***	0.506***
VARIABLE	2012	2013	2014	2015	2016	2017	2018	2019
FDI	0.254***	0.250***	0.204***	0.229***	0.260***	0.248***	0.255***	0.266***
MGEE	0.540***	0.592***	0.635***	0.566***	0.410***	0.428***	0.533***	0.643***

(2) LM Test

The purpose of LM test is to determine which model is more reasonable by comparing the likelihood values or information criteria of different models. According to the output results of Stata17.0 (Table 8), the P values of the spatial lag model and the spatial error model are significant at the level of 1%, indicating that both models can be used. Therefore, both models can be selected in this paper. Both models are estimated, and the optimal model is determined by analyzing and comparing the natural Log- likelihood function value and goodness of fit A of the two models.

Table 8 LM test results

Model	Test	P
Spatial error	LM test	***
	Robust-LM	***
Spatial lag	LM test	***
	Robust-LM	***

*Note: * * *, * * and * represent significant levels of 1%, 5% and 10% respectively.*

(3) Spatial lag and spatial error model

Based on the results of Hausman test and LM test, this paper chooses the spatial lag model and spatial error model of fixed effect to study, and the regression results are shown in Table 9. Columns (1) and (2) are spatial lag models, which contain an endogenous interaction effect (WY). In column (2), the interaction between FDI and marine industrial structure (STRU) is added. Before the introduction of the interaction between FDI and marine industrial structure (STRU), the spatial regression coefficient Rho of the spatial lag model is significantly positive at the level of 5%, which indicates that there is a spatial spillover effect in marine green economic efficiency (MGEE), that is, the improvement of marine green economic efficiency in this province can effectively improve the marine green economic efficiency in neighboring provinces, and this effect still exists after the introduction of the interaction between FDI and marine industrial structure. Columns (3) and (4) are spatial error models, and there is interaction between the error terms. In column (4), the interaction between FDI and marine industrial structure (STRU) is added. The spatial regression coefficient Lambada is significantly positive at the level of 10%, which indicates that the decisive factor (error term) of the omitted explained variable has spatial spillover effect.

Among other variables, the regression coefficients of foreign direct investment (FDI), marine industrial structure (STRU), interaction between FDI and STRU, marine economic scale (GOP), regional economic development level (Ln PGDP) and environmental regulation intensity (ENV) are all significantly positive, which is consistent with the benchmark regression results. Therefore, increasing the scale of foreign direct investment, promoting the upgrading of industrial structure, enhancing the scale of marine economy and developing regions. At the same time, the industrial transmission mechanism of FDI to the efficiency of marine green economy still exists.

Table 9 Estimation results of spatial lag and spatial error model

VARIABLE	SLM		SEM	
	(1)	(2)	(3)	(4)
Rho	1.032** (0.52)	1.416* (0.853)	---	---
Lambada	---	---	1.824* (1.099)	1.603* (0.966)
FDI	0.630*** (0.207)	0.665*** (0.182)	0.889*** (0.244)	0.752*** (0.229)
STRU	0.107** (0.046)	0.155** (0.070)	0.137** (0.065)	0.166** (0.071)
FDI*STRU	---	0.435** (0.178)	---	0.613** (0.308)
GOP	0.220** (0.091)	0.168* (0.097)	0.338** (0.136)	1.018* (0.578)
Ln PGDP	0.443** (0.197)	0.591** (0.277)	0.546** (0.223)	0.332** (0.152)
Ln TI	-1.020 (1.04)	-0.241 (2.005)	-0.182 (2.307)	-0.408 (2.074)
ENV	5.213*** (1.511)	4.933*** (1.35)	5.017*** (1.152)	4.736*** (1.125)
Log-Likelihood	542.3261	563.7416	-569.7821	566.3129
N	187	187	187	187
R^2	0.465	0.469	0.346	0.365

(4) Spatial dobbin model

Compared with the spatial lag model and the spatial error model, the spatial dobbin model introduces the spatial lag term of the core explanatory variable foreign direct investment (FDI) on the basis of considering the explained variable marine green economic efficiency (MGEE). The estimated results are shown in columns (5) and (6) in Table 10, and the interaction term between FDI and marine industrial structure (STRU) is added in column (6).

Firstly, by analyzing the explained variable marine green economic efficiency, the spatial lag coefficient of marine green economic efficiency (MGEE) is significantly positive before and after FDI and marine industrial structure (STRU) are added, which indicates that there is a spatial spillover effect of marine green economic efficiency, that is, the improvement of marine green economic efficiency in this province can effectively improve the marine green economic efficiency of neighboring provinces, which is consistent with the conclusions of spatial lag model and spatial error model.

Secondly, by analyzing the core explanatory variable foreign direct investment, the spatial lag coefficient of foreign direct investment (FDI) is significantly positive before and after joining FDI and marine industrial structure (STRU), which shows that there is a spatial spillover effect of foreign direct investment on marine green economic efficiency, that is, the promotion of foreign direct investment scale in this province can effectively improve the marine green economic efficiency of neighboring provinces. The main reason is that the advanced environmental protection technology and management experience brought by foreign direct investment will spread to neighboring provinces through capital effect, technical effect and environmental effect, which will have spatial externalities on the marine environment of neighboring provinces.

Finally, among the control variables, the estimated value of the parameter of marine industrial structure (STRU) is 0.132, and the estimated value of the parameter of the interaction between foreign direct investment and marine industrial structure (FDI*STRU) is 0.258, both of which pass the significance test of 5%, indicating that the influence of marine industrial structure on marine green economic efficiency has a significant positive effect. While foreign direct investment brings abundant capital to China, it will promote the efficiency of marine green economy through the continuous adjustment and optimization of industrial structure. The estimated value of the parameter of the marine economic scale (GOP) is 0.258, which passed the significance test at the level of 5%, indicating that the impact of the marine economic scale on the marine green economic efficiency is positive and significant. The larger the marine economic scale, the higher the marine green economic efficiency, indicating that the growth of the marine economic scale is conducive to the improvement of the marine green economic efficiency. The main reason may be that with the continuous expansion of the economic scale, the sewage treatment system and other infrastructure facilities conducive to marine environmental protection have been improved. The estimated value of the parameter of the marine environmental regulation intensity (ENV) is 10.30, and it has passed the significance test at the level of 1%, which shows that the environmental regulation intensity has a significant role in promoting the efficiency of marine green economy. With the further strengthening of environmental control, in the process of market competition, some enterprises with high pollution and high energy consumption will be banned, shut down or forced to transform, while clean enterprises with low pollution will win in the market competition, thus improving the efficiency of marine green economy.

Table 10 Estimation results of spatial Dobbin model

VARIABLE	SDM	
	(5)	(6)
Rho	1.331*** (0.369)	1.723*** (0.521)
W*FDI	1.289*** (0.423)	1.279*** (0.439)
FDI	0.850*** (0.294)	0.817*** (0.237)
STRU	0.177** (0.082)	0.132** (0.052)
FDI*STRU	---	0.258** (0.102)
GOP	0.171** (0.068)	0.258* (0.134)
Ln PGDP	0.402** (0.196)	0.644** (0.253)
Ln TI	-0.081 (3.707)	-0.148 (2.135)
ENV	12.21*** (4.321)	10.30*** (3.549)
Log-Likelihood	512.3642	501.9143
N	187	187

R^2	0.335	0.649

4.3.3 The Robustness Test

Because different spatial weight matrices may affect the robustness of the measurement results, in order to ensure the reliability of the research results, this paper tests the robustness of the research results by replacing the spatial weight matrices. Under the spatial weight matrix of economic distance, spatial lag model (SLM), spatial error model (SEM) and spatial Dobbin model (SDM) are used to regress the research object. The test results are shown in Table 11.

By comparison, it is found that all the variables are consistent except for a small change in coefficient, which shows that the above empirical results are robust. In addition, under the spatial weight matrix of economic distance, the positive spatial spillover effect of FDI is more significant.

Table 11 Test of robustness

VARIABLE	SLM	SEM	SDM
	Spatial weight matrix of economic distance		
Rho	1.852* (0.964)	---	1.736*** (0.389)
Lambada	---	1.083* (0.579)	---
FDI	2.850*** (0.294)	1.817*** (0.546)	0.937*** (0.123)
W*FDI	---	---	6.416*** (1.846)
STRU	0.077** (0.034)	0.132** (0.063)	0.310** (0.123)
FDI*STRU	0.103** (0.052)	0.204** (0.086)	0.327** (0.134)
GOP	0.171** (3.774)	0.258* (0.134)	0.349** (0.167)
Ln PGDP	0.402** (0.203)	0.644** (0.258)	0.763** (0.342)
Ln TI	-0.081 (3.707)	-0.148 (2.135)	-0.116 (3.496)
ENV	12.21*** (4.562)	10.30*** (3.654)	11.60*** (4.351)
67Log-Likelihood	536.0104	496.3789	531.7803
N	187	187	187
R^2	0.435	0.349	0.619

5 CONCLUSION

Firstly, based on the panel data of 11 coastal provinces and cities from 2004 to 2020, this paper calculates the efficiency of marine green economy in China coastal provinces and cities by using super-efficiency SBM model and traditional DEA model. Secondly, the spatial econometric model is selected to study the spatial spillover effect of foreign direct investment (FDI) on the efficiency of marine green economy. Based on the above research results, we can draw the following conclusions:

(i) Foreign direct investment can improve the efficiency of China's marine green economy and has a structural adjustment effect. The regression results of benchmark model show that the coefficients of foreign direct investment are all significantly positive, indicating that FDI can improve the efficiency of marine green economy, and verifying that the increase of foreign direct investment can promote the efficiency of marine green economy, which is also in line with the hypothesis of "pollution halo", that is, with the influx of FDI, it will bring advanced technology and management experience, marine resources development technology and marine pollution treatment technology to China's coastal provinces and cities. When the interaction between FDI and marine industrial structure is added, the coefficient is significantly positive. It shows that FDI has a positive regulatory effect on the efficiency of China's marine green economy.

(ii) Both the efficiency of marine green economy and FDI have spatial spillover effects, that is, the improvement of the efficiency of marine green economy in this province can effectively improve the efficiency of marine green economy in neighboring provinces, and the improvement of the scale of foreign direct investment in this province can effectively improve the efficiency of marine green economy in neighboring provinces. The main reason is that the advanced environmental protection technology and management experience brought by foreign direct investment will spread to neighboring provinces through capital effect, technical effect and environmental effect, which will have spatial externalities on the marine environment in neighboring provinces.

(iii) The structure of marine industry, the scale of marine economy and the intensity of marine environmental regulation have a significant positive impact on the efficiency of marine green economy in China. The continuous adjustment and optimization of marine industrial structure promotes the efficiency of marine green economy. The larger the scale of marine economy, the more funds are invested in marine environmental governance, and the better the development degree of marine economy. Similarly, the greater the intensity of marine environmental regulation, the more the enterprises with high pollution and high emission are restricted, and the more the marine-related enterprises will increase the research and development and investment in marine clean technology, thus improving the efficiency of marine green economy in China to some extent.

6 SUGGESTION

Marine ecology is related to the future of human ecological civilization. It not only provides precious resources and various ecosystem services, but also plays an important role in climate regulation and the maintenance of global ecological balance. To develop marine economy and build a maritime power, we need to stand at a long-term and overall height, aim at winning more sustainable development and a healthier marine ecological environment, and strive to achieve the marine economic goal of "ecological priority and green development". Under the goal of "double carbon", the marine economy has entered a new stage of development. To achieve the simultaneous development of marine economy and ecological environment protection, we must adhere to the high-quality development of marine economy driven by innovation. This paper puts forward the following suggestions:

(i) Improve the quality of foreign investment and obtain technology spillover effect.

China coastal provinces and cities have gathered large-scale foreign direct investment, and the marine economy is very active. In the past, China coastal provinces and cities did not strictly control the quality of foreign direct investment, which led to an extensive development model of marine economy. Nowadays, under the goal of vigorously promoting green economic growth, we should fully implement the concept of green development, optimize the structure of foreign investment, improve the quality of foreign investment, and realize the transformation of foreign investment from "scale dividend" to "quality dividend". For coastal provinces and cities in China, stricter environmental regulation standards should be formulated for introducing foreign capital, the supervision system and mechanism should be improved, the environmental investment of enterprises should be supervised and assessed, and the environmental responsibility of enterprises should be implemented. Encourage foreign capital to enter the high-tech field, optimize the investment structure, give full play to the spillover effect of foreign capital technology, cultivate new kinetic energy of economic development, promote the upgrading of industrial structure in coastal cities, reduce the number of highly polluting enterprises, and promote the transformation of enterprises, thus promoting the high-quality development of marine economy.

(ii) Promote the transformation of industrial structure and realize low-carbon marine development.

The structure of marine industry is very important to improve the efficiency of marine green economy. Therefore, a reasonable layout of marine industry is the focus of the development of modern marine system. First of all, actively explore the green and low-carbon development of marine industry, reduce some marine secondary industries with high pollution, high energy consumption and high emissions, and increase the proportion of marine tertiary industry. However, the optimization of marine industrial structure is not just a matter of industrial proportion. We should pay more attention to the rationalization of the internal structure of marine industry and ensure the coordinated development of industrial structure and environmental carrying capacity. Secondly, the government needs to formulate policy guidance for industrial transformation and green development, clarify objectives and tasks, and promote the concept of sustainable development, so as to transform the marine industry from high carbon to low carbon, and increase the proportion of marine tertiary industry with low pollution, high energy consumption and high emissions. Finally, increase support for environmental protection and clean technology, popularize and apply new technologies, promote industrial technology innovation and upgrading, and realize clean, efficient and sustainable production. Actively participate in international cooperation, learn from international advanced experience and technology, broaden the channels of industrial cooperation, and promote the development and sustainable cooperation of the global green economy.

(iii) Focus on marine technological innovation and lead the efficiency of green development.

In actively exploring the new mode of high-quality development of marine economy, marine technological innovation is the main force to realize the transformation of old and new kinetic energy of marine economy. First of all, we should change the traditional development model, promote the concept of sustainable development, make the marine industry transform from high carbon to low carbon, and increase the proportion of the marine secondary industry with low pollution, high energy consumption and high emissions. Secondly, we should strengthen the innovation of marine science and technology, explore the development of emerging fields, such as marine energy and environmental protection, and promote the low-carbon transformation of the marine industry. Third, we should promote the sustainable utilization of marine resources, reduce the waste of resources, and strengthen the comprehensive planning and management of marine resources. Fourth, enterprises should be encouraged to reduce greenhouse gas emissions, advocate green production, and achieve carbon emission reduction and other pollutant control. Finally, it is necessary to increase investment in marine ecological protection, build a green ocean, improve the marine environmental protection system, conduct strict environmental impact assessment and control on activities such as developing marine resources and building marine projects, and realize the parallel development of marine ecological protection and green development, thus promoting the transformation of marine industrial structure and realizing the low-carbon development of the ocean.

(iv) Improve the level of marine governance and implement environmental protection responsibilities.

The intensity of marine environmental regulation has a significant positive impact on the efficiency of marine green economy in China. Under different intensity of marine regulation, the efficiency of marine green economy varies among coastal provinces and cities in China. Reasonable intensity of marine environmental regulation can effectively improve the efficiency of marine green economy. Therefore, from the government's point of view, on the one hand, the coastal provinces and cities in China should make corresponding investment in marine environment management according to the specific situation of local marine ecology, including capital and personnel investment, so as to ensure that the total amount of marine resources development and marine waste discharge is within the bearing range of the marine environment; On the other hand, the government should play its macro-control role, formulate and improve the overall plan for marine green development, delimit the red line of marine ecological protection, strictly stipulate the intensity and timing of marine development, and promote the sustainable development of marine ecology. Finally, the government should formulate a series of marine governance policies to reduce pollution emissions and ensure the stability of marine ecology. At the same time, the government can protect the marine environment by strengthening the supervision and management of the industry, improving the planning management system and innovating the development mode and utilization mode of marine resources. From the point of view of enterprises, we should implement the responsibility of marine protection of enterprises, encourage marine enterprises to adopt advanced production equipment and technology, reduce the discharge of marine pollutants, and promote enterprises to embark on the road of green production.

(v) Coordinate regional development and build a high-quality marine ecology.

China's marine green economic efficiency presents a three-pole pattern around Tianjin in the north, Shanghai in the middle and Guangdong in the south, but there are still significant differences between coastal provinces and cities. In order to realize the coordinated development among marine regions and improve the level of green coordinated development of coastal provinces and cities in China, the following countermeasures should be made in the aspect of regional marine economic development. The coastal provinces and cities in China should help each other and learn from each other's strong points, so as to narrow the efficiency difference of marine green economy between regions and enhance the ability of marine coordinated development. Especially in Liaoning, Hebei, Guangxi, Hainan and other places, we should study, exchange and cooperate with neighboring provinces and cities with high marine economic efficiency, and apply each other's superior marine management experience and advanced marine governance technology to the marine economic development planning of this province, so as to promote the marine green economic efficiency of this province to be rapidly improved in a short time. Secondly, in order to give full play to the leading demonstration role of a strong marine economy, a sea can be established.

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REFERENCES

[1] BARRIOS,GORGH,STROBLE. Foreign direct investment,competition and industrial development in the host country［J］.European Economic Review, 2005,49(7):1761-1784.

[2] Cheng Wai, Simona. Study on the threshold effect of foreign direct investment on the efficiency of marine green economy [J]. Journal of China Ocean University (Social Science Edition), 2021(03):50-58.

[3] Di Ganbin, Gao Guangyue, Yu Zhe. Study on the high-quality development evaluation and influencing factors of marine economy in China [J]. Geographic Science, 2022,42(04):650-661.

[4] Ding Lili, Zheng Haihong, Wang Wei. Measurement and analysis of China's marine economic productivity based on the improved RAM-Undesirable model [J]. Journal of Central University of Finance and Economics, 2017(09):119-128.

[5] Gaimei, Zhu Jingmin, Sun Caizhi, Sun Kang. Spatial and temporal evolution of marine economic efficiency in coastal areas of China and analysis of its influencing factors [J]. Resource Science, 2018,40(10):1966-1979.

[6] HOLLENSTEIN H，BERGERM．Choice of foreign R＆D entry mode and its relation to firm performance: A firmlevel analysis for switzerland and Austria［J］． Economics，2015，9(01) .

[7] Wenhan Ren,Jianyue Ji,Lei Chen,Yi Zhang. Evaluation of China's marine economic efficiency under environmental constraints—an empirical analysis of China's eleven coastal regions[J]. Journal of Cleaner Production,2018,184.

[8] Xing Fei, Zhang Jianhua. The impact of foreign technology transfer on China's independent research and development [J]. Economic Research, 2009,44(6):94-104.

[9] Yan Bing. Inter-industry spillover effect of foreign direct investment in China: A preliminary analysis based on relevant data of China's industrial sectors [J]. Asia-Pacific Economy, 2006(1):90-93.

[10] Yan Yan,Tsydypova Ayagma,Zhang Yuanyuan. Evaluation of Marine Economic Efficiency of China's Coastal Provinces Based on DEA Model[J]. Journal of Coastal Research,2020,112(sp1).

[11] Zhao Liangshi,Hu Run,Sun Caizhi. Analyzing the spatial-temporal characteristics of the marine economic efficiency of countries along the Maritime Silk Road and the influencing factors[J]. Ocean and Coastal Management,2021,204.

[12] Zou Wei, Sun Caizhi, Qin Xionghe. Spatial evolution and influencing factors of marine economic efficiency in Bohai Rim region based on Bootstrap-DEA model [J]. Geographic Science, 2017,37(06):859-867.

[13] Zhao Xin, Li Shushu, Ding Lili. Does the spatial nature of FDI improve the efficiency of China's marine green economy? [J]. Marine Economy, 2018,8(02):7-16.

[14] Xinyue Y, Jifeng Z, Zirui Y, Luxue L. Research on the Measurement and Countermeasures of Marine Green Economy Efficiency in China under the Background of “Double-Carbon”. Asian Journal of Economics, Business and Accounting. 2023 May 3;23(12):1-6.