Original Research Article

Study on the influence of foreign direct investment on the efficiency of Marine green economy in China

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ABSTRACT

Aims: 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?

Methodology: Based on the panel data of 11 coastal provinces and cities in China from 2004 to 2019, 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 geospatial weight and economic geospatial weight, the FDI spatial index is constructed to study its influence on the efficiency of Marine green economy.

Conclusion: 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 Research 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. Underthe constraints of marine resources and environment, it isthe foothold to realizethe long-term development of China's marine industry to optimize the marine industrial structure, improve the quality and efficiency ofmarine economy and realize the high-quality sustainable development of marine economy.

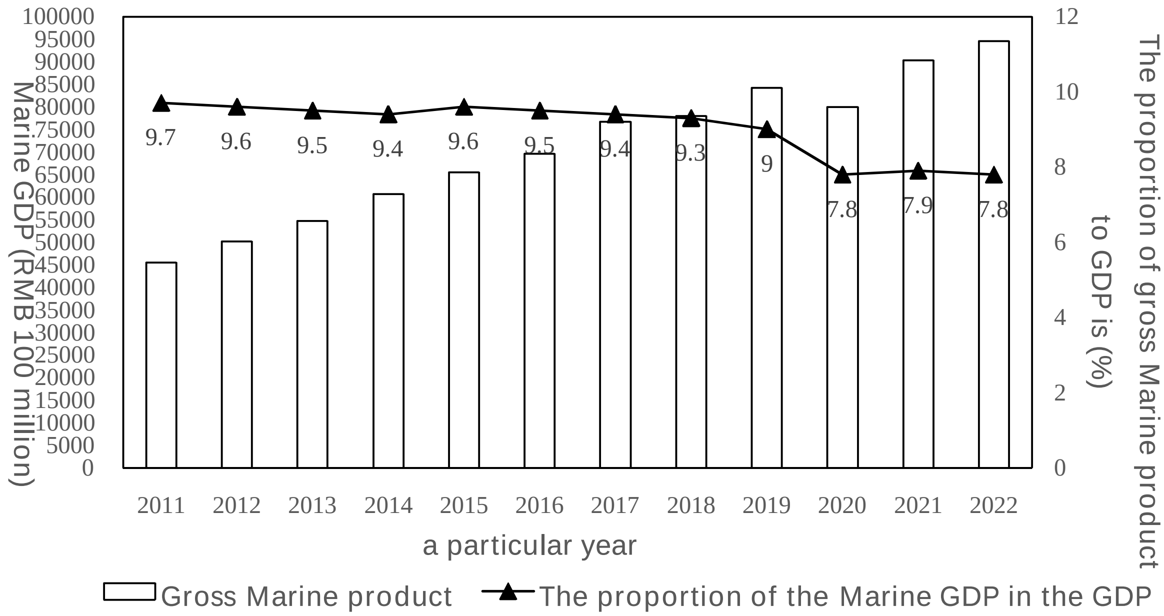

Figure1 Total Marine GDP and its proportion to GDP in 2011-2022

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. 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. 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 a new economic growth pole, the development efficiency and influencing factors of marine economy have attracted mo re attention. By sorting out the literature, it is found that:

When it comes to FDI and marine economic efficiency, most studies only take FDI as an influencing factor for simple dem onstration, and there is no unified answer to the influence of FDI on marine economic efficiency. Zou Wei (2017)[1] used D EA model and found that FDI has a significant negative effect on the efficiency of marine green economy. Zhao Xin (2018) [2]constructed the "comprehensive index of environmental governance investment" from the dual perspectives of environ mental 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 spati al spillover effect of FDI was more significant under the economic geographical weight. Ding Lili (2017) [3]and others believe that FDI has an insignificant negative effect on the comprehensive efficiency of the marine economy; Zhao Xin (2018)[1] and others found that FDI has a significant negative effect on marine economic efficiency, but it has a positive spatial spillover.

Generally speaking, there are not many research documents on the efficiency of FDI in marine green economy. The research results are different. The research methods are different, and the research on the spatial spillover effect of FDI is even less. Therefore, the research starting point in this paper is relatively novel, the model construction is appropriate and suitable, and it has relatively 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).

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:

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

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

Where P * is the efficiency of ocean green economy, j is the decision unit, t is the time, $x_j^t\ y_j^t\ b_j^t\ s_m^x\ s_l^y\ s_h^b\ \lambda$ 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 P * 1, the decision unit is effective, when P * <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. 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 output	Marine industrial wastewater is discharged directly into massive amounts (10,000 tons)	Reflecting the 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.

Statistics from 11 provinces, including Liaoning, Hebei, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Guangdong, Guangxi, Fujian and Hainan from 2004 to 2019. The original data are from China Marine Statistical Yearbook, 2005-2020, 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
	capital	Capital stock of the Marine economy (100 million)	11064.61	60867.19	135.35	7375.92	11635.59
Investment	labour force	The number of employed persons involved in the	295.17	868.5	58	208.4	203.83

index		sea (thousands of people)					
		Number of berths for port production wharf (one)	382.04	1335	30	212.5	385.54
	resource	Number of travel agencies (NA)	1118	3281	143	1053	665.51
		sea water breeding area (hectare)	176686	942050	6	111902	213060
Output indicators	Expect output	Gross Marine product (100 million)	3252.45	12811.75	108.71	2721.19	2787.83
	Undesired output	Industrial waste water is directly discharged into a massive amount (ten thousand tons)	22014.52	150443.1	368	8806	29986.98

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 2019 was calculated by using MaxDEA Ultra8.0 software. Results are presented in Table Table 3.

Table3 China 2004-2019 based on SBM method

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

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 1 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 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 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.

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 Spatial Measurement Model

Based on the relevant studies of spatial econometrics, it can be seen that each geographical unit is not isolated or close, or there is a certain degree of spatial effect between adjacent geographical units, which includes spatial dependence and spatial heterogeneity. Foreign direct investment will have direct and indirect effects on the Marine green ecological efficiency, and this effect has spatial interaction, and FDI has spatial spillover effect. The 11 provinces and cities in China's coastal areas are not only spatially interconnected due to Marine resources, but also have close social and economic exchanges. In the study of the factors affecting Marine economic efficiency, using common panel data may make the results inaccurate. Therefore, this paper also constructed the benchmark regression model (OLS) and spatial measurement model, the space measurement model mainly includes space dubin model (SDM), spatial lag model (SAR), spatial error model (SEM) based on the above reality, this paper in the dual perspective of geographical space and economic geographical space, build FDI spatial index, the spatial index can not only measure the space spillover effect between different decision units, but also can measure the performance of economic growth. The following panel data regression model is constructed:

(1) Benchmark regression mo$Y_{it} = \beta IFDI_{it} + \rho \sum_{j=1}^{N} w_{ij} FDI_{jt} + X_{it}\lambda + \alpha_i + \varepsilon_{it}$ del

(2) Space Durbin model: $Y_{it} = \lambda W Y_{it} + X_{it}\beta + W X_{it}\delta + \varepsilon_{it}$

(3) Space lag model: $Y_{it} = \rho W Y_{it} + X_{it}\beta + \mu_i + \lambda_t + \varepsilon_{it}$

(4) Spatial error model: $Y_{it} = X_{it}\beta + \mu_i + \lambda_t + \varepsilon_{it}$

Y_{it} X_{it} In the above formula: i represents the coastal provinces, t is time; it is the explained variable, namely Marine green economic efficiency value, is the level of foreign direct investment, β, ρ, λ are the set of other control variables and the regression coefficient of each variable, where ρ is the regression coefficient of spatial index, indicating the spatial spillover effect of FDI, the element of the spatial weight matrix, the spatial interaction degree of FDI, the individual effect and the random error term. W_{ij} α_i ε_{it}

4.1.2 Spatial Weight Matrix

The construction of the spatial weight matrix can to some extent reflect the degree of spatial association between the economic units studied. This paper constructs a spatial weight matrix containing both economic and geographical factors. The elements are the reciprocal square of the geographical distance between the two coastal provinces, the elements are the absolute reciprocal of the difference in per capita GDP between the two coastal provinces, and the spatial weight is the product of the two. The specific formula is expressed as follows:

$$W_{ij} = D_{ij} * E_{ij}$$

$$D_{ij} = \begin{cases} 0 \ (i = j) \\ \frac{1}{d^2} (i \neq j) \end{cases} \quad E_{ij} = \begin{cases} 0 \ (i = j) \\ \frac{1}{\left|\overline{Y_i} - \overline{Y_j}\right|} \end{cases}$$

4.1.3 Spatial Autocorrelation Test

Spatial autocorrelation tests can be used to measure the agglomeration degree of the same index attributes in different regions. The Global Moran Index (Moran's I) is used to test for the spatial correlation of the study subjects as a whole. The Moran's I index is used to verify the global spatial correlation of Marine green economic efficiency in 11 coastal provinces (urban areas) in China. The calculation formula is as follows:

$$\text{Moran's I} = \frac{i = \sum_{i=1}^{n} \sum_{j=1}^{n} W_{ij} (Y_i - \overline{Y})(Y_j - \overline{Y})}{S^2 \sum_{i}^{n} \sum_{j}^{n} W_{ij}}$$

In the above equation, the spatial weight matrix is represented. In this paper, the geographic adjacency distance matrix is used to represent the Marine green economic efficiency value of all coastal provinces of China. S is the variance, the annual mean of each province, n represents the number of study objects, and here refers to 11 coastal provinces and cities. The global Moran index can be used to illustrate whether there is a spatial correlation of the variable Y between regions and the magnitude of the correlation. The numerical interval of the global Moran index is [-1,1]. When the global Moran index is in the [-1,0] interval, the research object has spatial correlation; when the global Moran index is between

[0,1], it indicates a positive spatial correlation; when the global Moran index is equal to 0, there is no spatial correlation of Marine green economic efficiency.

4.2 Selection Of Indicators And Data Description

4.2.1 Selection Of Indicators

Marine economic efficiency is influenced by multiple factors. This paper mainly studies the impact of foreign direct investment (FDI) and its spatial indicators on the efficiency of China's Marine green economy from 2004 to 2019, Therefore, the static efficiency value (MGEE) is selected as the explained variable; Foreign direct investment (FDI) and FDI spatial indicators are the core explanatory variables; Marine science and technology investment (TI), Marine scientific research development level (RDL), port activity (PA), Marine economic scale (GP), Marine industrial structure (SC), regional economic development level (EDL) as control variables; The data are from the 2005-2020 China Marine Economy Statistical Yearbook, Marine Economy Statistical Bulletin, China Statistical Yearbook, etc.

(1) Interpreted variable: Marine green economic efficiency (MGEE). This paper is expressed by the static efficiency value of the super-efficiency SBM calculations considering the undesired output.

(2) Core explanatory variable: foreign direct investment (FDI). In order to avoid the multiple collinearity between variables and eliminate the influence of the time trend, the level of FDI is expressed by the proportion of FDI in GDP, namely FDI / GDP.

(3) Core explanatory variables: foreign direct investment (FDI) and its spatial indicators. This paper focuses on the degree of FDI spatial spillover, so we need to construct its spatial index and design the spatial weight matrix. This paper is mainly represented by the IFDI adjusted by the spatial weight matrix W. According to the relevant studies of economic geography, the geospatial weight matrix (w) and the economic geographic weight matrix (W) are selected to reflect the spatial spillover effect of IFDI from the perspective of geographical relationship and socio-economic relationship respectively. Accordingly, the spatial indicators of IFDI are w * IFDI and W * IFDI respectively. Among them, the geographic weight matrix (w) adopts the reciprocal of the distance between the provincial capital cities of the two provinces as the weight structure, and the economic geographic weight matrix (W) introduces the economic factors of different regions into the geographic weight matrix to construct.

(4) Control variable: Marine science and technology investment (TI) is represented by the number of Marine science and technology employees in 2004-2019; Marine research development level (RDL) is expressed by the number of scientific and technology projects of Marine research institutions; port activity (PA) is expressed by port cargo throughput; Marine economic scale (GDP) is expressed by the proportion of Marine GDP to GDP: GDP / GDP; Marine industrial structure (SC) is expressed by the proportion of tertiary industry GDP to GDP; and regional economic development level (EDL) is expressed by per capital GDP.

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 /% of GDP, namely FDI / GDP
	TI	Investment in	Number of Marine science and

controlled variable		Marine science and technology	technology practitioners / person
	RDL	Development level of Marine scientific research	Number of scientific and technological projects of Marine scientific research institutions
	PA	Port activity	Port cargo throughput / ten thousand tons
	GOP	Scale of Marine economy	Share of Marine GDP in GDP /% of GDP
	SC	Marine industrial structure	The GDP of the Marine tertiary industry accounts for /% of GDP
	EDL	Regional economic development level	Per capital GDP / 100 million yuan

4.2.2 Data Description

The above data are from the 2005-2020 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	176	0.707	0.385	0.283	2.029

explanatory variable	FDI	foreign direct investment	176	0.180	0.092	0.032	0.391
controlled variable	TI	Investment in Marine science and technology	176	1828.46	1337.885	32	6750
	RDL	Development level of Marine scientific research	176	691.069	706.397	10	3968
	PA	Port activity	176	61421.642	89674.884	2400	1112176
	GOP	Scale of Marine economy	176	4366.178	3942.305	121.6	19325.6
	SC	Marine industrial structure	176	0.502	0.083	0.313	0.696
	EDL	Regional economic development level	176	27118.45	22665.334	769.36	10761.07

4.3 Empirical Results And Analysis

4.3.1 Benchmark Regression

First, the correlation was tested for each variable, and the variance inflation factor was less than 10, which indicates that there is non-multicollinearity problem between the variables, and the next regression analysis can be conducted. The model setting form was tested by Hausman method and the results show that the model should be regression with fixed effect mode.

In this paper, OLS benchmark regression was performed using stata17., and the regression results are shown in Table 5-3. Column (1) is the most concise model, Only used to measure the impact of foreign direct investment (FDI) on the efficiency of the Marine green economy (MGEE), The coefficient of foreign direct investment is-0.860, Significant at the 1% level, Suggshows that each increased level of foreign direct investment, The Marine green economic efficiency value will be reduced by 86%; Column (2) to column (7), Control variables were added in turn for the regression, It can be seen that the overall degree of model fit is high, The parameter estimates of the coefficient of FDI are negative before and after the addition of control variables, And passed the significance test at the 1% level, It means that the increase of FDI will inhibit the efficiency of Marine green economy to some extent, This also fits with the "pollution paradise" hypothesis, The massive influx of the FDI, Will bring problems of wasted resources and environmental pollution to China's coastal provinces, With the increasing transfer of highly polluting industries, The structural effect of foreign direct investment will be more obvious.

In terms of control variables, the regression coefficient of Marine science and technology investment (TI), Marine scientific research development level (RDL), port activity (PA) and regional economic development level (EDL) was negative, and all passed the significance test, indicating that these four variables can have a significant inhibitory effect on the efficiency of Marine green economy. The reason is: □ China's coastal provinces for Marine environmental governance and resource saving talent investment has different degrees of increase, but the proportion of Marine employment is declining year by year, for the improvement of the Marine environment, and in recent years Marine related technology progress mostly from foreign technology learning and imitation, rather than internal technology breakthrough, so Marine science and technology, Marine research level failed to promote the efficiency of Marine green economy.□ Port activity higher, means that large-scale port cargo throughput will produce great pressure on the Marine coastal environment, in

the pursuit of a higher level of trade at the same time, tend to ignore the Marine environment, □ regional economic development level of the negative impact of Marine economic efficiency shows the Marine economy development is very fast, and the development of Marine resources and Marine environment loss has reached the threshold, the relationship between economic development and the Marine environment has become very serious.
The influence coefficient of Marine economy scale on the efficiency of Marine green economy is positive, and it has passed the significance test, indicating that the scale of Marine economy has an obvious promoting effect on the growth of Marine economy efficiency. Marine economy development level is higher province, the higher the importance of the Marine environment, at the same time, the greater the capital and technical support, for the promotion of Marine economic efficiency in the region provides a solid economic foundation, to a certain extent, to break the "pollution, after governance" traditional backward mode, thus forming a two-way promote the virtuous cycle.

Industrial structure (SC) has a positive and significant impact on the efficiency of Marine green economy, indicating that the higher the proportion of the output value of the Marine tertiary industry in the total Marine output value, the better the industrial structure, the lower the pollution degree of the Marine environment, and the higher the efficiency value of Marine green economy.

Table 6 Results of the base regression

VARIABLE	(1)	(2)	(3)	(4)	(5)	(6)	(7)
FDI	-0.860*** (0.494)	-0.753** (-2.91)	-0.840* (-1.80)	-0.432*** (-1.23)	-0.698** (-3.37)	-0.568** (-2.910)	-0.766*** (-0.470)
TI		-3.787* (2.237)	-2.829* (2.816)	-0.084* (2.038)	-0.196* (2.715)	-0.025* (2.014)	-0.366* (2).007
RDL			-6.087* (3.451)	-4.12** (3.759)	-9.336** (2.236)	-14.85** (0.155)	-10.62* (3.720)
PA				-11.23** (2.481)	-9.023** (1.184)	-7.123* (2.012)	-8.011** (2.338)
GOP					3.866*** (2.022)	2.741* (1.778)	3.110** (2.455)
SC						5.693* (2.018)	4.304* (1.339)
EDL							-4.662** (2.618)
CONS	1.181*** (0.0682)	36.62** (23.39)	78.38** (33.21)	125.6*** (33.55)	92.56*** (24.71)	104.6*** (28.54)	120.6*** (27.38)
N	176	176	176	176	176	176	176
R^2	0.149	0.264	0.173	0.149	0.255	0.341	0.196

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

4.3.2 Analysis Of FDI Spatial Spillover Effects

Between spatial measurement, it is necessary to test whether the research object has spatial effect. In this paper, the global Moran index is constructed by Moran's I). The Moran's I of foreign direct investment and Marine green economic efficiency based on the economic distance matrix is shown in Table 7 below, which shows a spatial correlation between the two at the significant level of 1%.

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

	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***
	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***

Through Hausman test and LM test, the spatial Dubin model and spatial lag model with fixed effects are selected, and the regression results are shown in Table 8 below. In Table 8, FDI has positive spatial spillover effects in both models and is more significant under the economic geographic weight. As can be seen, Under the geospatial weights, The parameter parameters of FDI are 0.820,0.951, But did not pass the significance test, It shows that the FDI in a certain province has a positive effect on the efficiency of Marine green economy in neighboring provinces, But if only considering the geographical associations between the provinces, The spillover effect of FDI was not significant; Under the economic-geographic weight, The spatial index of the FDI passed the significance test at the 1% level, And the parameter estimate is positive, Show that when the economic and geographical correlation of the provinces exist simultaneously, The FDI in this region will have a significant driving effect on the efficiency of Marine green economy in neighboring provinces.

Marine science and technology investment (TI), Marine scientific research development level (RDL), port activity (PA) and regional economic development level (EDL) all have a significant negative effect on the improvement of Marine economic efficiency, Comparison between Tables 5-3 and Table 5-5, The parameter estimates of Marine science and technology investment, Marine scientific research development level, port activity and regional economic development level are all negative, And all passed the significance test at the 10%, 5%, or 1% levels, When the FDI spatial index under the weight and the economic weight are added respectively, The parameter estimate for Marine science and technology investment has increased from-0.081 to-0.148 (in the SDM model), in like manner, The parameter estimates for the development level of Marine science and technology increased from-0.161 to-0.225, Parameter estimates of port activity increased from-0.199 to-0.523, The parameter estimates for the level of regional economic development increased from-0.402 to-0.644, This suggests that after considering the FDI spatial spillover effect under the economic weighting, Investment in Marine science and technology, development level of Marine scientific research, port activity and regional economic development level have a more significant role in inhibiting the efficiency of Marine green economy, It shows that in regions with strong economic ties, The spatial spillover effect of FDI is driven by the economic effect of FDI; After considering the spatial indicators of the FDI, The scale of Marine economy (GOP) and Marine industrial structure (SC), the parameter estimates of Marine green economy efficiency are still positive, And all passed the significance test at the 5% level, It shows that under the combined action of geographical location advantage and socioeconomic connection, The forward spatial spillover effect of FDI is even more significant, And the economic effect and industrial structure effect of FDI have a strong driving effect on its spatial spillover effect.

Table 8 Results of the FDI spillover effect by regression

VARIABLE	SDM		SLM	
	GEOGRAPHICAL DISTANCE	ECONOMIC DISTANCE	GEOGRAPHICAL DISTANCE	ECONOMIC DISTANCE
FDI	0.850*** (0.294)	0.817*** (8.023)	0.630*** (0.146)	0.665*** .0(714)
W*FDI	0.820 (0.589)		0.951 (0.510)	
W*FDI		1.289*** (0.585)		1.335*** (0.441)

TI	-0.081** (3.707)	-0.148*** (2.135)	-1.020** (2.889)	-0.241*** (2.005)
RDL	-0.161* (-1.729)	-0.225*** (-2.335)	-0.884* (-1.951)	-0.952*** (-2.772)
PA	-0.199*** (-4.436)	-0.523*** (-2.599)	-1.033*** (-2.236)	-0.825*** (-0.501)
GOP	0.171** (3.774)	0.258* (3.010)	0.220** (3.544)	0.168* (2.010)
SC	0.077** (0.485)	0.132** (0.510)	0.107** (0.2575)	0.155** (0.523)
EDL	-0.402** (-1.706)	-0.644** (-1.828)	-0.443** (-1.002)	-0.591** (-1.013)
CONS	126.3*** (34.46)	123.0*** (36.43)	103.3*** (25.84)	118.2*** (35.20)
N	176	176	176	176
R2	0.135	0.149	0.3365	0.419

4.3.3 The Robustness Test

Since different spatial measurement models and different measurement indicators may affect the robustness of the measurement results, in order to ensure the reliability of the research results, the robustness of the research results is tested by changing the explanatory variables, control variables and changing the measurement models. Foreign direct investment (FDI) is represented by the total amount of new investment, namely the increment of foreign direct investment; the measure of control variable is changed, the Marine science and technology investment (TI) is expressed by the number of Marine research and development personnel; the Marine research and development level (RDL) is expressed by the number of Marine professionals per thousand Marine employed personnel; the port activity (PA) is expressed by the number of ships in one month; the Marine economic scale (GOP) is expressed by the new Marine gross product; the Marine industrial structure level (SC) is expressed by the change value of Marine industrial structure in coastal provinces, the formula is the structure change $K_i = Q_{ij} - Q_{io}$ K_i Q_{io} Q_{ij} It represents the proportion of the output value in the reporting period; the regional economic development level is expressed by the per capital disposable income of residents; besides, the spatial error model (SEM) is used to conduct spatial regression of the research objects. The test results are shown in Table 9, which are consistent by comparison except for small changes in the coefficient, indicating that the above study results are robust.

Table 9 Test of robustness

VARIABLE	OLS-fixed effect		SEM	
	CHANGE EXPLANATORY VARIABLES	REPLACE CONTROL VARIABLES	GEOGRAPHICAL DISTANCE	ECONOMIC DISTANCE
FDI	-0.932*** (-2.131)	-0.873*** (-2.007)	0.889*** (0.462)	0.752*** (6.044)
w*FDI			0.788 (0.859)	
W*FDI				1.512*** (0.356)
TI	-0.410* (-0.155)	-0.216* (0.413)	-0.182** (2.307)	-0.408*** (2.074)
RDL	-9.8892* (2.459)	-11.25* (3.421)	-0.241* (-1.009)	-0.369*** (-0.701)
PA	-8.002** (-0.350)	-7.869** (2.074)	-0.202*** (-3.404)	-0.401*** (-2.213)
GOP	4.518** (-2.101)	2.903** (-0.911)	0.338** (2.164)	1.018* (2.413)
SC	3.852* (1.025)	4.314* (1.330)	0.137** (0.402)	0.166** (0.533)
EDL	-3.841** (2.876)	-4.193** (2.618)	-0.546** (-0.906)	-0.332** (-1.440)
CONS	118.6*** (29.36)	101.9*** (14.38)	148.2*** (28.73)	143.0*** (26.43)
N	176	176	176	176
R^2	0.229	0.401	0.346	0.295

5 Conclusion

Based on the panel data of 11 coastal provinces and cities in China from 2004 to 2019, first, excluding the multicollinearity problem, using the traditional panel data self-regression model regression, second, construct global moran index (Morran's I) to judge the spatial geographic weight matrix and spatial economy geographic weight matrix, through the Hausman test and LM test, this paper selects fixed effect space model, spatial lag model to study the spatial spillover effect of foreign direct investment (FDI) on the efficiency of Marine green economy. Finally, the robustness test was conducted by changing the explanatory variables, control variables, and spatial measurement models, and finally passed the test. The conclusions were drawn are as follows:

(1) Without considering spatial factors, the increase of FDI will inhibit the improvement of the efficiency of Marine green economy to some extent, and foreign direct investment has a significant negative impact on the efficiency of Marine green economy.

(2) foreign direct investment has a positive spatial spillover effect, FDI space can improve the efficiency of Marine green economy, and more significant spillover effect under the economic geographical weight, shows that when the provinces economic and geographical correlation exist at the same time, the FDI in the region to neighboring provinces of Marine green economic efficiency have obvious effect.

(3) whether considering space effect, Marine science and technology investment, Marine scientific research development level, port activity, regional economic development level of Marine green economic efficiency has significant negative effect, that the increase of the above four indicators will not drive the improvement of Marine environment, it will inhibit the efficient development of Marine green economy.

(4) The scale of Marine economy and Marine industrial structure have a positive and significant effect on the efficiency of Marine economy, indicating that the larger the scale of Marine economy, the more investment for the Marine environment management, the better the development degree of Marine economy; similarly, the more reasonable the Marine industrial structure, the lower the proportion of high Marine pollution industries, the higher the greening degree of Marine economy.

The results show that the coastal areas of Marine green economic efficiency 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 and provincial and local governments should give full play to their macro-control and governance roles, 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 sea areas, With a scientific Marine resource management system, To promote green development of the Marine economy and improve the environment, Maintaining Marine ecological security; 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 economy 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, give full play to the leading role of the area of Marine green economy to participate in the domestic and foreign scientific and technological cooperation, vigorously develop Marine emerging industries and high-tech industries, effectively improve the Marine ecological environment, strengthen the exchanges and cooperation with neighboring Marine provinces, and make a "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, improve the green economic efficiency; accelerate the development direction, 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.

(5) Promoting the adjustment of industrial structure in coastal cities. We will raise the level of utilization of foreign investment, To improve the economic quality and growth of coastal cities, Mainly to promote the adjustment of industrial structure through guidance, To guide foreign investment to high-tech industries and modern service industries, To support foreign investment in innovative enterprises, At the same time, coordinated development is for the purpose, We will improve the foreign investment orientation, With 21 pilot free trade zones (ports), By implementing high international standards of trade standards, Implement the pre-establishment national treatment and the negative list management system, We will guide the concentration of high-quality foreign investment and improve the investment structure, We will give full play to the spillover role of foreign technology, To foster new growth drivers of economic development, Promote the upgrading of the industrial structure of coastal cities, Reduce the number of high-polluting enterprises, Promote the transformation of enterprises, Thus promoting the high-quality development of the Marine economy.

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