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IMPACT OF GREEN TOTAL FACTOR PRODUCTIVITY IN MARINE ECONOMY BASED ON ENTROPY METHOD

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ABSTRACT

In order to improve the efficiency of marine economic production and realize the sustainable and healthy development of marine economy, the spatial-temporal and dynamic evolution trend of marine economic green production efficiency in coastal areas of China is analysed by means of SFA basic model, coefficient of variation, coefficient of Gini and entropy method. It mainly includes three aspects: the result analysis of marine economy green production efficiency; the dynamic trend analysis of marine economy green production efficiency; the analysis of factors affecting marine economy green production efficiency. The results show that the factors affecting the total factor productivity of the marine economy are: development level of marine economy, marine material capital, level of opening to the outside world, marine industrial structure, marine human capital and marine environmental governance.

Keywords: marine economy, green production efficiency, entropy method

INTRODUCTION

Based on the current situation of unbalanced marine economic development and environmental pollution in China, in the 12th Five-Year Plan, the state clearly put forward the idea of "adhering to the overall planning of land and sea, formulating and implementing marine development strategies, and improving the capacity of marine development, control and comprehensive management". The report of the Eighteenth National Congress of the Communist Party of China put forward "improve the capacity of marine resources development, develop marine economy, protect marine ecological environment, resolutely safeguard national marine rights and interests, and build a strong marine country." In promoting the green development of China's marine economy, the State Oceanic Administration will make great efforts to improve the policy system, enhance the innovation capacity, strengthen the protection of the ecological environment, and carry out international cooperation and exchanges. It is an urgent problem to be solved how to give consideration to the development of marine economy and environmental protection, improve the production efficiency of marine economy, make the marine economy and environment harmoniously and rapidly develop, achieve the maximum benefits, and ultimately achieve the goal of healthy and sustainable development of marine economy.

In the traditional evaluation of marine economy, most of them only take the gross marine product as the evaluation criterion, but neglect the marine environmental pollution caused by the development of marine economy. This kind of economic growth at the cost of environmental pollution cannot reflect the objective situation of marine economic development. Even some areas in the development of the marine economy pay much more environmental costs than the economic benefits of the marine economy. Based on this, when carrying out marine economic evaluation, the environmental cost is considered comprehensively, and the marine environmental evaluation index is incorporated into the quantitative system of the whole marine economic evaluation, so as to establish a more reasonable marine economic evaluation index system, which can be used to guide the marine economy of China develop towards a healthy and sustainable direction.

Based on the urgency of real environment and marine economic growth and the limitations of similar studies, the marine total factor rate is calculated and a comprehensive and systematic analysis is made. By means of entropy method, nuclear density estimation, Gini coefficient, coefficient of variation, α convergence and β convergence, the spatial-temporal analysis and dynamic evolution trend analysis of green production efficiency of marine economy in coastal areas of China are carried out. Quantitative analysis is made on the effect degree and role direction of various possible influencing factors on green production efficiency of marine economy. It has an important influence on the development of China's marine economy.

STATE OF THE ART

Some scholars put the marine environment and marine economy into a whole equilibrium model to study. And they concluded that the problem of marine environment is related to the huge population growth and that improving the marine environment must be based on the premise of controlling population growth [1,2]. On the basis of selecting the index system, the scholar Morrissey used the theory of marine ecology to divide the marine economic system, the marine environmental system and the social cultural system. The result shows that the transformation of the mode of marine economic development and the improvement of the marine environment are mutually reinforcing [3]. Some scholars also calculated the damping effect of the marine resources and environment on the marine economy in the Bohai Rim by Romer model, and put forward the countermeasures to improve the damping effect of the marine resources and environment on the marine economic development [4,5]. Relevant scholars decomposed the total factor productivity of the marine economy and found that there is a strong spatial spill-over effect between TFP index and technological progress index, and the degree of regional openness has a positive impact on TFP index and technological progress index [6,7]. Some scholars used the panel data of marine GDP of coastal provinces and cities and used SFA method to analyze the regional marine economic and technological efficiency. The results show that the regional marine economic and technological efficiency is high and there is an upward trend in the study period [8]. Some scholars used GRA-DEA to evaluate marine economic efficiency and put forward countermeasures and suggestions [9]. Relevant scholars used DEA to analyze the marine economic efficiency in coastal areas and found that the level of marine economic efficiency of 73% of the areas has not been fully developed [10].

METHODOLOGY

PRINCIPLES AND STEPS OF ENTROPY METHOD

In the selection of leading industries, it is usually necessary to consider the relative importance of each evaluation index. The most direct and simple method to indicate the importance is to give each index weight coefficient [11]. According to entropy theory, the amount and quality of information people obtain in decision-making is one of the decisive factors of decision accuracy and reliability. Entropy can measure the amount of useful information provided by the acquired data, and it is an ideal scale when applied to the evaluation of different decision-making processes or the evaluation of the effect of cases [12]. In information theory, entropy is a measure of uncertainty in information. The less the information is, the greater the information entropy is, and the greater the uncertainty of information is; otherwise, the smaller the information entropy is, the smaller the uncertainty of information is. According to the characteristics of entropy, the discrete degree of an index can be judged by calculating the entropy value [13]. The greater the discrete degree of the index is, the greater the impact of the index on the comprehensive evaluation is.

Basic steps: First, quantify the values of each index, and calculate the proportion of the j-th index on the i-th production index value.

$$P_{ij} = X_{ij} / \sum_{i=1}^{m} X_{ij} \tag{1}$$

Second, calculate the entropy e_j of the j-th index:

$$e_j = -k \sum_{i=1}^{m} p_{ij} \ln p_{ij} \tag{2}$$

In the above formulas, k>0 is related to m, and in general, k=1/lnm.

If the value of X_{ij} is all equal for all the given index j, then:

$$ej = -k \sum_{i=1}^{m} \frac{1}{m} \ln \frac{1}{m} = k \ln m \tag{3}$$

Then, e_j is the maximum value. If k=1/lnm, $0 \le e_j \le 1$ can be obtained.

Third, calculate the differential coefficient g_j of the j-th index:

Define the differential coefficient $g_j=1-e_j$, then the smaller the entropy of the i-th index is, the greater the corresponding entropy is, and the more important the index is.

Fourth, determine the weight of evaluation index: The essence of using entropy method to estimate the weight of each index is to use the value coefficient of index information to calculate. The higher the value coefficient is, the greater the importance of evaluation is. After the differential coefficient g_j of the j-th index is determined, then the corresponding weight coefficient d_j can be obtained.

$$d_j = g_j / \sum_{j=1}^{n} g_j \tag{4}$$

Fifth, calculate the evaluation values of each production.

$$T_i = \sum_{j=1}^{n} p_{ij} d_j \tag{5}$$

ANALYSIS OF CALCULATION RESULTS OF GREEN PRODUCTION EFFICIENCY OF MARINE ECONOMY

Using the stochastic frontier analysis model and Frontier 4.1 program, the green production efficiency of marine economy in 11 coastal provinces and cities in China from 2001 to 2012 is calculated [14]. The results show that, γ=0.810 and it is obvious at the level of 1%. It indicates that the difference between the actual output and the frontier production is caused by the inefficiency of technology. It is larger than 0 and close to 1, which suggests that it is reasonable and necessary to use SFA to calculate the green production efficiency of marine economy.

Tab. 1. Parameter estimation results for stochastic frontier analysis

predictor	coefficient	standard deviation	T Statistical value
β0	-130.44	97.926	-1.3320
β1	2.6361	0.5988	4.4026***
β2	0.9154	0.1032	8.8664***
β3	0.0005	0.0003	1.9118**
β4	0.5619	0.1854	3.0308***
β5	0.0062	0.0040	1.5486*
β6	0.0074	0.0089	1.8359**
σ^2	94799.5	1.4424	65724.7***
γ	0.8100	0.0254	31.948***
η	0.0366	0.0112	3.2727***
Log likelihood function			-860.22
Unilateral likelihood ratio test			118.68**

*Note: LR conforms to Chi square distribution; ***, ** and * represent the test at the obvious level of 1%, 5% and 10%.*

According to the output elasticity of the two traditional input factors of employment and marine capital stock, β1=2.6361, that is, the employment (10,000 people) in China's marine areas is increased by 1%, which can make GOP increase by 2.6361 percentage points; β2=0.9154, that is, the stock of marine capital (100 million yuan) is increased by 1%, which can make GOP increase by 0.9154 percentage points [15]. Labour and capital play a great role in pulling the marine economy, in which labour input plays a dominant role, and marine economic growth is mainly driven by labour force, belonging to the extensive mode of economic growth. Under the existing technological level, the development of China's marine economy is based on increasing the number of employees and transforming as much capital stock as possible. The sustainable development of marine economy needs to change the mode of economic growth, improve the technological level and enhance the ability to develop the ocean. The independent variable of β3=0.0005 is the discharge of industrial wastewater, the independent variable of β4=0.5619 is the ratio of polluted sea area, the independent variable of β5=0.0062 is the amount of pollutants carried into the sea by rivers, and the independent variable of β6=0.0074 is the area of red tide (km^2) [16]. According to the estimation result of environmental input factors, the growth of marine economic output is accompanied by the aggravation of marine environmental pollution. Comparing these marine environmental input factors, the proportion of industrial wastewater discharge is the largest when the marine economy increases the same proportion. Generally speaking, the contribution of marine traditional economic input to marine economic output value is greater than the dependence of marine output value on environmental input.

The results calculated by SFA can reflect the inter-annual variation trend of marine economic green productivity in coastal areas (table 2).

According to previous studies, the green production efficiency of marine economy in China is divided into six grades: low efficiency (0-0.400), medium and low efficiency (0.401-0.500), general efficiency (0.501-0.600), medium and high efficiency (0.601-0.700), relatively high efficiency (0.701-0.800), and high efficiency (0.801-1). Generally speaking, according to the above-mentioned classification principle, China's marine economic green production efficiency level

Tab. 2. The results of green production efficiency of marine economy

	Tianjin	Hebei	Liaoning	Shanghai	Jiangsu	Zhejiang	Fujian	Shandong	Guangdong	Guangxi	Hainan
2001	0.6306	0.6905	0.4970	0.5759	0.6118	0.5968	0.6293	0.4983	0.6838	0.6572	0.3697
2002	0.6438	0.7016	0.5151	0.5911	0.6257	0.6113	0.6426	0.5163	0.6952	0.6695	0.3924
2003	0.6566	0.7123	0.5325	0.6058	0.6392	0.6253	0.6555	0.5336	0.7061	0.6814	0.4142
2004	0.6689	0.7227	0.5492	0.6200	0.6521	0.6387	0.6678	0.5504	0.7167	0.6928	0.4352
2005	0.6808	0.7326	0.5654	0.6336	0.6646	0.6517	0.6798	0.5665	0.7268	0.7039	0.4555
2006	0.6923	0.7422	0.5810	0.6468	0.6767	0.6642	0.6913	0.5821	0.7366	0.7145	0.4750
2007	0.7033	0.7515	0.5961	0.6595	0.6883	0.6763	0.7024	0.5971	0.7461	0.7248	0.4939
2008	0.7140	0.7604	0.6106	0.6717	0.6995	0.6879	0.7130	0.6116	0.7552	0.7346	0.5121
2009	0.7243	0.7690	0.6246	0.6835	0.7103	0.6691	0.7233	0.6255	0.7640	0.7442	0.5296
2010	0.7342	0.7773	0.6380	0.6948	0.7207	0.7099	0.7333	0.6390	0.7725	0.7534	0.5465
2011	0.7437	0.7853	0.6510	0.7058	0.7307	0.7203	0.7429	0.6519	0.7806	0.7622	0.5628
2012	0.7529	0.7930	0.6636	0.7164	0.7404	0.7304	0.7521	0.6644	0.7885	0.7707	0.5785

from 2001 to 2012 can be divided into four categories: the first category of Hainan, the average of its marine economic green production efficiency is 0.4804, belonging to the medium and low efficiency level; the second category of Liaoning and Shandong, the average of the marine economic green production efficiency is 0.5853 and 0.5864, belonging to the general efficiency level; The third category of Tianjin, Shanghai, Jiangsu, Zhejiang and Fujian, the average green production efficiency of marine economy in these areas ranges from 0.601 to 0.700, belonging to the medium and high efficiency level; the fourth category is the higher efficiency level, including Hebei, Guangdong and Guangxi, and the average green production efficiency of marine economy is between 0.701 and 0.800. The spatial difference is more obvious, forming a pattern of "three regions are higher efficiency points, two regions are general efficiency points, most of the medium and high efficiency areas are clustered and distributed, and the medium and low efficiency is on the side".

DYNAMIC TREND ANALYSIS OF GREEN PRODUCTION EFFICIENCY OF MARINE ECONOMY

The calculation results of green production efficiency of marine economy in each region are input into Eviews6.0 software to calculate the nuclear density distribution of green production efficiency of marine economy in each year. The nuclear density distribution map of green production efficiency in China's marine economy is drawn from the calculation results in 2001, 2005, 2009 and 2012, which can reflect the annual changes of green production efficiency of marine economy.

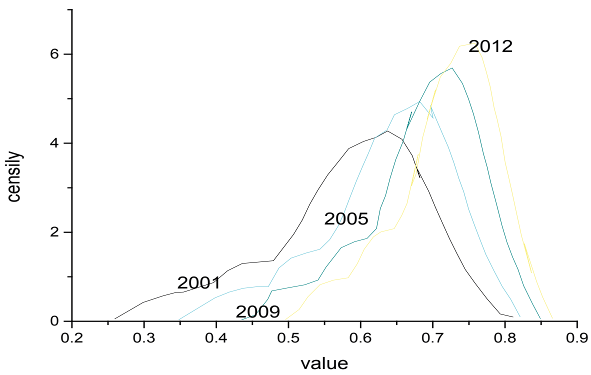

Fig. 1. The nuclear density distribution of green production efficiency of marine economy in China

The Gini coefficient is gradually decreased from 0.0922 in 2001 to 0.0500 in 2012, which proves that the difference of green production efficiency of marine economy in various regions of China is decreasing year by year. The coefficient of variation is decreased from 0.1644 to 0.0891 year by year, and the value of coefficient of variation becomes smaller and smaller, indicating that the gap between the green production efficiency of marine economy in various regions of China is narrowing with time.

Tab. 3. The convergence regression analysis

	A convergence		B convergence	
	Coefficient	T Test value	Coefficient	T Test value
α1	13.703	27.986***		
α2	-0.007	-27.737***		
β1			-0.004	-10.535***
β2			-0.041	-61.217***
R^2	0.986	0.997		
F value	769.333***	3747.479***		
Sig value	0	0		
μ value		0.0564		

*Note: *** represents obvious at 1% level, t test and F test both obvious at 1% level, and equation acceptable for Sig value less than 0.5.*

FACTORS AFFECTING GREEN PRODUCTION EFFICIENCY OF MARINE ECONOMY

The level of marine economic development (X1) is represented by the statistical data of per capita marine output value (10,000 yuan / person). The per capita marine output of each coastal area is increasing year by year. Generally speaking, from 2001 to 2012, the per capita marine output value of 10,000 yuan is the highest in Shanghai, 1.5819, followed by Tianjin, with 0.0707 in Guangxi Province as the lowest level.

The marine industrial structure (X2) is represented by the statistical data of the proportion of the third marine industries (%). The change trend of the marine tertiary industry in coastal areas is not consistent. The proportion of the marine tertiary industry in Tianjin and Shanghai shows a downward trend in the fluctuation. The marine tertiary industry in the other nine provinces is rising in the fluctuation. The marine tertiary industry occupies an important position in the marine economy, and the marine industrial structure tends to be reasonable.

Marine human capital (X3) is expressed by the proportion of marine professionals in marine employment. There are frequent fluctuations in marine human capital in coastal areas. Among them, the marine human capital in Tianjin, Shandong and Fujian declines in fluctuations, while the other areas have risen to varying degrees. Generally speaking, more and more attention has been paid to the training of high-quality marine personnel in various regions, and marine professional and technical personnel play an important role in the development of marine economy.

Marine material capital (X4) is expressed in terms of the ratio of the total formation of marine fixed capital to the number of employees involved in the marine area. In addition to the slight fluctuation in individual years, the marine material capital in coastal areas shows a rising trend as a whole. With the further development of marine economy in various regions, the amount of marine capital investment in each region will also increase.

The intensity of marine environmental management (X5) is expressed by the number of wastewater and solid waste treatment items. On the one hand, it is related to the demand of marine economic development. In some areas, the degree of marine environmental pollution needs a greater degree of control, while others do not. The main aspect is related to the degree of attention paid to the control of the marine environment. Some areas pay more attention to the control of the marine environment and will provide greater financial support to deal with the marine environment.

The level of opening to the outside world (X6) is expressed by the statistical data of international tourism foreign exchange receipts (million US dollars). Among the statistical indicators of international tourism foreign exchange income, most of the regions show a regular trend of development and change. After 2003, the international tourism foreign exchange income is lower than that after 2002, and the international tourism foreign exchange income after 2004 shows a trend of increasing year by year.

RESULTS

Tab. 4. Regression result of the green production efficiency of marine economy in China

Coefficient		Standard error	Z statistics	P value
X1	-0.044749	0.016565	-2.701469	0.0069***
X2	0.00036	0.00043	0.837932	0.4021
X3	-0.069216	0.138095	-0.501216	0.6162
X4	0.16343	0.002928	5.582459	0***
X5	4.47E-05	4.17E-05	1.073592	0.283
X6	0.001075	0.00027	3.97943	0.0001***
C0	0.577029	0.01923	30.00706	0***

Development level of marine economy: Regression results show that the green production efficiency of marine economy decreases by 0.045 units per capita per unit of marine output value. From 2001 to 2012, China's per capita marine output value rose from 0.14 million yuan to 108,000 yuan. The level of marine economic development has been constantly improving, which has a negative effect on the green production efficiency of China's marine economy. The relationship between marine economic development and marine environment is a unity of opposites.

Marine material capital: Regression results show that marine material capital has a positive role in promoting the green production efficiency of marine economy. Every unit of labour density of marine capital increases, the green production efficiency of marine economy rises by 0.016. The higher the marine material capital is, the higher the marine technological progress occurs with capital input, which promotes the development of marine industry, reduces the pollution and promotes the green production efficiency of marine economy.

The level of opening to the outside world: it has a positive effect on promoting the green production efficiency of marine economy. The results show that the green production efficiency of China's marine economy increases by 0.001 per unit of international tourism foreign exchange income. On the one hand, the increase of international tourism income in coastal areas improves economic output and economic benefits, so environmental protection has become an inevitable choice and trend.

Marine industrial structure: The change of marine industrial structure also has an impact on the green efficiency of marine economy. Compared with the first and second industries, the regression results show that the proportion of marine tertiary industry has no obvious effect on the green efficiency of marine economy.

Marine human capital: Marine professional and technical personnel have higher labour productivity and creativity, which is conductive to improving the efficiency of marine economic decision-making and promoting the scientific and rational development of marine economic. The regression results show that the impact of marine human capital on marine economic green production efficiency is not obvious.

Marine environment governance: The regression results show that the impact of environmental governance on the green production efficiency of marine economy is not obvious. Overall, China's marine environment governance has not played an effective role in the green production efficiency of marine economy.

CONCLUSION

The constant decrease of coefficient of variation and Gini coefficient shows that the difference of green production efficiency of marine economy in China is gradually becoming smaller. From the perspective of influencing factors, the development level of marine economy plays a negative role in promoting the green production efficiency of marine economy. The main reason is that the economic benefit of marine development is less than the cost of resource destruction and environmental pollution. Marine material capital and the level of opening to the outside world play a positive role in promoting the green production efficiency of marine economy. Marine industrial structure, marine human capital and environmental governance have not passed the model test and have no obvious impact on the green production efficiency of marine economy. Adopting the means of changing the economic growth mode, adjusting the industrial structure and improving the utilization rate of technology are all effective measures to save energy and reduce emissions from the source of production while pursuing the maximum economic benefits. The follow-up environmental governance work is also essential to the promotion of economic production efficiency.

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