Evaluation of marine green economy efficiency and its influencing factors in China

Jianhua Tang¹, ², Shujuan Wu¹ and Jianhua Xiao¹

¹ School of Economics and Management, Wuyi University;
²Corresponding author’s e-mail: 1909214436@qq.com

Abstract. In order to measure the sustainable development ability of marine economy and provide reference for improving the sustainable development ability of marine economy in China, after constructing a resource input index based on the entropy method, the paper uses the SBM-DEA model with undesirable output to evaluate the marine green economy efficiency of 11 coastal provinces(cities or districts) in China from year 2006 to 2016. Further, Tobit regression model is used to analyze the marine green economy efficiency of influencing factors. It is found that according to the sustainable development ability, the 11 coastal provinces(cities or districts) can be divided into 4 levels: Tianjin, Guangdong, Shandong, Shanghai, and Jiangsu are of highest level, Zhejiang and Fujian are of the high level, Liaoning and Hebei are of the median level, and Guangxi and Hainan are of the low level; the marine industry structure and marine science and technology level have significant positive impacts on the marine economy’s sustainable development ability, even though the impact of marine industry structure is weak, while the environmental regulation tools have a weak insignificant negative impact on the sustainable development of the marine economy. Based on the above conclusions, this article provides some suggestions for the sustainable and healthy development of China’s marine economy.

1. Introduction
Since the 1990s, marine economy in China has entered a stage of rapid development and become a new driving force for the development of the national economy. The report of the 19th National Congress of the Communist Party of China proposed that the development of the marine economy needs to adhere to land and sea coordination, so as to promote the construction of a marine power and promote the high-quality development of the marine economy. However, the current marine economic development in China is under the extensive developing mode, which is of high input but low output. With the rapid development of the marine economy, this mode of marine economy development has caused a series of problems, such as low utilization of marine resources and damaged marine ecological environment and so on. It runs counter to the response of the "Strategic Proposal for Implementing Marine Negative Emissions and Practicing Carbon Neutrality" initiated at the 2020 International Forum on Marine Ecological Economy. It has become a stumbling block for the sustainable development of the marine economy. In this context, it is very important to use scientific evaluation indicators to measure the sustainable development of the marine economy. How to improve the sustainability of marine economic development and to explore a low-energy, high-efficiency marine economic development method has become a challenge for our country. Therefore, this paper evaluates the marine green economy efficiency and analyses the influencing factors in coastal provinces (cities or districts), aiming to provide basis approaches for promoting the sustainable development ability of marine economy.
In recent years, marine green economy efficiency is generally defined as a ratio of inputs i.e. human resources, capital, technology and other production factors in marine economy to outputs i.e. GDP and environment loss, under the premise of limited marine resources and marine environment. It aims to measure the sustainable development of marine economy [1-3].

In recent years, relevant domestic researches mainly include: Lin Xu [4] evaluated the efficiency of financial support of 11 coastal provinces(cities, districts) in China by adopting the panel SFA model, and used gray correlation analysis to verify the financial development and the correlation between the marine economy; Tianyi Gao [5] measured the scientific and technological innovation efficiency of its marine economy based on the Qingdao City by adopting data envelopment analysis (DEA), and analyzed the relationship between the marine economy and technological innovation from both dynamic and static perspectives; Lingui Qin [6] measured marine green TFP of the 11 coastal provinces(cities, districts) by adopting the SBM-DEA model, and emphasized the impact of technological innovation on marine green TFP; Mei Gai [3] measured marine economy efficiency of 11 coastal provinces(cities, districts) by adopting stochastic frontier analysis (SFA) model, and studied its spatial-temporal differences and influencing factors; Wei Zou [7] measured marine economy efficiency of 17 cities in the Bohai Sea region by adopting bootstrap-DEA model, and used the standard deviation ellipse and barycenter coordinates to analyze the spatial pattern characteristics. XiXi Zhang [8] measured the green efficiency of marine carbon sink fishery of major coastal marine carbon sink fishery production areas in China by adopting the Super-SBM model 9, and analyzed its influencing factors and spatial spillover effects.

In addition to Chinese scholars, others have been engaged in related research, mainly including: Jamnia [9] adopted SFA model to evaluate the technical efficiency of fishery production in Bahar region in southern Iran; Wanke [10] study the cargo handling efficiency of Brazilian ports and evaluate the integration efficiency of internal production and operation equipment by adopting network DEA model.

Summarizing the previous literature reviews, we can know that the amount of research on marine economy efficiency evaluation has been quite rich, but there are still some shortcomings: first, most of the existing studies used the traditional DEA model. However, this model only consider the desirable output of marine economy, and it can not resolve the problem of input-output slack; Second, only a small number of scholars carried out the study of green efficiency around the marine economy, and failed to fully consider the impact of the undesired output of the marine environment and the environmental resource input elements. In view of this, this paper takes 11 coastal provinces(cities or districts) in China as the research object, on the basis of fully considering the elements of resource input, uses SBM-DEA model considering undesirable output to calculate their marine green economy efficiency. This not only solves the problem of input-and-output slack, but also improves the input index system to make efficiency measurement results more accurate; Second, this article constructs a Tobit regression to study the influencing factors of its green efficiency; Finally, useful suggestions in this paper are provided for accelerating the construction of a maritime power, improving the efficiency of the use of marine resources, and realizing the high-quality development of the marine economy.

2. Model construction and index system

2.1. Construction of index system

In view of the complexity of marine economic activities and the availability of data, it is impossible to take all the input-output production factors into account when carrying out the empirical research on the marine green economy efficiency. Therefore, on the basis of fully considering the elements of resource input, uses SBM-DEA model considering undesirable output to calculate their marine green economy efficiency. This not only solves the problem of input-and-output slack, but also improves the input index system to make efficiency measurement results more accurate; Second, this article constructs a Tobit regression to study the influencing factors of its green efficiency; Finally, useful suggestions in this paper are provided for accelerating the construction of a maritime power, improving the efficiency of the use of marine resources, and realizing the high-quality development of the marine economy.

2.1.1. Input factor Index. Based on the definition of marine green economy efficiency and the character of marine economy activities, this paper selects labour input factors, capital input factors and resource input factors as investment indexes.
In terms of labor input factors, it is measured by the number of sea related employees in each province (city, district).

On the basis of fully considering the three main industries of marine economy, this paper uses the entropy method to construct the resource input index for the length of coastal large-scale production ports, the number of star hotels and the marine fishing output, so as to serve as the resource input factors.

As far as the capital input factors are concerned, it is measured by the number of sea related employees in each province (city, district). Since there is no data related to the stock of marine fixed assets in the Marine Statistical Yearbook, combined with the research results of Jun Zhang [11], Runsong Jia and Guangshun he, this paper uses the perpetual inventory method to calculate the stock of fixed assets in coastal provinces, i.e.:

$$K_{it} = (1 - \delta_i) \times K_{it-1} + \frac{I_t}{P_t}$$

Where, $K_{it}$ indicates the capital stock of i province (city, district) in t year, $K_{it-1}$ indicates the capital stock of the province (city, district) in the t-1 year, $I_t$ represents the fixed capital formation of i province (city, district) in t year. $P_t$ represents the fixed asset price index in year t. Taking into account that the faster the regional economic development, the higher the capital depreciation rate, so this paper learn from Runsong Jia's [12] practice of using different depreciation rates for different provinces, that is, choose i depreciation rates $\delta_i$ for i province (city, district).

The actual capital stock of each province is measured with the stock of fixed assets in 2005 as the base period, and then the calculation method of Guangshun He [13] is used to calculate marine capital stock of coastal provinces (cities, districts). The formula is:

$$Y_{it} = K_{it} \times \frac{GOP_{it}}{GDP_{it}}$$

Where, $Y_{it}$ represents the marine capital stock of i provinces (city, district) in the t year. $GOP_{it}$ represents the gross marine economic product of i province (city, district) in the t year, $GDP_{it}$ represents gross domestic product of i province (city, district) in the t year.

### 2.1.2. Output factor Index

The gross ocean product and industrial wastewater discharge are selected as output indicators to respectively represent the desirable output and undesirable output of the marine economy.

#### 2.2. SBM-DEA model of undesirable output

Data envelopment analysis (DEA) is analytical tool which uses mathematical programming to evaluate the relative efficiency of decision-making units (DUM) with multiple inputs and outputs. Based on the Slack-Based Measure (SBM) model considering undesirable output proposed by Tone [14], this paper introduces the slack variable into the objective function, which not only overcomes the slack problem of input-output index in the traditional DEA model, but also overcomes the impact of undesirable output on the accuracy of efficiency measurement. Therefore, this paper uses the SBM-DEA model considering the undesirable output to measure the marine economy green efficiency of 11 coastal provinces (cities, districts). Not only that, this index value is used to evaluate the sustainable development ability of marine economy.

#### 2.3. Data sources

The research period of this study is 2006-2016, and the research objects are 11 coastal provinces (cities and districts). Relevant data comes from China Marine Statistical Yearbook, China Statistical Yearbook and China Urban Statistical Yearbook, which finally are compiled into panel data of 11 coastal provinces (cities, districts) from 2006 to 2016.

#### 3. Empirical results of marine green economy efficiency

Samples in this study included 11 coastal provinces (cities, districts) in China, each of which is treated as a DUM under DEA-SBM analysis. The MATLAB 2017(b) software is adopted for calculating results displayed in Table 1. According to the research results of Zhanxin Ma [15], the score of marine green economy efficiency is divided into four level: if the efficiency value is in the interval of $0.8 \leq \rho^* \leq 1$, it
indicates that the sustainable development ability of marine economy is of highest level; if the efficiency value is in the interval of $0.5 \leq \rho^* < 0.8$, it indicates that the sustainable development ability of marine economy is of the high level; if the efficiency value is in the interval of $0.4 \leq \rho^* < 0.5$, it indicates that the sustainable development ability of marine economy is of the median level; if the efficiency value is in the interval of $0 \leq \rho^* < 0.4$, it indicates that the sustainable development ability of marine economy is of the low level.

Generally speaking, the empirical results show that Tianjin, Guangdong, Shandong, Shanghai and Jiangsu are of highest level. Compared with other coastal provinces, the marine economic production in these provinces (cities, districts) consumes the least resources and causes minimal damage to the marine environment; Zhejiang and Fujian are of high level; Liaoning and Hebei are in the median efficiency value interval. This shows that the sustainable development ability of this provinces (cities, districts are in the median level; Guangxi and Hainan are in the low efficiency value range. Compared with other coastal provinces (cities, districts), their marine economy development has the greatest damage to marine resources and environment. This shows that the sustainable development ability of marine economy in Guangxi and Hainan are of low level.

The reasons why the sustainable development ability of marine economy in coastal provinces (cities, districts) have the above characteristics are:

1. The marine industrial structure of Tianjin, Guangdong, Shandong and Shanghai is "3 2 1". These coastal provinces (cities and districts) rely on the development of the tertiary industry to extend the industrial chain of marine products and services, improve the added value of products, and enhance the sustainable development ability of marine economy. Not only to optimize the industrial structure, Tianjin, Guangdong, Shandong, Shanghai and Jiangsu vigorously relies on marine science and technology innovation to improve the utilization efficiency of marine resources, reduces the amount of invalid investment in production and reduces the degree of environmental pollution.

2. Although the marine industrial structure of Zhejiang and Fujian has achieved "3 2 1", there is still a certain degree of waste in traditional industries, such as shipping industry and marine salt industry. The technical level of marine industry is low and there is a phenomenon of more invalid investment, which aggravates the deterioration of the marine environment.

3. The marine primary industries of Liaoning, Guangxi and Yunnan account for a large proportion of GOP, which indicates that their marine industrial structure is unreasonable. Moreover, insufficient investment in marine science and technology has led to more low-end seafood and failed to increase the added value of output. In recent years, Hainan Province long-termly presents the "3 2 1" industrial structure, and its marine green economy efficiency shows a rising state. However, its marine tourism resources development fails to achieve scale efficiency, and the investment scale is small, which leads to the marine resources not being fully utilized.

### Table 1. Marine green economy efficiency of coastal provinces (cities and districts).

| Year | TianJin | HuBei | LiaoNing | ShangHai | JiangSu | TianJin | ZheJiang | FuJian | ShangDong | GuangDong | GuangXi |
|------|---------|-------|----------|----------|---------|---------|----------|-------|-----------|-----------|--------|
| 2006 | 1.00    | 1.00  | 0.45     | 1.00     | 0.86    | 0.50    | 0.52     | 1.00  | 1.00      | 0.38      | 0.28   |
| 2007 | 1.00    | 1.00  | 0.45     | 1.00     | 1.00    | 0.55    | 0.56     | 1.00  | 1.00      | 0.38      | 0.34   |
| 2008 | 0.84    | 1.00  | 0.41     | 1.00     | 1.00    | 0.50    | 0.50     | 1.00  | 1.00      | 0.30      | 0.30   |
| 2009 | 1.00    | 0.49  | 0.41     | 1.00     | 1.00    | 0.53    | 0.52     | 1.00  | 1.00      | 0.31      | 0.30   |
| 2010 | 1.00    | 0.57  | 0.43     | 1.00     | 1.00    | 0.55    | 0.54     | 0.72  | 1.00      | 0.32      | 0.36   |
| 2011 | 1.00    | 0.47  | 0.43     | 1.00     | 1.00    | 0.55    | 0.49     | 1.00  | 1.00      | 0.27      | 0.36   |
| 2012 | 1.00    | 0.47  | 0.41     | 1.00     | 1.00    | 0.55    | 0.49     | 1.00  | 1.00      | 0.27      | 0.35   |
| 2013 | 1.00    | 0.47  | 0.42     | 1.00     | 1.00    | 0.55    | 0.48     | 1.00  | 1.00      | 0.28      | 0.38   |
| 2014 | 0.74    | 0.56  | 0.43     | 1.00     | 1.00    | 0.72    | 1.00     | 1.00  | 1.00      | 0.41      | 0.33   |
| 2015 | 1.00    | 0.46  | 0.36     | 1.00     | 1.00    | 0.49    | 0.53     | 1.00  | 1.00      | 0.27      | 0.37   |
| 2016 | 1.00    | 0.41  | 0.29     | 1.00     | 1.00    | 0.49    | 0.54     | 1.00  | 1.00      | 0.27      | 0.43   |
4. Analysis on the factors influencing the efficiency of marine green economy efficiency

4.1. Selection of influencing factors and model setting of marine green economy efficiency

The rationalization of marine industrial structure can not only show the coordination degree of marine industry, but also show the reasonable utilization degree of marine resources. With the transfer of marine production factors from low productivity to high productivity in marine industries, the marine industrial structure tends to be rationalized, the utilization rate of marine resources is greatly improved, the pollution of the ocean is constantly reduced, and the marine green economy efficiency is enhanced; Investment in marine pollution control can slow down the deterioration of marine resources, but there are different views on whether it can improve the sustainability of marine resources; Under other conditions unchanged, advanced marine science and technology can improve the production efficiency of various industries, enhance the added value of products and services, and enhance the sustainable development ability of marine economy.

Therefore, in the comprehensive consideration of the above situation, this paper chooses marine green economic efficiency \(Y\) as the dependent variable to measure the sustainable development ability of marine economy in China’s coastal provinces (cities, districts); chooses marine industrial structure \(X_1\), marine environmental regulations \(X_2\) and the level of marine science and technology \(X_3\) as explained variable to study the factors affecting the sustainable development of the marine economy. The structure of the marine industry \(X_1\) is expressed by the proportion of the gross output of the marine tertiary industry in the gross marine production. Marine environmental regulation \(X_2\) is measured by investment in marine environmental industrial pollution control. The level of marine science and technology \(X_3\) is measured by the number of patents accepted by marine scientific research institutions.

After calculating the marine green economy efficiency, this paper explores the factors that affect the marine green economy efficiency. Since the efficiency score calculated in the previous article is between 0 and 1, the data type is merged data. If the least squares method is used to explore the factors affecting the marine green economy efficiency, the results will be biased. Therefore, this paper uses the Tobit model to construct a regression model. The model is as follows:

\[ Y_{it} = \beta_0 + \beta_1 X_{1it} + \beta_2 X_{2it} + \beta_3 \ln X_{3it} + \varepsilon_t \]  

(3)

Where \(\beta_0\) represents a constant; \(\beta_1-\beta_3\) respectively represents the parameter value of each variable; \(\varepsilon_t\) represents the error term. According to this model, this paper uses STATA16.0 for empirical analysis, and the empirical results are shown in Table 2.

Table 2. Regression analysis on influencing factors of marine green economy efficiency in coastal provinces.

| \(Y\) | Coef. | \(P > |t|\) | [95% Conf.] | Interval |
|---|---|---|---|---|
| \(X_1\) | 0.0167 | 0.0050 | 0.0052 | 0.282 |
| \(X_2\) | -0.0034 | 0.2530 | -0.0092 | 0.0024 |
| \(X_3\) | 0.1541 | 0.0000 | 0.1060 | 0.2022 |
| _cons | 0.2392 | 0.0180 | 0.0417 | 0.4366 |
| var(e.Y) | 0.1529 | 0.0180 | 0.1012 | 0.2311 |

4.2. An empirical analysis of the factors influencing the marine green efficiency economy

According to the empirical results:

(1) Marine industrial structure has a significant positive impact on marine green economy efficiency, and its estimated value of the parameter is 0.0167. This shows that reasonable marine industrial structure can improve the sustainable development ability of marine economy, but its driving force is relatively weak. The possible reasons are as follows. with the continuous development of marine industrial structure adjustment and the continuous optimization of marine industrial structure, 11 coastal provinces (cities, districts) in China have basically achieved the “3 2 1” industrial structure, and their influence on the sustainable development ability of marine economy has gradually weakened.
(2) Environmental regulation tools have a negative impact on marine green economy efficiency. The estimated value of the parameter is -0.0034, but the estimated result does not pass the significance test. This shows that the negative effect of environmental regulation tools on the sustainable development ability of marine economy is not significant. Even so, the empirical results show that the estimated value of the parameter is negative, which indicates that the marine economy development mode of "pollution before treatment" is not desirable, which is not conducive to the sustainable development ability of marine economy.

(3) The scientific and technological level of marine industry has a significant positive impact on marine green economy efficiency, the estimated value of the parameter is 0.1541. This shows that advanced marine science and technology can improve the sustainable development ability of marine economy. This proves that the advanced marine science and technology can improve the production efficiency of marine industry, that is, to obtain more output with less input of resources and more green production mode.

5. Conclusion and Enlightenment

5.1. Conclusion
Based on the resource input index constructed by entropy method, this paper uses the SBM-DEA model of undesirable output to evaluate the marine green economy efficiency of 11 coastal provinces (cities and districts) from year 2006 to 2016. Tobit regression model is established to analyze its influencing factors. the main conclusions are as follows:

(1) The sustainable development ability of marine economy of 11 coastal provinces (cities and districts) can be divided into four levels: Tianjin, Guangdong, Shandong, Shanghai and Jiangsu are of highest level, and the input and output are in the ideal state; Zhejiang and Fujian are in the high level; Liaoning and Hebei are in the median level; Guangxi and Hainan are in the low level.

(2) Marine industrial structure has a significant positive impact on marine green economy efficiency. However, its driving force to marine green economy efficiency is relatively weak, the estimated value of the parameter is 0.0167. The scientific and technological level of marine industry has a significant positive impact on the marine green economy efficiency, with an estimated value of 0.1541. Environmental regulation tools have a negative impact on the marine green economy efficiency, but they have not passed the significance test.

5.2. Inspiration
According to the evaluation results of marine green economy efficiency and the analysis conclusions of its influencing factors, in terms of enhancing the sustainable development ability of marine economy, we get the following enlightenment:

At the theoretical level, this paper uses SBM-DEA model to evaluate marine green economy efficiency in coastal provinces, which not only improves the accuracy of efficiency evaluation, but also provides a case material for the existing theoretical research of efficiency evaluation and makes the existing theoretical research more abundant. Moreover, on the basis of the existing efficiency evaluation index system, this paper improves the resource input factors to make the results more in line with the definition of marine green economic efficiency.

At the practical level, through the empirical research on the influencing factors of marine green economy efficiency, it provides guidance for improving the sustainable development ability of China's marine economy in the future. First of all, scientific and technological innovation of marine economy is the main focus to improve the sustainable development ability of marine economy. In order to accelerate the transformation of marine industrial production from scale efficiency to technical efficiency and improve the sustainable development ability of marine economy, we should increase investment in marine science and technology innovation, create a good atmosphere for marine science and technology innovation. Then, we should develop low energy consumption and environment-friendly marine industry and eliminate backward and low value-added production capacity. We will promote the
adjustment of marine industry to a more advanced "three two one" industrial structure and develop coastal tourism services with higher added value. Finally, the marine environmental protection mode that pollution end treatment can not be an effective way to enhance the sustainable development of marine economy.

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