

Green finance and high-quality development of marine economy

Green finance

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Abstract

Purpose – With the Chinese marine economy developing rapidly, the environmental problem has been occurring frequently, which needs green finance that supports energy conservation, environmental protection, and sustainable development to solve.

Design/methodology/approach – In this paper, the entropy method is used to measure the development level of green finance, the DEA-ML index is used to measure the green total factor productivity which is used to indicate the high-quality development level of the marine economy in 11 coastal provinces (cities), then the grey correlation degree between them whose result shows that there is a certain correlation between the two variables is calculated. The fixed-effect model was used to analyze the relationship between them.

Findings – The results show that the development level of green finance can promote the high-quality development of the marine economy, but there are still some problems in the process of green finance supporting the marine economy.

Originality/value – This paper seeks new growth drivers, green finance, for the high-quality development of the marine economy, which few scholars have studied.

Keywords Green finance, High-quality development of the marine economy, DEA-ML, Fixed-effect model

Paper type Research paper

1. Introduction

In the past, the Chinese marine economy which plays an increasingly important role in the national economy has paid too much attention to the speed of development in the context of excessive dependence on the input of factors of production, for which the marine economy develops at the expense of resource and environment. Therefore, Wang *et al.* (2021b) pointed out that assessing the level of high-quality development of the Chinese marine economy, seeking new momentum for economic growth, has become the focal point of marine economy development at the present stage.

Green finance that conforms to the trend of green development to protect the environment will help drive the transformation of marine industrial structure, promote innovation in marine science and technology and raise people's awareness of environmental protection to transform the marine economy from high-speed to high-quality development raised by Yu *et al.* (2021). However, the complicated approval procedures, small financing amount of green finance contrary to the characteristics of large financing demand, and the long cycle in the marine industry become the obstacle that promotes high-quality marine economy

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development. In addition, [Xu et al. \(2019\)](#) indicated that marine industries account for only a small part of the industries supported by green finance because of the lack of green financial products related to the marine industry. So, it is important to study the relationship between green finance and the high-quality development of the marine economy while few scholars have studied the relationship between them.

Slightly different from other scholars, the green finance index system whose weight of specific indicators is determined by not only objective evaluation like the entropy method which [Liu et al. \(2021a\)](#) has used in their papers but also subjective assessment, such as expert scoring is established to measure the development level of green finance in coastal provinces in this paper. Meanwhile, the environmental pollution index is established to measure undesired outputs. When calculating the green total factor productivity, unlike other scholars who choose a single indicator, for example, [Lin et al. \(2021\)](#) and [Wu \(2018\)](#) used the quantities of industrial wastewater as unexpected output indicator to measure marine green total factor productivity.

In this paper, firstly, the relevant researches on green finance and high-quality development of marine economy are sorted out; secondly, method used in this paper, the entropy value method, DEA-ML index, the grey correlation analysis and the fixed-effect model, are introduced; then, relevant results are presented; at last, this paper looks into the future development of green finance and high-quality development of the marine economy, and puts forward relevant suggestions.

2. Literature review and mechanism analysis

2.1 Literature related to green finance

In the 1970s and 1990s, environmental problems arise for the rapid development of developed countries. With finance support for environmental protection arousing widespread concern, environment finance, another name of green finance, appeared. Scholars claimed that the purpose of green finance was to achieve environmental protection and sustainable economic development. With analyzing from finance institutions, green finance is considered as a behavior of financial institutions to reduce environmental risk and promote environmental quality. After the promulgation of the Equator Principles in 2003 and worldwide climate problems, green finance has taken off. Scholars turned their attention to solving environmental pollution and the greenhouse effect for sustainable economic development.

In China, [Gao \(1998\)](#) discussed the connotation of green finance for the first time, he thought finance institutions could use green finance as a means for the coordinated development of the environment and economy. In the early days, green finance mainly concentrated on green credit, green bonds, green stock, green funds, green insurance, and so on. After the 18th CPC National Congress, Exploring the establishment of a green financial system has become a priority. [Wang et al. \(2021c\)](#) thought the construction of green finance index system has gradually become an important method to measure the development level of green finance. The entropy method is used by many scholars to determine the weight of each index; some scholars such as [Zeng et al. \(2014\)](#) also determine the weight subjectively according to the actual operation of each index. Both approaches have their limitations, as for the entropy evaluation method, individual indicators may be particularly heavy for uneven development between regions, reflecting the unreal situation. The other approach is too subjective. This paper combines these two methods to measure the development level of green finance.

2.2 Literature related to the high-quality development of marine economy

[Jiang et al. \(2014\)](#) indicated since the 1990s, the Chinese marine economy has developed rapidly and become one of the important pillars of the national economy. The report to the

19th CPC National Congress pointed out that maritime power should be built rapidly, and China has taken the most seriously to the marine economy. But in the process of marine economic development, [Luo et al. \(2014\)](#) considered that the seriously polluted marine environment, the shortage of marine resources, the unbalanced regional development, and other problem have been getting worse and worse. Under the requirement of high-quality economic transformation, it is important to seek indicators for evaluating high-quality marine development and new drivers. There are mainly two methods to evaluate the high-quality development level of the marine economy by combing existing papers. The first one is to establish an indicator system for high-quality development of the marine economy, which uses the entropy evaluation method or other methods to calculate the weight of each. However, different results will be generated for scholars choosing indicators through different focuses. The other one is to measure the marine green total factor productivity which is deemed to be the source of high-quality development. This paper chooses the second method to measure the high-quality development level of the Chinese marine economy, and a comprehensive index system of environmental constraints is established to measure the undesired output, unlike most existing papers which use one single indicator, for example, [Ren et al. \(2018\)](#) chose the volume of industrial wastewater discharged directly into the sea as undesirable output indicators.

2.3 Literature related to the relationship between finance and the high-quality development of marine economy

In the context of the current economic slowdown, [Dong \(2019\)](#) stated that new growth drivers should be sought and utilized to support the high-quality development transformation of the marine economy. Green finance, which could promote the high-quality development of the marine economy from many aspects, is one of them. [Zhu \(2018\)](#) thought green finance can promote the transformation and upgrading of marine industrial structures. Upgrading the marine industrial structure can reduce energy consumption and promote technological innovation, as the marine industry after transformation is mostly clean, and technical industries, which were pointed out by [Yang et al. \(2019\)](#). [Li and Gan \(2021\)](#) indicated that green finance can also promote international trade for higher quality products manufactured by marine enterprises after transformation, by which high-quality development of the marine economy can be actuated. [Liu et al. \(2021b\)](#) thought funds, an important factor of production, are reallocation from the high energy consumption marine industry to the green and energy-saving industry through green finance. Unlike the emerging marine industry, such as the marine biopharmaceutics industry belonging to the environmental protection industry, lots of energy is consumed in the process of development by the traditional marine industry, which is represented by the marine communications and transportation industry, fishery industry. More capital is given to emerging marine industries by green finance, promoting the transformation of traditional marine industries into emerging industries, which conform to the requirements of high-quality development of the marine economy.

Technological innovation in the marine industry could be promoted by green finance, which was thought by [Hong et al. \(2021\)](#). Green finance will provide funds for technological innovation in the marine industry, which alleviates the bottleneck problem of insufficient funds in the process of marine technology innovation. [Wang et al. \(2021a\)](#) indicated that the long cycle, the high cost, and the high risk are the three characteristics of the marine science and technology innovation, which make it difficult to get financing, leading to the contradiction between the supply and demand of funds. With the development of green finance, [Ling et al. \(2020\)](#) pointed out that money gradually flows into green finance, then financial institutions provide green financial products for marine enterprises, especially green credit that provides long-term funds for technological innovation. On the one hand, [Wu and Liu \(2021\)](#) indicated that technological innovation promotes the high-quality

development of the marine economy through the transformation of the traditional marine industry. Technological innovation in the marine industry makes the production process of enterprises more specialized. While improving labor productivity, the marine industry will be transformed from energy-consuming to technology-intensive. Breakthroughs and upgrades in marine technology stimulate new consumer demand and economic growth points, which fosters new marine industries. On the other hand, [Wu et al. \(2020\)](#) also thought that technological innovation in the marine industry directly promotes high-quality economic development. Endogenous growth theory holds that technological progress is the decisive factor of economic growth, which makes products more efficient, improves the quality of the workforce, and promotes the improvement of the management system to drive economic growth. Technological innovations in marine industries can be directly applied to production, improve productivity and reduce environmental pollution, promoting high-quality development of the marine economy.

With the support of government policy, funds scattered among individuals could be gathered by finance to generate green investment through floating interest rate, differentiated credit, or other methods, which supports the green marine project. In addition, [Peng and Zheng \(2021\)](#) pointed out that a green single is brought by green finance to the market. People pay more attention to the marine enterprises with green development when they invest, which gives these enterprises more opportunities. The green single also makes people establish the concept of energy conservation and environmental protection. It is shown below that the analysis figure of the mechanism of green finance promoting high-quality development of the marine economy (see [Figure 1](#)).

In order to verify the relationship between green finance and high-quality development of marine economy to move forward a single step, firstly, the grey correlation analysis which was considered by [Liu et al. \(2013\)](#) as a better model that needs less data, is used to study the relationship between the two. Then, the entity fixed-effect model is used to study the regression relationship between the two for the different development levels of marine economy in each coastal province which was pointed out by [Liu et al. \(2017\)](#).

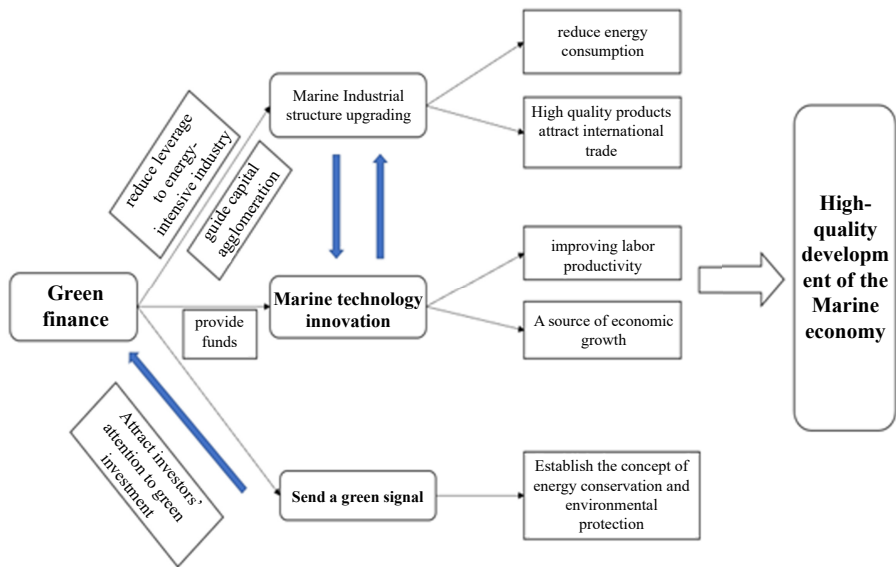


Figure 1.
Mechanism analysis
diagram

3. Methodology and data

3.1 Methodology

3.1.1 Entropy evaluation method. In this paper, the entropy method is used to confirm the green fiancé development level of 11 coastal provinces (cities). The entropy method, which is used to determine the weight coefficient according to the different degrees of each evaluation index, avoiding the interference of human factors and reflecting the importance of indicators in the comprehensive evaluation system objectively, belongs to the objective weighting method. In the entropy method, the greater the dispersion degree of data, the greater is the information entropy, which has a greater impact on comprehensive evaluation and greater weight. The obvious tendency and subjective judgment are overcome in the entropy method, which makes it widely used in various disciplines thought by [Xu et al. \(2018\)](#).

The procedures of the entropy method are described as follows,

Standardize the raw data, if the indicator is positive,

$$y_{ij} = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})}$$

If the indicator is negative,

$$y_{ij} = \frac{\max(x_{ij}) - x_{ij}}{\max(x_{ij}) - \min(x_{ij})}$$

Normalization processing,

$$y'_{ij} = \frac{y_{ij}}{\sum_{i=1}^n y_{ij}}$$

Avoiding to calculate $\ln$ affected by 0, add 0.1^{-8} to the calculated result,

$$z_{ij} = y'_{ij} + 0.1^{-8}$$

Calculate the index weight

$$\left\{ \begin{array}{l} k = \frac{1}{\ln m} \\ e_j = -k \sum_{i=1}^n z_{ij} (\ln z_{ij}) \\ g_j = 1 - e_j \\ w_j = \frac{g_j}{\sum_{j=1}^m g_j} \end{array} \right.$$

3.1.2 DEA-Malmquist index. Under the assumption that returns to scale are constant, Malmquist-Leuenberger (ML), proposed by Fare, is chosen by this paper to measure green total factor productivity (GTFP), representing the level of high-quality development of the marine economy. GTFP is divided into technical efficiency (Effch) which is divided into pure technical efficiency (Pech) and economics of scale (Sech), technical progress (Tech).

$$M_t = TFP = Effch \times Tech = (Pech \times Sech) \times Tech$$

$$\begin{aligned}
 Mt(x^{t+1}, y^{t+1}, x^t, y^t) &= \sqrt{\frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)}} \times \frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \\
 &= \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \times \sqrt{\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})}} \times \frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)} = Effch \times Tech
 \end{aligned}$$

(x^t, y^t) and (x^{t+1}, y^{t+1}) are t input and output vector at stage t and $t+1$ stage respectively; D^t and D^{t+1} are distance functions which use t and $t+1$ stage as technical reference.

3.1.3 Grey correlation analysis. After years of development, the grey correlation proposed by Chinese professor Julong Deng, which judges the degree of correlation by the degree of sequence correlation within the system between variables theory has become mature. The specific calculation process is as follows.

First, the reference sequence and comparison sequence should be clarified.

The reference sequence: $X_0 = \{X_0(1), X_0(2), \dots, X_0(n)\}$

The Compare sequence: $X_i = \{X_i(1), X_i(2), \dots, X_i(n)\}$

The standardized two sets of data using the methods of dividing by the average to avoid dimensional variance in estimation.

$$Y_i(n) = \frac{X_i(n)}{\frac{1}{K} \sum_{n=1}^K X_i(n)} \quad n = 1, 2, \dots, k; i = 1, 2, \dots$$

Then, calculate the difference between the reference sequence and the comparison sequence after being standardized.

$$\begin{aligned}
 \Delta_i(n) &= |Y_0(n) - Y_i(n)| \quad n = 1, 2, \dots, k; i = 1, 2, \dots \\
 \Delta_i &= (\Delta_i(1), \Delta_i(2), \dots, \Delta_i(n)) \quad i = 1, 2, \dots
 \end{aligned}$$

Finally, the correlation coefficient and correlation degree are calculated.

$$\varepsilon_i(k) = \frac{\min\{\min|X_0(k) - X_i(k)|\} + \rho \cdot \max\{\max|X_0(k) - X_i(k)|\}}{|X_0(k) - X_i(k)| + \rho \cdot \max\{\max|X_0(k) - X_i(k)|\}}$$

Among them, $\rho = 0.5$

The grey correlation degree is. $Y_i = \frac{1}{n} \sum_{k=1}^n \varepsilon_i(k)$

3.1.4 Entity fixed-effect model. In general, the panel data model can be written in the following form.

$$y_{it} = \alpha_{it} + \beta_{it}X_{it} + u_{it}, \quad i = 1, 2, \dots, N, \quad t = 1, 2, \dots, T$$

If the intercept term of the model only varies with the cross-section, rather than time, this model is called the entity fixed-effects model. It is the basic assumption of the entity fixed-effect model that $E(u_{it}|\alpha_i, X_{it}) = 0$, $i = 1, 2, \dots, N$. The entity fixed effects model can be expressed in the following form.

$$y_{it} = \alpha_i + \beta_{it}X_{it} + u_{it}, \quad i = 1, 2, \dots, N, \quad t = 1, 2, \dots, T$$

In the above model, y_{it} is the explained variable, α_i is the intercept term whose number is equal to cross-section, and u_{it} is the stochastic error term.

3.2 Data

3.2.1 Selection of green finance indicators. By referring to research of relevant scholars, green finance mainly includes four aspects: green credit, green securities, green insurance, and green investment. Relevant data come from China Industrial Statistics Yearbook and Insurance Yearbook and Wind database.

- (1) *Green credit*: There are two three-level indicators, the proportion of green credit and the proportion of interest expenditure of high energy consumption and high pollution industries. On the one hand, bank credit can positively support, while restraining the development of energy-intensive industries. On the other hand, contrarian indicators also need to be considered. Because of the lack of loan disclosure information on high energy consumption and high pollution industries, the proportion of interest expenditure of these two industries is chosen as one of the indicators of green credit.
- (2) *Green securities*: The proportion of the total market value of environmental protection enterprises in the total market value of regional stocks is selected to measure the index, which reflects the financing situation of environmental protection enterprises in the market.
- (3) *Green insurance*: The green insurance index includes the Proportion of agricultural insurance scale referring to the proportion of environmental liability insurance income, and the agricultural insurance loss rate referring to the ratio of agricultural insurance expenditure to income. China has introduced corporate environmental liability insurance since 2013, so systematic statistics are lacking. The development of green insurance can be replaced by agricultural insurance data, because of the deep relationship between agriculture and the natural environment.
- (4) *Green investment*: The green investment includes government spending on environmental protection and investment in environmental governance as a percentage of GDP.

To sum up, the established index system is shown in the following [Table 1](#).

3.2.2 Selection of DEA-ML index indicators. First, input and output indicators need to be identified. Labor and capital are sources of economic growth, which is claimed by neoclassical economics. This paper chooses ocean-related employed personnel and marine capital stock which were calculated by using the following formula referring to [Zhang \(2004\)](#) and [Ding and Zhu \(2015\)](#) as input indicators.

$$K_t = (1 - \delta)k_{t-1} + I_t/p_t$$

$$kt' = GOP/GDP \times k_t$$

Level 1 indicators	Level 2 indicators	Level 3 indicators
Green finance indicator system	Green credit	The proportion of green credit The proportion of interest expenditure on high energy consumption and high pollution industries
	Green securities	The proportion of the total market value of environmental protection enterprises
	Green insurance	The proportion of agricultural insurance scale The agricultural insurance loss rate
	Green investment	The proportion of government spending on environmental protection
		The proportion of investment in environmental governance

Table 1.
The green finance indicator system

Energy consumption which uses provincial data multiplied by the ratio of GOP to GDP is taken as an input index unlike other scholars choosing science and technology input index. Output indicators are divided into desirable output and undesirable output. Gross ocean production which is adjusted by price indices, is chosen as the desired output. A comprehensive index system of undesired output that contains industrial waste gas, effluents and solid waste is established. Specific indicators are listed in the following table, and then the entropy method introduced above was used for evaluation. The data of input, desirable output, and undesirable output come from China Marine Statistical Yearbook and China Environmental Statistics Yearbook (see [Table 2](#)).

3.2.3 Variable selection of grey correlation analysis. This paper uses GTFP which is measured by DEA-ML, representing the development of high-quality development of the marine economy and the level of green finance development which is obtained by the entropy method above to perform grey correlation analysis.

3.2.4 Variable selection of fixed-effect regression. GTFP is selected as an explained variable, and the level of green finance development is used as a core explanatory variable. After reviewing other scholars' research, it is found that GTFP is also affected by the level of foreign direct investment (fdi), degree of openness (ope), and degree of affluence of residents (yd). So these three variables, measured by the ratio of foreign direct investment to GDP, the ratio of total exports to GDP, and the disposable income of urban residents, are selected as control variables. This paper constructs the following regression equation, which takes the natural logarithm of all the variables to alleviate the impact of heteroscedasticity on the estimation results.

$$\ln GTFP_{it} = u_i + \beta_1 \ln gre_{it} + \beta_2 \ln fdi_{it} + \beta_3 \ln y_d + \beta_4 \ln ope_{it} + e_{it}$$

4. The results

4.1 The result of the entropy evaluation method

After calculation, the weight of each indicator is shown in the following [Table 3](#) Weight 1.

Due to the data on green insurance varies greatly in time and space, green insurance accounts for a larger proportion, which is not consistent with the fact that green insurance develops slowly. In this paper, the subjective method is used to reconfirm the weight of indicators. The weight of green credit, green securities, green investment, and green insurance respectively are 50%, 15%, 10%, 15%, and evenly distributed within the secondary index referring to the research of relevant scholar [Zeng et al. \(2014\)](#). By averaging the weights obtained by the two methods, the heaviest weight can be obtained. The final results are shown in the following [Table 3](#) Weight 2.

The development level of green finance in each region each year can be got by multiplying the normalized y'_{ij} by the weights in the table above. Then, replace individual outliers by trend function and draw the development level of green finance in each province each year on a map.

Composite indicator	Level 1 indicators	Level 2 indicators
Input indicators	Labor Capital	ocean-related employed personnel marine capital stock
Desirable output indicators	energy consumption gross ocean production	Total energy consumption GOP
Undesirable output indicators	Pollution index	industrial waste gas industrial effluents industrial waste gas (CO ₂ , SO ₂ , and dust)

Table 2.
The input and output
indicator

Table 3.
The green finance
index system and
weight

Level 1 indicators	Level 2 indicators	Level 3 indicators	Weight 1	Weight 2
Green finance indicator system	Green credit	The proportion of green credit	0.0221	0.136
		The proportion of interest expenditure of high energy consumption and high pollution industries	0.0495	0.1497
	Green securities	The proportion of the total market value of environmental protection enterprises	0.037	0.0938
	Green insurance	The proportion of agricultural insurance scale	0.0301	0.065
		The agricultural insurance loss rate	0.0279	0.0639
	Green investment	The proportion of government spending on environmental protection	0.4577	0.2663
		The proportion of investment in environmental governance	0.3747	0.2248

The following conclusions can be drawn from the above Figure 2, (1) The development level of green finance in 11 coastal provinces shows an obvious wave-like uplift trend, Especially Shanghai, Guangdong, and Liaoning rising faster. (2) In 2008, the development of green finance in different regions is unbalanced. Jiangsu is at the peak of its development in the past decade for balanced development and higher green insurance. But in 2009, its level falls sharply for the decline in expenditure on energy conservation and environmental protection. Tianjin was at its lowest level for nearly a decade, and then it grows quickly. (3) In 2018, all coastal provinces (cities) have a high level of green finance development that is almost the highest over the past decade. Green finance in Hebei has been well developed, while Tianjin and Fujian are on the low side.

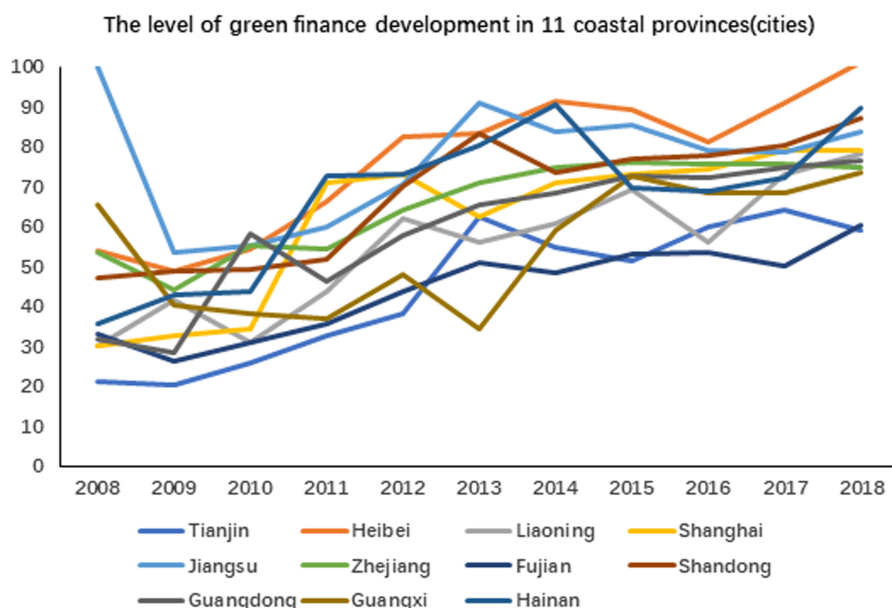


Figure 2.
Time series plot of
green finance

4.2 The result of the DEA-ML index

The GTFP is calculated by MAX DEA software and drawn on a graph. When GTFP is greater than 1, it indicates that the high-quality development level of the marine economy has improved compared with last year. On the contrary, it indicates a decline in the level of development.

The following conclusions can be drawn from the above Figure 3, (1) From 2008 to 2018, the high-quality development level of the Tianjin marine economy has been rising for proper environmental governance. (2) The development level of Hebei province is poor, especially from 2008 to 2013 perhaps because of the undesired increase in output during development. (3) In 2008, Only Tianjin improves over last year, while other provinces are down from last year, Especially Hainan province. (3) In 2018, except for Liaoning province seeing a slight decline, the development levels of other provinces improve. With the implementation of green finance policies, the marine green total factor productivity of all provinces is basically greater than 1, which means the level of marine economic development has improved from 2013.

4.3 The result of the grey correlations

The grey correlations between green finance and marine high-quality development which are shown in the following Table 4 are calculated by the above formula in 11 coastal provinces (cities).

As can be seen from the results in Table 4 above, the data of the grey correlation degree of 11 coastal provinces (cities) is basically greater than 0.6, at about 0.65, which shows that there is a certain correlation between green finance and the high-quality development of Marine economy. Hainan, Guangxi, and Tianjin have higher correlation degrees, while the correlation degree is low in Shanghai and Fujian.

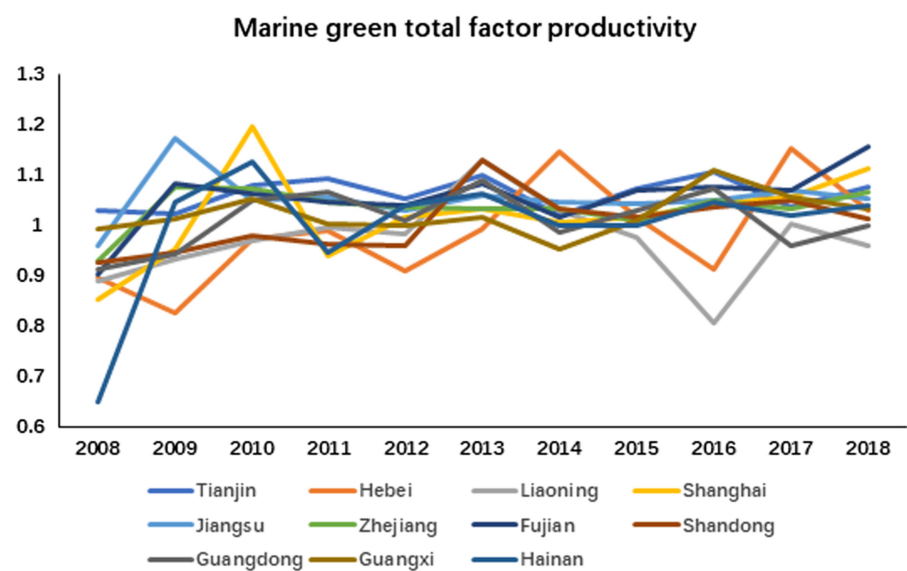


Figure 3.
Time series plot
of GTFP

Table 4.
The results of grey
correlation degree

Province	Tianjin	Hebei	Liaoning	Shanghai	Jiangsu	Hainan
Results	0.6908	0.6032	0.6168	0.5944	0.6535	0.7027
	Zhejiang	Fujian	Shandong	Guangdong	Guangxi	Average
	0.6463	0.5841	0.6847	0.6298	0.697	0.6458

4.4 The results of fixed-effect regression

4.4.1 The benchmark return. Based on panel data of 11 coastal provinces from 2008 to 2018, this paper uses stata15 for estimation and analysis and chooses the method of stepwise regression to avoid the effect of multicollinearity on the results. At the same time, the hypotheses that all data have the same variance were modified by using the robust command. The estimated results are shown in the following Table 5.

Judging from the regression results, as the control variables are added one by one, the core explanatory variable (gre), the level of green finance development, maintains a certain positive correlation with the explained variable (GTFP), high-quality development of the marine economy represented by green total factor productivity, while the significance declines. The value of DW is around 2, which indicates that residual sequences are unlikely to have sequence correlation. The value of the F statistic also rejects the null hypothesis that the independent variable of the equation is 0. In all overviews, it is suitable for the established regression which has guiding significance to the development of green finance and the marine economy.

The coefficient between the variables lnGTFP and lngre is positive from the above table, which is shown that green finance will promote the high-quality development of the marine economy as expected.

4.4.2 Stability test. This paper adopts the method of reducing sample data to make regression again which are selected from 11 coastal provinces randomly to test the stability, avoiding accidental factors for the erroneous conclusion. Besides, the data in the preceding part of the paper are winsorized and then regressed to eliminate estimation bias caused by outliers. The regression results are shown in the following table, Models 5 and 6 are the results of sample reduction, and Model 7 is the result of winsorization (see Table 6).

	FE(1)	FE(2)	FE(3)	FE(4)
lngre	0.0443** (2.27)	0.0301* (2.01)	0.0340* (2.01)	0.0306* (1.89)
lnyd		0.7618*** (3.40)	1.1147*** (3.60)	0.9475*** (3.84)
lnfdi			0.0469 (1.54)	0.0528* (1.88)
lnope				-0.0745*** (-4.92)
Intercept item	0.2081** (2.33)	-1.6266** (-2.93)	-2.1658*** (-3.58)	-1.8952*** (-3.70)
DW value	2.0475	2.1071	2.1578	2.1561
F statistic	5.15	13.77	6.96	11.19

Note(s): *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively. The numbers in parentheses are *t* values

Table 5.
The results of fixed-effect regression

	FE(5)	FE(6)	FE(7)
lngre	0.0476* (2.32)	0.0472* (1.97)	0.0293** (2.31)
lnyd	0.5599* (1.98)	1.0701** (3.10)	0.8866*** (3.91)
lnfdi	-0.0233 (-1.05)	0.0635 (1.07)	0.0563* (1.94)
lnope	-0.0445** (-2.33)	-0.0623** (-2.51)	-0.007*** (-3.37)
Intercept item	-1.279 (-1.80)	-2.0310** (-3.03)	-1.7118*** (-3.67)
DW value	1.742	2.1711	1.9502
F statistic	11.01	6.75	10.64

Note(s): *, **, and *** indicate significance at 10%, 5%, and 1% levels, respectively. The numbers in parentheses are *t* values

Table 6.
The results of the stability test

After processing the data, the sign and significance level of variable $\ln gre$ do not change significantly in the result of regression again, so this model which explains the relationship between green finance and high-quality development of the marine economy is basically stable.

5. Conclusion and outlook

5.1 Research conclusion

First, according to the grey correlation degree analysis, the grey correlation degree between green finance and GTFP at about 0.65 in 11 coastal provinces (cities), which can be considered preliminarily that there is a certain relation between green finance and high-quality development of the marine economy represented by GTFP. Hainan and Guangxi have the highest correlation probably because of smaller economies of scale for greater operational efficiency of green finance. Tianjin and Shandong followed while Shanghai and Fujian are at the bottom. May be marine industry is relatively small in the region's economic development; as a result, green finance does not support it enough.

In the empirical test, from the regression results, the regression coefficient of the core explanatory variable is 0.0306 and significant at the 10% level, which means that the development of green finance will promote the high-quality development of the marine economy. The coefficient of the variable gre is low, because it is small for the order of magnitude of green financial data obtained by the entropy method. With the addition of control variables, there was a slight decrease in the significance level of variable gre , it may be that the transmission mechanism of green finance to support high-quality development of the marine economy is not smooth enough. Marine industries are not the only ones, on the contrary, just a small part supported by green finance and there is no marine green finance product. It is complex to apply for green credit and the amount applied is small, which contraries the characteristics of the long cycle and a large amount of financing demand of Marine enterprises. In addition, the high-quality development of the marine economy has a certain substance. These reasons lead to that although green finance can promote the development of the marine economy, its significance level is low.

The coefficient of the control variable yd and fdi is positive, which means levels of affluence and foreign direct investment will promote the high-quality development of the marine economy in line with expectations, while the control variable ope expressed as the ratio of exports to GDP whose empirical result is contrary to expectations is expected to develop into a positive relationship with the high-quality of marine economy. In the early days, Chinese exports were dominated by low-technology, highly labor-intensive goods, then there were energy products such as coal, which do not lead to the upgrading of industrial structure, nor produce technological innovation, and the massive exploitation of fossil fuels can cause serious environmental problems. Although in recent years, Chinese export products have been transformed to be technical, a time lag exists in the development of the high-quality marine economy. These reasons restrict the high-quality development of the marine economy, leading to the negative intercept of the variable ope .

5.2 Suggestions

With China transforming from old growth drivers to new ones and the proposal of maritime power policy, green finance which promotes the high-quality development of marine economy from the above study, while the transmission mechanism between the two is not yet smooth, needs to be vigorously developed. This paper put forward the following suggestions for the current problems between green finance and marine economy development.

First, the roles of the government and financial institutions need to be fully played. The government should formulate reasonable, scientific, and effective policies, and strengthen

enforcement and supervision based on understanding the characteristics of the marine economy and the connotation of green finance. The government should direct the flow of funds through financial incentives and tax breaks to guide financial institutions to support the marine economy. The existing state-owned financial institutions should be specialized in the marine business, which leads their business to be separate from the traditional financial business and be connected with the marine economy. Strengthen international cooperation, actively carry out cooperation with international financial institutions, which guides international green financial funds to flow into the marine industry, and strives for high-quality capital supply from the international green bank, environmental fund, and other financial institutions.

Blue finance should be vigorously developed based on green finance market to solve the problem that only a small part of green finance supports marine industries. Blue bonds whose characteristics of long term, low redemption risk, and not changing the ownership structure of the enterprise can solve the financing problem of sea-related enterprises very well as an important tool of blue finance. In addition, attention should be paid to marine-themed investments, attracting more investors who have a long-term investment perspective to enter.

5.3 Outlook

Limited by the lack of marine data in the writing process, for some data, this paper has to use other methods instead. For example, ocean data are replaced by using provincial data multiplied by the ratio of GOP to GDP, which, to some extent, has led to a bias in estimation.

From the theoretical analysis, there may be an intermediary effect that is not significant in empirical tests probably because of the bias in data collection between green finance and the high-quality development of the marine economy. In the future, we will continue to collect more accurate data for further research.

With the gradual development of green finance, people pay more attention to the efficiency of development rather than the absolute amount of development. In the future, we will measure the efficiency of green finance development in 11 coastal provinces (cities) to study the impact of green finance development efficiency on marine economy transformation.

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Further reading

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