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Research Article

Empirical Analysis on the Correlation between Low-Carbon Economy and Marine Industry Development

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In order to analyze the correlation between the low-carbon economy and marine industry development, an empirical analysis method of the correlation between the low-carbon economy and marine industry development is proposed. The decomposition analysis method of marine industry carbon emission structure based on the input-output table is adopted to analyze China's marine industry carbon emission structure and obtain the influencing factors of marine industry carbon emission. The calculation method of total factor productivity of marine low-carbon economy is used to calculate the productivity of all influencing factors of a marine low-carbon economy and analyze the technical effect after the integrated development of low-carbon economy and marine industry. The panel data model is used to analyze the relationship between the transformation and upgrading of the marine industry and the development of the low-carbon economy. The empirical analysis results show that the sustainable development of marine low-carbon economy can only be realized by improving low-carbon technology, and the advanced degree of the marine industrial structure plays the greatest role in the marine low-carbon economy. The marine industry needs to optimize low-carbon technology and improve the advanced degree of industrial structure in order to realize the integrated development of a low-carbon economy and marine industry.

1. Introduction

When China's economic development speed increased, the problem of uneven supply and demand of land resources has gradually become prominent. One of the preconditions for the management of land resource shortage is the rational use of marine resources [1]. The ocean is the focus of global attention, and the competition of coastal countries for the commanding heights of the marine industry is also very fierce [2]. In 2012, after China put forward the strategy of becoming a maritime power, the development speed of the marine economy increased. In 2017, China's marine GDP exceeded 7 trillion yuan, accounting for more than 9% of GDP in 2017 and more than 16% of GDP in coastal areas. The marine economy has become an important blue engine in China's economic development process [3].

In 2016, China's traditional marine industries, such as marine oil and gas industry, fishery, and shipbuilding industry, slowed down, and their economic benefits deteriorated. In 2017, such traditional industries showed a state of restorative development, and the rapid development of marine emerging industries promoted the transformation and upgrading of marine industries [4].

At present, the new goal of China's marine economic development is to complete the green environmental protection and low carbon of the marine industry [5]. Coastal countries around the world follow the standards of resource conservation and environmental protection to develop the marine industry and abandon the extensive development model with serious traditional energy consumption [6]. Therefore, when China puts forward the concept of green development and the strategy of marine power, analyzing the correlation between a low-carbon economy and marine industry has practical significance for promoting the optimization of marine industrial structure [7].

Low carbon economy and low-carbon technology have become hot issues of global concern. China is a developing country with complex energy, industry, and trade structure and more greenhouse gas emissions [8]. With the advent of a low-carbon economy, China must pay attention to the integrated development of the marine industry and low-carbon economy.

Taking the correlation between low-carbon economy and marine industry development as the research content, this paper puts forward an empirical analysis method of the correlation between the low-carbon economy and marine industry development, which provides reference materials for the research on the correlation between the low-carbon economy and marine industry development.

2. Literature Review

At this stage, many scholars have studied the low-carbon economy with a view to the coordinated development of the low-carbon economy and various industries to improve economic benefits. Literature [9] studied the sustainable development process of low-carbon pilot cities, constructed 35 evaluation indicators based on the basic development level of the city and the development level of low-carbon cities, and used the entropy method to evaluate economic development, social progress, and environmental quality. The comprehensive analysis provides reference materials for the development of low-carbon cities, but this method is not comprehensive enough to analyze the relationship between a low-carbon economy and industry. Literature [10] analyzed the impact of energy price, technology, and disaster shocks on my country's energy environment and economic system and constructed a dynamic stochastic general equilibrium (DSGE) model to analyze the impact of energy price, technology, and disaster shocks on China's energy-environment-economy (3E) system impact. It also studies the stylized facts of the system, as well as cointegration and error correction dynamic analysis. The catastrophic shock is modeled as a two-state Markov switching process, but this method is not thorough enough to analyze the carbon emission results, resulting in ineffective analysis. Literature [11] discusses the impact of economic growth and trade openness on urbanization. Taking a large developing economy in India as an example, regression is used to simulate the impact of these variables on carbon emissions. The estimated coefficients of economic growth and energy consumption are positive, and significantly, sustainable and practical energy policies were explored, but the study did not forecast factors of production, leading to problems with the low accuracy of the research methodology. At present, most of the research on the low-carbon development of the economy by domestic and foreign researchers is mainly based on the low-carbon development model, and there are few studies on the correlation between the low-carbon economy and the development of the marine industry.

In response to the above problems, this paper deeply analyzes the correlation between the low-carbon economy and the development of the marine industry.

3. Empirical Analysis Method of Correlation between Low-Carbon Economy and Marine Industry Development

3.1. Decomposition Analysis Method of Carbon Emission Structure of Marine Industry Based on Input-Output Table. Based on the structural decomposition model of the input-output table, this paper decomposes the factors affecting carbon emissions of China's marine industry into direct carbon emissions, indirect carbon emissions, and carbon emissions of imported and exported products.

3.1.1. Decomposition Analysis of Direct Carbon Emission Structure. The calculation method of direct carbon emission is as follows:

$$P_1 = S \times F = [s_1 s_2 \cdots s_n] \times \begin{bmatrix} f_{11} & f_{12} & \cdots & f_{1m} \\ f_{21} & f_{22} & \cdots & f_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ f_{n1} & f_{n2} & \cdots & f_{nm} \end{bmatrix}, \quad (1)$$

in the publicity, S and F are the carbon emission coefficient matrix and energy consumption matrix of the marine industry in turn; $s_j \in s_n$ and $f_{ji} \in f_{nm}$ are the carbon emission coefficient of the j sector of the marine industry, followed by class I marine energy consumption of the j sector.

Use the Kaya deformation formula to decompose the structure of F, and the results are as follows:

$$F = FR \times \widehat{F}I \times \widehat{D}R \times Y, \quad (2)$$

in the formula, FR and $\widehat{F}I$ are the energy consumption structure matrix and energy intensity diagonal matrix of the marine industry in turn; $\widehat{D}R$ and Y is the diagonal matrix of marine industrial structure and the total output value of each department in the input-output table.

The decomposition method of direct carbon emission change is as follows:

$$\begin{aligned} \Delta P_1 = {} & \frac{1}{2} S \Delta Y \left(FR_0 * \widehat{F}I_0 * \widehat{D}R_0 + FR_1 * \widehat{F}I_1 * \widehat{D}R_1 \right) + \frac{1}{2} S \left(Y_1 * \Delta FR * \widehat{F}I_0 * \widehat{D}R_0 + Y_0 * \Delta FR * \widehat{F}I_1 * \widehat{D}R_1 \right) \\ & + \frac{1}{2} S \left(Y_1 * FR_1 * \Delta \widehat{F}I * \widehat{D}R_0 + Y_0 * \Delta FR_0 * \Delta \widehat{F}I * \widehat{D}R_1 \right) + \frac{1}{2} S \left(Y_0 * FR_0 * \Delta \widehat{F}I_0 + Y_1 * \Delta FR_0 * \Delta \widehat{F}I_0 \right) \widehat{D}R, \end{aligned} \quad (3)$$

in the formula, subscripts 0 and 1 represent the base period and reporting period, the same below. The total output effect is a; b. C is energy structure effect and energy intensity effect, respectively.

3.1.2. Decomposition Analysis of Indirect Carbon Emission Structure. The calculation method of indirect carbon emission is as follows:

$$P_2 = C' \times \widehat{Y} \times DJ, \quad (4)$$

where C' is the transposition of all consumption coefficients in the input-output table; DJ is the carbon emission intensity value.

The structural decomposition method of indirect carbon emissions is as follows:

$$\Delta P_2 = \frac{1}{2}\Delta C'\left(\widehat{Y}_1 * DJ_1 + Y_0 * DJ_0\right) + \frac{1}{2}\left(C_1' * \Delta Y * DJ_0 + C_0' * \Delta Y * DJ_1\right) + \frac{1}{2}\Delta\ DJ\left(C_1' * Y_1 + C_0' * Y_0\right). \quad (5)$$

Among them, the change in indirect carbon emission is $\Delta C'$; $\Delta\ DJ$ is the carbon emission intensity effect.

To sum up, the information on industry carbon emission components and influencing factors is shown in Table 1.

3.1.3. Decomposition Analysis of Carbon Emission Structure of Import and Export Products

(1) The calculation method of carbon emission of export products is as follows:

$$P_3 = H\ D\widehat{J} * FYR * HFY, \quad (6)$$

in the formula, $H\ D\widehat{J}$ is the diagonal matrix of complete carbon emission intensity of each sector; FYR is the column vector of export product structure of the marine industry, and HFY is the total export volume of the marine industry.

The decomposition formula of the change structure of export carbon emissions of the marine industry is as follows:

$$\Delta P_3 = \frac{1}{2}\Delta H\ D\widehat{J}\left(FYR_0 * HFY_0 + FYR_1 * HFY_1\right) + \frac{1}{2}\left(H\ D\widehat{J}_1 * \Delta FYR_0 * HFY_0 + H\ D\widehat{J}_0 * \Delta FYR_0 * HFY_1\right) + \frac{1}{2}\left(H\ D\widehat{J}_1 * FYR_1 + H\ D\widehat{J}_0 * FYR_0\right). \quad (7)$$

The complete carbon emission intensity is $\Delta H\ D\widehat{J}$; ΔFYR is the effect of the export product structure of the marine industry.

(2) The carbon emission calculation formula of imported products of the marine industry is as follows:

$$P_4 = H\ D\widehat{J} * JNR * HJN, \quad (8)$$

JNR and HJN is the column vector and import volume of imported products of marine industry.

The structural decomposition method of import carbon emission change is as follows:

$$\Delta P_4 = \frac{1}{2}\Delta H\ D\widehat{J}\left(JNR_0 * HJN_0 + JNR_1 * HJN_1\right) + \frac{1}{2}\left(H\ D\widehat{J}_1 * \Delta FYR * HJN_0 + H\ D\widehat{J}_0 * \Delta JNR * HJN_1\right) + \frac{1}{2}\left(H\ D\widehat{J}_1 * JNR_1 + H\ D\widehat{J}_0 * JNR_0\right)\Delta HJN. \quad (9)$$

The structure effect of imported products is ΔJNR.

The summary information of import and export factors is shown in Table 2.

3.2. Calculation of Total Factor Productivity of Marine Low-Carbon Economy. After analyzing the carbon emission structure of China's marine industry in Section 3.1, this section uses the measurement method of total factor productivity of the marine low-carbon economy. After the integrated development of the low-carbon economy and marine industry, the total factor productivity of marine low-carbon economy can reflect the technical structure after the integrated development of low-carbon economy and marine industry.

3.2.1. Research Methods. When evaluating the efficiency of marine low-carbon economy, in order to analyze the causes of productivity changes, the directional distance function is usually used to decompose the Malmquist-Luenberger productivity index into technical progress index and

Table 1: Information on industry carbon emission components and influencing factors.

Carbon emission type	Influencing factors (code)
Direct	Total output ($a1$)
	Energy-resource structure ($a2$)
	Energy intensity ($a3$)
	Industrial structure ($a4$)
Indirect	Complete consumption coefficient ($b1$)
	Sector output ($b2$)
	Carbon emission intensity ($b3$)

technical efficiency index so as to achieve the consistent change of "expected" output and "unexpected" output [12].

(1) Directional Distance Function. The core of the development of the marine low-carbon economy is to reduce carbon dioxide emissions (not belonging to the expected output) and increase marine economic benefits (belonging to the expected output) [13]. Undesired outputs can be described by directional distance function $\overline{E}_o$:

$$\overline{E}_o(H, Z, F, X, D; f) = \sup\{\alpha:\ (X, D) + \alpha f\}, \tag{10}$$

in the formula, H, Z, F, X, D and f are capital input, labor input, energy input, GDP, carbon dioxide emission, and direction vector in turn. The increase of X can increase the economic benefits of the marine industry, which belongs to the expected output. D is unexpected output; the bigger, the better. X and D all belong to outputs.

Table 2: Summary of import and export factors.

Carbon emission type	Influencing factors (code)
Export	Complete carbon emission intensity ($c1$)
	Export product structure ($c2$)
	Total exports ($c3$)
Import	Complete carbon emission intensity ($d1$)
	Structure of imported products ($d2$)
	Total imports ($d3$)

According to the variable size of unexpected parameters, the direction distance function must set the direction vector of difference. This paper analyzes the following two states:

State a: set the direction vector to $f = (X, 0)$ and do not analyze the role of unexpected output D. In this state, the binding force of carbon emission does not need to be analyzed.

State b: the direction vector is set to $f = (X, -D)$, and the unexpected output D has the characteristics of unexpected output. In this state, it is necessary to analyze the binding force of carbon emission.

If $\overline{E}_o$ value is 0, the production technology of the marine industry in this area is effective. Otherwise, the technology is invalid [14].

(2) Malmquist-Luenberger Productivity Index. Taking state B as an example, the productivity index is as follows:

$$\begin{aligned} N_t^{t+1} &= \left\{\frac{1+\overline{E}_o^t(H^t, Z^t, F^t, X^t, D^t; X^t, -D^t)}{1+\overline{E}_o^t(H^{t+1}, Z^{t+1}, F^{t+1}, X^{t+1}, D^{t+1}; X^{t+1}, -D^{t+1})} \times \frac{1+\overline{E}_o^{t+1}(H^t, Z^t, F^t, X^t, D^t; X^t, -D^t)}{1+\overline{E}_o^{t+1}(H^{t+1}, Z^{t+1}, F^{t+1}, X^{t+1}, D^{t+1}; X^{t+1}, -D^{t+1})}\right\}^{1/2} \\ &= \frac{1+\overline{E}_o^t(H^t, Z^t, F^t, X^t, D^t; X^t, -D^t)}{1+\overline{E}_o^t(H^{t+1}, Z^{t+1}, F^{t+1}, X^{t+1}, D^{t+1}; X^{t+1}, -D^{t+1})} \times \left\{\frac{1+\overline{E}_o^{t+1}(H^t, Z^t, F^t, X^t, D^t; X^t, -D^t)}{1+\overline{E}_o^t(H^t, Z^t, F^t, X^t, D^t; X^t, -D^t) \times \times \dfrac{1+\overline{E}_o^{t+1}(H^{t+1}, Z^{t+1}, F^{t+1}, X^{t+1}, D^{t+1}; X^{t+1}, -D^{t+1})}{1+\overline{E}_o^t(H^{t+1}, Z^{t+1}, F^{t+1}, X^{t+1}, D^{t+1}; X^{t+1}, -D^{t+1})}}\right\}^{1/2}, \end{aligned} \tag{11}$$

t stands for the period. Formula (2) is decomposed to obtain the technical efficiency index FE and technical progress index HF:

$$N_t^{t+1} = FE \times HF. \tag{12}$$

If the value of FE is greater than 1, the technical efficiency is higher, and if the value of FE is less than 1, the technical efficiency is lower. If the value of HF is greater than 1, the technological progress index is larger; if the value of HF is less than 1, the technological progress index is smaller.

3.2.2. Index Selection and Data Description. In order to fully evaluate the development of China's marine low-carbon economy, this paper uses the data of 11 coastal areas, Yangtze River Delta, Pearl River Delta, and Bohai Rim, from 2011 to 2020. The three input variables used in the empirical analysis are marine capital stock, marine employment, and marine economic energy consumption, and the two output variables are marine GDP and marine economic carbon emissions. The data are extracted from the China Ocean statistical yearbook.

(1) *Input Variable*

(a) Marine capital stock H

When calculating the total factor productivity of marine low-carbon economy, the paper adopts the capital factor input index. Because there is no statistical data on 14 coastal regions at present, this paper first calculates the overall implementation of each coastal region in China and then modifies the implementation of coastal regions according to the proportion of marine GDP in the GDP of coastal regions to obtain the final results.

(b) Labor input Z

Labor input is set as Z.

(c) Energy input F

Put F of marine economy in equation (10). Since energy consumption is one of the influencing factors of economic growth, its binding force is large. Because the energy consumption data of the marine economy cannot be extracted directly, according to the conversion coefficient of energy, this paper converts all kinds of energy in 14 coastal regions into standard coal to obtain the overall energy consumption of each region [15]. Finally, according to the proportion of marine GDP in the GDP of coastal areas, the needs F of the marine economy are calculated.

(2) *Output Variable*

(a) Gross marine product X

X of the coastal area belongs to the expected output, which can describe the marine economic output of each province in the coastal area [16].

(b) Carbon dioxide emissions D

The unexpected output in the development of marine economy in coastal areas is carbon dioxide emission D, which can describe the reduction value of ineffective loss of energy in the development of marine low-carbon economy [17]. Because the current carbon dioxide emission data of the marine economy is not in the statistical yearbook, this paper uses the Kaya equation to calculate D:

Table 3: Energy emissions coefficient.

Types of energy	Emission coefficient
Coal	0.7477
Petroleum	0.5826
Natural gas	0.4436
Hydropower and nuclear power	0

$$CO_2 = \frac{CO_2}{FM} \times \frac{FM}{G\,DP} \times \frac{G\,DP}{QOQ} \times QOQ = DC_i \times \widehat{F}I_i \times XY_i \times QP_i. \quad (13)$$

FM, $G\,DP$ and QOQ are primary energy consumption value, DC_i, $\widehat{F}I_i$, XY_i and QP_i are carbon dioxide emissions per unit of energy consumption, energy intensity, per capita GDP, and total population. Energy emission factors are shown in Table 3.

Because the influence of DC_i, $\widehat{F}I_i$, XY_i and QP_i on carbon dioxide emission is analyzed by calculus in the past, there will be an imbalance on both sides of the equation due to the influence of residuals. Therefore, this paper optimizes the Kaya equation and obtains the improved Kaya equation as follows:

$$\Delta CO_2 = \Delta CO_2(t) - \Delta CO_2(0) = DC_{af} + \widehat{F}I_{iaf} + XY_{af} + QP_{af}, \quad (14)$$

ΔCO_2 is the result of the overall change of carbon dioxide emissions after t years from year 0.

Such changes can continue to be decomposed into DC_{af}, $\widehat{F}I_{iaf}$, XY_{af} and QP_{af} which describe the action value of emission intensity effect, energy intensity effect, economic effect, and population effect.

(3) Decomposition of Total Factor Productivity of Marine Low-Carbon Economy. This paper assumes two kinds of situations: one is to calculate the total factor productivity HGQ of the conventional marine economy without analyzing carbon emissions and only analyzing the expected output. One is to analyze carbon emissions, set carbon dioxide as an unexpected output with weak disposability, and calculate the total factor productivity DHGQ in the marine low-carbon economy.

3.3. Correlation Analysis between Marine Industry Transformation and Upgrading and Low-Carbon Economy Based on Panel Data Model

3.3.1. Explained Variable Setting. Low carbon economy is inseparable from energy, but the development degree of a low-carbon economy cannot be judged simply by the total energy consumption [18]. In order to increase the persuasiveness of this analysis, this paper uses carbon emission intensity DJ as an index to judge the development degree of China's low-carbon economy. It can describe economic development and has significant practical economic significance. When DJ value is small, indicating that the emission per unit output is small and the economic development model is close to a low-carbon economy [19]. After calculating the coastal area ΔCO_2, the carbon emission intensity value can be obtained:

$$DJ = \frac{\Delta CO_2}{SK_{it}}, \quad (15)$$

SK_{it} is the real gross marine product.

3.3.2. Setting of Explanatory Variables. The explanatory variables are set as advanced marine industrial structure $E1$, rationality of marine industrial structure $E2$, and efficiency of marine industrial structure $E3$. When setting the detailed description mode of explanatory variables, this paper sets the natural logarithm $LnE1$, $LnE2$ and $LnE3$ of $E1$, $E2$ and $E3$ as the explanatory variable.

3.3.3. Model Construction. The model is constructed as follows:

$$DJ = \delta_1 LnE1 + \delta_2 LnE2 + \delta_3 LnE3 + \varepsilon_i + \gamma_{it}, \quad (16)$$

ε_i, γ_{it} is the unobservable effect and random error value. δ_1, δ_2 and δ_3 are the coefficients of $LnE1$, $LnE2$ and $LnE3$ in turn.

Carbon emission intensity is not only affected by the adjustment of marine industrial structure. In order to fully analyze the influence of other factors and take into account the subjectivity of the setting of control variables, equation (16) is optimized as follows:

$$DJ = \delta_1 LnE1 + \delta_2 LnE2 + \delta_3 LnE3 + \delta_4 (DJ \times LnE1) + \delta_5 (DJ \times LnE1) + \delta_6 (DJ \times LnE1) + \delta_7 DJ(-1)\varepsilon_i + \gamma_{it}, \quad (17)$$

δ_n is the coefficient of other factors.

3.3.4. Estimation Method Setting. When implementing the regression research of the panel data dynamic model, this paper uses the differential generalized moment estimation method to deal with the endogenous problem of the dynamic model and avoid the error of the fixed-effect estimator [20]. In this paper, the residual sequence obtained by estimation is detected by autocorrelation to judge whether the random error term has a second-order sequence correlation problem so as to evaluate the rationality of the result of differential generalized moment estimation [21].

4. Results

4.1. Decomposition Analysis Results of China's Carbon Emission Structure. The decomposition analysis results of the direct carbon emission structure of China's marine industry are shown in Table 4.

TABLE 4: Decomposition analysis results of direct carbon emission structure.

Influence factor	Contribution value (10000 tons of carbon)	Contribution rate (%)
*a*1	105627.25	286.7
*a*2	−2597.09	−6.86
*a*3	−48832.68	−128.9
*a*4	−16151.18	−48.7
Direct carbon emission change	37913.59	100

According to the data in the analysis table, the output and change of each department of the marine industry can promote the change in direct carbon emissions, with a contribution rate of 286.7%. The change of energy structure, energy intensity, and industrial structure can curb the change of direct carbon emissions of the marine industry, with a contribution rate of −6.86%, −128.9%, and −48.7%. Because of this, the output and drive of each department of the marine industry can lead to an increase in direct carbon emissions. The change in energy intensity and industrial structure can control the increase of carbon emissions. The energy consumption structure has no significant effect on the change in carbon emissions. The optimization of low-carbon energy technology and the increase of energy utilization can effectively control the direct carbon emission without increasing it. The adjustment of industrial structure is the core entrance to reducing the direct carbon emission.

The decomposition analysis results of indirect carbon emission structure of the marine industry are shown in Table 5.

According to the data in the analysis table, the changes in output effect and complete consumption coefficient effect of the marine industry sector can promote the changes in indirect carbon emission, with a contribution rate of 181.6% and 43.4%, and the contribution rate of carbon emission intensity effect is - 125.4%, which has a restraining effect. If the output effect and complete consumption coefficient effect of the marine industry sector become larger, the indirect carbon emission will become larger.

The change decomposition results of influencing factors of carbon emission from import and export products of the marine industry are shown in Tables 6 and 7.

It can be seen from Table 6 that the change in carbon emission intensity is the core factor among the influencing factors of carbon emission of marine industry export products, and its contribution rate is as high as 108.4%. The change in export product structure and total export volume has little effect on the carbon emission of marine industry export products. The utility of export product structure can promote the carbon emission of export products. If there are more export products, the carbon emissions will increase, and the total export effect of the marine industry does not promote the carbon emissions of export products.

According to the analysis of Table 7, the change in carbon emission intensity and the change in import structure of the marine industry have a positive effect on the carbon emission of imported products, with a contribution rate of 379% and 83.4%, respectively. The total import effect of the marine industry has a restraining effect on the carbon emission of imported products, with the contribution rate of −361.4%

4.2. Calculation Results of Total Factor Productivity of Marine Low-Carbon Economy. Table 8 shows the analysis results of HGQ and DHGQ indexes of the marine low-carbon economy.

Based on the analysis from the national perspective, without analyzing carbon emissions, the HGQ index of China's traditional marine economy is 1.046, representing the average annual growth of the HGQ index from 2011 to 2020 is 46%, and the contribution rate of technological progress is 6.0%. This shows that the HGQ index increases

Table 5: Decomposition analysis results of indirect carbon emission structure of the marine industry.

Influence factor	Contribution value (10000 tons of carbon)	Contribution rate (%)
*b*1	404408.6	181.6
*b*2	87272.9	43.4
*b*3	−245966	−125.4
Indirect carbon emission change	245716.5	100

Table 6: Decomposition results of influencing factors of carbon emission of marine industry export products.

Influence factor	Contribution value (10000 tons of carbon)	Contribution rate (%)
*c*1	−38499.6	108.4
*c*2	−13073.5	36.9
*c*3	16016.5	−46
Export carbon emission change	−35556.7	100

Table 7: Change decomposition results of influencing factors of carbon emission of imported products of the marine industry.

Influence factor	Contribution value (10000 tons of carbon)	Contribution rate (%)
*d*1	−35848.2	379
*d*2	−7895.6	83.4
*d*3	34260.4	−361.4
Import carbon emission change	−9482.8	100

Table 8: Analysis results of HGQ and DHGQ indexes of marine low-carbon economy.

Time	Do not analyze carbon emission constraints			Analyze carbon emission constraints		
	HGQ	FE	HF	DHGQ	FE	HF
2011~2012	1.030	0.989	1.043	1.032	1.002	1.073
2012~2013	1.079	1.020	1.059	1.040	1.009	1.031
2013~2014	1.090	0.936	1.165	1.070	0.997	1.023
2014~2015	1.085	1.024	1.060	1.064	1.004	1.065
2015~2016	1.038	0.984	1.056	1.040	0.999	1.061
2016~2017	1.060	0.991	1.071	1.012	0.992	1.042
2017~2018	0.984	0.962	1.024	0.958	0.991	1.021
2018~2019	1.074	0.994	1.081	1.045	1.006	0.968
2019~2020	0.974	0.989	0.986	0.931	1.005	0.928
Mean value	1.046	0.988	1.060	1.021	1.000	1.024

mainly due to the increase in the technological progress rate.

Under the condition of analyzing carbon emissions, the average annual growth of the DHGQ index from 2011 to 2020 is 1.021, which is less than the HGQ index without analyzing carbon emissions, which means that the calculation results of the traditional HGQ index are not in line with the actual marine economic efficiency. In the DHGQ index, the contribution rate of the technological progress index is 2.4%. Therefore, after analyzing the carbon emission conditions, the contribution rate of the technological progress index decreases rapidly, so in the low-carbon economy, the contribution rate of the technological progress index decreases, and the technology needs to be optimized.

Table 9 shows the decomposition results of total factor productivity of marine low-carbon economy in coastal areas.

Based on the analysis from the regional perspective, the HGQ index of coastal areas except Liaoning has positive growth (the index is greater than 1) without analyzing carbon emissions. Under the condition of analyzing carbon emission, the provinces with negative growth of DHGQ index (index less than 1) are Liaoning, Hebei, Shandong, Guangxi, and Bohai Rim. The marine industrial structure of such provinces has obvious “2, 3, and 1” structural characteristics and the high-carbon consumption level of marine chemical industry and coastal industry in the secondary industry is high, which obviously interferes with the development of marine low-carbon economy in their respective provinces. After analyzing the carbon emission conditions, the total factor productivity of the marine low-carbon economy in Jiangsu Province becomes smaller and larger, which means that the cost of resources and the environment becomes more, and the growth rate of technological progress and technical efficiency also becomes significantly smaller during the economic development of Jiangsu Province. The increase in total factor productivity of the marine low-carbon economy in Zhejiang and Guangdong is mainly due to the synchronous growth of technical efficiency and technological progress. However, the technological changes in Tianjin and Fujian are small because the growth rate of technological progress is also lower. The increase in the total factor productivity of the marine low-carbon economy in Shanghai is more obvious. The total factor productivity of the marine low-carbon economy in the Bohai Rim region has negative growth. After analyzing the carbon emission constraints, there is no obvious difference in the change in technical efficiency in each province and city, but the change in the technological progress index is more significant in Hebei, Shandong, and Hainan. Without analyzing the constraints of carbon emissions, the technological progress index is not less than 1, but under the constraints of carbon emissions, the technological progress index is not more than 1, which means that there is no increase but a decrease in cutting-edge technologies. The governments of such provinces must pay attention to this problem and improve low-carbon technologies in order to realize the sustainable development of the marine low-carbon economy.

4.3. Results of Correlation Analysis between Transformation and Upgrading of Marine Industry and Low-Carbon Economy

4.3.1. Stability Test and Cointegration Test of Panel Data. Before regression analysis, the unit root test is performed on the panel data through the unit root test method and the PP Fisher test method. This operation can prevent the

Table 9: Decomposition results of total factor productivity of marine low-carbon economy in coastal 14 areas.

Region	Do not analyze carbon emission constraints			Analyze carbon emission constraints		
	HGQ	FE	HF	DHGQ	FE	HF
Tianjin	1.056	0.986	1.072	1.035	0.996	1.040
Hebei	1.009	0.972	1.039	0.995	1.016	0.981
Liaoning	0.992	0.938	1.058	0.945	0.996	0.950
Shanghai	1.104	1.001	1.104	1.080	1.001	1.080
Jiangsu	1.075	1.003	1.072	1.032	1.001	1.032
Zhejiang	1.049	1.000	1.030	1.050	1.007	1.044
Fujian	1.044	0.987	1.058	1.029	0.990	1.040
Shandong	1.022	0.976	1.048	0.991	1.001	0.991
Guangdong	1.045	1.002	1.053	1.049	1.002	1.068
Guangxi	1.013	0.974	1.041	0.992	0.981	1.012
Hainan	1.055	1.014	1.040	1.012	1.013	0.998
Changjiang delta	1.086	1.005	1.082	1.054	1.003	1.048
Pearl river delta	1.042	0.994	1.048	1.030	0.997	1.012
Circum Bohai sea	1.020	0.968	1.054	0.992	1.002	0.998
Mean value	1.047	0.988	1.060	1.020	1.000	1.020

occurrence of pseudoregression problems. The test results are shown in Table 10.

In Table 10, DJ, LnE1, LnE2, and LnE3 all belong to zero order single integration and meet the cointegration test standard.

The panel cointegration test was performed using the Kao test method, and the results are shown in Table 11.

In Table 11, there is no abnormality in the cointegration test of DJ, LnE1, LnE2, and LnE3.

4.3.2. Regression Result Analysis. Table 12 shows the regression results of the impact of marine industrial structure adjustment on a low-carbon economy.

In Table 12, model 1 is a static model, and only the regression results of LnE1, LnE2, and LnE3 are given. According to the Hausman test results, the fixed-effect model is selected for regression analysis. In order to judge the stability of model 1, model 2 introduces control variables and AR model. Model 3 is a dynamic model. According to the exogenous test results, the use of tool variables is effective. According to the autocorrelation test results of residual sequence in Table 13, the difference in generalized moment estimation does not reject the original hypothesis and meets the consistency condition, so the result of the difference generalized moment estimation is reasonable.

The regression results show that the explanatory variables are different in the static model and dynamic model, which indicates that the adjustment of China's marine industrial structure has an impact on the low-carbon development of the marine economy to a certain extent. LnE1, LnE2, LnE3, and DJ all have a negative correlation, which means that the more significant the efficiency and efficiency level of marine industrial structure, the lower the carbon emission intensity. The higher the development level of marine industrial structure, the faster the development of marine service industry and high-tech industry, which

Table 10: Unit root test.

Variable	Unit root test	PP Fisher test	Stable?
DJ	0.0000	0.0002	Yes
LnE1	0.0000	0.0000	Yes
LnE2	0.0000	0.0004	Yes
LnE3	0.0458	0.0000	Yes

Table 11: Panel cointegration test results.

Inspection method	Unit root
T statistic	−2.638
P value	0.0043

improves the level of economic development, the proportion of low-energy consumption industry, and the development of the low-carbon economy. Due to the improvement of scientific and technological level, the advanced level of machinery and equipment has also been improved. Under these conditions, the social labor productivity increases, the resource allocation efficiency of the marine industry increases, and the industrial resources will develop into high-efficiency departments in low-efficiency departments. Energy resources belong to industrial resources, and the utilization rate of energy resources can also be increased.

LnE2 and DJ have a positive correlation, which means that the greater the rationality of marine industrial structure, the smaller the carbon emission intensity, which has a positive impact on the development of a low-carbon economy. China's resource consumption is large, and the traditional extensive development model of the marine economy has not been completely abandoned. In the energy consumption of the marine industry, traditional energy accounts for a large proportion. Even though our government has used many methods to reduce the pressure of carbon emission, the total amount of carbon emission continues to increase. Therefore, while ensuring the stable growth of the marine economy, high-tech industries with low-energy consumption also need to develop rapidly, reduce carbon emissions and complete the development of a low-carbon economy.

By analyzing the values of LnE1, LnE2, and LnE3-coefficients, it can be seen that in the static model, the efficiency of marine industrial structure has a positive effect on carbon emission intensity. In the dynamic model, the efficiency of the industrial structure has a significant positive effect on carbon emission intensity. The "3, 2, 1" structure of the marine industry is more suitable for the development of the low-carbon economy.

By analyzing the meaning of LnE1, LnE2, and LnE3 coefficients, it can be seen that the elastic coefficients of the advanced, reasonable, and efficient level of marine industrial structure on carbon emission intensity are 1.019, 0.796, and 0.842, respectively. When the advanced level of marine industrial structure increases by 1%, the carbon emission intensity decreases by 1.019 units, and when the rationality level of marine industrial structure increases by 1%, the carbon emission level decreases by 0.842 units. Then the high-level degree of marine industrial structure has the most

Table 12: Regression results of the impact of marine industrial structure adjustment on low-carbon economy.

Explanatory variable	Model 1	Model 2	Model 3
D	4.663*** (0.27)	2.599*** (0.178)	
LnE1	−0.656*** (0.098)	−0.248*** (0.088)	−1.019*** (0.287)
LnE2	0.225*** (0.082)	0.494*** (0.058)	0.796** (0.322)
LnE3	−0.662*** (0.082)	−0.566*** (0.067)	−0.842*** (0.206)
DJ ∗ LnE1		0.126*** (0.037)	0.363*** (0.182)
DJ ∗ LnE2		−0.215** (0.033)	−0.247*** (0.093)
DJ ∗ LnE3		0.198*** (0.022)	0.174* (0.092)
AR(1)		0.951 (0.001)	
AR(2)		−0.164(0.112)	
DJ(−2)			0.137* (0.074)
Exogenous test observations	89	67	67

Note: ***, **, and * describe the inspection degree of 1%, 5%, and 10% in turn, with significance. The values in the brackets of regression coefficient belong to standard error, and the values in the brackets of AR and Sagan test results are p values.

significant interference on the low-carbon economy, the second significant degree of rationality of marine industrial structure, and the least obvious effect of high-efficiency of marine industrial structure.

Table 13: Autocorrelation test results of residual series.

Variable	AR(1)	AR(2)
Coefficient	1.843	8.248
Prob.	0.0656	0.0000

5. Discussion

Under the influence of a marine low-carbon economy, China needs to keep pace with the times. Under the development mode of a low-carbon economy, we should set up appropriate strategies, give full play to our advantages, and achieve rapid economic development and low-carbon integration. Moreover, "low-carbon" must be placed in the national development strategy. It is necessary to set the marine low-carbon economy as the strategic core and balance the development of sea and land. In the existing research, all focus on the marine industry, analyze the structure of the industry, the enterprise level, the product level, etc., and the analysis of the low-carbon economy is not deep enough, which leads to limitations in the conclusions drawn by the research. For example, the research mainly focuses on relevant theories. In terms of the analysis of China's marine economy and the discussion of the low-carbon development model of the marine economy, there are few studies on the correlation between the marine industry and the low-carbon level of the marine economy. Quantitative analysis of the contribution rate of the marine industry to economic growth, using grey correlation analysis method to measure and empirically analyze the low carbonization level of marine industry clusters and marine economy. There is less analysis of the carbon economy. Compared with the existing research, the research in this paper is more comprehensive and specific, and it has carried out an in-depth analysis of the low-carbon economy, and at the same time, it has given specific development suggestions. Specific recommendations are as follows:

(1) With the goal of sustainable development and under the construction of marine low-carbon civilization, the overall planning of sea and land will be set as the development path. In detail, we need to set the scientific outlook on development as the value core of marine low-carbon economic development, take sustainable development as the goal, and realize the integrated development of the sea and land economy. The ocean and path are inseparable. The overall planning of sea and land is mainly to realize the unified planning of sea and land industrial development, sea and land infrastructure construction, sea and land environmental management, and the allocation of sea and land production factors.

(2) Set China's basic national policies as resource conservation and environmental protection. Under the guidance of the development objectives of China's marine development plan, set up the development strategy of marine low-carbon economy, and take the development of the marine low-carbon economy as one of the hot issues concerned by the country. Based on the perspective of sustainable development, we should set up the development path of a marine low-carbon economy and obtain the path of combining a low-carbon economy with a national development strategy.

(3) We will focus on energy conservation and emission reduction in the development of a marine low-carbon economy and include the development and use of Shanghai Ocean renewable resources in China's marine energy development and construction plan. The last resource treasure house of the Earth is the ocean. Based on the analysis of technical and economic feasibility, tidal energy in marine energy can obtain very valuable returns through mature technology. Both marine wind energy and tidal energy are very important.

(4) Establish a marine low-carbon economy demonstration area. In order to promote the development of a marine low-carbon economy, a marine low-carbon economy demonstration zone can be established so as to further adjust industrial structure

and optimize the economic development model. We should also strengthen the management of pollutants discharged into the sea, protect marine ecological security, and realize the double progress of marine environmental protection and economic development under the influence of marine low-carbon economy demonstration areas.

6. Conclusion

After the empirical analysis of the correlation between a low-carbon economy and the development of the marine industry, this paper mainly draws the following conclusions:

(1) The optimization of low-carbon energy technology and the increase of energy utilization can effectively control the direct carbon emissions without increasing them. The adjustment of industrial structure is the core entrance to reducing direct carbon emissions. The output effect and complete consumption coefficient effect of the marine industry sector become larger and the change in import and export carbon emission intensity is the core factor in the influencing factors of carbon emission of export products.

(2) In a low-carbon economy, the contribution rate of the technological progress index becomes smaller, and technology needs to be optimized. Provinces with a low total factor productivity index of the marine low-carbon economy must improve low-carbon technology in order to realize the sustainable development of the marine low-carbon economy.

(3) The higher the efficiency level of marine industrial structure, the lower the carbon emission intensity; The greater the rationality of marine industrial structure, the smaller the carbon emission intensity. The high degree of marine industrial structure has the most significant interference on the low-carbon economy, the rationality of marine industrial structure is significant, and the high efficiency of marine industrial structure is the least significant.

(4) This paper fully analyzes the decomposition results of China's carbon emission structure, calculates the total factor productivity of the marine low-carbon economy, and fully confirms the correlation between the transformation and upgrading of the marine industry and the low-carbon economy.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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