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Influence of the Evolution of Marine Industry Structure on the Green Total Factor Productivity of Marine Economy

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Abstract: The 14th five-year plan emphasizes the importance of marine ecology and environmental protection, and the green concept is incorporated into the high-quality development system of the marine economy. This research used the data of 11 coastal provinces and cities in China from 2006 to 2016, based on the super-efficiency slack-based measure model and global Malmquist index model. The objective was to calculate the green total factor productivity (GTFP) of the marine economy, to study the impact of the evolution of the marine industrial structure on marine economic GTFP. The study found the following: (1) in general, the upgrade of marine industrial structure promoted the growth of marine economic GTFP and presented an inverted "U" trend of initially promoting and then suppressing. Spatially, only the advancement and rationalization of industrial structure in the Yellow and Bohai Sea regions inhibited the growth of marine economic GTFP. In terms of time, the advanced marine industrial structure promoted the growth of GTFP from 2006 to 2010, whereas that of industrial structure inhibited the growth of GTFP from 2011 to 2016. (2) The GTFP of the marine economy showed an increasing trend, but the conversion rate of production technology is low. Falling into the "efficiency trap" of highly advanced technology input and low-efficiency technology output should be avoided. (3) Affected by the mismatch of regional resources or industrial structure, government intervention showed an "opposite" mechanism in areas with different marine economic strengths. Government intervention in areas with higher marine economic strength was conducive to GTFP growth, whereas government intervention in areas with weaker marine economic strength would hinder GTFP growth.

Keywords: marine industry; evolution of industrial structure; marine economy; green total factor productivity (GTFP)

Citation: Wei, X.; Hu, Q.; Shen, W.; Ma, J. Influence of the Evolution of Marine Industry Structure on the Green Total Factor Productivity of Marine Economy. *Water* **2021**, *13*, 1108. https://doi.org/10.3390/w13081108

Academic Editor: Robert C. Burns

Received: 14 March 2021
Accepted: 15 April 2021
Published: 17 April 2021

1. Introduction

The 21st century is the century of blue ocean. The concept of "promoting green development and promoting harmonious coexistence between human and nature" in the 14th five-year plan for Economic and Social Development of the People's Republic of China (the 14th five-year plan) will push the marine economy into a green development stage in China. Since the 21st century, the Chinese marine industry has a trend of alternating evolution of "2-3-1" and "3-2-1." Since 2011, the Chinese marine tertiary industry has maintained the industrial pattern of "3-2-1" for eight consecutive years. In 2019, the marine economic output exceeded 1359 billion dollars in China, contributing 9.1% to national economic growth. In addition, the added value of the three industries of the marine economy accounted for 4.2%, 35.8%, and 60% of the gross ocean product (GOP), respectively. The emerging industries with advanced technology and high utilization rate of marine resources have eliminated the traditional industries with low efficiency. Replacing old growth drivers with new ones in the marine industry has continuously optimized the allocation of resources, driving the improvement of factor productivity, such as labor and capital. The evolution of industrial structure promotes the transfer of resources from low- to high-productivity industrial sectors [1], focusing on the change of total factor productivity. The evolution of industrial structure has improved the allocation of production factors. Optimizing the industrial structure and improving total factor productivity are significant topics for scholars to explore the high-quality development of the Chinese economy. However, they are mainly focused on terrestrial industries or the overall industrial level, and research in the marine field is limited. The interaction of economic and social factors makes the evolution of the marine industrial structure different from that of the terrestrial industrial structure.

The evolution of the industrial structure is the process of the absorption of technological innovation by economic growth and the replacement of leading industrial sectors in turn. Technological innovation or technology introduction results in the improvement of total factor productivity [2]. As economics included the category of industrial structure in the research, the adjustment of the industrial structure has been regarded as an important driving force of economic growth [3]. According to the Theory of Endogenous Growth, total factor productivity is also the driving force of sustainable economic growth [4]. Moreover, green total factor productivity (GTFP) considering environmental factors can carry out economic accounting objectively and comprehensively [5]. Therefore, attaching importance to the two major driving forces of economic growth is of great significance to evaluate the green development level of the marine economy.

Academic research on the marine industrial structure focused on the changing characteristics and evolution path of the marine industry [6–8], the contribution of industrial changes to the marine economy [9–11], the influence of environmental regulation, and other factors on the marine industrial structure [12–14]. Given the particularity of the marine territory (danger, mutability, construction difficulties, deep-water pressure, high-tech agglomeration demand, etc.), the evolution of the ocean industrial structure is significantly different from that of the terrestrial industry. First, the development of the marine economy started late, and the caliber of marine statistics lagged behind. Second, different from the evolution mode of "1-2-3" in the terrestrial industry, the marine presented a fluctuating evolution, and its industrial leading force had experienced the evolution law of "1-3-2-3" [15]. Finally, the development space of the three marine industries is relatively large. Marine statistics show that the evolution direction of the industry was dominated by "2-3" industry alternately, where the secondary industry had a great role in the driving economy [6]. The added value of marine primary and secondary industries was large, and the joint development of the secondary and tertiary industries was accompanied by the emergence of industries [11]. A situation where the added value space of the primary and secondary industries was limited similar to the terrestrial industry would be unlikely. Therefore, the evaluation of the marine is different from that of the land, and a comprehensive index including the three industries should be established.

Research on GTFP focused on its measurement [16], influencing factors [17], economic efficiency and high-quality economic development [18], and the impact between environmental regulation, technological innovation, foreign investment, and GTFP [19]. In the marine domain, science and technology could promote the total factor productivity of the marine economy [20], and the contribution of science and technology was regionally heterogeneous [21]. The total factor productivity of marine economy considering environmental factors has a downward trend [22,23]. Moreover, GTFP is a scientific index to measure green development and a scientific test of the effectiveness of environmental governance under the background of the construction of ecological civilization [24].

Research on the impact of industrial structure on GTFP can be roughly divided into three aspects: (1) the evolution of industrial structure has a positive role in promoting GTFP, which is mainly manifested in the advanced and rationalized industrial structure to promote the growth of GTFP [25,26]. (2) Industrial structure adjustment may have a negative impact on GTFP, that is, the "Structural Burden Hypothesis" [27]. Li et al. [28] found that the adjustment of the tertiary industry had a negative impact on GTFP, which was mainly reflected in the scale changes of high- and low-pollution industries. The upgrading of the service industry with insignificant economic benefits would instead lead to a decline in production efficiency [29]. Moreover, the industrial advanced adjustment of the service-oriented tendency of industrial structure would lead to the structural deceleration of the economy [30]. (3) The adjustment of the industrial structure had a differential influence on GTFP. Ding [31] proved that changes in the industrial structure had a positive impact on overall green technological progress and had a negative impact on biased green technological progress. Han et al. [32] also explained that the advancement of the urban industrial structure had a positive effect on GTFP, and the effect of rationalization on GTFP varied significantly in different cities at various development stages. Then, Liu [33] expounded that the rationalization of the industrial structure had a positive impact on GTFP, whereas the advanced industrial structure had regional heterogeneity. She et al. [34] pointed out that the advancement of industrial structure improved GTFP, and the rationalization effect was not significant. Furthermore, Cai and Zhou [35] considered that the impact of industrial structure adjustment on GTFP was not significant in the research of the influence mechanism of environmental regulation on GTFP.

At present, studies on the impact of industrial structure and GTFP are mainly focused on the terrestrial industry and the overall industry in China, whereas the research in the marine field is relatively limited. Moreover, research in the marine field seldom considered the impact of environmental constraints and ecological governance. First, considering the dynamic change of caliber in marine statistics, research in the marine area is relatively late, and the particularity of the marine areas indicates that the research of the marine economy is different from the terrestrial economy. Second, with the improvement of the level of science and technology, the marine industrial structure changes by leap-forward. The evolution of industrial structure is in a critical period of replacing old growth drivers with new ones, and the coordinated development of the environment and the economy [36]. Third, the level of green development of the marine economy and the effectiveness of marine ecological governance can be scientifically assessed only by completely considering environmental constraints and including undesired indicators. Under the background of the strategy of marine power and the increasingly stringent supervision of ecological environmental protection, the impact of the evolution of industrial structure in ocean on GTFP should be urgently researched. Resource and environmental constraints are tightening day by day, and GTFP, which fully considers the environment, can scientifically measure the level of green development of the marine economy. Taking into account the completeness of marine statistics, this study uses the 2006–2016 data of China coastal to evaluate the impact of the evolution of marine industry structure on marine economic GTFP. This aspect is of great practical significance to measure whether the Chinese marine economy is developing in a healthy, green, and high-quality way.

2. Materials and Methods

2.1. Measurement Model

The continuous absorption of technological innovation in the marine industry has brought about the improvement of structural benefits, and the GTFP comprehensively reflects the dual impact of the economy and the environment. This study constructs a two-way fixed-effect model based on the panel data of 11 coastal provinces and cities in China from 2006 to 2016 to test the impact of marine industrial structure on marine economic GTFP. We control the influence of factors that change with an individual (or time) but not with time (or individual) on the explained variables to improve the accuracy of the estimation results. The model is shown in Equation (1).

$$GTFP_{it} = \beta_0 + \beta_1 advanced_{it} + \beta_2 rational_{it} + \sum_{j=3}^{7} \beta_j X_{it} + \mu_i + \nu_t + \varepsilon_{it} \quad (1)$$

In Equation (1), $GTFP_{it}$ represents the GTFP of province and city i in year t; $advanced_{it}$ represents the advanced level of marine industrial structure; $rational_{it}$ is the rationalization level of marine industrial structure; X_{it} is a group of control variables, including marine economic development level, resource endowment, pollution control level, government intervention, degree of opening to the outside world, infrastructure, and urban level. μ_i and ν_t are introduced to denote the fixed effects of coastal provinces and cities and the fixed effects of years, respectively. The objective is to completely control the estimation bias caused by factors that do not change with time and along the coastal provinces, and the factors that change over time without the variety in coastal provinces and cities. Then, ε_{it} is a random disturbance term.

2.2. Variable Selection and Data Sources

2.2.1. GTFP

GTFP can incorporate undesired output indicators into the accounting system. As an explained variable, the green development level of the marine economy is calculated scientifically, which is an important basis for whether the marine economy can realize green sustainable development. The research uses the MaxDEA Ultra tool (Beijing Ruiwo Maidi Software Co. Beijing, China.) to measure the green efficiency value of the marine economy using dynamic and static methods.

1. Static Calculation based on super-SBM

The super-efficiency slack-based measure (super-SBM) model can calculate the technical efficiency value of the current year and the production technical level of each decision-making unit (DMU) based on the relationship between input and output. The super-SBM model can distinguish the effectiveness of the DMU, and the slack variable increases free disposability of inputs and outputs. To measure the impact of undesired output, we use a non-oriented super-SBM model to examine the green technical efficiency of the marine economy [37]. Based on the equivalence of the production frontier in technical efficiency, the efficiency values of different DMUs in the same period are comparable.

To calculate the green technical efficiency of the marine economy, assuming n DMUs, $x \in R^m$, $y \in R^q$ and $z \in R^n$ represent the input, expected output, and undesired output of the marine economy, respectively. X, Y, and Z are the matrix sets of x, y, and z, respectively. We set the efficiency target value of the DMU as $x_k = X\lambda + s^-$, $y_k = Y\lambda - s^+$, and $z_k = Z\lambda + s^-$, where λ is the weight of the DMU, s^- and s^+ are slack variables representing excess input (or output) and insufficient input (or output), respectively. λ, s^-, and $s^+ \geq 0$ are based on the non-oriented super-SBM model, as shown in Equation (2).

$$
\begin{aligned}
&MGTE = min\frac{\frac{1}{m}\sum_{i=1}^{m}\frac{\overline{x}_i}{x_{ik}}}{\frac{1}{q+n}\left(\sum_{i=1}^{q}\frac{\overline{y}_i}{y_{ik}}+\sum_{i=1}^{n}\frac{\overline{z}_i}{z_{ik}}\right)}\\
&s.t.\ x_k = X\lambda + s^-, y_k = Y\lambda - s^+, z_k = Z\lambda + s^-\\
&\overline{x} \geq \sum_{j=1}^{n}\lambda_j x_j, \overline{y} \leq \sum_{j=1}^{n}\lambda_j y_j, \overline{z} \leq \sum_{j=1}^{n}\lambda_j z_j\\
&\overline{x} \geq x_k, 0 \geq \overline{y} \leq y_k, 0 \geq \overline{z} \geq z_k, , s^-, s^+ \geq 0
\end{aligned}
\quad (2)
$$

In Equation (2), $MGTE$ is the green technology efficiency value of the marine economy. $MGTE \geq 1$ indicates that DMU is efficient, and $MGTE < 1$ indicates that DMU is inefficient.

2. Dynamic Calculation based on GMI [38,39]

The static efficiency score calculated by the super-SBM model can observe the green production technology level of the marine economy in the same period from the national level. On the contrary, the dynamic calculation based on the global Malmquist index (GMI) can compare the changes of marine economic efficiency from two dimensions of time and space. The indicators selected take into account the impact of the environment, which is expressed by the GTFP index ($GTFPI$). The $GTFPI$ represents the rate of change of GTFP in two periods, and the cumulative processing of the $GTFPI$ in a certain period represents the rate of change of GTFP between the current DMU and the base period. The global reference Malmquist model refers to the frontier jointly constructed by all periods (global frontier), and all periods refer to the same global frontier. Thus, only one $GTFPI$ exists. The model is shown in Equation (3).

$$\begin{aligned} GTFPI\left(x^t, y^t, x^{t+1}, y^{t+1}\right) &= \frac{D^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D^t\left(x^t, y^t\right)} \times \left\{ \frac{D\left(x^{t+1}, y^{t+1}\right)}{D^{t+1}\left(x^{t+1}, y^{t+1}\right)} \times \frac{D^t\left(x^t, y^t\right)}{D\left(x^t, y^t\right)} \right\} \\ &= \frac{TE^{t+1}\left(x^{t+1}, y^{t+1}\right)}{TE^t\left(x^t, y^t\right)} \times \left\{ \frac{D\left(x^{t+1}, y^{t+1}\right)/D^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D\left(x^t, y^t\right)/D^t\left(x^t, y^t\right)} \right\} \\ &= EC\left(x^t, y^t, x^{t+1}, y^{t+1}\right) \times TC\left(x^t, y^t, x^{t+1}, y^{t+1}\right) \end{aligned} \quad (3)$$

In Equation (3), t represents time change, D^t is the distance function based on output in period t, and D is the set of output distance functions in all periods. $GTFPI$ can be decomposed into technical efficiency change (EC) and technological change (TC). $GTFPI > 1$ means productivity increases, and $GTFPI < 1$ means productivity decreases.

3. Index system of $GTFPI$

The statistical caliber of marine data in China was adjusted in 2005. Given the integrity and availability of the data, this study selects the panel data of 11 provinces and cities along the coast of China for 11 years as samples. All variables involving prices are adjusted to the constant price in 2005 as the base year, and $GTFPI$, EC, and TC are treated as cumulative values.

Input indicators were selected from three aspects, namely, labor, sea resources, and capital. Then, we selected the number of sea-related employees as labor elements and selected charge for the sea area resource as sea area resource elements. Sea area resources play the same role as land in production, and the charge for the sea area resource can represent the value of sea area resources and reflect the input of marine production activities. We selected marine fixed capital stock as the capital element. The proportion of the GOP in the gross product of coastal provinces and cities is used as the weighted value of the fixed capital stock of coastal provinces and cities for estimation because of the lack of statistics related to the stock of marine fixed capital. Using the calculation method of fixed capital stock for reference [40], the depreciation rate of 10.96% is selected, and the perpetual inventory method is adopted. The equation is as follows:

$$K_t = K_{t-1}(1 - \delta) + I_t \quad (4)$$

In Equation (4), K_t is the capital stock of provinces and cities in year t, K_{t-1} is the capital stock of provinces and cities in year $t - 1$, I_t represents social fixed asset investment, and δ represents the capital depreciation rate.

Output indicators measured by expected and undesired standards not only represent the output benefits of marine production activities but also reflect the output of destroying the environment and polluting the ocean and represent the true level of green development of the marine economy. The expected output selects GOP and adjusts GOP to real values at constant prices in 2005. Then, the undesired output selects the concentration of inorganic nitrogen and active phosphate in seawater. According to the *Bulletin on Environmental Quality of China's Coastal Waters* from 2006 to 2016, the water quality monitoring of state-controlled environmental quality monitoring sites in inshore waters, state-controlled sections of rivers entering the sea, and direct discharge of sewage into the sea are mainly inorganic nitrogen and active phosphate. From the annual *Bulletin on Environmental Quality of China's Coastal Waters*, concentration indicators of inorganic nitrogen and active phosphate are searched in various provinces and cities as non-desired outputs that measure the offshore environmental pollution. The pollution from various production activities flows into the sea, accelerating the deterioration of the environment [41], and the main pollution factors of the seawater quality are inorganic nitrogen and active phosphate [42,43]. Compared with simply using land-based pollution emission indicators, these two concentration indicators more directly reflect the final pollution of the ocean caused by production activities.

2.2.2. Explanatory Variables

1. Core Explanatory Variables

The evolution of the industrial structure is a dynamic process. The academic measurement of the evolution of industrial structure is mainly divided into two dimensions, that is, advanced and rationalized industrial structures. The development of the marine industry, the law of evolution, and the evolution direction of the leading industry are significantly different from those of the land industry [6–8,11,15]. Fishery in coastal areas is an important economic support for fishermen. Under the trend of the economic structure as a service, the secondary industry represented by "Science and Technology" still occupies an important position. According to the Petty-Clark theorem, the employment ratio of labor in the tertiary industries represents the industrial structure. The successive increase in the added value of the three industries represents changes in the industrial structure. The evolution of industrial structure is the result of the increase in labor productivity in various industries, that is, the improvement of "structural benefit." Referring to the ideas of Liu et al. [44], the advanced industrial structure (*advanced*) is expressed by the labor productivity of each industry weighted by the weighted average sum of industrial proportions. The weighted average sum represents the flow of various resource elements from industrial sectors with low labor productivity to industrial sectors with high labor productivity, thereby realizing the upgrading of industrial structure and the improvement of structural benefits, as follows:

$$advanced = \sum_{i=1}^{3}\left(\frac{Y_{imt}}{Y_{mt}} \times \frac{Y_{imt}}{L_{imt}}\right) \tag{5}$$

The rationalization of industrial structure (*rational*) not only reflects the degree of coordination of industrial structure but also represents the degree of effective utilization of marine resources and the transformation ability between the industrial structure. The study improves the Theil entropy defined by Gan et al. [45]. Theil entropy retains the economic basis of the deviation degree of industrial structure, which can reflect the regional output value structure and employment situation. Moreover, the Theil entropy takes the reciprocal of Theil entropy as the indicator of industrial structure rationalization, as follows:

$$rational = \frac{1}{\sum_{i=1}^{3}\left(\frac{Y_{imt}}{Y_{mt}}\right) ln\left(\frac{Y_{imt}}{L_{imt}} / \frac{Y_{mt}}{L_{mt}}\right)} \tag{6}$$

where Y_{imt} represents the output value of marine industry i in area m during year t, Y_{mt} represents the GOP in area m during year t, L_{imt} indicates the number of sea-related employees of industry i in area m during period t, and L_{mt} indicates the total number of sea-related employees in area m during period t. The increase in *dvanced* value indicates the upgrading of the industrial structure. According to the definition of Theil entropy, if the economy is in equilibrium, then Theil entropy is 0. Then, if Theil entropy is positive and closer to 0, then the industrial structure is more reasonable. On the contrary, the industrial structure is unreasonable. To facilitate the understanding, the *rational* adopted in this research is the reciprocal of Theil entropy. As the *rational* value increases, the industrial structure becomes more reasonable.

2. Control Variables

Referring to the relevant studies of other scholars [30,46], the control variables include the following: (1) the development level of marine economy (*lnpergop*). The growth of the marine economy represents the improvement of technological innovation and productivity, which is expressed by the logarithm of the ratio of GOP to the number of employees involved in the sea. (2) Resource endowment (*lnresour*) uses per capita marine fixed capital stock to represent marine resources, such as factors of production. (3) The level of pollution control (*control*) reflects the intensity of ecological treatment in the green development of the marine economy. *Control* is expressed by the ratio of total investment in environmental pollution control to GOP. (4) Government intervention (*govern*) refers to the game between regional governments that will have an impact on regional economic efficiency. *Govern* is expressed by the ratio of government fiscal expenditure to GDP. (5) The degree of openness (*open*) is the absorption of external funds conducive to promoting economic development. *Open* is expressed by the amount of foreign capital actually used. (6) Infrastructure ($lninfra$) represents the level of hard power of facilities construction in terms of the logarithm of public transport vehicles per 10,000 people. (7) Urban level ($lncity$) uses the logarithm of the number of Internet users to represent the level of urban soft power in the information age.

2.2.3. Data Description

The data of GOP, the number of sea-related employees, and the charge for sea area resources are mainly derived from the *China Marine Statistical Yearbook*. The data used in the calculation of the fixed capital stock and the control variables are mainly derived from the *China City Statistical Yearbook*, *China Environmental Statistical Yearbook*, and provincial or municipal statistical yearbooks. Then, the data of inorganic nitrogen and active phosphate come from the *Bulletin on Environmental Quality of China's Coastal Waters*.

From a spatial perspective, the 11 coastal provinces and cities along the coast of China shown in Figure 1 are bordered by the Yellow Sea, Bohai Sea, East China Sea, and South China Sea. Coastal economic activities may vary depending on the location of sea areas, which will affect the changes in industrial structure. To measure the influence of sea area heterogeneity, based on the integrity of provincial administrative regions, the 11 coastal provinces and cities are further divided into the Yellow Sea and Bohai Sea areas (including Liaoning, Hebei, Tianjin, Shandong, Jiangsu, abbreviated *YB*), the East China Sea area (including Shanghai, Zhejiang, Fujian, abbreviated *E*), and the South China Sea (including Guangdong, Guangxi, Hainan, abbreviated *S*).

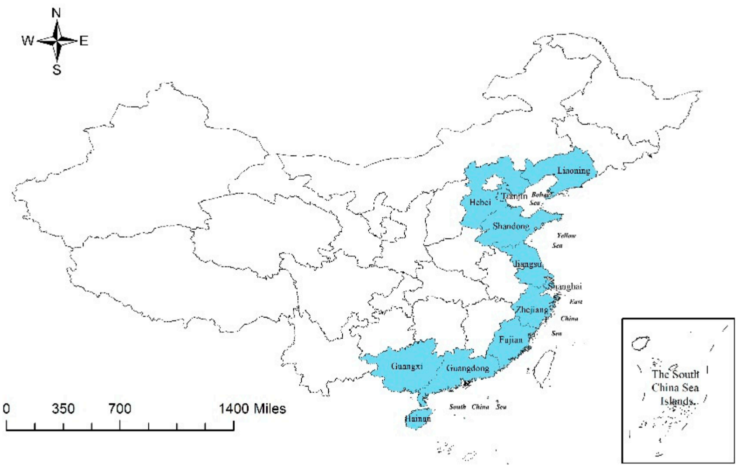

Figure 1. Regional map of 11 provinces and cities along the east coast of China.

In terms of time, Chinese government reports over the years have shown significant changes in marine policies around 2011 and pay more attention to the marine economy. Furthermore, the turning point of marine functional zoning within the research scope was in 2011. Marine functional zoning guides marine production activities macroscopically, adjusts marine industrial structure and production layout, and has an impact on the economic benefits of the marine environment. In addition, the calculation data show that $GTFPI$ has reached an inflection point in its changing value around 2011 ($GTFPI > 1$). Taking 2011 as the point, the research divides the development of the marine economy into two periods: 2006–2010 and 2011–2016. Table 1 shows the descriptive statistical analysis of variables.

Table 1. Descriptive Statistics of Variables.

Variable Classification	Variable	Mean	Std. Dev.	Min	Max
Explained variable	$GTFPI$	1.245	0.761	0.199	4.399
	EC	0.989	0.423	0.256	2.148
	TC	1.252	0.538	0.551	3.930
Explanatory variable	$advanced$	6.463	4.126	1.085	18.653
	$rational$	2.445	1.551	1.005	8.294
Control variable	$lnpergop$	2.450	0.606	1.013	3.528
	$lnresour$	3.113	0.678	1.352	4.298
	$lninfra$	2.447	0.223	1.747	2.944
	$control$	0.0115	0.004	0.003	0.031
	$govern$	0.162	0.057	0.083	0.340
	$open$	0.036	0.022	0.003	0.120
	$lncity$	15.649	1.067	12.582	17.762

3. Results and Discussion

3.1. Evolution of Green Efficiency of Marine Economy

The green efficiency of the marine economy is measured from two aspects, that is, technical efficiency value and GTFP change rate. Figure 2 shows the changing trend of green efficiency of the marine economy from 2006 to 2016. $MGTE$ is the static technical efficiency value, which represents the current production technology level. Then, $GTFPI$ is a dynamic technical efficiency value, which represents the change of GTFP compared with the previous year. Taking 2006 as the base period, the changing trend of GTFP is evaluated by accumulating $GTFPI$. (1) From the static technology level, the level of green production technology in the marine economy has not changed much in the past decade, and the level of production technology is relatively low ($MGTE < 1$). In terms of dynamic technological change, the growth rate of GTFP continues to accelerate, the fluctuation trend of technological change (TC) is the same as that of GTFP, whereas the green technical efficiency change (EC) shows a fluctuating downward trend. (2) The fluctuation nodes of marine technical efficiency change (EC) and technological change (TC) are roughly same. However, the fluctuation directions are different, showing a trend of "obvious deviation", which is consistent with the findings of Yu et al. [18], but different from the findings of Han et al. [22]. Green technological change has driven the growth of GTFP in the marine economy, which is the same as the findings of Hu [23] and Ding [31]. (3) Since 2009, the gap between the growth rate of marine economic GTFP and green technical efficiency change has increased year by year, and $GTFPI > 1$ exists in 2011, which has realized a positive growth of marine economic GTFP. One reasonable explanation is that after entering the 21st century, China began to emphasize "protection and rational utilization of marine resources." In five years of government reports, "sea pollution should be controlled" has been clearly stated [47,48]. The intensity of marine environmental protection policy was evidently higher than that of marine open policy. With the deepening of the green concept, the marine industry has gradually bid farewell to the previous extensive model of high energy consumption and high pollution. The transformation of the industrial structure has brought about the overall outward movement of the production frontier of advanced production technology. Technologically, this transformation has achieved more output with the input of established elements. However, the national marine green production technology level is low, the technology conversion efficiency is not high, and the efficiency of factor allocation and utilization is relatively low, which needs further improvement.

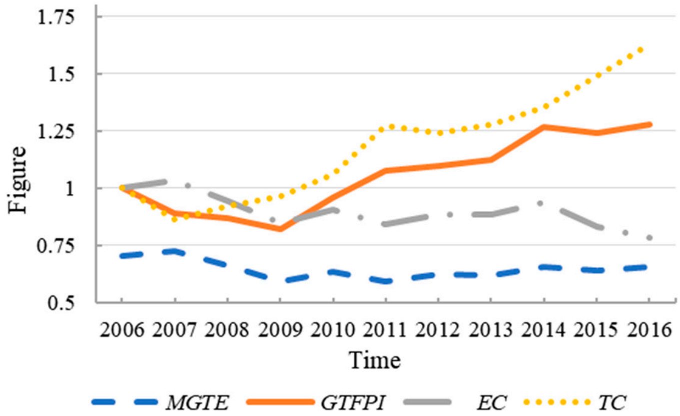

Figure 2. Changes in green efficiency of marine economy from 2006 to 2016.

3.2. Benchmark Regression of Marine Industrial Structure to GTFP

Table 2 shows the regression effects of the advanced and rationalized marine industrial structure on marine economic $GTFPI$, technical efficiency change (EC), and technological change (TC).

Table 2. Empirical Results of Marine Industrial Structure Evolution on Marine Economic GTFP.

Variables	(1) *GTFPI*	(2) *GTFPI*	(3) *EC*	(4) *TC*
$advanced$	0.1518 *** (0.0168)	0.2947 *** (0.0589)	0.0496 (0.0318)	0.3382 *** (0.0570)
$advanced^2$		−0.0047 ** (0.0019)	−0.0008 (0.0013)	−0.0069 *** (0.0019)
$rational$	0.1051 ** (0.0361)	0.6999 ** (0.2346)	0.1006 * (0.0500)	0.4841 ** (0.2096)
$rational^2$		−0.0536 ** (0.0191)	−0.0088 (0.0067)	−0.0344* (0.0179)
$open$	1.3990 (2.0731)	−0.6820 (2.3646)	−0.0289 (0.4915)	9.3304 *** (2.6774)
$govern$	−8.0213 *** (1.6063)	−6.2172 *** (1.0261)	−2.9303 (1.7963)	−5.5308 ** (2.1568)
$lnpergop$	1.0012 ** (0.3523)	0.8236 *** (0.2585)	1.2637 *** (0.2586)	−2.5203 *** (0.3563)
$lnresour$	−0.1295 (0.2863)	−0.2091 (0.2654)	−0.5744 *** (0.1194)	1.4516 *** (0.2778)
$lninfra$	0.0658 (0.1467)	0.0703 (0.1462)	−0.0039 (0.1114)	0.1225 (0.1152)
$lncity$	0.2162 (0.1259)	0.1411 (0.1599)	−0.0310 (0.1147)	0.1857 (0.1213)
$control$	−0.2263 (6.2139)	−1.0498 (5.6357)	−0.9022 (2.1054)	−6.6163 (8.1080)
$Constant$	−1.1489 *** (0.2092)	−1.9832 ** (0.7480)	0.1432 (0.3557)	−0.2156 (0.4198)
Province effect Year effect	control control	control control	control control	control control
N R^2	121 0.74	121 0.76	121 0.55	121 0.77

Note: ***, ** and * indicate that they have passed statistical significance test at the significance level of 1%, 5% and 10%, respectively. Driscoll–Kraay standard errors are in brackets.

The upgrading of the industrial structure promotes the growth of GTFP. The specific manifestations are as follows: (1) The first-order coefficients of the advancement and rationalization of the industrial structure are significantly positive at the statistical level of 1% and 5%, respectively. The advancement of the industrial structure has realized the transformation of resource elements from low to high productivity. The rational allocation of production factors in industrial structure and the coordination of supply and demand structure also promote the growth of GTFP. (2) The quadratic coefficient of $advanced$ and $rational$ is negative at the 5% statistical level, which reflects that the advancement and rationalization of the ocean industrial structure are non-linear to the growth of GTFP and present a relationship that promotes first and then inhibits. (3) We calculate the inflection point and find that the data from 2006 to 2016 show the impact of advanced and rationalized industrial structure on GTFP growth has not yet reached the turning point, which is in the left half of the inverted "U" shape. Currently, China's marine economy is still in the development stage. Affected by the concept of ecological economy and green development, the development of the marine industry has entered a stage of adjustment of environmental protection and pollution prevention. The advanced and rationalized industrial structure has promoted the transformation of the industrial model from labor-intensive to technology-intensive and environment-friendly, which has promoted the growth of GTFP. (4) The $advanced$ and $rational$ have different effects on the technological change (TC) and technical efficiency change (EC) of the $GTFPI$ decomposition. The advanced and rationalized industrial structure mainly improves GTFP growth by promoting TC, whereas EC did not pass the significance test. TC is the main driving force for changes in the marine economic GTFP, which verifies the above-mentioned result on the evolution of green efficiency in the marine economy.

The regression results of control variables show the following: (1) Government intervention ($govern$) has an inhibitory effect on GTFP growth of the marine economy at a 1% significant level. This finding is consistent with the view of Wang et al. [49] and Nie et al. [50] but different from that of Liu et al. [26] and Han et al. [32]. The market occupies an important position in promoting GTFP growth, and the government mainly plays an auxiliary role in making up for market failure, providing supervision, management, and services in industrial development. Excessive government intervention will reduce the allocation efficiency of production factors and restrict the innovation capability of advanced production technology. (2) The development of the marine economy ($lnpergop$) has brought about GTFP growth, which got rid of the development model of extensive utilization of resources and environmental pollution. A more environmentally friendly, intensive, and efficient economic model has promoted technological change and technical efficiency and achieved green economic benefits. The influence of other variables is not evident.

3.3. Heterogeneity Test of Marine Industrial Structure to GTFP

3.3.1. Heterogeneity Test based on Sea Area

To assess whether regional heterogeneity in the influence of marine industrial structure on GTFP exists, the 11 coastal provinces and cities along the coast of China are divided into the Yellow and Bohai Sea Region (YB), the East China Sea Region (E), and the South China Sea Region (S).

Table 3 show the following: (1) in the Yellow Sea and Bohai Sea area, the advanced and rationalized ocean industrial structure has shown a significant inhibitory effect on the growth of GTFP, which is in a "U" shape. The reasonable interpretation is the unbalanced industrial development among the provinces in the region. As a large marine province, Shandong has a higher level of industrial structure than other provinces, resulting in "extreme value" effect. Affected by the equilibrium effect, the development of ocean industry in the Yellow Sea and Bohai Sea area is unbalanced. There is an uneven transition from the primary industry to the secondary industry and then to the tertiary industry. The structural upgrading of the tertiary industry in advance results in resource mismatches and efficiency losses within and between industries, thereby reducing the marine economic

GTFP. In the East China Sea and the South China Sea, the evolution of the marine industry structure promotes the growth of the marine economy GTFP, which is the same as the overall trend. (2) Compared to other aspects of the three regions, the development of the marine economy in the East China Sea has an advantage, which belongs to the "leader" driving green development of the national marine economy. Resource endowment of the Yellow Sea and Bohai Sea is beneficial to the improvement of technological progress and technological innovation ability. Marine economic development in the South China Sea is weaker than that in the East China Sea, and opening to the outside world is conducive to promoting technological efficiency. (3) Government intervention (*govern*) can promote GTFP growth in the East China Sea, but in the Yellow Sea, Bohai Sea, and South China Sea, the interventions may hinder the improvement of technological progress and technical efficiency. The reasonable explanation is that in areas with good marine economic strength, moderate government intervention is conducive to strengthening green standards and promoting green economic development. On the contrary, in areas with relatively weak development, over-regulation hinders technological innovation, and structural mismatch under regulation reduces technical efficiency. Therefore, the government should intervene in accordance with local conditions and implement "flexible intervention."

Table 3. Heterogeneity Test Based on Sea Area.

Variables	(1) *YB-GTFPI*	(2) *EGTFPI*	(3) *SGTFPI*	(4) *YB-EC*	(5) *E-EC*	(6) *S-EC*	(7) *YB-TC*	(8) *E-TC*	(9) *S-TC*
advanced	−0.9635 *** (0.2572)	0.8062 *** (0.0976)	−0.3127 (0.5897)	−0.2609 (0.1480)	0.4614 *** (0.1357)	−0.6769 * (0.3393)	−0.7866 ** (0.2592)	0.3717 ** (0.1450)	0.3469 (0.3229)
$advanced^2$	0.0335 *** (0.0072)	−0.0231 *** (0.0025)	0.0232 (0.0292)	0.0054 (0.0044)	−0.0125 ** (0.0040)	0.0403 ** (0.0169)	0.0280 *** (0.0080)	−0.0111 ** (0.0043)	−0.0162 (0.0158)
rational	−3.3303 * (1.6135)	0.9068 (2.7006)	0.1173 (0.2484)	−0.0549 (0.8472)	−5.2318 (3.6807)	−0.5092 ** (0.1940)	−3.8824 ** (1.6702)	3.3469 (1.8558)	0.4525 (0.2654)
$rational^2$	0.5784 (0.3352)	−0.2930 (0.5859)	−0.0086 (0.0172)	−0.0219 (0.1615)	1.1036 (0.8302)	0.0429 ** (0.0168)	0.7301 * (0.3458)	−0.7574 (0.4382)	−0.0352 (0.0202)
open	2.6057 (4.9585)	−14.0047 (8.1597)	−10.6582 (10.2132)	−4.5133 ** (1.9727)	−7.1795 (7.6880)	12.7548 ** (5.7005)	19.4673 *** (4.6025)	−4.4082 (2.9981)	−17.9192 (13.2789)
govern	−0.1272 (6.7838)	11.2069 *** (1.9558)	−9.3364 ** (3.7757)	6.3959 (4.6559)	9.2735 (5.6490)	−5.9954 *** (1.5238)	−9.8431 *** (1.5236)	2.5912 (4.9697)	−5.6797 * (2.8235)
lnpergop	5.6372 *** (1.2209)	−1.6180 (0.9295)	1.4069 (1.6510)	3.1335 *** (0.7417)	−2.0842 * (1.0509)	0.8285 (1.0120)	0.2278 (0.6641)	0.1465 (0.5384)	−0.2959 (1.0696)
lnresour	−0.8133 (0.9341)	−0.1447 (0.2978)	−0.6518 (0.9966)	−0.5888 (0.5730)	0.2803 (0.5265)	−0.8098 (0.7226)	2.6853 *** (0.5173)	−0.3893 (0.3167)	0.2792 (0.5852)
lninfra	0.6064 (0.8180)	−0.0953 (0.1911)	−0.7378 (0.6474)	0.5416 (0.7097)	−0.8186 (0.5004)	−0.3075 (0.5796)	−0.7105 (0.5003)	0.5245* (0.2525)	−0.4448 *** (0.1352)
lncity	−0.5800 (1.1624)	0.1390 ** (0.0501)	0.7360 (0.7868)	0.1995 (0.7968)	0.4156 *** (0.0647)	1.0097 (0.7220)	0.1267 (1.1187)	−0.1861 *** (0.0520)	0.1984 (0.3108)
control	−8.7517 (15.7913)	5.9761 (6.9858)	−3.7664 (4.6335)	−1.5051 (8.7434)	6.6497 (9.0941)	7.8597 * (3.9504)	−20.2993 (16.0691)	0.3735 (2.5238)	−9.5316 *** (1.6005)
Constant	−1.3985 (4.6108)	0.2108 (4.2497)	1.7822 (2.3362)	−5.1268 * (2.6759)	8.6217 (5.3746)	1.8445 (1.5140)	1.8045 (2.0372)	−4.0236 (2.2747)	1.2496 (1.1336)
Province effect	control	control	control	control	control	control	control	control	control
Year effect	control	control	control	control	control	control	control	control	control
N	55	33	33	55	33	33	55	33	33
R^2	0.89	0.98	0.91	0.74	0.83	0.93	0.91	0.99	0.95

Note: ***, ** and * indicate that they have passed statistical significance test at the significance level of 1%, 5% and 10%, respectively. Driscoll–Kraay standard errors are in brackets.

3.3.2. Heterogeneity Test based on Two Periods

According to the time inflection point of the change of China's marine policy, the action mechanism of ocean industry on marine economic GTFP in 2006–2010 and 2011–2016 is calculated respectively, as shown in Table 4. (1) The advancement of marine industrial structure promoted the growth of GTFP from 2006 to 2010. However, this mechanism of action was "reversed" from 2011 to 2016. The advancement of industrial structure mainly hindered the growth of GTFP by restraining changes in technical efficiency (*EC*). The rationalization of industrial structure in both periods has a positive effect on GTFP growth. A reasonable explanation is that China's marine economic development strategy from 2006 to 2010 is not prominent and at the level of biological resource protection and traditional use [47,51]. During this period, the advanced and rationalized marine industrial structure may promote industrial development to get rid of the mode of high energy consumption, high pollution, and low efficiency. This structure may also improve the level of production technology, thus promoting the growth of marine economic GTFP. From 2011 to 2016, the level of marine production technology has been continuously improved but only pays attention to the technological level, ignoring the technological conversion rate of production factors, such as resources. The upgrading of industrial structure has become an obstacle to the improvement of technical efficiency. The "opposite" mechanism of the impact of the advanced industrial structure on GTFP in the two periods may be an important reason why the dominant force in the evolution of marine industrial structure has undergone a "secondary–tertiary" industrial alternation. (2) The negative influence mechanism of government intervention on GTFP is that the government mainly suppressed technical efficiency (*EC*) from 2006 to 2010 and restricted technological progress from 2011 to 2016. A reasonable conjecture is that the degree of coordination among government levels is limited [52], excessive government intervention from 2006 to 2010 led to a "structural mismatch" in the development of the marine industry. Under the same level of production technology, the input–output ratio of production factors such as resources is out of balance, which reduces the technical efficiency. From 2011 to 2016, the problems of industrial structure and resource allocation had been alleviated, and the level of marine technology tended to pull an inward–outward progress. During this time, excessive government intervention would hinder technological innovation and restrict the development of advanced technology. (3) Marine pollution control efforts had an "opposite" effect on the GTFP growth around 2011. In 2006–2010, marine pollution control efforts focused on restricting technological change (*TC*) to hinder GTFP growth, whereas in 2011–2016, marine pollution control efforts focused on promoting technical efficiency change (*EC*) to increase GTFP growth. According to the GOP data in the China Marine Statistical Yearbook, the marine primary and the secondary industries in 2006–2010 were the main driving force for marine economic development. Because of the 2005 data caliber adjustment, it is difficult to scientifically estimate the increased value of the total value of the ocean production in 2006; therefore, the proportion of the total value of the three industries is used. In 2006, the three marine industries accounted for 5.69%, 47.32% and 46.99% of the total output value, respectively. The added value of the three marine industries in 2007 was 13.56%, 17.55%, and 20.37% respectively; the added value of the three marine industries in 2008 was 21.42%, 14.36%, and 17% respectively; the added value of the three marine industries in 2009 was 9.6%, 8.67%, and 7.62% respectively; the added value of the three marine industries in 2010 was 8.09%, 26.75%, and 21.55% respectively. During this period, the changing order of marine leading industry was "2-3-1-1-2". A reasonable explanation is that the main driving force of marine economic development from 2006 to 2010 was the primary and secondary industries represented by marine fisheries, and marine ships and offshore oil, respectively. At this time, increasing pollution control efforts not only restricted technological progress but also limited offshore operation. The efforts to control pollution suppresses the growth of GTFP. However, with the implementation of policies, such as marine pollution control, marine ecological environment, and marine power from 2011 to 2016, the state began to attach importance to marine ship pollution control and marine pollution prevention and management, and carried out the construction of marine ecological civilization demonstration zones. The main policies are as follows: In 2011, the "Regulations on the Political Ocean Environmental Prevention and Treatment of the People's Republic of China" (revised in 2013); In 2012, "opinions of the State Oceanic Administration on carrying out the construction of 'marine ecological civilization demonstration zone'", "the 12th five-year Plan for the Development of National Marine economy", etc. The concrete deployment of the strategy of "building marine power" was expounded at the 18th National Congress of the Communist Party of China. In 2014, the "opinions of the State Oceanic Administration on further strengthening the quality management of marine ecological environment monitoring", "some opinions of the State Oceanic Administration on strengthening the monitoring and evaluation of the marine ecological environment," and "the notice of the State Oceanic Administration on the issuance of the measures for National claims for Marine Ecological damage." In 2016, "the 13th five-year Development Plan for National Marine Standardization", "the circular of the State Oceanic Administration on issuing the guidance on strengthening Marine quality Management," and "the guidance of the National Development and Reform Commission and the State Oceanic Administration on promoting the construction and development of marine economic development demonstration zones." The specific action program of the marine power strategy had been deployed. Strengthening pollution control could increase the output efficiency of green technology. The marine economy tended to have environment-friendly development models, such as environmental protection and energy savings, thus promoting the growth of GTFP.

Table 4. Heterogeneity Test Based on Two Periods.

Variables	**2006–2010**			**2011–2016**		
	(1) ***GTFPI***	**(2)** ***EC***	**(3)** ***TC***	**(4)** ***GTFPI***	**(5)** ***EC***	**(6)** ***TC***
advanced	0.5528 *** (0.0938)	0.2220 (0.1554)	0.2388 (0.1837)	−0.1184 * (0.0537)	−0.0495 * (0.0207)	0.0332 (0.0314)
$advanced^2$	−0.0151 *** (0.0022)	−0.0039 (0.0074)	−0.0080 (0.0065)	0.0064 *** (0.0015)	0.0024* (0.0011)	−0.0022 ** (0.0007)
rational	0.5797 * (0.2218)	0.2932 ** (0.0742)	0.2473 (0.1768)	0.6084 ** (0.2299)	0.2374 * (0.1106)	0.0230 (0.1354)
$rational^2$	−0.0434 * (0.0197)	−0.0155 * (0.0069)	−0.0211 (0.0169)	−0.0564 * (0.0235)	−0.0230 * (0.0090)	−0.0058 (0.0142)
open	−2.5921 (1.2797)	−4.6980 ** (1.0238)	2.9469 ** (0.7907)	1.2295 (1.1168)	0.1930 (0.5831)	8.4658 *** (1.4005)
govern	−2.9276 (2.3088)	−6.5919 *** (0.9484)	−0.8256 (0.9876)	−3.3342 (2.2160)	2.2393 * (0.8867)	−6.4549 *** (0.8361)
lnpergop	0.0948 (0.2642)	0.5962 (0.8091)	−0.7277 (0.5375)	1.1550 (0.8144)	0.5076 ** (0.1677)	−1.1921 ** (0.3150)
lnresour	−0.8792 (0.5841)	−0.6317 (0.4684)	0.0389 (0.0734)	0.5500 (0.5149)	0.2777 * (0.1375)	0.5881 (0.3288)
lninfra	0.4561 (0.3840)	0.2290 (0.1564)	0.2091 (0.1778)	1.2912 (0.6601)	0.1001 (0.1499)	0.6506 * (0.3227)
lncity	0.2935 ** (0.0667)	0.1828 * (0.0809)	0.1088 (0.0701)	−1.4516 ** (0.4769)	−0.4502 * (0.2178)	−0.3358 (0.3430)
control	−10.2142 * (3.8643)	−4.4721 (2.2585)	−3.3148 ** (0.9865)	9.9128 * (4.5134)	7.6046 ** (2.2416)	−8.8029 (7.8541)

Table 4. *Cont.*

Variables	2006–2010 (1) GTFPI	(2) EC	(3) TC	2011–2016 (4) GTFPI	(5) EC	(6) TC
Constant	−0.9257 (0.9566)	0.2266 (0.8236)	0.4136 ** (0.1147)	0.0000 (0.0000)	0.0000 (0.0000)	0.0000 (0.0000)
Province effect	control	control	control	control	control	control
Year effect	control	control	control	control	control	control
N	55	55	55	66	66	66
R^2	0.62	0.59	0.61	0.61	0.70	0.82

Note: ***, ** and * indicate that they have passed statistical significance test at the significance level of 1%, 5% and 10%, respectively. Driscoll–Kraay standard errors are in brackets.

3.4. Robustness Test

To verify the robustness of the research results, the indicators of core explanatory variables were replaced. Referring to the indicator calculation methods of Ding et al. [53] and Cui [54], the advancement of industrial structure is measured using the Moore index, which reflects the change and evolution of industrial structure, that is, $advanced = arccos\frac{\sum_{i=1}^{3}\left(\frac{Y_{i,t-1}}{Y_{t-1}} \times \frac{Y_{i,t}}{Y_t}\right)}{\left\{\sum_{i=1}^{3}\left(\frac{Y_{i,t-1}}{Y_{t-1}}\right)^2\right\}^{\frac{1}{2}} \times \left\{\sum_{i=1}^{3}\left(\frac{Y_{i,t}}{Y_t}\right)^2\right\}^{\frac{1}{2}}}$. The rationalization of the industrial structure is measured by structural entropy, which reflects the orderliness of the industrial structure from a static perspective, that is, $rational = \sum_{i=1}^{3}\left(\frac{Y_{i,t}}{Y_t}\right)\ln\left(\frac{1}{Y_{i,t}/Y_t}\right)$. After excluding the influence of extreme values, the signs and robustness of the main variables shown in Table 5 have not changed significantly, thereby verifying the robustness of empirical results.

Table 5. Estimated Results Excluding the Influence of Extreme Values.

Variables	(1) GTFPI	(2) EC	(3) TC
advanced	0.2947 *** (0.0589)	0.0496 (0.0318)	0.3382 *** (0.0570)
$advanced^2$	−0.0047 ** (0.0019)	−0.0008 (0.0013)	−0.0069 *** (0.0019)
rational	0.6999 ** (0.2346)	0.1006 * (0.0500)	0.4841 ** (0.2096)
$rational^2$	−0.0536 ** (0.0191)	−0.0088 (0.0067)	−0.0344 * (0.0179)
open	−0.6820 (2.3646)	−0.0289 (0.4915)	9.3304 *** (2.6774)
govern	−6.2172 *** (1.0261)	−2.9303 (1.7963)	−5.5308 ** (2.1568)
lnpergop	0.8236 *** (0.2585)	1.2637 *** (0.2586)	−2.5203 *** (0.3563)
lnresour	−0.2091 (0.2654)	−0.5744 *** (0.1194)	1.4516 *** (0.2778)
lninfra	0.0703 (0.1462)	−0.0039 (0.1114)	0.1225 (0.1152)
lncity	0.1411 (0.1599)	−0.0310 (0.1147)	0.1857 (0.1213)

Table 5. *Cont.*

Variables	**(1)** ***GTFPI***	**(2)** ***EC***	**(3)** ***TC***
control	−1.0498 (5.6357)	−0.9022 (2.1054)	−6.6163 (8.1080)
Constant	−1.9832 ** (0.7480)	0.1432 (0.3557)	−0.2156 (0.4198)
Province effect	control	control	control
Year effect	control	control	control
N	121	121	121
R^2	0.76	0.55	0.77

Note: ***, ** and * indicate that they have passed statistical significance test at the significance level of 1%, 5% and 10%, respectively. Driscoll–Kraay standard errors are in brackets.

4. Conclusions

The study estimated the impact of advanced and rationalized Chinese marine industrial structure on the GTFP of the marine economy. By calculating the panel data of 11 coastal provinces and cities in China from 2006 to 2016, the real level of green development of marine economy considering resource and environmental constraints is evaluated. The main conclusions are as follows:

(1) The level of green efficiency of China's marine economy is relatively low, the innovation momentum of advanced marine technology is sufficient, whereas the technical conversion efficiency is low and even shows a downward trend. This view was supported by Hu et al. [23], Ding et al. [31], and Di et al. [55]. The changing trend of "obviously deviating" between technological change and technical efficiency is the internal mechanism of alternating change of the dominant forces of marine secondary and tertiary industries and the key reason why the marine industrial structure is different from the evolutionary law of the terrestrial industrial structure. Therefore, we pay attention to the conversion efficiency of technology to production factors and avoid falling into the "efficiency trap" of high-tech input and low-efficiency output.

(2) In general, the upgrade of the marine industry is conducive to promoting the growth of marine economic GTFP, and this mechanism is an inverted "U" shape. At present, the impact of advancement and rationalization of the marine industry on GTFP is in the left half of the inverted "U" shape. In terms of maritime space, only in the Yellow Sea and Bohai Sea does the advanced and rationalized marine industrial structure have a "U" shaped inhibitory effect on the growth of GTFP, which is contrary to the overall trend. The marine economy in the East China Sea has become the "leader" in driving the development of the national marine green economy. In terms of time periods, the advanced marine industrial structure promoted the growth of GTFP from 2006 to 2010. However, this mechanism was reversed from 2011 to 2016, and the advanced ocean industrial structure inhibited the growth of GTFP. This phenomenon may be due to simply paying attention to the improvement of the technical level of equipment while neglecting the technical conversion rate of production factors, such as resources. In addition, the mismatch between industrial structure and resources has become a barrier to improving technical efficiency.

(3) The latecomer power of the Chinese ocean industrial structure is relatively weak under the influence of the traditional extensive model. That is, industrial transformation and upgrading lead to the improvement of the technological level of large-scale production, and the technological innovation capabilities have been significantly improved. However, the conversion efficiency of production factors is relatively low. Under the premise of the same technological level, the "deviation" of inter-industry structure, the "mismatch" of intra-industry resources, and the "stagnation" of inter-industry factors may be the key factors to reduce technical efficiency, which is also an important reason for the spatiotemporal heterogeneity of the impact of industrial structure evolution on GTFP. In addition to production technological innovation, the realization of the optimal allocation of all-factor

resources and structural coordination can increase the technological potential to achieve high-efficiency output and cross the "efficiency trap."

(4) The government's "flexible intervention" is conducive to promoting the green development of the marine economy. The intensity of intervention is tailored to local conditions, strengthening green standards for areas with advantages in marine economic development, and increasing intervention in high-polluting and high-emission industries. Moreover, the government's "flexible intervention" can moderately deregulate areas with weaker economic development, provide public services for the development of marine industries, and allow the market to play a major role in technological innovation. These aspects can help in achieving the free flow of production technology and other factors, which is conducive to the improvement of technical efficiency. Interestingly, the flexible intervention of the government may cause other similar problems such as "pollution transfer". Therefore, in the planning of the green development of the marine economy, the issue of government intervention is worth further exploration.

Author Contributions: Conceptualization: X.W., Q.H. Methodology: X.W. and W.S. Validation: X.W., W.S., Q.H. and J.M. Draft Writing, Review and Editing: X.W., Q.H., W.S. and J.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Major Projects of Social Planning in Zhejiang Province (No. 19XXJC02ZD), the general program of Chinese National Natural Science Foundation (No. 71874092), the key projects of Chinese National Social Science Foundation (No. 19AZD004), and Research and Innovation Fund for Graduate students of Ningbo University (No. IF2021111).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: The authors gratefully thank the editor and anonymous reviewer for their review.

Conflicts of Interest: The authors declare no conflict of interest.

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