

Dynamic Evaluation of Ecological Efficiency and Total Factor Productivity of Marine Fisheries in China

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Abstract

China's marine economy started late. With the continuous improvement of China's marine economic strength, the problems of marine environmental pollution and ecological damage are becoming more and more serious. The traditional marine fishery urgently needs transformation to improve the marine ecological environment and industrial ecological efficiency. Taking the total carbon emissions in the development of marine fisheries as the unexpected output, this paper uses the DEA Malmquist index model to analyze the total factor productivity of Marine Fisheries ecological efficiency in China from 2005 to 2019. The results show that: (1) from the measurement results of total factor productivity and its decomposition index, the change in time; During the study period, the total factor productivity index, pure technical efficiency index and scale efficiency index of fishery ecological efficiency in the study provinces changed gently, while the technical efficiency progress index fluctuated and increased, but most of the time, the values of the four indexes were in a positive development state greater than 1; In terms of spatial change, China's marine fishery ecological efficiency and total factor productivity increased significantly during the study period, and the difference between regions gradually decreased; (2) From the perspective of internal mechanism, scientific and technological capability has become the main driving force to promote the development of marine fishery ecological efficiency and total factor productivity. At present, the marine fishery ecological efficiency is in the stage of diminishing returns to scale and pure technical returns. The development model of simply increasing factor investment has restrained the growth of marine fishery ecological efficiency, and the innovative development model led by technological progress has become an important force leading the development of marine fishery economy.

Keywords

Coastal Areas; Total Factor Productivity; Malmquist Index.

1. Introduction

Over the past 40 years of reform and opening up, fishery has made remarkable achievements in food supply and economic growth. Among them, the traditional pillar industry marine fishery has played an indelible role in promoting the progress of China's marine economy [1]. In 2019, the total output value of fishery economy in the whole society was 2640.65 billion yuan, accounting for 30% of the total output value of marine economy. However, in recent years, mariculture, fishing boat waste, land-based pollutants and oil spill accidents have caused serious pollution in China's offshore waters, and the marine ecosystem is in a sub-health or unhealthy state, accelerating the depletion of fishery resources. According to the 2019 bulletin on the status of China's fishery ecological environment, at

present, the pollution of China's marine natural important fishery waters seriously exceeds the standard. Excessive nitrogen, phosphorus, chemical oxygen demand and other chemical substances lead to frequent outbreaks of red tides in the offshore, which poses a serious threat to offshore aquaculture areas and natural fishing boats. The destruction of marine ecology and the reduction of marine animal species are also closely related to water eutrophication. In 2013, the state proposed to unswervingly build a strong marine country, take accelerating the transformation of the development mode of marine fisheries as the main line, adhere to the principle of giving priority to ecology, combining aquaculture and fishing, controlling offshore, expanding open seas and developing pelagic production, strive to strengthen the protection of marine fishery resources and ecological environment, and constantly improve the sustainable development capacity of marine fisheries; The "14th five year plan" of 2021 proposes to optimize the layout of offshore green aquaculture, build marine pastures and develop sustainable Pelagic Fisheries.

In recent years, scholars' research on the ocean has mainly focused on the marine giant system, but due to its late start, the research results are not rich enough. Hu QiuGuang et al. (2018) took the lead in measuring the ecological efficiency of marine ecosystem. The study found that the overall marine ecological efficiency in China is low, and the regional differences are obvious [2]; Hu Wei and Han Zenglin used energy theory and SBM model to explore the development efficiency of China's marine eco economic system from 2004 to 2013, and tried to analyze various influencing factors through Malmquist index and Tobit model. The research results show that technological progress is the leading factor to promote the development of marine eco economy [3]; Han Zenglin et al. (2019) calculated the ecological efficiency of Marine Fisheries in China's coastal areas from 2006 to 2015 based on the SBM model. The research shows that the overall ecological efficiency of Marine Fisheries in China is at a medium level [4]; Wang Zeyu et al. (2020) used the SBM model to calculate the ecological efficiency of marine fisheries from 2007 to 2016, and introduced the generalized matrix estimation model to analyze its influencing factors. They believed that there was still much room to improve the ecological efficiency of Fisheries in China[5].

Generally speaking, the existing research on marine fishery ecological efficiency focuses on analyzing the temporal and spatial evolution of current marine fishery ecological efficiency, and there is little research on its total factor productivity. Therefore, this paper uses DEA Malmquist index to calculate the total factor productivity of marine fishery ecological efficiency in coastal provinces and cities of China from 2005 to 2019, and dynamically analyzes the relationship between its internal mechanisms, It makes up for the deficiency of the existing research on the internal mechanism of marine fishery ecological efficiency, and has important practical significance for improving the quality of fishery economic development and ecological environment.

2. Research Methods and Index Data

2.1 Dea Malmquist Index

DEA model is generally used in the study of static model, and Malmquist model is usually considered to process panel data and conduct dynamic analysis of data. Malmquist productivity index can evaluate the change of total factor productivity of decision-making units from t to $t + 1$, and can dynamically analyze the historical evolution of marine fishery ecological efficiency in various provinces and cities. With the help of this model, we can deeply understand the reasons for the change of ecological efficiency in the research period. This study adopts the decomposition method proposed by fare et al. The productivity index ($Tfpch$) in the adjacent period can be decomposed into the product of technical progress index ($Tech$) and technical efficiency change index ($Effch$), and the comprehensive technical efficiency index can be decomposed into pure technical efficiency change index ($Pech$) and scale efficiency change index ($Sech$). The relevant calculation formula is as follows:

$$T\uparrow pch = Effch * Tech = (Pech * Sech) * Tech$$

$$Effch = \frac{D^{t+1}(X_{t+1}, Y_{t+1})}{D^t(X_t, Y_t)}$$

$$Tech = \left[\frac{D^t(X_{t+1}, Y_{t+1})}{D^{t+1}(X_t, Y_t)} * \frac{D^t(X_t, Y_t)}{D^{t+1}(X_t, Y_t)} \right]$$
(1)

In formula (1), the above efficiency index value greater than 1 represents the increasing return to scale, that is, the efficiency is improved; A value equal to 1 means that the return to scale remains unchanged and the efficiency does not change. A value less than 1 means that the return to scale decreases, that is, the efficiency decreases.

2.2 Index Selection and Data Processing

There are differences between different regions and research objects, so the construction of the index system should be combined with the specific situation of China's marine fishery development to ensure the practical significance and research significance of the research problems.

In terms of index selection, based on the construction principle of ecological index efficiency in the existing reference[6], the evaluation index system is constructed from the two dimensions of input and output. In this study, the input dimension is constructed from three aspects of capital, labor and resource consumption, and the output dimension will be constructed from two aspects of expected output and unexpected output. The specific index system is summarized in Table 1.

Table 1. evaluation index system of marine fishery ecological efficiency

Dimension layer	Criterion layer	Subcriteria layer	Indicator description
input	Capital investment	Marine fishery capital stock	Marine fishery capital stock = marine fishery GDP * capital stock of each province / GDP of each province / Region
	Labor input	Marine fishery practitioners	Number of fishery employees
	resource consumption	Aquaculture area	Aquaculture area
		Fishing vessel ownership	Energy consumption of fishing vessels
output	Expected output	Total fishery economic development	Gross economic product of marine fishery
	Unexpected output	carbon emission	Carbon emissions from Marine Fisheries

The data used above are from China Statistical Yearbook, China fishery statistical yearbook and China energy statistical yearbook over the years. Since there is no specific index of fishery capital investment in the marine fishery Yearbook, this paper uses the single hero algorithm to calculate the marine fishery capital stock. The fishery capital stock can reflect the synthesis of various capital invested in the process of fishery development, so this index is selected as the capital investment. The capital stock of each province and region is obtained through the perpetual inventory method[7]. The specific calculation formula is shown in Table 1. In terms of unexpected output, there is no direct data on carbon emissions from marine fisheries in China, and there is no unified calculation standard

for carbon emissions from marine fisheries. Therefore, after reading a large number of documents on carbon emissions, this paper calculates the carbon emissions from marine fisheries by referring to the research methods in the existing research results [8]. The specific calculation formula is:

$$C = \sum_k m_{ik} * \delta_k * p_{it} \tag{2}$$

In formula (2), C refers to the total carbon emission of marine fisheries; m_{ik} Refers to the standard coal consumption obtained by multiplying the K-type energy consumption of T Province in the i-th year by the standard coal conversion coefficient; δ_k Refers to the carbon emission coefficient of class k energy; p_{it} refers to the proportion of the total output value of Marine Fisheries in t Province in the regional GDP in I year.

3. Analysis of Total Factor Productivity Level of Marine Fishery Ecological Efficiency

3.1 Time Evolution Analysis

Marine fishery ecological efficiency total factor productivity dynamically analyzes the changes of marine fishery ecological efficiency from the perspective of input-output, which reflects the allocation, utilization and scale agglomeration ability of marine fishery ecological factor resources. In this paper, max-dea software is used to measure the ecological efficiency of Marine Fisheries and its decomposition indicators, and the results are compared and analyzed.

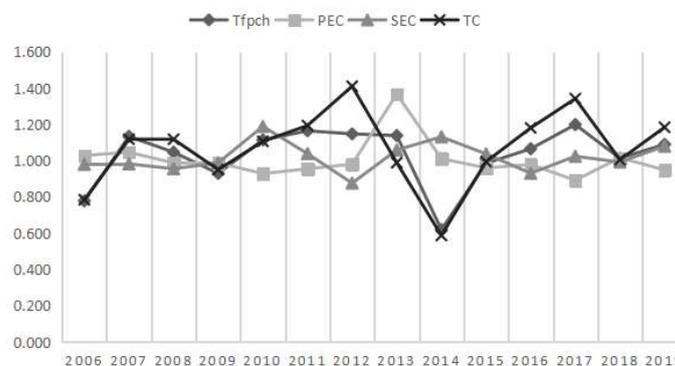


Fig. 1 total factor productivity of marine fishery ecological efficiency in China's coastal areas from 2005 to 2019

In terms of time, in terms of the change trend of the total factor productivity index (tfpch) of ecological efficiency, the total factor productivity of China's marine fishery ecological efficiency was in a positive development state for most of the time from 2006 to 2019. Except for the negative growth of the index less than 1 in 2006 (0.779), 2009 (0.930), 2014 (0.620) and 2015 (0.986), the index values in other years were greater than 1; In terms of pure technical efficiency index (PEC), the fluctuation range of the index is small, and there is a slight downward trend. From 2006 to 2007, the index is greater than 1, and the maximum value is 1.047. From 2008 to 2017, except for 2013 (1.034) and 2014 (1.012), the index values of other years are in a negative inhibition state of less than 1, And in 2017, it decreased from 1.047 to the lowest value of 0.892 in the whole study period. After 18 years, the index began to rise and return to a positive promotion state; As far as the scale efficiency index (SEC) is concerned, from 2006 to 2009, the index value was less than 1, showing an upward trend after 2010. Except for the negative growth of less than 1 in 2012 (0.877), 2016 (0.931) and 2018 (0.993), it was in a positive promotion state of more than 1 in other times; In terms of technical

progress index (TC), the index value in the early stage of the study (2006) was less than 1 (0.785). From 2007 to 2012, the index value increased steadily, which played a positive role in promoting total factor productivity. From 2013 to 2015, the fluctuation of the index value decreased, from positive promotion to negative inhibition. After 16 years, the index value rebounded to 1.181, and later years were greater than 1.

On the whole, the changes of Malmquist index, pure technical efficiency index (PEC) and scale efficiency index (SEC) of fishery ecological efficiency in all provinces during the study period are relatively flat, while the technical efficiency progress index (TC) is in a fluctuating and rising state, which plays a positive role in promoting. Analyze its internal mechanism, it shows that the changes of Malmquist index of fishery ecological efficiency in coastal provinces in China during the study period are mainly affected by pure technical efficiency and scale efficiency, These two restrict the development of marine fishery ecological efficiency. Therefore, in the future, we should try to change the agglomeration scale of regional investment, adjust the industrial structure of marine fishery, actively develop the secondary and tertiary industries of fishery, reasonably allocate resources, promote the rationalization of industrial structure, increase the investment of fishery scale, develop diversified fishery economy and increase the scale efficiency of fishery economy, so as to drive the overall improvement of the ecological efficiency level of marine fishery.

3.2 Spatial Evolution Analysis

From the perspective of space, on the whole, from 2006 to 2019, the difference of total factor productivity of marine fishery ecological efficiency among coastal provinces and cities was gradually narrowing, and the total factor productivity was significantly improved at the end of the study. It can be seen from Figure 2 that from 2005 to 2006, the total factor productivity of marine fishery ecological efficiency in 9 coastal provinces and cities in China was less than 1, and the total factor productivity in the whole study area increased negatively; From 2006 to 2011, the total factor growth rate increased rapidly. Except that the total factor productivity of Liaoning Province is still less than 1, the total factor productivity of other regions is greater than 1, and the productivity of Hebei Province is more than 1.3; From 2015 to 2016, compared with the previous study period, the total factor productivity value of all provinces decreased to varying degrees. However, except that the productivity value of Liaoning and Hebei was less than 1, which was inhibited, the total factor productivity value of other provinces and cities was still greater than 1, realizing the positive promotion of total factor productivity; From 2018 to 2019, the total factor productivity of marine fishery ecological efficiency in Hebei and Liaoning developed. The total factor productivity of marine fishery in nine coastal provinces and cities was greater than 1, which was significantly higher than that in the early stage of the study. It can be seen from figure 2D that the difference in total factor productivity among coastal areas was further reduced.

This shows that in the early stage of marine fishery development (2005-2006), insufficient resource investment and low level of industrial agglomeration lead to negative inhibition of marine fishery ecological efficiency and total factor productivity in all coastal provinces in China; In the second stage of marine fishery development (2010-2011), China's marine fishery ecological efficiency and total factor productivity made significant progress, which may be due to the initial stage of the 12th Five Year Plan. Before that, the 17th National Congress put forward the concept of ecological civilization for the first time. After that, China's fishery development followed the national pace and introduced the concept of ecological civilization into the fishery development plan. In the 12th Five Year Plan for fisheries in 2011, the favorable conditions for promoting the development of China's fishery economy and the unfavorable factors for restraining the development of fishery economy in the last five-year specification period were analyzed and summarized in detail, and six principles for the development of China's fishery during the 12th Five Year Plan Period were put forward, That is, "pay equal attention to ensuring supply and improving quality, production development and ecological conservation, industrial development and fishermen's development, structural optimization and consolidating the foundation, domestic development and overseas expansion, and

based on industry and the overall situation". Under the guidance of the correct policy, China's marine fishery ecological efficiency and total factor productivity have been significantly improved, Realize the positive growth of total factor productivity in most regions; The decline of efficiency value in the third and fourth stages of the study period may be due to China's vigorous development of marine economy and the continuous growth of fishery economy during this period, but the economic growth has brought about the aggravation of ecological damage. The mismatch between extensive economic development mode, backward industrial structure and economic development speed has led to the neglect of economic quality and environmental benefits in the process of fishery development, Thus, the marine fishery ecological efficiency and total factor productivity showed a continuous downward trend to a certain extent. During the study period, the cities with leading marine fishery development took the lead in recognizing the importance of balancing the industrial structure, and their structural distribution gradually tended to be reasonable; The less developed provinces, due to insufficient attention to environmental pollution and imperfect treatment measures, are more likely to undertake the fishery industry with large environmental pollution and high resource consumption, resulting in a gradual gap in the ecological efficiency of Marine Fisheries among provinces.

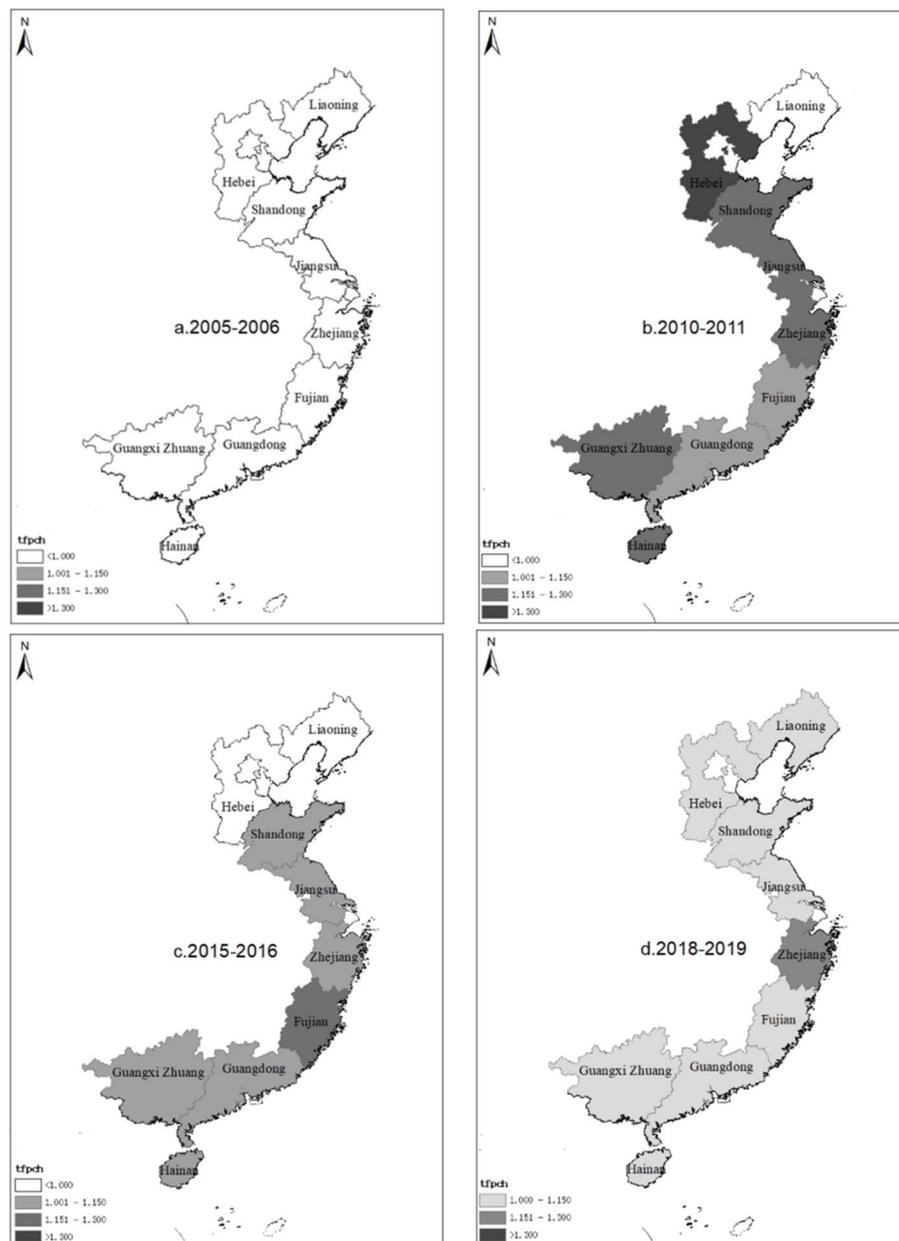


Fig. 2 spatial pattern distribution of total factor productivity of marine fishery ecological efficiency

4. Countermeasures and Suggestions

(1) From the measurement results of total factor productivity and its decomposition index, the change in time; During the study period, the total factor productivity index, pure technical efficiency index and scale efficiency index of fishery ecological efficiency in the study provinces changed gently, while the technical efficiency progress index fluctuated and increased, but most of the time, the values of the four indexes were in a positive development state greater than 1; In terms of spatial change, China's marine fishery ecological efficiency and total factor productivity increased significantly during the study period, and the difference between regions gradually decreased;

(2) From the perspective of internal mechanism, scientific and technological capability has become the main driving force to promote the development of marine fishery ecological efficiency and total factor productivity. At present, the ecological efficiency of marine fisheries is in the stage of diminishing returns to scale and PEC. The development model of simply increasing factor investment has restrained the growth of ecological efficiency of marine fisheries, and the innovative development model led by technological progress has become an important force leading the development of marine fishery economy.

According to the research results of this paper, the following suggestions are put forward:

(1) Strengthen the innovative consciousness of marine fishery economy, adhere to the strategy of "rejuvenating the sea through science and technology" and the concept of green and sustainable development, promote the transformation of marine fishery from extensive development to high-quality and high-efficiency development, constantly adjust the industrial structure of marine fishery, optimize the primary industry, upgrade and expand the secondary and tertiary industries, actively develop aquatic product processing industry and leisure fishery, promote industrial integration, and actively develop emerging industries, Such as intelligent fishing gear and intelligent marine shipbuilding industry, increase fishery diversity and accelerate the transformation of the driving force of marine fishery economy, so as to drive the transformation and upgrading of industrial structure and promote the rational and efficient development of marine fishery economy.

(2) Strengthen the comprehensive quality of China's marine fishery practitioners, cultivate high-level marine fishery technical talents, improve the talent introduction mechanism, improve the treatment of scientific researchers, improve the research environment, introduce new technologies, enhance the ability of independent innovation, and promote the transformation and upgrading of China's marine fishery industrial structure through scientific and technological innovation.

(3) While developing marine fishery economy in coastal areas, we must pay attention to the protection of marine ecological environment and reduce marine sewage and waste discharge. We should not only seek the high-quality development of China's marine fishery, but also ensure the sustainable development of China's marine fishery. First of all, we should actively eliminate backward production capacity and reduce pollution emissions at the source. Secondly, management institutions at all levels should strictly abide by the Convention, the constitution of the people's Republic of China and other relevant laws and regulations, strengthen the protection of the marine environment, protect marine resources and prevent pollution and damage. Maintain ecological balance. Strengthen the publicity of marine environmental protection, enhance the public's marine ecological awareness, strengthen the law enforcement and management of fishery administration, improve the supervision and management system, increase the management of fishing vessels, eliminate the "three noes" fishing vessels, protect marine health, control the ecological damage in the process, and finally actively repair the damaged ecological environment and promote the sustainable development of fishery economy.

(4) We will actively expand Pelagic Fisheries, establish policies for the development of deep-water waters in the open sea, develop offshore aquaculture, expand the area of mariculture, solve the problem of insufficient supply of fishery resources in inland seas and bays, and extend the industrial chain of aquatic products.

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