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An Efficiency Analysis of Fishery Output in Coastal Areas of China

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Abstract

The purpose of this study is to measure the productivity of fisheries in China's coastal areas (including inland and marine fisheries) and to analyze the factors influencing the development of fishery economy in each province by comparing regional differences. The input indicators used for efficiency analysis are fish farms, ships and staff numbers, and the output indicators are fish catch and net income. In this paper, we used six years of data from 2013-2018 and DEA-Malmquist index was used to analyze the efficiency of coastal fisheries production in 11 areas of China's coast. According to the analysis from 2013 to 2018, the fishery output efficiency in China's coastal areas has improved to some extent, but most provinces and regions are characterized by technological progress, and the technological efficiency still needs to be further improved. The conclusion can provide reference for the development planning and policy measures of regional fishery industry in China's coastal areas.

Keywords: *Fishery industry, DEA, Malmquist index, Efficiency, Coastal areas of China*

1. Introduction

The year 2018 was the first year for China to implement the Rural Revitalization Strategy. The structure of the agricultural industry has been continuously improved, and the total output value of agriculture, forestry, animal husbandry and fishery has reached a record high of 11.135795 trillion Yuan. China's agricultural supply-side structural reform has not only provided high-quality agricultural products for the domestic and international markets, but also provided considerable impetus for China's agricultural economic development and farmers' income growth. In addition to traditional crop cultivation and animal husbandry, China's agricultural industry has also witnessed steady growth in the output value of fishery. In 2013, China's fishery output value accounted for 9.93% of the total output value of agriculture, forestry, animal husbandry and fishery, and reached 11.28 percent in 2018. The changes of China's total agricultural output value and fishery output value from 2013 to 2018 are shown in Figure 1.

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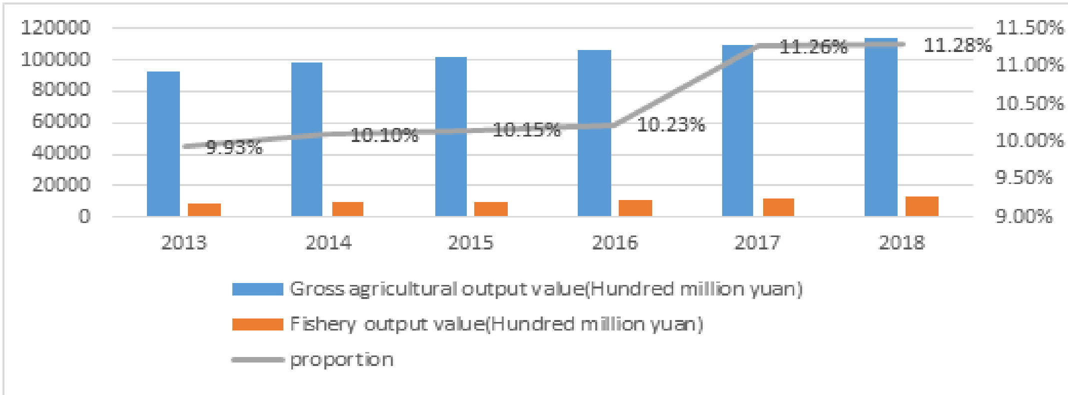

Figure 1. Changes in China's total agricultural output and fisheries in 2013-2018

Coastal provinces are the regions with the highest concentration of fishery resources in China. In 2018, the fishery output value of 11 coastal provinces was 911.668 billion Yuan, accounting for 71.14% of the national fishery output value. The fishery industry in China's coastal provinces leads the development of China's fishery economy. In a hyperconnected society, the introduction of high-tech into traditional Agriculture of the past is absolutely necessary [1]. The development of the fishery industry, especially the marine fishery, provides an important guarantee for the optimization of China's agricultural industrial structure and the income increase of fishermen. The Internet of things (IOT) is remodeling the agribusiness empowering the agriculturists through the extensive range of strategies, for example, accuracy as well as practical farming to deal with challenges in the field [2]. However, with the rapid development of China's fishery industry, problems such as overfishing of marine fishery and low utilization efficiency of investment factors of fishery resources have resulted in unsustainable fishery industry and low income of fishermen. How to change the economic growth mode of fishery industry and promote the sustainable development of fishery industry has become an urgent problem to be solved. Therefore, it is of great significance to study and analyze the dynamic changes and regional differences of China's fishery industry efficiency for the sustainable growth of China's fishery economy and the optimization of the fishery industry structure.

At present, the research on fishery economy is mainly divided into freshwater aquaculture and marine fishery. For example, Gao Qiang et al. conducted an empirical study on the production efficiency of freshwater aquaculture in China from 2000 to 2007 by using data enveloping-analysis (DEA) model. Zhang Meng and Ma Shurui both measured the productivity of marine fisheries in 11 provinces (municipalities directly under the central government and autonomous regions) in China's coastal areas. These studies all compare the fishery industry in different provinces of China from one aspect of freshwater aquaculture or marine fishery, which cannot fully reflect the actual development of regional fishery industry. Meanwhile, in the research of freshwater aquaculture, output factors such as freshwater fishing are often ignored. Yu Shuhua et al. used the fishery related input-output indicators of 11 coastal provinces from 2002 to 2009 to analyze the fishery industry efficiency of coastal provinces by using the Malmquist index. However, only three input and output indicators were selected for this study, and the calculated results were obtained. In the existing literature, studies on the efficiency of the fishery industry mostly use time series or cross-sectional data, or only focus on one aspect of the fishery industry, such as freshwater aquaculture or marine fishery, without analyzing the differences between different periods or regions. The purpose of this study is by selecting the appropriate input and output indicators, using DEA and Malmquist index method of 11 provinces in China's coastal fisheries (including inland and marine fishery) changes in the output efficiency and composition analysis, explore the bottleneck which restrict the development of the coastal province of fisheries industry, in order to promote the development of the coastal province of fishery economy.

2. Literature Review

Most studies on the efficiency of the fishery industry adopt empirical methods, from the perspective of property rights transaction and management policies. Most of the research methods adopt DEA or stochastic frontier model. For example, Tom Kompas and Tuong Nhu Che used relevant data from 1992 to 2000 to study the impact of trade quota changes on the efficiency improvement and cost reduction of southeast Australian trawl fishery industry by using a random cost boundary model. The results showed that the increase of trade quota led to the improvement of fishery efficiency and the reduction of cost [3]. Diana Tingley et al. used the SRF model and DEA analysis thinking to study the influencing factors of fishery production efficiency in the English channel. Through method comparison, they believed that the two methods were inherently consistent [4]. Fabio Madau et al using data collected in 2003, using DEA model to evaluate the Mediterranean region a national park of small-scale fisheries production capacity and economic efficiency, the results show that the region fleet overcapacity in the short term and long term existence, and suggests that under the condition of existing technology fishermen can increase the effective fixed for people to realize the output increase [5]. Many Chinese scholars study the efficiency of the fishery literature from a macro level study of the fishery industry as a whole output efficiency, Zhang Tong of China's coastal provinces by using the model of marine fishing productivity was analyzed, and the results showed that the pure technical efficiency is higher, China's marine fishing industry scale inefficiency is the main reason for the low economic efficiency [6]. Xiao Shan and Sun Caizhi used DEA method to evaluate the input-output relative effectiveness of marine fishery economy of 11 coastal provinces and cities, and concluded that DEA effective provinces and non-DEA effective provinces in 2004, and analyzed and adjusted non-DEA effective provinces and cities, providing a basis for the effective development of fishery economy in the future [7]. Gao qiang et al. conducted an empirical study on the production efficiency of freshwater aquaculture in China from 2000 to 2007 by using DEA model, and the results showed that the overall efficiency of freshwater aquaculture in China was low [8]. Yu Shuhua 2002-2009, such as the coastal fishery of 11 provinces of the input and output indicators, using the Malmquist index analysis of China's coastal provinces fisheries industry efficiency, measuring the total factor productivity, mainly to measure the different provinces of technical efficiency, scale efficiency and pure technical efficiency, coastal provinces is analyzed from the angle of input and output efficiency factor in the development of fishery economy and differentiation of different provinces [9]. Zhang Meng used the input and output data of fishery resources of 11 coastal provinces and cities from 2005 to 2012, and used the Malmquist index analysis method and DEA method to analyze the marine fishery output efficiency of 11 coastal provinces and cities from dynamic and static perspectives [10]. Ma Shurui used DEA and Malmquist index methods to calculate the output efficiency of Marine fisheries in China's coastal provinces and cities. The results show that total factor productivity (TFP) increases in technical efficiency and technical progress, but the increase in technical efficiency is slightly less than that in technical progress. There are still enough output and input redundancy in some provinces and cities [11].

To sum up, DEA model and Malmquist index analysis are the main methods used in current researches on China's fishery industry. However, due to different indicators, the analysis results are quite different. Literature mainly focused on a particular aspect of the fishery industry, such as fresh water aquaculture, marine fishery, marine fishing or lack of recent or regional difference analysis. Therefore, this study by selecting the appropriate input and output indicators using data from 2013 to 2018 estimates China's coastal provinces inland

and marine fishery output efficiency and its changes. Put forward countermeasures and Suggestions to promote the sustainable and healthy development of China's fishery industry structure optimization.

3. Analytical Methods

3.1 DEA Model

DEA (Data Enveloping-analysis Method) was proposed by American operations research scientists Charns and Rhodes in 1978. Based on the concept of relative efficiency, DEA is a non-parametric analysis method to evaluate the relative effectiveness of similar multi-index input and multi-index output economic systems [12].Its basic idea is: each Unit or department to be evaluated is regarded as a Decision Making Unit (DMU for short), and the evaluation group is constituted by DMUs. Each DMU in the same evaluation group has the same kind of resource consumption, that is, each DMU has the same input index and the same output index. After index and DMUs, the use of mathematical programming model is between the relative efficiency of DMU, the comprehensive analysis of the input-output ratio, to get the quantitative index of comprehensive efficiency of each DMU, to determine the highest relative efficiency of DMU (namely DEA effective), and the DMUs are lined up on the grade, at the same time also can give a non DEA efficient DMU DEA efficient DMU and the gap between the data, as adjusting the efficient DMU, the effective mode to the direction and the number of input or output item adjustments on the basis of [13].The basic models mainly include BCC model with variable radial return to scale and CCR model with constant return to scale. However, the above two basic radial models do not add the relaxation variable to the objective function, which is likely to cause the deviation of the measurement results caused by the radial and Angle. In view of this, Tone proposed a non-radial SBM model based on relaxation variable slack-based measure (SBM), which not only solved the problem of relaxation change of input and output, but also included the non-expected output into the efficiency evaluation [14]. However, both radial and non-radial DEA models have certain disadvantages, that is, when multiple decision making units are relatively effective and the efficiency value is 1, traditional models such as CCR and BCC cannot further explain them. Therefore, on this basis, a super efficiency model that can further evaluate and rank multiple decision making units more accurately is introduced, which can eliminate the evaluated DMU from the efficiency boundary, and recalculate the distance between the eliminated DMU and the new efficiency boundary formed on the basis of the remaining DMU [15].

3.2 Malmquist Index Method

The Malmquist index was first put forward by Swedish economist and statistician Malmquist in 1953.In 1994, Fare et al. established the Malmquist productivity index model to investigate TFP growth [16]. This method makes up the gap that the traditional DEA model cannot carry out dynamic analysis of efficiency changes. The specific concept is as follows in equation (1):

$$TFP = TEch \times TECHch - PEch \times SEch \times TECHch \quad (1)$$

In equation (1), TEch represents the change of technical efficiency from stage t to stage t+1. When TEch>1, it indicates that the technical efficiency has been improved; otherwise, it indicates a decline. TECHch represents the influence of the technology progress index from t to t+1 on the efficiency change trend. When TECHch>1, it indicates that the technology has made progress and brought about the improvement of regulatory efficiency; otherwise, it indicates that the technology progress has not brought about the improvement of regulatory efficiency [17].

In the empirical analysis of this study, each province (municipality directly under the central government or autonomous region) in the coastal areas was taken as a decision-making unit(DMU) using the Malmquist index method of DEA to calculate and analyze the changes of total factor productivity (TFP) in China's coastal areas.

3.3 Selection of Indicators

Most of the research literature selected fishery breeding area, year-end ownership of fishing vessels, fishery practitioners, fixed assets investment, scientific research practitioners, and total fishery output value as input and output indicators [10]. But these studies only measure marine fisheries or inland fisheries and fail to analyze the inland and marine fisheries of a province as a whole. At present, the literature available on the overall output efficiency of inland and marine fisheries in Chinese provinces only selects three input-output indicators as fishery breeding area, year-end ownership of vessels and total fishery output value [9]. In fact, the total value of fishery in a region includes three items, including the value of fishery, the value of fishery industry and construction, the value of fishery circulation and the value of service industry. Therefore, this study in China's coastal regions of 11 provinces, municipalities and autonomous regions as the research object, selecting fishery breeding area, fishing boats at the end of the ownership and fishery workers, such as item 3 as input index, selection of fishery output and per capita net income of the fishermen two as output indexes. Input-output indicators are shown in Table 1. Among them, fishery breeding area including freshwater aquaculture area and mariculture area; Ownership of fishing vessels at the end of the year includes ownership of motor fishing vessels at the end of the year and ownership of non-motor fishing vessels at the end of the year. Fishery output value only selects fishery primary industry output value, excluding fishery industry and construction value, fishery circulation value and service value. The selection of these indicators is different from previous studies on China's fishery output efficiency [9].

Table 1. Input-output indicators

Item	Indicators	Unit
Input	Aquiculture area	Hektare
	Number of fishing boats owned	Gross ton
	Number of fishery employees	Person
Output	Fishery output value	Wan Yuan
	Net income per fisherman	Yuan

3.4 Data Sources and Research Objects

The data used in this study are from China Fishery Statistical Yearbook 2014-2019.The DMU of this study are 11 provinces, municipalities directly under the central government and autonomous regions in the coastal areas of China, in the order of China Fishery Statistical Yearbook: Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi Zhuang autonomous region and Hainan. The calculation was performed using the Malmquist exponential analysis method.

4. Empirical Analysis

4.1 Result of DEA Model

Table 2, Table 3 and Table 4 were drawn from the fishery input and output variables of 11 provinces in China's coastal areas during 2013-2018 calculated by DEA software.

Firstly, the results of CCR-output model show that the fishery output efficiency of Fujian, Hainan, Shanghai and Tianjin (4 provinces and municipalities directly under the central government) were effective from 2013 to 2017. In 2018, Fujian, Hainan, Jiangsu, Shanghai and Tianjin (5 provinces and municipalities directly under the central government) achieved effective fishery output efficiency. The average efficiency during 2013-2018 were 0.798, 0.799, 0.804, 0.777, 0.849 and 0.839. Please refer to Table 2 for the above data. The overall efficiency of DMUs indicated that the fishery output efficiency in China's coastal areas was medium and good, showing the characteristics of increasing fluctuation.

Table 2. Result of DEA model about CCR-output in 2013-2018

DMU	Year						Mean
	2013	2014	2015	2016	2017	2018	
Fujian	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Guangdong	0.746	0.782	0.785	0.763	0.942	0.940	0.826
Guangxi	0.693	0.740	0.759	0.675	0.831	0.808	0.751
Hainan	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Hebei	0.458	0.441	0.461	0.450	0.542	0.526	0.480
Jiangsu	0.789	0.798	0.804	0.798	0.973	1.000	0.860
Liaoning	0.667	0.661	0.643	0.620	0.561	0.469	0.604
Shandong	0.821	0.794	0.776	0.702	0.778	0.746	0.770
Shanghai	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Tianjin	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Zhejiang	0.604	0.568	0.619	0.538	0.710	0.743	0.630
Mean	0.798	0.799	0.804	0.777	0.849	0.839	0.811

Then, the calculation results using the BCC-output model show that the fishery output efficiency of Fujian, Hainan, Jiangsu, Liaoning, Shandong, Shanghai and Tianjin (5 provinces and municipalities directly under the central government) were effective in 2013. In 2014-2015, the fishery output efficiency of Fujian, Hainan, Jiangsu, Liaoning, Shandong, Shanghai, Tianjin and Zhejiang (8 provinces and municipalities directly under the central government) were effective. In 2016, the fishery output efficiency of Fujian, Hainan, Jiangsu, Shanghai and Tianjin (5 provinces and municipalities directly under the central government) were effective. The 2017-2018 fishery output efficiency of Fujian, Hainan, Jiangsu, Shanghai, Tianjin and Zhejiang (6 provinces and municipalities directly under the central government) were effective. From 2013 to 2018, the average efficiency were 0.940, 0.946, 0.956, 0.934, 0.922 and 0.905. The efficiency data was higher than CCR model, and the overall DMU efficiency value decreased. Please refer to Table 3 for the above data.

Table 3. Result of DEA model about BCC-output in 2013-2018

DMU	Year					
	2013	2014	2015	2016	2017	2018
Fujian	1.000	1.000	1.000	1.000	1.000	1.000
Guangdong	0.875	0.941	0.965	0.936	0.964	0.940
Guangxi	0.876	0.876	0.920	0.839	0.865	0.832
Hainan	1.000	1.000	1.000	1.000	1.000	1.000
Hebei	0.595	0.588	0.631	0.607	0.596	0.613
Jiangsu	1.000	1.000	1.000	1.000	1.000	1.000
Liaoning	1.000	1.000	1.000	0.992	0.796	0.702
Shandong	1.000	1.000	1.000	0.947	0.924	0.872

Shanghai	1.000	1.000	1.000	1.000	1.000	1.000
Tianjin	1.000	1.000	1.000	1.000	1.000	1.000
Zhejiang	0.990	1.000	1.000	0.951	1.000	1.000
Mean	0.940	0.946	0.956	0.934	0.922	0.905

As shown in Table 4, according to the scale efficiency calculation results, the scale efficiency of fishery output in Fujian, Hainan, Shanghai and Tianjin (4 provinces and municipalities directly under the central government) were effective from 2013 to 2017. In 2018, the scale efficiency of fishery output in Fujian, Guangdong, Hainan, Shanghai and Tianjin (5 provinces and municipalities directly under the central government) were effective. The average scale efficiency during 2013-2018 were 0.846, 0.841, 0.837, 0.836, 0.916 and 0.918.

Table 4. Result of DEA model about SE in 2013-2018

DMU	Year					
	2013	2014	2015	2016	2017	2018
Fujian	1.000	1.000	1.000	1.000	1.000	1.000
Guangdong	0.853	0.831	0.813	0.815	0.977	1.000
Guangxi	0.791	0.845	0.825	0.805	0.961	0.971
Hainan	1.000	1.000	1.000	1.000	1.000	1.000
Hebei	0.770	0.750	0.731	0.741	0.909	0.858
Jiangsu	0.789	0.798	0.804	0.798	0.973	1.000
Liaoning	0.667	0.661	0.643	0.625	0.705	0.668
Shandong	0.821	0.794	0.776	0.741	0.842	0.856
Shanghai	1.000	1.000	1.000	1.000	1.000	1.000
Tianjin	1.000	1.000	1.000	1.000	1.000	1.000
Zhejiang	0.610	0.568	0.619	0.566	0.710	0.743
Mean	0.846	0.841	0.837	0.826	0.916	0.918

The total technical efficiency consists of two parts. Technical efficiency (CCR) = Pure technical efficiency (BCC) × Scale efficiency (SE). Pure technical efficiency refers to the production efficiency generated by management, technology and other factors, while scale efficiency refers to the production efficiency generated by scale and other factors. From a macro perspective, the average fishery technical efficiency of Fujian province (1.00), Hainan province (1.00), Shanghai city (1.00) and Tianjin city (1.00) ranked among the top four fishery industries in China's coastal areas from 2013 to 2018. This shows that the utilization of input resources, internal management and operation scale were relatively effective. In comparison, Hebei province (0.48) had the lowest average technical efficiency.

4.2 Result of Malmquist Analysis

In order to analyze the fishery productivity and changes in China's coastal provinces, this study adopted the Malmquist index method to analyze the variation trend and structural characteristics of fishery output efficiency in coastal provinces. The Malmquist index (MPI) represents total factor productivity, which can be divided into technological efficiency change (TECI) and technological change (TCI). The analysis results of fishery productivity of China's coastal provinces from 2013 to 2018. First, the overall productivity analysis results of the provinces in the coastal areas show that the MPI of the fishery in the coastal areas has been in a state of growth in the past 10 years, with an average of 1.067 in 2013-2014, an increase of 6.7%. The average value from 2014 to 2015 was 1.027, an increase of 2.7%. The average value from 2015 to 2016 was 1.051, up 5.1%. The average value from 2016 to 2017 was 1.017, up 1.7%. The average for 2017-2018 was 1.044, up 4.4%. From 2013 to 2018, the total factor productivity of the fishery industry in China's coastal areas increased by 4.4%, mainly due to technological progress, which shows that the development of the fishery industry has played a significant role. Please refer to Table 5 for the above data.

Table 5. Analysis results of productivity in 2013-2018

Year	Index	DMU											Mean
		FJ	GD	GX	HN	HB	JS	LN	SD	SH	TJ	ZJ	
2013/2014	MPI	1.028	1.096	1.077	1.138	1.071	1.083	1.076	1.038	1.000	1.043	1.086	1.067
	TECI	1.000	1.075	1.000	1.000	0.989	1.000	1.000	1.000	1.000	1.000	1.010	1.007
	TCI	1.028	1.020	1.077	1.138	1.082	1.083	1.076	1.038	1.000	1.043	1.075	1.060
2014/2015	MPI	1.032	1.024	1.060	1.032	1.115	1.033	0.980	1.011	0.939	1.000	1.075	1.027
	TECI	1.000	1.025	1.050	1.000	1.073	1.000	1.000	1.000	1.000	1.000	1.000	1.014
	TCI	1.032	0.999	1.009	1.032	1.039	1.033	0.980	1.011	0.939	1.000	1.075	1.013
2015/2016	MPI	1.128	1.066	0.998	1.103	1.059	1.097	1.075	1.001	1.005	1.000	1.027	1.051
	TECI	1.000	0.970	0.912	1.000	0.961	1.000	0.992	0.947	1.000	1.000	0.951	0.976
	TCI	1.128	1.099	1.094	1.103	1.102	1.097	1.084	1.056	1.005	1.000	1.080	1.077
2016/2017	MPI	1.042	1.080	1.106	0.991	1.001	1.062	0.820	0.985	1.041	0.892	1.170	1.017
	TECI	1.000	1.030	1.031	1.000	0.983	1.000	0.802	0.976	1.000	1.000	1.052	0.989
	TCI	1.042	1.048	1.072	0.991	1.019	1.062	1.022	1.010	1.041	0.892	1.113	1.028
2017/2018	MPI	1.062	1.060	1.015	1.129	1.087	1.100	0.955	0.994	0.963	1.010	1.106	1.044
	TECI	1.000	0.975	0.962	1.000	1.028	1.000	0.882	0.944	1.000	1.000	1.000	0.981
	TCI	1.062	1.087	1.056	1.129	1.057	1.100	1.082	1.053	0.963	1.010	1.106	1.064

※ FJ-Fujian; GD-Guangdong; GX-Guangxi; HN-Hainan; HB-Hebei; JS-Jiangsu; LN-Liaoning; SD-Shandong; TJ-Tianjin; SH-Shanghai; ZJ-Zhejiang

The direction of MPI index change can be seen from TECI and TCI. As shown in Figure 4. The total factor productivity of eight provinces in Fujian, Guangdong, Guangxi, Hainan, Hebei, Jiangsu, Shandong and Zhejiang all improved to varying degrees, with the highest increase of 9.3% in Zhejiang. Hainan was the second, up 7.9%. Technological progress is the main reason for the improvement of total factor productivity. Three provinces including Liaoning, Shanghai and Tianjin, their total factor productivity fell. Liaoning was the lowest, down 1.9%, mainly because of a shortage of TECI.

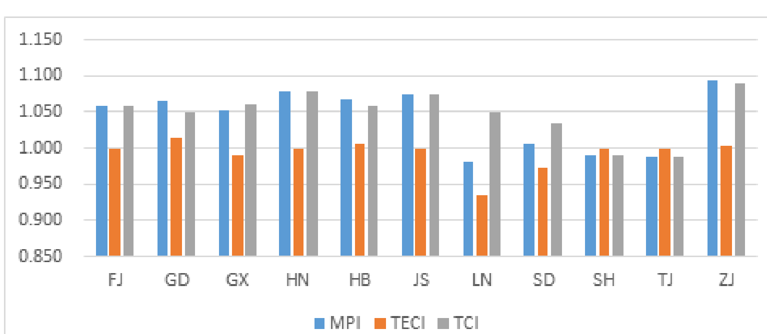

Figure 2. Mean changes of MPI, TECI and TCI in coastal areas in 2013-2018

Figure 3 shows the change trend of TECI in China's coastal provinces from 2013 to 2018. As can be seen from the Figure 3, TECI of the fishery industry in Liaoning province, first maintained a stable state and then decreased to 0.802 in 2016-2017, indicating that there were problems in its internal resource allocation and it needed to be optimized. TECI fishery industry in other provinces was relatively stable.

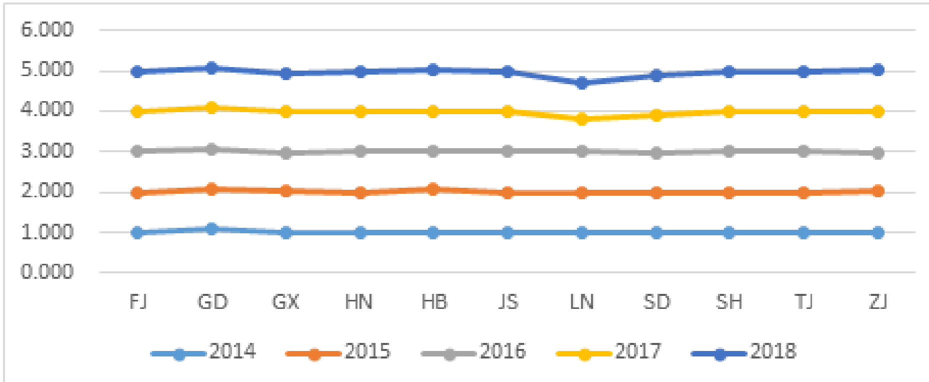

Figure 3. Trend chart of fisheries TECI in coastal provinces of China in 2013-2018

5. Conclusions

We used the DEA based Malmquist index method to calculate the fishery output efficiency of 11 coastal provinces of China from 2013 to 2018, and reached the following conclusions.

The average fishery technical efficiency of Fujian province (1.00), Hainan province (1.00), Shanghai city (1.00) and Tianjin city (1.00) ranked among the top four fishery industries in China's coastal areas from 2013 to 2018.This shows that the utilization of input resources, internal management and operation scale were relatively effective. In general, the efficiency of fishery industrialization in China's coastal areas made some progress from 2013 to 2018, increasing by 4.4%, indicating that economic growth was not only achieved by factor input, but mainly by the growth of total factor productivity brought by technological progress. The total factor productivity of the provinces in the coastal areas showed regional imbalance, and the rate of technological progress was greater than the contribution of technological efficiency.

As for the discussion based on DEA, the selection of different sample size or input output variables will have an important impact on the results. The limitation of this study is that only 11 provinces in China's coastal areas were selected for fishery input-output data. In the future, the research scope can be extended to 31 provinces in China's coastal and inland areas to calculate the efficiency of China's fishery industry.

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