Analysis of Factors Affecting Total Factor Productivity in the Marine Economy

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Abstract. In the new era of building a strong marine country, China is focusing on promoting the high-quality development of the marine economy and continuously optimizing the spatial layout of marine economic development. This paper studies the influencing factors of total factor productivity in the marine economy, aiming to formulate economic policies to promote the sustained growth of the marine economy. The raw data of this paper comes from 11 coastal provinces in China Marine Economic Statistics Yearbook, and the DEA model is used to measure total factor productivity, and the corresponding impulse response and variance decomposition are derived according to the PVAR model test.

Keywords: Maritime economy, Total factor productivity, DEA model, PVAR model

1 Introduction

With the development of globalization, China's coastal provinces, with rich marine resources, developed marine industries and marine science and technology, have become the main driving force of economic growth, but still face some challenges. In the academic research on total factor productivity of marine economy, Zhang et al [1] measured and analyzed the development trend of marine economy; Cui et al [2] used principal component analysis to derive the influencing factors of marine economy. In terms of science and technology innovation and employment, relevant scholars [3-9] measured the total factor productivity of the marine economy and analyzed the relationship between marine science and technology innovation and marine total factor productivity in China by constructing a model through the entropy weight-TOPSIS method, the PVAR model, and the DEA-Malmquist index. In recent years, with the rapid progress of science and technology, the total factor productivity of the marine economy has seen more new research directions [10-12].

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2 Data and Methodological Aspects

2.1 Data Selection

In this paper, the data from China Statistical Yearbook and China Marine Economy Statistical Yearbook for 11 coastal provinces in China from 2012 to 2020 are intercepted and integrated, and based on the four basic principles of "scientific", "comparability", "completeness", and "economy", we constructed the first-level indicators in four dimensions and 15 second-level indicators, and used linear interpolation to make up for the missing data, and the data indicators are shown in Table 1.

Table 1. Table of descriptions of indicators.

primary indicators	Secondary indicators	Unit
technological innovation	Internal Expenditure of R&D Funds	ten thousand yuan
	Scientific and technological achievements	piece
	Number of R&D personnel	people
	Share of S&T personnel in sea-related employment	%
human capital	Doctoral Students for Scientific and Technical Staff	people
	Master's Degree Students	people
	Undergraduate Students	people
	Number of Schools	individual
environmental factor	Total Nitrogen Emissions from Wastewater	million tons
	Water resources per capita	cubic meters per person
	Electricity consumption	billion kilowatt-hours
	Total water supply	billion cubic meters
Capital inputs	General Public Expenditure	billions of dollars
	Gross Regional Product	billions of dollars
	Fixed Asset Investment	billions of dollars

2.2 Data Measurement-DEA-malmquist Index

The DEA-Malmquist index is used as a non-parametric method for assessing changes in productive efficiency and total factor productivity (TFP). The calculation formula from period t to period t+1 is shown in equation (1):

$$M_0(x_{t+1}, y_{t+1}, x_t, y_t) = \left[\frac{d_0^t(x_{t+1}, y_{t+1})}{d_0^t(x_t, y_t)} \times \frac{d_0^{t+1}(x_{t+1}, y_{t+1})}{d_0^{t+1}(x_t, y_t)} \right]^{\frac{1}{2}} \tag{1}$$

$M_0(x_{t+1}, y_{t+1}, x_t, y_t)$is the Malmquist index of total factor productivity, (x_t, y_t) and (x_{t+1}, y_{t+1}) denote the input and output vectors for periods t and t+1, respectively; and $d_0^t(x_t, y_t)$ and $d_0^{t+1}(x_t, y_t)$ denote the distance function with reference to technology in periods t and t+1, respectively.

In this paper, through the DEAP Version 2.1 software, the gross marine product is chosen as the output index; the investment in fixed assets is used as the input index of capital, the number of marine-related employees is used as the input index of labor, and the sum of the number of scientific researchers, the number of scientific research projects and the number of scientific research institutions is used as the input index of science and technology. The total factor productivity of the marine economy from 2012 to 2020 was calculated, and the results are shown in Table 2:

Table 2. 2012-2020 Total factor productivity of the marine economy in 11 provinces.

Area	2012	2013	2014	2015	2016	2017	2018	2019	2020
Tianjin	0.877	1.062	1.048	0.909	0.898	1.157	1.694	0.986	0.655
Hebei	0.889	0.986	1.19	1.068	0.999	1.121	0.465	1.256	0.834
Liaoning	0.72	1.089	0.838	0.919	1.793	0.987	1.519	1.086	0.778
Shanghai	0.953	0.973	0.962	1.048	1.239	1.128	1.074	1.086	0.583
Jiangsu	1.133	1.124	1.034	1.178	1.365	1.040	0.834	1.015	1.135
Zhejiang	0.756	0.974	0.934	1.028	1.062	1.020	1.240	1.127	0.911
Fujian	0.707	1.001	1.173	1.106	1.114	1.128	0.940	1.120	0.997
Shandong	1.139	1.07	1.162	1.059	1.174	1.093	0.755	0.864	0.849
Guangdong	1.126	0.998	1.057	0.955	1.268	1.095	0.873	1.039	0.646
Guangxi	0.895	1.162	0.828	1.026	2.133	1.101	0.370	1.054	1.06
Hainan	0.578	1.11	2.069	0.712	0.976	1.099	0.301	1.120	0.893
mean	0.869	1.048	1.083	0.993	1.232	1.087	0.805	1.064	0.832

In terms of the mean value, the total factor productivity index of each of the 11 provinces and cities declined to different degrees in some years, which may be closely related to local technological innovation and industrial upgrading; while the rest of the years showed a positive development with an increase, which indicates that the rest of the years had a favorable policy environment, educational resources, and technological level.

2.3 PVAR Model Building

2.3.1 Model Introduction.

The PVAR model is built on the basis of the vector autoregressive model (VAR) for processing panel data containing multiple cross-sections, capturing inter-individual heterogeneity, and identifying dynamic causal relationships among variables. In this paper, the PVAR model is constructed as shown in Equation (2):

$$Y_{i,t} = \sigma_i + X_0 + \sum_{j=1}^{p} X_j X_{i,t-j} + \theta_{i,t} + \varepsilon_{i,t} \tag{2}$$

In Eq. (2), σ_i denotes the intercept term, $\theta_{i,t}$ denotes the time effect, i and t denote the eleven coastal provinces as well as the different years, respectively. j denotes the lagged order, and $\varepsilon_{i,t}$ denotes the random fluctuation perturbation term.

2.3.2 Data Selection and Processing.

This paper calculates the weights of 15 secondary indicators and selects one secondary indicator with a larger weight in each first-level indicator as the data indicator for constructing the PVAR model and calculates it using Eviews12 software. In order to eliminate the unit difference of each indicator, this paper has logarized five indicators. Descriptive statistics of the selected data yielded Table 3:

Table 3. Descriptive statistics for data selection.

	Total Factor Productivity	Fixed Asset Investment	Internal Expenditure on R&D Funds	Water resources per capita	Share of R&D doctoral students in the number of personnel
Mean	1.02802	23958.84	100579.9	56132.32	0.226519
Median	1.04	22308.40	72115	1592.1	0.218455
Maximum	2.133	59251.02	529782	961360	0.653846
Minimum	0.301	2145.4	0	51.9	0
Std.Dev.	0.269034	16090.33	98502.22	182168.2	0.100042
Skewness	1.110316	0.541829	1.713276	3.618494	0.82721
Kurtosis	7.935818	2.281291	6.637682	15.57462	5.826163
Jarque-Bera	120.8357	6.974794	103.0177	868.2924	44.23776
Probability	0	0.03058	0	0	0
Sum	101.774	2371925	9957415	5557100	22.42542
Sum Sq.Dev.	7.093176	2.54E+10	9.51E+11	3.25E+12	0.980818
Observations	99	99	99	99	99

In this paper, only two tests are taken, LLC test and PP-Fisher test, if the original hypothesis of the existence of a unit root is rejected in both tests then it means that this series is smooth, and vice versa, it is not smooth. According to the results of the data, the P-value of the results of the LLC test and the PP-Fisher test for the five data indicators is less than 0.05, and it can be concluded that the series of the data all show smoothness.

2.3.3 Selection of Lag Order.

According to the lag order selection table obtained by examining the initial data, this paper chooses the lag order of 3 as the optimal solution of the VAR model. According to the AR root table, it is confirmed that the Modulus values are less than 1, so it shows that the PVAR model presented in order 3 is stable.

2.3.4 PVAR Model Test.

According to the table of test results of the 3rd order PVAR model, it can be seen that most of the R^2 and adjusted R^2 values of the five variables are close to 1, which indicates that the test results of the model are relatively good and can be followed by subsequent analysis.

2.3.5 Granger Causality Test.

According to the results of Granger causality test, when the independent variables are the logarithmic forms of the share of R&D doctoral students in the number of personnel, total factor productivity and internal expenditure on R&D funding, their p-values for the overall variables are 0.0000, 0.0088 and 0.0014 respectively.

The internal expenditure on R&D can be effectively predicted by the share of R&D doctoral students in the number of personnel; total factor productivity can be effectively predicted by the share of R&D doctoral students in the number of personnel; and the share of R&D doctoral students in the number of personnel can be effectively predicted by the internal expenditure on R&D.

2.3.6 Impulse Effect Analysis.

In order to further analyze the relationship between the proportion of R&D doctoral students on other influencing factors and their own influence, this paper sets the proportion of R&D doctoral students as a shock factor, and the period of the shock effect is 10 periods, and the impulse response function graphs between the variables are obtained through 500 Monte Carlo simulations as shown in Fig. 1.

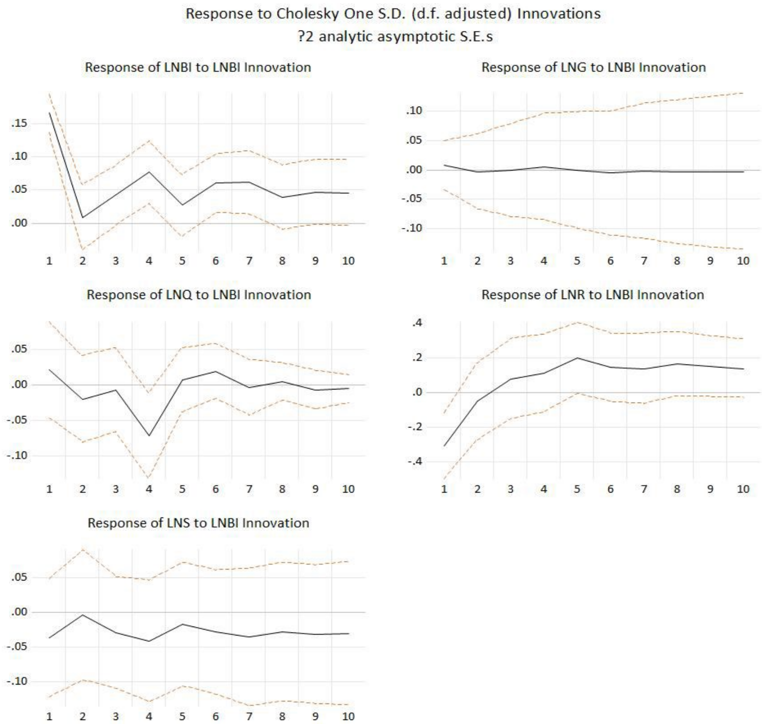

Fig. 1. Impulse Response Function Plot of Variables on the Share of R&D Doctoral Students in the Number of Personnel.

As can be seen from Fig. 1, when the proportion of R&D doctoral students is used as a shock factor, the shocks to per capita water resources and internal R&D expenditures are stronger in the first five periods, and then gradually flatten out; the fluctuation of its shock to total factor productivity is the most obvious, and reaches a peak in the fourth period, and then gradually flattens out in the seventh period; its impact on itself fluctuates the most obvious in the fourth and the fifth periods, and gradually flattens out in the seventh period; and the impact on the amount of investment in fixed assets is the least obvious.

2.3.7 Variance Decomposition.
The variance decomposition analyzes the proportion of the standard deviation of the forecasted residuals that is affected by shocks to different new interest rates, i.e., the proportion of the standard deviation that corresponds to the contribution of the endogenous variable.

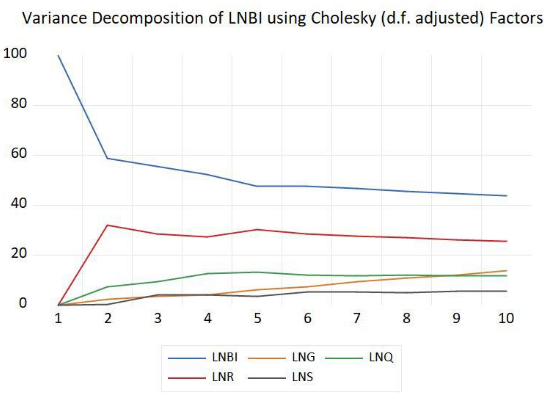

Fig. 2. ANOVA test plot on the share of R&D PhD students in the number of personnel.

As shown in Fig. 2, we can know that the impact ratio of internal R&D expenditures is the largest impact factor after the ratio of R&D doctoral students to the number of personnel in the second period, and the situation of internal R&D expenditures remains the second largest impact factor in the later period as well. From the details, we can see that the share of total factor productivity reaches about 10%, while the fixed asset investment which increases from period to period even exceeds the influence of total factor productivity in the 9th period.

3 Conclusions and Recommendations

Firstly, the total factor productivity of the marine economy in most of China's 11 coastal regions tends to grow steadily from 2012 to 2020, and the inter-regional development differences are gradually narrowing. Secondly, by using the PVAR model test, it can be obtained that the use of the proportion of R&D doctoral students to the number of personnel can be effectively predicted to the data of total factor productivity and internal expenditure on R&D funding; at the same time, most of the factors on the impact of the proportion of R&D doctoral students to the number of personnel have also produced different degrees of impulse response; further variance decomposition of the proportion of R&D doctoral students to the number of personnel can also be seen that The impact of internal R&D expenditures is second only to its own impact, the impact of total factor productivity is third, and the impact of per capita water resources is negligible.

This paper puts forward several policy recommendations based on the results of the study: first, the government should incentivize technological research and development through scientific research funding and preferential policies. Secondly, establish a perfect education and training system, strengthen personnel training, carry out international scientific and technological exchanges and cooperation, and introduce advanced management concepts and technologies. Finally, implement marine ecological protection and restoration projects to realize the win-win situation of economic and ecological benefits.

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