On Influencing Factors of Innovation Efficiency in China's Marine Enterprises

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Abstract

To a considerable extent, the innovation ability in China's marine filed is determined by the innovation efficiency of marine enterprises. In this paper, 51 marine listed companies taken as the samples are conducted with calculation and measurement of innovation efficiency by using Malmquist index, so as to analyze the internal and external factors influencing the innovation efficiency of marine enterprises by building the regression model. The results show that the government subsidy as an external factor has no significant impact on the innovation efficiency of marine listed companies; in terms of internal factors, employee educational level has a positive impact on enterprise innovation efficiency, and the enterprise R & D investment has no significant impact on total factor production of innovation efficiency. Therefore, with the perfection of government subsidy policy by our country, marine enterprises should focus on the using efficiency of R & D investment and strengthen talent construction, so as to promote the improvement of enterprise innovation efficiency.

Keywords: *Marine enterprises, Malmquist index, Influencing factor*

I. Introduction

As the birthplace of earth life and the treasure-house of material resources in the world, the ocean is not only a new strategic territory related to national security but also an important field for scientific exploration, whose attentions and relevant researches has reached an unprecedented height since entering the 21st century. In 2016, the *First World Ocean Assessment* of the United Nations launched and assessed the state of marine health for the first time; in 2017, the first *Global Ocean Science Report: The Current Status of Ocean Science around the World* was prepared by the Intergovernmental Oceanographic Commission of UNESCO; the resolution 72/73 passed by the General Assembly of the United Nations in December 2017 decided the launching of the plan for United Nations Decade of Ocean Science for Sustainable Development from 2021, with the version 2.0 of its draft *Implementation plan* completed at the end of July 2020.

In recent years, the much attentions of China as a great marine country paid to marine economy have promoted the issuance of a series of supportive policies by central and local governments for the strengthening of marine development and utilization as well as the innovation of marine technology. In China, the increase of gross marine product from 3.8 trillion RMB in 2019 to 8.4 trillion RMB in 2019 with an annual average increase rate of 8% has pushed the ocean to become an important strategic space for China's economic and social development and provide a new driving force for China's economic development. However, simultaneously, the slowdown in growth, the unbalanced development and other problems of marine economy have also gradually become prominent. With a decrease from 12.8% in 2010 to 6.2% in 2019, the growth rate of gross marine product affected by COVID-19 and other factors especially was -5.3% in 2020, namely, the first negative growth since 2001.

In the new era, the realization of marine economic transformation from rapid growth to high-quality development must rely on marine technological innovation to improve marine total factor productivity. As the micro main body of China's marine economy, marine enterprises can directly affect the successful innovation-leading-oriented and

quality-benefit-oriented transformation of marine economy by their quality of innovation efficiency. In view of this, marine enterprises in China are taken as the research objects in this paper to analyze the influencing factors of their innovation efficiency according to the building of innovation efficiency evaluation model, thereby providing micro decision support for marine economic development in China.

II. Literature Overview

The sci-tech innovation efficiency as the basis to measure the quality of a country's economic development has numerous relevant research literatures with a large involvement scope, from the macro international comparison to the comparison between enterprises and institutions. Thomas (2011) et al. [1] estimated the R & D efficiency of the United States by using patent and publication indicators; Abramo (2009) et al. [2] evaluated the allocation efficiency and technical efficiency of scientific research activities in Italian University by using DEA evaluation; the measurement and calculation conducted by Ren (2018) et al. [3] on the green efficiency of China's marine economy under environmental constraints by using the Malmquist-Luenberger index model show that the improvement of green efficiency of China's marine economy relies on technological progress.

The domestic researches on marine innovation mainly focus on the evaluation and the influencing factors of marine innovation efficiency, in which, the evaluation of marine innovation efficiency is carried out from two levels: The first is to compare the marine innovation efficiency of coastal provinces and cities in China from the macro level, for example, Zhang Yanyan (2016) [4] conducted the SBM model-based measurement on the static technical efficiency of marine economy in 11 provinces; Li Bin (2010) et al. [5] analyzed the technical efficiency of marine economy in 11 coastal provinces and cities; Liu Dahai (2018) [6], Wang Qing (2020) [7] and other scholars also carried on some researches; the second level is to take some coastal provinces as objects for analysis, for example, Li Bin and Dai Guilin (2014) [8] evaluated the marine sci-tech innovation ability of the Shandong Peninsula Blue Economic Zone; Fang Hao (2018) et al. [9] conducted researches on the marine agriculture in Zhejiang and its industrial sci-tech innovation strategy; Gao Tianyi [10] and Chen Qian [11] conducted the relevant researches on Qingdao, the Bohai Rim and other specific regions.

The main researches on influencing factors of marine innovation efficiency are as follows: Ning Ling and Song Zeming (2020) [12] analyzed the influencing factors of marine sci-tech innovation efficiency in 11 coastal areas of China by using the established Tobit model; Fu Xiumei, Wang Shiqi (2020) and other scholars [13] calculated the industrial innovation efficiency by using stochastic frontier analysis method to analyze its influencing factors; Xie Ziyuan, Ju Fanghui (2012) and other scholars [14] used the super efficiency DEA model to calculate the marine sci-tech innovation efficiency in relevant regions of China and analyze the possible influencing factors.

The existing researches on marine innovation have provided valuable reference for marine economic development in China, but the above researches with the main focus on coastal provinces or cities in China seldom pay attention to marine enterprises in our country from a micro perspective. As the micro main body of China's marine economy and the main force of marine economic development, marine enterprises can directly affect the quality of marine sci-tech innovation by their innovation efficiency. Based on which, marine enterprises in China are taken as the research objects to analyze the influencing factors of their innovation efficiency, so as to form the micro research results on marine economic innovation by theoretically enriching the research contents of China's marine economy and practically provide necessary data support and decision reference for the innovation efficiency improvement of marine enterprises.

III. Innovation Efficiency Measurement of Marine Listed Company

3.1 Sample selection and model determination

Marine enterprises usually refer to the various kinds of enterprises engaged in marine related business, involving

the three industries. The considerations on the marine enterprises with wide business range, the lack of authoritative government statistical data, and the availability of data have pushed the marine listed companies listed on Shanghai and Shenzhen stock exchanges to be selected as the research objects of this paper, with the specific process of sample selection as follows: First, search the listed companies in the "ocean plate" of securities networks such as Straight flush, JRJ.com and Sina Finance; then, eliminate the companies with financial abnormalities and missing data such as ST, *ST, etc.; finally, check the "main business of the company during the reporting period" disclosed in the company's annual report one by one, thus 51 sample companies are finally selected as research samples according to the rule that whether the company's main business belongs to marine industry or not, with the time period of samples in this study determined as from 2017 to 2019. The patent quantity data in this paper comes from baiteng.com and the official website of the State Intellectual Property Office; other data are directly from the information publicly disclosed by cninfo.com, Shanghai and Shenzhen stock exchanges, Sina Finance and other major securities websites.

As the most commonly used method to measure innovation input and output efficiency, the traditional DEA models include CCR model with constant returns to scale and BCC model with variable returns to scale, which can be only used for cross-sectional data analysis, while based on the input-output relationship, the Malmquist index can evaluate the tfpch (total factor productivity change) of each decision unit through the analysis on panel data containing observations at multiple time points, thereby studying the dynamic production efficiency of multi-period input and output variables, which has the more comprehensive analysis contents relative to traditional CCR and BCC models, thus this method is adopted in this paper to measure and calculate the innovation efficiency of marine listed companies. When the efficiency value is greater than or equal to 1, it means that the decision-making unit is valid, and when the efficiency value is less than 1, it means that the decision-making unit is invalid.

Tfpch (total factor productivity change can be further decomposed into effch (efficiency change) and techch (technological change). The approach of efficiency change measurement decision unit to the current production frontier from the period t to the period t + 1 is mainly reflected in the improvement of management system and resource allocation; the movement of technical change measurement decision unit to the technical boundary from the period t to the period t + 1 is mainly reflected in the improvement of manufacturing process, production skills and other aspects.

3.2 Input and output indicators

Based on the research objectives of this paper and the innovation state of marine listed companies, the comprehensive consideration on the availability of data and the measurability of indicators has promoted this paper to adopt the following input and output indicators to evaluate the innovation performance of marine enterprises.
Innovation investment is the investment of enterprises in the operation of innovation activities. Among the measurement of innovative manpower investment and innovation fund investment in this paper, innovative manpower referring to the human capital related to innovation activity is specifically reflected by the number of R & D personnel disclosed in the annual report of sample company; the innovation fund investment is the total R & D investment of the company in the current year, including expense and capitalization.

As the achievement formed in enterprise innovation activity, innovation output is mainly reflected in the following two aspects: The first is knowledge innovation output, referring to the number of sample company's patents being granted this year, and the second is the economic benefit of innovation output, which is measured by the company's operating income in that year.

3.3 Innovation Efficiency Measurement Results

The panel data of the 51 sample companies from 2017 to 2019 is analyzed by using Deap2.1 software with the

adoption of Malmquist index, and the calculation results of the overall efficiency value of sample companies are shown in Table 1.

Table 1 Malmquist index of marine companies from 2017 to 2019

Year	Effch	Techch	Tfpch
2017-2018	1.225	0.768	0.964
2018-2019	1.234	0.784	0.967
Mean value	1.244	0.776	0.966

As shown in Table 1, due to the joint impacts of efficiency change (effch) and technological change (techch), the total factor productivity change (tfpch) index of marine listed companies in innovation from 2017 to 2019 is 0.966, with a decrease of 3.4%. The technological change index is 0.776, showing a larger decrease, which is possibly because the severe international environment in recent years has driven the marine enterprises to slow down the R & D and adoption of new products and new process, with the failing of improvement in production skills, thus leading to the decrease in technological change index. Oppositely, the efficiency change index showing large improvement has increased by 24.4%, indicating that the gradually perfection of innovation administration system and the gradually enhancement of resource allocation level of the marine listed companies in the recent three years have made the efficiency change index increased.

The specific Malmquist Index of 51 sample companies are shown in Fig. 1.

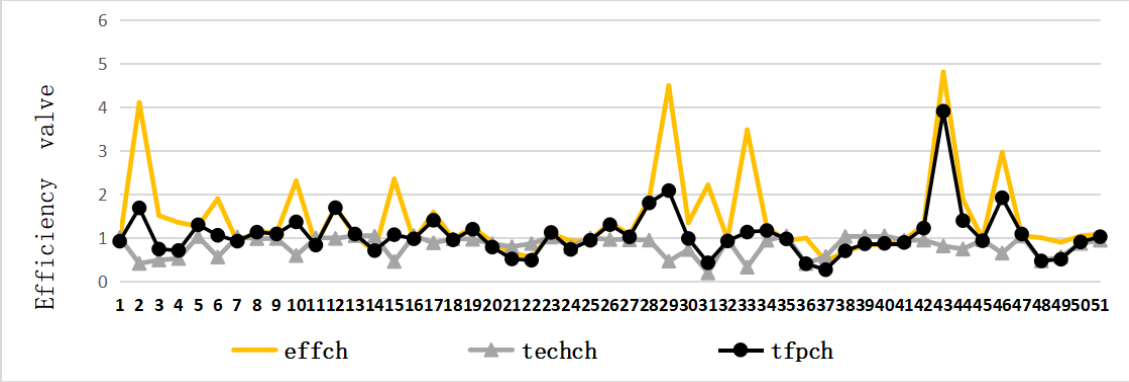

Fig 1: Malmquist index of 51 sample companies

As shown in Fig. 1, among the 51 sample companies, there are 24 companies with the tfpch index greater than 1, accounting for about 47% of the total, thus indicating the realization of innovation efficiency improvement in nearly half of the companies. As a national high-tech enterprise and a key high-tech enterprise of National Torch Plan, the company No. 43 has an enterprise technology center recognized by the state and the highest tfpch index valued 3.902, with the effch index of 4.801 and the techch index of 0.813, which is engaged in radar industry, smart industry and energy industry. There also are 27 companies with the tfpch index less than 1, in which, the company No. 37 has the lowest tfpch index valued 0.268, with the effch index of 0.468 and the techch index of 0.571. Generally speaking, the macro background of building a marine power in China has promoted the significant improvement of sci-tech innovation efficiency in some marine enterprises, but a considerable number of marine enterprises with the relatively low level of innovation efficiency still have huge room for improvement.

IV. Regression Analysis

4.1 Variable determination

In this paper, the tfpch index of sample companies calculated above is selected as dependent variable to study the

comprehensive impact of various factors on enterprise innovation efficiency; in addition, the effch index and the techch index that are further decomposed from tphch index are also taken as the dependent variables in this paper to further study the impact of various factors on efficiency change and technological change.

In this paper, government subsidy, enterprise's R & D investment and employee educational level are selected as independent variables from the perspective of internal and external factors affecting enterprise innovation activities, in which, government subsidy belongs to external factor, while the other two belong to the enterprise internal factors. Firstly, government subsidy refers to the government provided monetary or non monetary assets that the enterprise can obtain without pay. Among a series of supportive policies issued by the governments at all levels in recent years to promote the marine economic development, government subsidies have become one of the important sources of funds for some marine enterprises to carry on R & D activities. In this paper, the total amount of government subsidies disclosed in the annual report of enterprises is taken as the government subsidy measurement standard of sample companies. Secondly, enterprise's R & D investment as the most direct innovation investment of enterprises is also one of the commonly used indicators for the researches on relevant innovation activities, whose data comes from the amount of R & D investment projects disclosed in the annual report of enterprises. The third is the employee educational level, while the individuals with different educational levels have different abilities, thus generally speaking, the stronger ability of the employees with high education level makes them more likely to participate in enterprise innovation activities, which is more conducive to the improvement of enterprise innovation ability and the formation of innovation achievements. In this paper, the ratio of personnel at university level and above to all employees disclosed in the annual report of enterprises is taken as the indicator to measure the employee educational level of marine enterprises.

The control variables in this paper select some indicators from capital structure, enterprise scale and profitability for control and adjustment. In terms of capital structure, the asset liability ratio is selected to reflect the enterprises with the efficiency of operating activities by utilizing the funds provided by creditors and the ability of bearing debt risks, which has certain impact on enterprise innovation investment; the existing researches show the easier accessibility of large-scale enterprises to external resources. Therefore, enterprise scale as one of the control variables in this paper adopts the logarithm of assets, and the profitability selects the earnings per share, while generally, the higher profitability of the company indicates the higher enterprise administration efficiency, thus making full use of company's resources to create value, with more possibility to promote the improvement of enterprise innovation efficiency.

The following three models are built according to the above variables:

$tfpch = \alpha_0 + \alpha_1 Sub + \alpha_2 RD + \alpha_3 Employ + \alpha_4 Size + \alpha_5 EPS + \alpha_6 Lev + \varepsilon$ Model (1)
$effch = \alpha_0 + \alpha_1 Sub + \alpha_2 RD + \alpha_3 Employ + \alpha_4 Size + \alpha_5 EPS + \alpha_6 Lev + \varepsilon$ Model (2)
$techch = \alpha_0 + \alpha_1 Sub + \alpha_2 RD + \alpha_3 Employ + \alpha_4 Size + \alpha_5 EPS + \alpha_6 Lev + \varepsilon$ Model (3)

Where,

Sub=Government subsidies;
RD=Research and development investment of enterprises;
Employ=Education level of employees;
Size=Enterprise scale;
EPS=Earnings per share;
Lev=Asset liability ratio.

4.2 Analysis on regression results

Table 2 Regression results

Variable name	Model (1)	Model (2)	Model (3)
Sub	-0.023 (-1.216)	-0.026 (-0.980)	0.003 (0.416)
RD	-0.013 (-0.972)	-0.098*** (-5.281)	0.026*** (5.511)
Employ	0.991** (2.356)	1.312** (2.243)	0.123 (0.862)
Size	-0.152** (-2.293)	(2.243) -0.080	(0.862) -0.05**
EPS	0.681*** (3.576)	0.962*** (3.634)	(-2.225) -0.001
Lev	0.686 (1.44)	0.785 (1.189)	0.024 (0.149)
R square F value	0.291 3.014**	0.544 8.743***	0.538 8.537***

Notes: ***, ** and * respectively denote the significance at the statistical level of 1%, 5% and 10%; the numbers in brackets are T values.

As shown in Table 2, the three models all pass the F test, with their respective significance level of 5%, 1% and 1%, thus indicating the existence of a significant linear relationship between the dependent variables and all independent variables of each model. Model (1) shows the significant impacts of employee education level, enterprise scale and earnings per share on the tfpch index of enterprise innovation; model (2) shows that the independent variables significantly affecting enterprise's effch inex include R & D investment, employee educational level and earnings per share, respectively; model (3) shows the significant impact of R & D investment and enterprise scale on enterprise's techch index.

Specifically, the government subsidy in the independent variables has no significant impact on dependent variables in the three models, thus indicating that at present, the single government subsidy fails to play a positive role in the improvement of enterprise innovation efficiency. Failing to significantly affect the tfpch index of innovation, R & D investment has the significant impact on enterprise's effch and techch index, but with the opposite effect of impact. The negative R & D investment coefficient in model (2) indicates that the increase in R & D investment of marine enterprises cannot improve the technological efficiency of enterprise innovation, but plays the opposite role, while the positive R & D investment coefficient in model (3) indicates the increase in R & D investment has significantly positive impact on enterprise techch index. The positive coefficients of employee educational level in models (1) and (2) all pass the 5% significance level test, indicating that the more the number of employees with high education level in marine enterprises, the higher the innovation efficiency of enterprises.

The enterprise scale in control variables passes the 5% significance level test in model (1) and model (3), but with the negative coefficient symbol, thus indicating that the innovation efficiency of the large-scale marine enterprises fails to be improved, but may be restricted due to the inflexible management system and complex institutions; the earnings per share passes the 1% significance test in model (1) and model (2), thus indicating that the enterprises with strong profitability can better improve the enterprise innovation efficiency; the asset liability ratio fails to pass the test in the three models.

V. Conclusions and Recommendations

The marine listed companies in China taken as the samples in this paper are conducted with measurement and calculation of enterprise innovation efficiency, so as to analyze its influencing factors. The results of empirical research show that government subsidy has no significant impact on the innovation efficiency of marine listed

companies, and the R & D investment, failing to significantly affect the total factor productivity change, has the significant impact on enterprise's efficiency change and technological change index, but with the opposite effect of impact, while the employee educational level of marine enterprises has the positive impact on enterprise innovation efficiency. The following countermeasures are put forward in this paper according to the research results.

Firstly, perfect government subsidy policies and formulate various support policies.

At present, the realization of transformation from rapid growth to high-quality development for China's economy that is in the key period of from factor-driven to innovation-driven transformations has promoted the governments at all levels to continuously increase government subsidies in the hope of promoting innovation development. However, the research results in this paper show the failing of government subsidies to significantly improve the innovation efficiency of marine enterprises, thus governments should formulate a series of more effective systems or perfect the relevant policies to avoid the single financial subsidy model, for example, optimize preferential tax policies, appropriately relax the application scope of innovation activities, and appropriately increase the additional deduction of R&D expenses; build the university-industry-research platforms through the strengthening of the connection between enterprises and local scientific research and education institutions, so as to strive for more innovation and development space for enterprises, thereby effectively promoting the improvement of innovation efficiency in marine enterprises.

Secondly, improve the using efficiency of R & D funds and enhance the sustainable innovation ability of enterprises.

The requirement of fund investment by innovation output does not mean that the more R & D funds, the better, while only by focusing on the improvement of R & D efficiency can marine enterprises continuously enhance their innovation ability. The empirical research results show that the R & D funds fail to significantly enhance the enterprise's innovation ability, and the further analysis finds that being significantly and positively correlated to technological progress, the R & D investment has a negative impact on comprehensive technical efficiency, thus indicating that the available adoption of more new technologies and new equipments realized by R & D investment has made the manufacturing process and production skills of enterprises improved, but without the perfection in administration system and resource allocation, thus resulting in the decrease of enterprises' comprehensive technical efficiency. Therefore, with an increase in R & D investment, marine enterprises should pay more attention to the improvement of innovation system and resource allocation, so as to ensure the using efficiency of R & D funds in enterprises.

Thirdly, strengthen talent construction and improve the overall knowledge level of employees in marine enterprises.

Talent competition is the key for science and technology competition. Fundamentally, the improvement of innovation ability and innovation performance ultimately relies on the quantity and quality of sci-tech personnel in enterprises. With the quality of sci-tech talents as the key factor of marine sci-tech innovation ability, marine enterprises should formulate the fair and just talent assessment and competition mechanism as well as the relevant policies related to the introduction and evaluation of marine sci-tech innovation talents, so as to completely tap and utilize the innovation potentials of sci-tech talents, ensure the standing out og excellent talents, improve innovation efficiency, and provide complete human resources guarantee for marine enterprises to improve innovation efficiency.

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