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Effect of Blue Finance and Marine Environmental Quality on the Marine Fishery Economy

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Abstract: This study investigates the effects of blue finance and marine environmental quality of the marine fishery economy using panel data for marine fisheries in China's coastal provinces spanning 2011–2023. We use entropy, moderating effects, and threshold effects to calculate the level of blue finance and marine environmental quality, the moderating role of marine environmental quality in blue finance's effect on the marine fishery economy, and the threshold effect of blue finance and marine environmental quality on the marine fishery economy. We find that (1) blue finance can improve the marine fishery economy, with an influence coefficient of 0.245. (2) The quality of marine environment plays a transmission mechanism role in the impact of blue finance on the development of marine fishery economy quality. (3) Blue finance and marine environmental quality both have a first-order threshold effect on the marine fishery economy, showing a U-shaped curve relationship.

Keywords: blue finance; marine fishery; moderating effect; economic quality

Key Contribution: This study's contributions are as follows. First, it reveals the driving role of blue finance development in the development of the marine fishery economy, enriching the relevant theories of blue finance development and literature related to the development of marine fisheries economy. Second, this article analyzes the mechanism of its role in the development of the marine fishery economy, which is a beneficial expansion of the relevant theories on the development of blue finance and empirical research on the development of the marine fishery economy. This article combines the characteristics of the quality development of the marine fishery economy, analyzes the regulatory role of marine environmental quality in promoting the development of the marine fishery economy through blue finance, marine environmental quality, and other factors, as well as the marginal effects of blue finance and marine environmental quality on the development of the marine fishery economy. It clarifies the effective path of blue finance promoting the development of the marine fishery economy, which can provide scientific reference for the government to formulate effective policies for blue finance and the marine fishery economy's development.

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1. Introduction

Marine fisheries promote employment in coastal areas, increase fishermen's incomes, help satisfy people's diverse dietary needs, help transform and upgrade the marine industry, ensure national food security, and help safeguard national maritime sovereignty.

According to the Food and Agriculture Organization, the world's fishery and aquaculture output reached 223.2 million tons in 2022, of which 62% came from marine fisheries (69% from capture fisheries, 31% from aquaculture). Marine capture fisheries produced 79.7 million tons of aquatic animals, remaining the main source of the total global aquatic animal output (43%). A total of 89% of aquatic animal production is for human consumption, with a per capita consumption of 20.7 kg [1]. However, with the growing uncertainty posed by climate change, the increasing risks to marine environmental quality, and the reckless expansion of marine resource development, the marine fishery economy now faces problems, such as resource decline, environmental deterioration, and diminishing overall benefits. At the same time, overfishing and inadequate fishing methods in marine fisheries have also caused problems, such as damage to the marine ecological environment, the loss of biodiversity, the depletion of fishery resources, and the disruption of the marine fishery industry chain. In response, coastal regions are promoting the greening of marine fishery and developing blue finance to improve the marine environment and solve the problems of the marine fishery economy. In 2021, for example, the United Nations Environment Programme released Tide to the Future: Finance for a Sustainable Ocean Recovery, a practical guide to help financial institutions finance a sustainable blue economy [2]. In January 2022, International Finance Corporation issued the Blue Finance Guidelines, emphasizing sustainable development goals, marine environment protection, and the sustainable development of the marine industry [3]. In China, the 14th Five-Year Plan for the Development of the Marine Economy and the 14th Five-Year Plan for the Protection of the Marine Ecological Environmental focused on the reform and diversified development of marine investment and financing, offering policy guidance for blue finance. Blue finance refers to financial activity that specifically serves the blue economy. Based on functions such as resource allocation, risk management, and market pricing, it supports the reduction in marine plastic pollution, marine ecosystem restoration, and the sustainable development of marine-related industries [4]. However, the development of blue finance also faces practical problems, such as the uneven distribution of funds and the risk of "blue washing". For example, some developing countries and small fishing enterprises (many small island countries and indigenous groups in large countries, such as Canada) are facing financing and technological challenges [5]. Due to various reasons, it is difficult to obtain effective financing. Some fishing enterprises rely on nominal green and low-carbon transformation and development to obtain financial support. So, can blue finance effectively promote the sustainable development of the marine fishery economy? At the same time, as an important characteristic indicator of the development of marine fishery economy, the quality and efficiency level of the marine ecological environment will be affected by the development of blue finance, which will directly or indirectly affect the development of marine fishery economy. Can blue finance and marine environmental quality jointly promote the marine fishery economy? What is the mechanism by which the two influence the marine fishery economy? Investigating such questions holds theoretical significance for promoting blue finance and the marine fishery economy, as well as practical value for coastal regions aiming to achieve the "blue transformation" of the marine economy.

Research on blue finance and the marine fishery economy mainly focuses on the meaning of blue finance and its promotion of the marine economy. The Asian Development Bank defines blue finance as an emerging area in climate finance, where blue bonds and blue loans serve as innovative financing instruments, and funds are invested in blue economy domains, such as water and wastewater management, marine plastic reduction, marine ecosystem restoration, sustainable shipping, eco-friendly tourism, and offshore renewable energy [6]. Bosmans et al. (2023) explained why water and oceans should have a specific classification label in the field of sustainable finance, linking the development of blue bonds

to broader sustainable finance topics, and conducting a comprehensive analysis of blue bond trading worldwide [7]. Olsen (1995) provides a detailed exposition of debt for nature tools, their advantages, and contributions to conservation efforts, adding a global perspective [8]. Hu Jinyan et al. (2018) proposed that blue finance is a concentrated reflection of the "green" concept in the marine field that encourages investors to participate in marine environmental protection using blue financial instruments [9]. Investigating financial support for the marine economy and marine environmental protection, He Dan (2021) highlighted blue finance and related financial products as the main areas for development [10]. Deng Yu (2023) reviewed and summarized the development and practices of domestic and international blue finance and suggested the following for its further development: clarify the development goals and main tasks of blue finance, set up professional departments or specialized institutions for blue finance, accelerate innovations in blue finance investment and financing models, and deepen international cooperation [11]. Keen et al. (2017) suggested that blue finance is essential for promoting sustainable blue economy development and protecting marine ecosystems [12]. Wabnitza and Blasiak (2019) focused on the practical functions of blue finance, noting that it raises funds from international investors and invests them in ocean-related projects [13]. Chen Lingxiang (2022) noted that blue bonds promote the segmentation and improvement of the green bond market, optimize local debt structures, and help achieve the goal of carbon neutrality [14]. Considering the development advantages of the Guangdong–Hong Kong–Macao Greater Bay Area, Meng Fanchen (2023) proposed that a blue financial system could be built in the area through measures such as coordinating forces, improving rules, cultivating subjects, innovating tools, establishing think tanks, and preventing risks [15]. Chen Tingting (2022) noted that constructing a blue financial system could further promote the blue economy and support the high-quality development of the marine economy [16]. Cheng Baozhi (2023) characterized blue finance as an open financial system containing diversified financing channels, risk-control tools, and financial products that can guide the role of capital in structurally adjusting the marine industry and transforming its development. For example, blue bonds, an innovative investment tool in the capital market, can optimize the allocation of marine production factors and overcome the financing constraints of marine-related enterprises [17]. Like green finance, blue finance can perform the function of "resource allocation" and leverage capital-oriented financial resources to flow to blue projects through products, such as blue credit, bonds, and funds [18].

Studies have mainly focused on blue finance's effect on marine economy development. Few, however, have specifically studied blue finance and the development of the marine fishery economy through empirical investigation. This study, therefore, takes the marine fishery economies of China's coastal provinces and cities as the research object and explores blue finance's effect on the marine fishery economy. Furthermore, we analyze marine environmental quality as a moderator in blue finance's effect on the marine fishery economy and reveal the marginal effects of blue finance and marine environmental quality on the marine fishery economy.

This study's contributions are as follows. First, we explore the effects of blue finance and marine environmental quality in China's coastal provinces and cities on the marine fishery economy and reveal blue finance's promotion of the marine fishery economy. This enriches the relevant theories of blue finance development and literature in the field of marine fishery economic development. Second, existing studies mainly analyze the mechanisms and development paths of marine fishery economy development in terms of upgrading marine fisheries and developing the digital economy. They do not, however, consider the effect of blue finance and marine environmental quality on the marine fishery economy. Based on the characteristics of the marine fishery economy. We reveal the

regulating role of marine environmental quality in blue finance's promotion of the marine fishery economy and the marginal effects of blue finance and marine environmental quality on the marine fishery economy. We further clarify the path by which blue finance promotes the marine fishery economy. This can serve as a reference for governments to formulate policies for blue finance and the marine fishery economy.

2. Study Design and Methods

2.1. Study Area

We select 11 coastal provinces (cities) in China as the research objects: Liaoning, Tianjin, Hebei, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Guangxi, and Hainan. We calculate data related to blue finance and marine environmental quality to explore the relationship between the two and their effect on the marine fishery economy. The study period is 2011–2023. The data used mainly come from the China Statistical Yearbook, China Environmental Statistical Yearbook, and China Fishery Statistical Yearbook.

2.2. Indicator System Construction

Blue finance and the marine environment are relatively complex systems. We, therefore, construct an index system to accurately measure the level of blue finance and marine environmental quality. Blue finance is divided into seven indicators: blue credit, blue investment, blue insurance, blue bonds, blue support, blue fund, and blue equity. (1) Blue credit: This refers to loans provided by banks or other financial institutions to finance sustainable projects in the marine economy (e.g., desalination, marine engineering equipment manufacturing). (2) Blue investment: This is an investment method that integrates environmental protection and sustainable development concepts into investment decision making. Blue investment includes clean marine energy, marine environmental protection, and marine water resource management. (3) Blue insurance: This provides risk protection for activities in marine and coastal areas (e.g., climate index insurance) to deal with risks arising from climate change. (4) Blue bonds: These are similar to green bonds but are specifically designed to finance sustainable projects in marine and coastal areas, such as marine conservation and renewable energy. (5) Blue support: This refers to the proportion of government investment in marine environmental protection in general budget expenditure. (6) Blue fund: This is an investment fund focused on ocean-related projects, such as marine ecosystem restoration and marine biodiversity conservation. (7) Blue equity: Similar to green rights and interests, it aims to use market mechanisms to reduce pollution or greenhouse gas emissions and promote the green, low-carbon development of the ocean. It can include carbon markets, emission rights trading, energy use rights trading, and water rights trading. All of these indicators play an important role in blue finance and are, therefore, selected to construct a blue finance indicator system.

We construct an evaluation index system for marine environmental quality using previously selected indicators, mainly classified into the following two dimensions: marine resource quality and marine ecological quality. For the measurement of marine resource quality, we select the relative annual variation in sea levels, the area of coastal wetland, and the proportion of stations whose sea sediment conditions meet the quality standard of class I marine sediment. Marine ecological quality is measured by four indexes: chemical oxygen demand of phytoplankton diversity index, zooplankton diversity index, benthic biodiversity index, and annual average number of fecal coliforms in the water. Table 1 shows the specific indicators.

Table 1. Indicator system for evaluating blue finance and marine environmental quality.

Target Layer	Rule Layer	Index Layer	Index (Positive/Negative)	Weight
Blue finance level	Blue credit	Total credit of provincial marine environmental protection projects (billion CNY)/total credit of the province (billion CNY)	Positive	0.1715
	Blue investment	Total investment in marine environmental governance (billion CNY)/GDP (billion CNY)	Positive	0.1105
	Blue insurance	Income from environmental pollution liability insurance (billion CNY)/total premium income from environmental protection (billion CNY)	Positive	0.1721
	Blue bonds	Total amount of blue bonds issued (billion CNY)/total amount of all bonds issued (billion CNY)	Positive	0.1328
	Blue support	Fiscal expenditure on environmental protection (billion CNY)/fiscal expenditure from general budget (billion CNY)	Positive	0.1084
	Blue fund	Total market value of blue funds (billion CNY)/total market value of all funds (billion CNY)	Positive	0.1591
	Blue equity	Total amount of carbon trading, energy trading, and emission trading (billion CNY)/total amount of equity market trading (billion CNY)	Positive	0.1457
Marine environmental quality level	Marine resource quality	Relative annual variation of sea level (mm)	Negative	0.1331
		Coastal wetland area (thousand hectares)	Positive	0.3582
		Proportion of stations where the sediment conditions in the sea area meet the quality standards of class I marine sediments (%)	Positive	0.0808
	Marine ecological quality	Phytoplankton diversity index chemical oxygen demand	Positive	0.1175
		Diversity index of planktonic animals	Positive	0.0536
		Benthic biodiversity index	Positive	0.2392
		Annual average number of fecal coliforms in water (PCS/L)	Negative	0.0176

Note: Weights are calculated using the method given in Section 2.3.2.

2.3. Methods

2.3.1. Data Standardization

Because of differences in the dimensions and positive and negative indicators of blue finance and marine environmental quality, it is necessary to standardize the indicator data. The specific treatment methods are as follows:

The positive indicator is

$$D_{ij}^{+} = \left[x_{ij} - min(x_{ij} \cdots x_{nj})\right] / \left[max(x_{ij} \cdots \cdots x_{nj}) - min(x_{ij} \cdots x_{nj})\right]. \quad (1)$$

The negative indicator is

$$D_{ij}^{-} = \left[max(x_{ij} \cdots x_{nj}) - x_{ij}\right] / \left[max(x_{ij} \cdots \cdots x_{nj}) - min(x_{ij} \cdots x_{nj})\right]. \quad (2)$$

2.3.2. Entropy Method

There are many methods for measuring the weight of indicators, and each has its own advantages and disadvantages. However, the entropy method has the advantages of strong objectivity and high precision, and it can effectively avoid the index weight error caused by index weight subjectivity. Thus, it is widely used in economics, management, and other fields for weight calculation. Entropy is a physical concept derived from thermodynamics and introduced by C. E. Shannon into information theory. It has now been widely used in research fields such as social economics. In information theory, entropy is a measure of the degree of disorder in a system, while information is a measure of the degree of order in a system. The absolute values of the two are equal, but their signs are opposite. If the degree of variation in the indicator value of a certain indicator is greater and the entropy is smaller, the information provided by the indicator should be greater, and its weight should also be greater; on the contrary, the smaller the degree of variation in the indicator value of a certain indicator, the greater the entropy, and the smaller the amount of information provided by the indicator, the smaller its weight [19,20]. We, therefore, select the entropy method to calculate the weight and comprehensive score of each index of blue finance and marine environmental quality. The calculation formula for index entropy is as follows:

$$e_j = -\frac{1}{\ln k}\sum_{i=1}^{n} \mathrm{B}_{ij} \ln\left(\mathrm{B}_{ij}\right), \tag{3}$$

where $\mathrm{B}_{ij} = \mathrm{D}_{ij} / \sum_{i=1}^{n} \mathrm{D}_{ij}$. B_{ij} represents the specific gravity matrix of the sample index values; D_{ij} represents the standardized data matrix of each indicator; e_j represents the index entropy value, where $0 \leq e_j \leq 1$; n represents the number of indicators; and k is the total number of research objects.

Index weight calculation:

$$\rho_j = \left(1 - \mathrm{e}_{ij}\right) / \sum_{i=1}^{n} \left(1 - \mathrm{e}_{ij}\right), \tag{4}$$

where ρ_j represents the weight of each indicator layer.

$$\mathrm{T}_{ij} = \sum_{j=1}^{n} \rho_j \times \mathrm{B}_{ij}, \tag{5}$$

where T_{ij} represents the comprehensive score of marine environmental quality.

2.3.3. Moderation Model

First, the following benchmark measurement model is established to verify blue finance's effect on the marine fishery economy:

$$\ln FE_{it} = \alpha_0 + \alpha_1 \ln BF_{it} + \alpha_2 \ln X_{it} + \mu_i + \lambda_t + \varepsilon_{it}, \tag{6}$$

where $\ln FE_{it}$ represents the level of the marine fishery economy, $\ln BF_{it}$ represents the level of blue finance, $\ln X_{it}$ represents the control variable, μ_i represents the individual fixed effect and controls the differences between marine fishery economies in different provinces, λ_t represents the time-fixed effect and controls variables related to time, and ε_{it} is the random disturbance term.

Second, to determine whether marine environmental quality plays a regulatory role in promoting the marine fishery economy through blue finance, the following model is established:

$$\ln FE_{it} = \varphi_0 + \varphi_1 \ln OE_{it} + \varphi_2 \ln X_{it} + \mu_i + \lambda_t + \varepsilon_{it}, \tag{7}$$

$$\begin{aligned} \ln FE_{it} = {} & d_0 + d_1 \ln BF_{it} + d_2 \ln OE_{it} + d_3 \ln BF_{it} \times \ln OE_{it} \\ & + d_4 \ln X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \end{aligned}, \tag{8}$$

where $\ln OE_{it}$ represents the level of marine environmental quality, is the moderating variable; and $\ln BF_{it} \times \ln OE_{it}$ is the interaction term. The remaining variables are consistent with the above meanings.

2.3.4. Threshold Model

We use a panel threshold regression model proposed by Hansen (1999) to test whether there is a nonlinear relationship among variables, such as blue finance, marine environmental quality, and the marine fishery economy [21]. As a nonlinear econometric model, the essence of threshold regression is to find the threshold variable among the variables reflecting the causal relationship. The panel threshold regression model is

$$\begin{aligned} \ln FE = {} & \phi_0 + \phi_1 \ln BF \cdot 1(\ln OE \le \delta) + \phi_2 \ln BF \cdot 1(\ln OE > \delta) \\ & + \theta \ln X + \mu_1 \end{aligned} \tag{9}$$

In the formula, $1(\cdot)$ is an indicative function. When the expression in parentheses is false, the value is 0; otherwise, it is 1. According to whether the threshold variable $\ln OBE$ is greater than the threshold value δ, the sample interval can be divided into two regimes. The slope values ϕ_1 and ϕ_2 are used to distinguish the two regimes.

Similarly, based on the one-threshold model, the case of multiple thresholds in the model can also be considered. Next, the two-threshold model is taken as an example, and the above model is

$$\begin{aligned} \ln FE = {} & b_0 + \beta_1 \ln BF \cdot 1(\ln OE \le \delta_1) + \beta_2 \ln BF \cdot 1(\delta_1 < \ln OE \le \delta_2) \\ & + \beta_3 \ln BF \cdot 1(\ln OE > \delta_2) + \kappa \ln X + \mu_1 \end{aligned} \tag{10}$$

where $\delta_1 < \delta_2$. The calculation process of the two-threshold model is similar to that of the one-threshold model, which is to estimate the second threshold value when the first threshold value is fixed.

2.4. Variable Description

(1) Explained variable: We take the marine fishery economy as the explained variable, use the output value level of marine fishery to measure ($\ln FE_{it}$), and take the logarithm of these values. (2) Explanatory variable: This study takes blue finance as the explanatory variable ($\ln BF_{it}$), uses the blue finance index system shown in Table 1 for calculation, and takes the logarithm of these values. (3) Regulating variable: Marine environmental quality is selected as the regulating variable of the model ($\ln OE_{it}$). Similarly, we use the marine environmental quality index system shown in Table 1 for calculation and take the logarithm of these values. (4) Threshold variable: Blue finance and marine environmental quality are used as threshold variables to measure whether they have a nonlinear relationship with the marine fishery economy. (5) Control variable: We select factors that might affect marine fishery economy development as control variables, including the level of marine fishery infrastructure, which is represented by the year-end ownership of marine production fishing vessels ($\ln OST$). The production capacity of marine fisheries is expressed by the total amount of marine products ($\ln OIP$). The output capacity of marine fisheries is

expressed by the value of marine fishing (ln *OMC*), and the logarithm of these variables is taken to eliminate heteroscedasticity and multicollinearity. As shown in Table 2.

Table 2. Descriptive statistics of the variables.

Variable Type	Specific Variables	Variable Symbol	Observations	Mean	Standard Deviation	Maximum Value	Minimum Value	*Coefficient of Variation*
Explained variable	Marine fishery economy	ln *FE*	143	−1.324	1.371	0.4503	−4.611	−1.0355337
Explanatory variable	Blue finance	ln *BF*	143	−1.363	0.523	−0.403	−3.131	−0.3848626
Regulating variable	Marine environment	ln *OE*	143	−0.781	0.300	−0.282	−1.682	−0.38387408
Control variable	Production of fishing boats	ln *OST*	143	−0.867	1.17	0.928	−3.778	−1.3554619
	Seafood products	ln *OIP*	143	−1.904	1.525	−0.239	−5.563	−0.8006338
	Marine fishing value	ln *OMC*	143	−2.185	1.129	−0.323	−5.505	−0.51692772

3. Empirical Analysis

3.1. Blue Finance and Marine Environmental Quality Analysis

In Figure 1, blue finance shows a wavy upward trend, with a low overall level and obvious gaps between provinces. During the study period, the blue finance level of coastal provinces increases significantly, with an average increase of nearly four times, from 0.129 to 0.508, and an average annual growth rate of 3%. Blue finance grows the fastest in Shandong, with the blue finance index rising from 0.043 to 0.457, a nearly tenfold increase. The blue finance index in Hainan increases from 0.361 to 0.668, an increase of nearly 1.85 times, with an average annual growth rate of 6%. This shows that China has attached importance to blue finance in recent years, innovated investment and financing models, enhanced the role of blue finance in the marine field, and supported the sustainable development of the marine economy. However, in terms of the blue financial index of each province, the overall level is low. The average value of the blue financial index only reached 0.508 by the end of 2023. Regarding heterogeneity in blue finance development, it varies greatly between provinces. Among them, the blue finance level of Hainan is relatively high, with an average of 0.503; by the end of 2023, it had reached 0.667. Guangdong's blue finance development level is second only to Hainan, reaching 0.609 by the end of 2023. Meanwhile, Liaoning, Guangxi, Zhejiang, and Shandong all have relatively low levels of blue finance. All were at around 0.45 by the end of 2023, significantly lower than the average for that year. Among them, Liaoning had the lowest blue finance level, with an average value of only 0.267—about half the average value of the blue finance index of Hainan.

In Figure 2, the overall level of marine environmental quality shows a steep upward trend in China's coastal provinces and cities, averaging about 0.559. However, interprovincial differences are still significant. During the study period, the marine environmental quality of all provinces and cities showed significant improvement. Among them, the marine environmental quality of Jiangsu remained at a high level, with an average value of 0.645. That of Shandong ranks second, with an average of 0.631. Hainan's marine environmental quality showed the fastest growth, with an average annual growth rate of nearly 7%. At the end of 2023, marine environmental quality was 0.558. This shows that, since China implemented the construction of marine ecological civilization, marine environmental quality has greatly improved, the quality and stability of the marine ecosystem have been enhanced, and the carrying capacity and resilience of the marine environment have been strengthened. Nevertheless, there is an obvious, widening gap in marine environmental quality between regions. During the study period, marine environmental quality in Jiangsu rose from 0.551 to 0.716, with an average of 0.645, while that of Tianjin rose slowly from 0.274 to 0.425, with an average of 0.336. Shanghai's marine environmental quality rose from

0.349 to 0.395, with an average of only 0.311. The average level of marine environmental quality in Tianjin, Shanghai, and other areas was clearly lower than that of the coastal regions and was only half that of Jiangsu, indicating polarization in marine environmental quality among provinces.

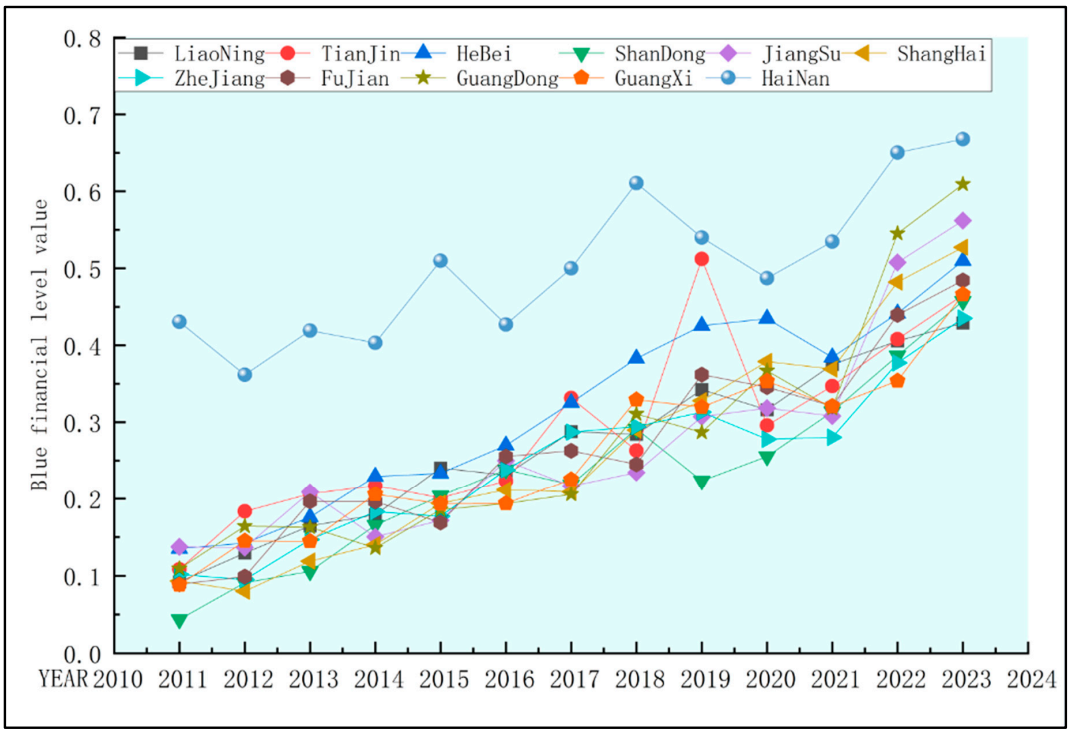

Figure 1. Levels of blue financial development in China (2011–2023).

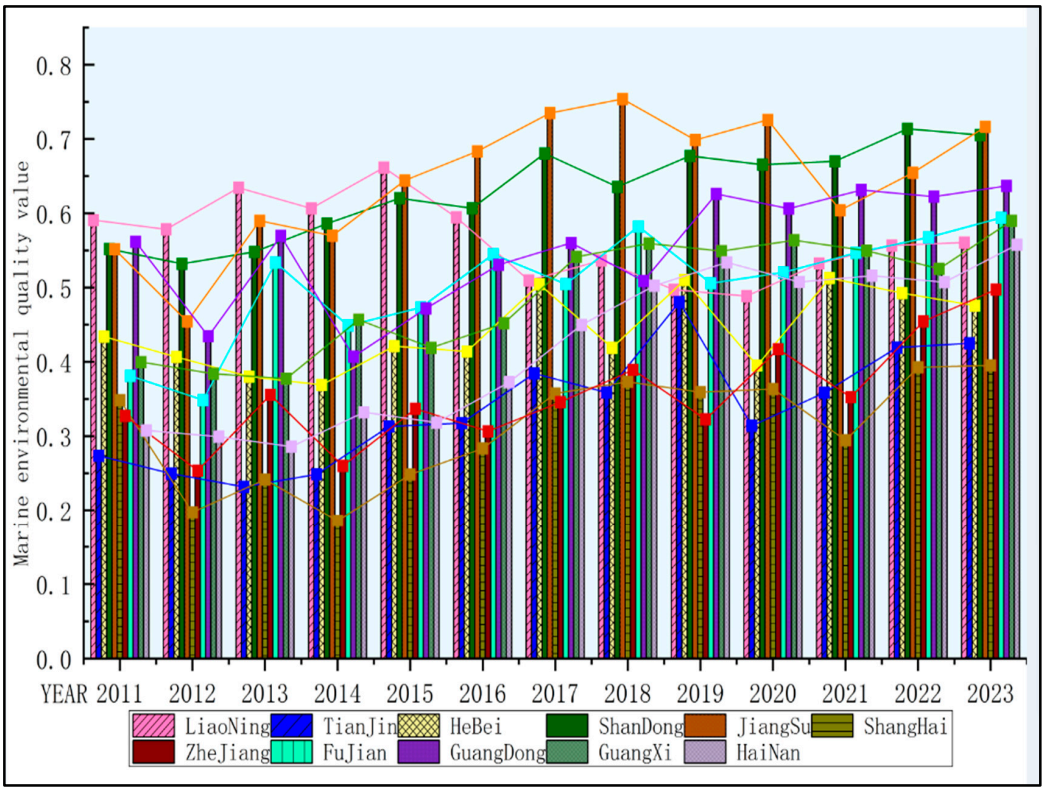

Figure 2. Marine environmental quality in China (2011–2023).

3.2. Benchmark Regression Results

Table 3 lists the baseline regression results for blue finance's effect on the economic development of marine fisheries. Column (1) shows the regression results when controlling the fixed effects of province and year but without adding control variables. We can prove that blue finance has a significantly positive effect on the marine fishery economy, passing the significance test at the level of 1%. Column (2) shows the regression results of the random-effect model after adding control variables. Column (3) shows the regression results of the fixed-effect model after adding control variables. After the Hausman test, the fixed-effect model is better. Column (4) shows the results of the two-way fixed-effect model. The coefficient of blue finance's effect on the marine fishery economy fails the significance test. Therefore, the regression results in column (3) are better. In conclusion, the estimated coefficient of blue finance on the marine fishery economy is significantly positive at the 1% level, and the result is 0.2447. This shows that blue finance development can improve the marine fishery economy. Meanwhile, marine fishery infrastructure, production capacity, and output capacity all pass the significant test at the 1% level, showing a positive effect.

Table 3. Benchmark regression results.

Variable	Ordinary Model (1)	Random Effect (2)	Fixed Effect (3)	Two-Way Fixed Effect (4)
	ln*FE*	ln*FE*	ln*FE*	ln*FE*
ln *BF*	0.4766 (***)	0.2574 (***)	0.2447 (***)	0.055 (0.239)
ln *OST*		0.1213 (0.112)	0.2397 (***)	0.188 (**)
ln *OIP*		0.303 (***)	0.2501 (***)	0.3997 (***)
ln *OMC*		0.703 (***)	0.7109 (***)	0.6197 (***)
−cons	−0.6747 (***)	1.245 (***)	1.247 (***)	0.7972 (***)
AIC	−23.915	−256.513		
Hausman		Chi2(5) = 203.65 (***)		
Sample size	143	143	143	143
Adjusted R^2	0.864	0.943	0.935	0.952

Note: **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

3.3. Moderating Effect Results

Column (1) of Table 4 shows the results for blue finance's effect on the marine fishery economy. Column (2) shows that the influence coefficient of marine environmental quality on the marine fishery economy is 0.5342 and passes the significance test at the level of 1%. Column (2) shows the regression results of the fixed effects model with control variables added. Similarly, blue finance has a significant positive driving effect on the marine fishery economy. By comparing the AIC results, it can be concluded that the AIC value of the fixed effects model is −256.513, which is significantly lower than the AIC value of the least squares method. Therefore, the fixed effects model has more advantages than the least squares method model. Column (3) shows the regression results of the random effects model with control variables added. After Hausman's test, it was found that the fixed effects model performed better. Column (4) shows the results of the bidirectional fixed effects model, and the coefficient of the impact of blue finance on the economic level of marine fisheries did not pass the significance test. Therefore, compared with the results of column (2), the regression results of column (2) are better. In summary, the estimated coefficient of blue finance for the level of marine fishery economy is significantly positive at the 1% level, with a result of 0.2447. This fully demonstrates that the development of blue finance has a positive impact on the economic level of marine fisheries. Meanwhile, the infrastructure, production capacity, and output capacity of marine fisheries have all passed

a significant test at the 1% level and have a positive impact on the economic development of marine fisheries.

Table 4. Measurement results for the adjustment effect.

Variable	ln*FE* (1)	ln*FE* (2)	ln*FE* (3)
ln *BF*	0.2447 (***)	0.1906 (***)	0.4532 (***)
ln *OE*		0.5342 (***)	1.003 (***)
ln *BF* * ln *OE*			0.325 (***)
ln *OST*	0.2397 (***)	−0.252 (***)	−0.2868 (***)
ln *OIP*	0.2501 (***)	0.6438 (***)	0.6642 (***)
ln *OMC*	0.7109 (***)	0.5216 (***)	0.5335 (***)
−*cons*	1.247 (***)	1.50 (***)	1.901 (***)
Sample size	143	143	143
Adjusted R^2	0.935	0.9807	0.982

Note: Standard errors in parentheses; * $p < 0.1$, *** $p < 0.001$.

3.4. Threshold Effect Results

Taking the marine fishery economy as the explained variable, blue finance will serve as the core explanatory variable for the level of marine environmental quality, with blue finance as the threshold variable. A threshold model will be used to estimate whether there is a threshold value for blue finance, whether there is one threshold value, and whether there are two threshold values. Referring to Hansen's (1999) bootstrap method, the *p*-value corresponding to the test statistic is obtained by repeated sampling 1000 times to determine whether there is a threshold effect. Table 5 shows the results. In the one-threshold model, the F-statistic is significant at the 1% level; that is, the *p*-value is less than 0.01. Therefore, there is a threshold value in the model. In Table 5, according to the principle of the threshold model, the threshold estimate is the corresponding value when the likelihood ratio (LR) statistic approaches 0. Figure 3 shows the threshold estimate of −1.0586 for blue finance and the LR function diagram under the 95% confidence interval. Similarly, taking the marine fishery economy as the dependent variable, blue finance as the core explanatory variable, and the level of marine environmental quality as the threshold variable, threshold models are used to estimate whether there is a threshold value for marine environmental quality, whether there is one threshold value, and whether there are two threshold values. Figure 4 shows the LR function diagram of the threshold estimate of −1.0285 for marine environmental quality. Among them, the lowest point of the LR statistic is the corresponding true threshold value; the dashed line indicates the critical value of 7.35. Since the critical value of 7.35 is obviously greater than the threshold value, the above threshold value can be considered true and effective.

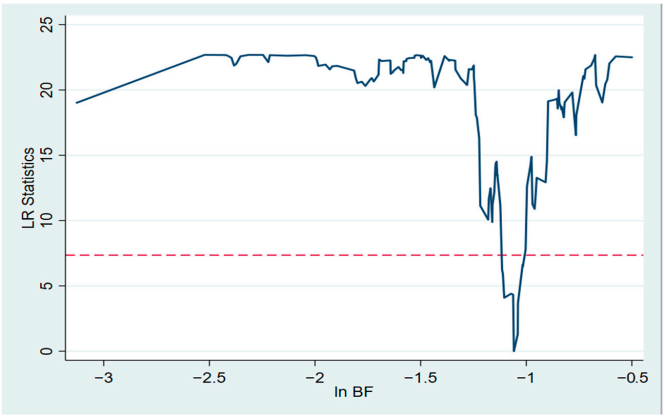

Figure 3. Blue finance 1 intermediate threshold estimation results.

Table 5. Threshold effect measurement results.

Category	Blue Finance		Marine Environmental Quality	
Threshold Number	**1**	**2**	**1**	**2**
F-value	50.69	10.53	15.00	2.63
p-value	0.019	0.298	0.02	0.865
10% critical value level	30.58		10.445	
5% critical value level	38.51		12.298	
1% critical value level	56.93		16.995	
Threshold value	−1.0586		−1.0285	
Corresponding value	0.3469		0.3575	
95% confidence interval	(−1.092, −1.04)		(−1.048, −1.026)	
$\ln OST$	0.4377 (***)		0.189 (***)	
$\ln OIP$	0.3762 (***)		0.201 (***)	
$\ln OMC$	0.7682 (***)		0.756 (***)	
$\ln OE \cdot 1(\ln BF \leq -1.0586)$	0.1537 (**)			
$\ln OE \cdot 1(\ln BF > -1.0586)$	0.0812 (0.37)			
$\ln BF \cdot 1(\ln OE \leq -1.0285)$			0.2123 (***)	
$\ln BF \cdot 1(\ln OE > -1.0285)$			0.2826 (***)	
$-cons$	1.515 (***)		1.238 (***)	
R^2	0.944		0.922	
Sample size	143		143	

Note: Standard errors in parentheses; ** $p < 0.05$, *** $p < 0.001$.

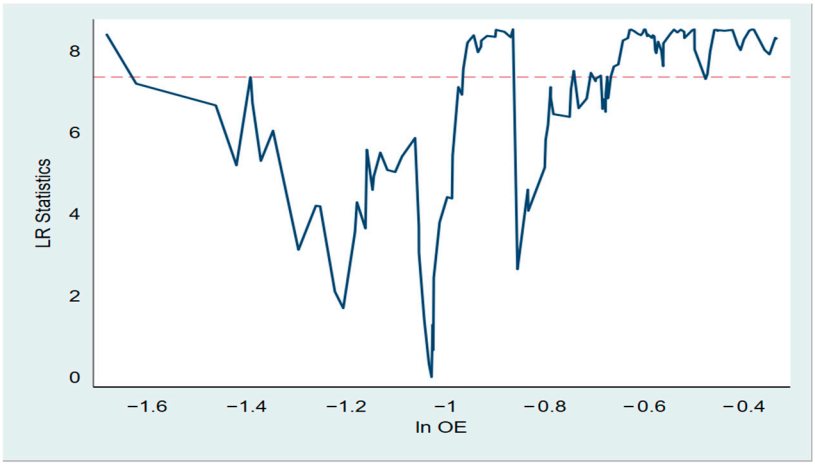

Figure 4. Marine environmental quality 1 intermediate threshold estimation results.

In addition to the threshold values, the panel threshold regression results for blue finance and marine environmental quality are obtained, as shown in Table 5. When the threshold variable is $\ln BF$, there are significant differences in the impact of marine environmental quality on marine fishery economy under different lnBF values. When blue finance develops in the middle and early stages ($\ln BF \leq -1.0586$), the coefficient of the impact of marine environmental quality on the economic level of marine fisheries is 0.1573, which is significant at the 1% level and has a positive driving effect on the development of the marine fisheries economy but shows a gradually decreasing trend. This is mainly due to the early development of blue finance, where some funds flow into marine environmental governance and protection, and some marine fishery enterprises receive financial support. With sufficient funds, they can carry out green and low-carbon transformation and development, which will overall promote the level of marine environmental quality and the development of the marine fishery economy. However, during this period, some enterprises may rely on improper means to obtain financial support and invest in high-cost equipment (such as clean energy fishing boats) and technology introduction in the early stage of green transformation, which may increase the short-term burden on

small fishermen, and the mechanisms for financial regulation and risk assessment are not sound. These reasons make it difficult for blue finance to fully play its role and even lead to financial instruments being transformed into purely profit-seeking means. The quality of the marine environment cannot be comprehensively improved, and its role in promoting the marine fishery economy will gradually weaken. When blue finance reaches the middle and late stages ($-1.0586 < \ln BF$), the regression coefficient becomes 0.0812 and fails the significance test. However, as shown in Figure 3, the quality of the marine environment has a marginal effect on the development of the marine fishery economy. This may be due to the gradual strengthening of regulatory and certification standards for blue finance, the innovative development of financial instruments, the increasingly perfect micro loans and risk assessment mechanisms, the deep integration between blue finance and marine environmental quality, the guidance of capital flow, the reshaping of the development model of marine fisheries economy, and the promotion of its shift from "predatory development" to "sustainable utilization". It can be inferred that, under the influence of blue finance, the impact of marine environmental quality on the development of the marine fishery economy presents a "U" state. When it exceeds the threshold value of -0.1586, the impact of marine environmental quality on the marine fishery economy may gradually increase with the continuous improvement of blue finance level.

When the threshold variable is $\ln OE$, there are significant differences in the impact of blue finance on the marine fishery economy under different $\ln OE$ values. When marine environmental quality is in the middle and early stages ($\ln OE \leq -1.0285$), the influence coefficient of blue finance on the marine fishery economy is 0.2123, which is significant at the level of 1%. It also plays a significant positive role in promoting marine fishery economy development but shows a gradual decline. This is due to the fact that, when the level of marine environmental quality is in the middle and early stages, marine environmental quality will have an impact and pressure on marine fishery resources, costs, and markets. The development of blue finance has injected important capital power into the marine environment and marine fishery, promoting the improvement of marine environmental quality and the development of the marine fishery economy. However, the level of marine environmental quality is relatively low, and blue finance will gradually flow into marine environmental governance and protection through diversified tools and methods, such as innovative blue loans, debt, funds, and equity. The impact of blue finance on the marine fisheries economy will gradually decrease, while investment costs will gradually increase, and returns will gradually decrease. When marine environmental quality reaches the middle and late stages ($-1.0285 < \ln OE$), the regression coefficient becomes 0.2826, which passes the significance test at 1%. This indicates that blue finance plays a significant role in promoting the marine fishery economy, and the impact of blue finance on the economic level of marine fisheries is gradually increasing. This is mainly due to the comprehensive improvement of marine environmental quality, providing a good ecological environment for the development of marine fisheries, reducing fishery production costs, and stabilizing the market, enhancing the resilience of marine fisheries economy. Blue finance will flow more towards the transformation and development of marine fisheries and improving quality and efficiency, reducing investment risks and increasing investment returns, significantly enhancing the impact on the development of marine fisheries economy. In conclusion, the influence of marine environmental quality on the marine fishery economy is U-shaped. When marine environmental quality is below the threshold value of -1.0285, blue finance plays a positive role in promoting the development level of marine fishery economy, but this effect will gradually weaken. When the threshold of -1.0285 is exceeded, the promoting effect of blue finance on the development of the marine fishery economy will show an upward trend, as the level of marine environmental quality continues to increase.

4. Discussion

This study reveals the mechanism by which blue finance and marine environmental quality influence the marine fishery economies of China's coastal provinces and cities. We conclude the following: First, blue finance has a significant positive effect on the marine fishery economy. The regression results in column (3) in Table 3 show that the coefficient of blue finance's effect on the marine fishery economy is 0.2447 and statistically significant. This is because blue finance can provide diversified financial instruments and service innovations for marine fishery development, optimize resource allocation, meet different market players' needs, help upgrade the marine fishery industry, help optimize the structure of the marine fishery economy, and enhance its quality. This aligns with previous findings indicating that blue finance is necessary for promoting the sustainable development of the blue economy [11–15]. Blue bonds, an innovative investment tool in the capital market, help optimize the allocation of marine production factors and overcome the financing constraints of marine-related enterprises [8–10]. Thus, our study supports and extends the findings of previous research in many ways.

Second, marine environmental quality plays a significant regulatory role in blue finance's promotion of the marine fishery economy. As shown in Table 5, the regression coefficient of the moderating effect is 0.325, which is significantly positive. This means that improving marine environmental quality can enhance the resource allocation and risk management of blue finance in its effect on the marine fishery economy and promote marine fisheries' sustainable development. Previous studies have focused on blue finance's effect on marine economy development and marine environmental quality, as well as marine environmental quality's effect on the marine economy. They have not, however, analyzed the mechanism of marine environmental quality in blue finance's promotion of the marine fishery economy. We confirm this mechanism, thus broadening research in this area. This holds significance for accelerating blue finance system construction, improving marine environmental quality, and enhancing the quality of the marine fishery economy.

Third, blue finance and marine environmental quality have marginal effects on promoting marine fishery economy development. As shown in Table 5, blue finance and marine environmental quality both have a first-order threshold effect on the marine fishery economy, with threshold values of −1.058 and −1.0285, respectively, and the effect coefficients under the first-order thresholds are 0.1537 and 0.2123. This demonstrates that blue finance is crucial for the sustainable development of the marine fishery economy. At the same time, blue finance and marine environmental quality jointly affect the marine fishery economy. However, there is a nonlinear relationship in the effect of blue finance and marine environmental quality on the marine fishery economy. This is because, as part of a long-term process, in the early stage of blue finance development, it can provide financial support for the marine fishery economy through resource allocation, risk management, and market pricing, while also promoting marine ecosystem health to balance the growth of the marine fishery economy and marine environmental protection. Examples include blue loans and loans provided by banks or other financial institutions to finance sustainable marine fishery projects (such as the development of deep-sea fisheries, the modernization of marine pastures, and the construction of zero carbon fishing islands, etc.). Blue funds focus on investing in marine-type projects, such as marine ecosystem restoration and marine biodiversity conservation. Based on this, various forms of blue finance have come into being, and the blue finance market has been growing. However, as the amount of blue finance investment rises and the scale expands, the related risks and the cost of intermediary transactions also increase. Problems with financial technology and development mechanisms are also gradually exposed, resulting in market failure. This will hinder the optimal allocation of resources and the control of risk, and blue finance's effect on the

marine fishery economy will be weakened. However, with the continuous improvement of blue finance policies, technologies, and mechanisms, blue finance will further promote the utilization and allocation of marine fishery resources, thus having favorable effects on the marine fishery structure and economy. The effects of marine environmental quality are similar.

We analyze the driving effect of blue finance on the quality of the marine fishery economy in terms of the relationship between finance and economic development. This holds both theoretical and practical value for promoting blue finance's ability to serve the blue economy. First, this improves our understanding of the development trends of blue finance and its role in marine fishery economy development, enriching research in this area and providing a new perspective on blue finance's use of financial instruments and services to promote the marine fishery industry. In this way, we offer a new research framework for the diversified promotion of the high-quality development of marine fisheries. Second, we provide a realistic path and policy reference for the high-quality development of the marine fishery economy. Although this study is based on data on China's blue finance, its conclusions are equally applicable to other coastal countries and regions (such as Europe, South Africa, Indonesia, etc.) and can provide decision-making references for other countries and regions to formulate high-quality blue finance development policies. Coastal countries and regions can establish blue finance standards to clarify the admission conditions for fisheries projects, accelerate the innovation of financial instruments, and explore new models, such as fishery carbon trading and marine ecological compensation funds, as well as implementing inclusive financial coverage and designing micro loans and risk sharing mechanisms for small-scale fishermen. However, some research has been conducted on the lack of financial resources inflow, risk control, and low ecological product benefits faced by the development of marine fishery economy in some countries and regions. For example, some small island countries and Indigenous regions in Canada face common challenges, such as limited resources, geographical isolation, the impact of climate change, and inadequate socio-economic development [22]. These countries and regions alleviate financing difficulties by improving community led financing models, such as Indigenous Trust Funds and community insurance plans in small island countries; innovating digital financial tools; using blockchain technology to track the use of climate funds; developing financial products that are suitable for small-scale, high-risk areas (such as small insurance and resilient credit); monetizing ecosystem services, such as carbon sinks and biodiversity; and attracting private sector investment to break through financing bottlenecks, achieving the sustainable and inclusive development of the marine fisheries economy. Regarding the geopolitical market environment and ecological risks faced by marine fisheries in different regions and countries, the healthy development of blue finance can provide cross regional funding for marine fishery projects; loan fishermen for cooperative operation; invest in infrastructure construction; optimize resource allocation; reduce geopolitical risks; innovate financial tools and support the digital transformation of the marine fishery economy; improve fishery production efficiency; reduce trade barrier risks; support marine fishery cooperatives; strengthen the integration of fishery data; and stabilize the fishery market, as well as issuing bonds and subsidies to support marine ecological restoration and sustainable fishing, investing in marine environmental monitoring systems, and mitigating environmental risks for fishermen and businesses. For example, Norway uses blue bonds to provide financial support for low-carbon aquaculture technology in marine fisheries, effectively promoting a 30% reduction in carbon emissions; Indonesia has implemented the "Blue Forest Plan" to raise funds through blue carbon credit trading, restore mangroves, and support the development of eco-friendly fisheries in surrounding communities. Therefore, this article verifies that the development of blue finance empowers the development of

the marine fishery economy and expands the path of the high-quality development of the marine fishery economy [23–27].

Although this article empirically calculates the impact and regulatory mechanism of blue finance and marine environmental quality on the quality of marine fishery economy, it objectively confirms the positive driving effect and threshold effect of blue finance on the marine fishery economy. However, this study also has certain limitations that are worth further research in the future. Due to limitations in data availability, it is inevitable that some indicators may not be included in the evaluation index system, which can affect the accuracy of empirical results. For example, indicators such as risk management assessment were not included in the model calculation due to the unavailability of data. In the future, relevant risk indicators will be included in the evaluation system to more accurately measure the impact of blue finance on the marine fisheries industry [28–30]. At the same time, this article lacks in-depth analysis on whether the impact of blue finance on the quality of the marine fisheries economy has regional heterogeneity, and whether blue finance can reduce the adverse effects of climate change on the development of marine fisheries economy. This will also be a focus of future research.

5. Conclusions

By measuring the effects of blue finance and marine environmental quality on the marine fishery economy in 11 regions of China from 2011 to 2023, we derive the following conclusions:

(1) Blue finance can promote the improvement of the marine fishery economy. Blue finance has a positive driving effect on the marine fishery economy, and the estimated coefficient is significantly positive at the 1% level, with a result of 0.2447. This indicates that the development of blue finance can effectively enhance the marine fishery economy [31].

(2) Marine environmental quality has a significant moderating effect on blue finance's effect on the marine fishery economy. Under the regulation of marine environmental quality, the coefficient of influence of blue finance on the marine fishery economy is 0.4532 and passes significance at the 1% level. This indicates that marine environmental quality can further enhance the promotion effect of blue finance on the marine fishery economy.

(3) Blue finance and marine environmental quality have a nonlinear relationship in their effect on the marine fishery economy. Blue finance and marine environmental quality have a first-order threshold effect on the marine fishery economy. The threshold value of blue finance is −1.0586, and its effect coefficient on the marine fishery economy is 0.1573. This indicates a significant positive driving effect on the marine fishery economy but with a gradually decreasing trend. The threshold value of marine environmental quality is −1.0285. When marine environmental quality is below the threshold value of −1.0285, it has a positive driving effect on the marine fishery economy, but the influence will be gradually weakened. When the threshold value of −1.0285 exceeds, the promotion effect of marine environmental quality on the marine fishery economy will show a rising trend with marine environmental quality continuously increasing [32,33].

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