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Resource Constraints and Economic Growth: Empirical Analysis Based on Marine Field

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Abstract: To explore the contribution of marine resources to marine economic growth, this study uses panel data from 2006–2019 across 11 coastal provinces and cities in China and establishes threshold regression models using marine capital, labor, and science and technology as threshold variables affecting marine resources and economic growth. The findings reveal that the impact of marine resources on marine economic growth only demonstrates a single threshold effect under the primary industry marine resources; in general, with increased capital investment, the marine economy presents a positive development trend. The impact of primary and secondary marine resources on marine economic growth has a single threshold effect of labor input, while the impact of tertiary marine resources on marine economic growth has a double threshold effect of labor input. With investment in marine science and technology, marine resource development and utilization in the primary industries have played a consistent role in promoting marine economic growth. However, the impact of this role is gradually decreasing; marine resource development and utilization in the secondary and tertiary industries shows a development pattern wherein the driving effect of marine economic growth is first large, then small, and then large again. Based on the above analysis, China should promote the transformation of labor-intensive to capital-intensive industries by increasing investment in marine capital, training marine talent, and developing marine science and technology innovation to increase the development level of China's marine economy.

Keywords: marine economic growth; marine resource; marine production factor; panel threshold model

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1. Introduction

The ocean not only supports the development of fisheries, the chemical industry, tourism, and other industries, but also provides convenient transportation routes for expanding international trade [1]. In recent years, the development of China's economy has changed dramatically. The drawbacks brought by the traditional development approach that relies on factors and investment are becoming more and more obvious, such as low economic efficiency, serious environmental pollution, and especially the increasing scarcity of land resources. Therefore, people have started to turn their attention to the ocean [2–4]. Developing and utilizing the ocean and promoting the blue economy have become not only important vehicles for coastal countries to expand their economic and social space but also new engines of world economic growth [5,6]. As early as 2013, during his visit to Southeast Asian countries, General Secretary Xi proposed a major initiative to build the "21st Century Maritime Silk Road". Subsequently, China was explicitly requested in the report of the 19th Party Congress to "adhere to the integration of land and sea, and accelerate the construction of a strong marine state", sounding the trumpet once again for constructing the same. According to the 2021 China Marine Economy Statistical Bulletin, China's gross marine product exceeded CNY 9 trillion in 2021, accounting for 15% of coastal the country's gross domestic product. This shows that the maritime economy has become an integral part of China's economic growth. Moreover, in the post-COVID-19 era, new industries have continued to expand, and the tertiary industry of coastal tourism has experienced restorative growth. Therefore, to ensure its dynamism, we need to explore the factors that contribute to marine economy growth.

Marine resources are basic but necessary, and an important driving force of marine economic development. Marine resource development and utilization play decisive roles in the structure of marine industry, marine resource competition, and marine economic development [7–9]. In the early stage of China's marine economic growth, marine resources were abundant and easily available, and a new pattern of three industries competing for development was gradually formed, along with primary industries such as marine fisheries and secondary industries such as the marine oil and gas industry, supplemented by tertiary industries, such as the marine transportation industry [10]. As the utilization of marine resources gradually approaches the limit of marine carrying capacity, the economic output of marginal marine resources has been decreasing [11]. The economic development rate has slowed considerably, and the proportion of primary and secondary industries for resource-based development has gradually declined, while the proportion of tertiary industries has gradually increased. Thus, considering the marine resource constraints, an exploration to identify methods of promoting sustainable marine economic development is urgently needed.

Increased investment in marine capital [12], marine labor [13], and marine technology [14,15] may facilitate more effective marine resource utilization to promote marine economic growth. The marine economy comprises many industries, such as fisheries, shipping, oil industries, and marine space development, most of which are asset-heavy operations; therefore, marine economic development cannot be achieved without capital investment [12]. Labor is an endogenous driver of economic growth and important evaluation indicator of regional differences at the economic-development level, also playing an important role in marine economic development [16]. The marine economy is key to promoting the high-quality development of China's economy, and marine economic development led by science and technology innovation provides essential support in constructing a strong marine state. China's technological innovation has become a vital force in driving marine economic development at a time when it has become increasingly powerful due to scientific and technological prowess [17]. In summary, if these three elements work synergistically with marine resources, they can better promote marine economic development.

The US, an early adopter of global marine resources, has long been plagued by marine resource scarcity [18]. To rationally develop marine resources, the US has increased government support and applied high-technology solutions to marine resource cultivation, which has improved the efficiency of marine resource utilization and promoted marine economic development. The present study explores whether China can increase its investment to use ocean resources more effectively based on the US experience, and whether China can increase its investment in capital and technology, considering the low cost of labor and the high cost of capital and technology in the country. In addition, different inputs have different effects on resources for economic growth; thus, the question remains as to what should be the reasonable way to increase inputs for China. Based on the above considerations, we empirically analyzed the specific situation in China and put forward corresponding policy recommendations. In this paper, using data from the China Marine Statistical Yearbook, marine data were collected from across 11 coastal provinces and cities in China. The study period is 2006–2019 because sea-related data after 2019 are not yet available.

In this empirical study, first, we classify the environmental assets as per the SEEA central framework and marine resource characteristics, and then marine resources according to their contributions to the three major industry types. For example, marine fishing and mariculture belong to marine fishery, which is the primary industry, while the marine oil and gas and marine chemical industry mainly provide energy support as the secondary industry, and the marine transportation industry is the tertiary industry. Second, we develop a fixed-effects model to explain the growth of marine resources and the marine economy, with capital, labor, and technology inputs as control variables. On this basis, these three inputs are used as thresholds to explore the mechanism of the role of marine resources in the marine economic growth process and the characteristics of change, respectively. We identify a single threshold effect of capital investment only for the relationship between primary marine resources and economic growth; however, in general, capital investment is a constant driver of marine economic growth. A double threshold effect of labor input exists only for the relationship between tertiary marine resources and economic growth, and a single threshold utility for primary and secondary marine resources. A double threshold effect of science and technology investment is observed on the relationship between marine resources and economic growth.

Below, we identify the shortcomings of the existing literature and make improvements or extensions accordingly. First, the previous literature focuses on the interaction between marine resources and the economy [8,19] or factors affecting the marine economy [8], and does not provide a detailed classification of marine resources. We divide marine resources according to their characteristics and industrial contribution to more precisely study the relationship between marine resources and marine economic growth. Second, most studies ignore the interaction between capital, labor, and technology and resources [12–14]. In this study, we fully consider these interactions and construct a threshold effect model using capital, labor, and technology as threshold variables.

2. Literature Review

The increasing population and overexploitation of terrestrial resources in China have resulted in resource depletion and environmental damage. Therefore, to achieve sustainable development, humans are gradually turning toward the ocean [2,5,6]. Since being elevated to a national development strategy in the 1990s, the marine economy has entered a period of rapid development and become a new growth point for the national economy. In particular, the introduction of the "Eleventh to Thirteenth Five-Year Plan" for the development of China's marine economy has played a substantial role in promoting the development of China's marine economy, which accounts for over 9% of the gross domestic product, indicating that the ocean is becoming an integral part of the economy. However, marine development still faces many problems, such as climate change, damage to the marine environment, water shortage, and depletion of marine resources, which seriously affect the development of marine economy [20–24]. Among them, the connection between marine resources and marine economy is the closest and has become the focus of the scholars' research [25].

Scholars have discussed the relationship between marine resources and the marine economy from different perspectives. Marine economic development requires the input of marine resources as support [7]; thus, the research direction has mainly been developed with marine resource input as the explanatory variable and marine economic development as the explained variable. For example, Kiran et al. [8] note that the ability to maximize the use of marine fishery resources will enable Pakistan to have a voice in domestic and international markets, thereby leading to the economic development of the country. Similarly, Odeku [9] argues that intensively developing and utilizing South Africa's rich marine resources will foster tremendous economic growth.

However, due to resource constraints, the actual rate of economic growth has been slower than expected. Nordhaus [26], who uses the term "growth dampening" to refer to the extent to which resource constraints reduce economic growth, compares neoclassical growth models with and without resource constraints to measure natural resources' resistance to economic growth in the US. Bruvoll et al. [27] measure the welfare loss in Norway caused by environmental "damping". Based on an analysis of the impact of energy shortages on US economic growth, Uri [28] reports that crude oil shortages had a significant impact on US economic growth from 1889 to 1992. In summary, resource constraints are an obstacle to economic growth. With the rapid development of China's marine economy and marine resources, the depletion of marine resources, environmental pollution of near-shore waters, and other problems are becoming increasingly prominent. Further, the role of the use of marine resources in promoting the marine economy has gradually diminished, and the conditions of the factors supporting marine economic development have also undergone profound changes. As a result, countries worldwide are actively exploring other influencing factors to promote marine economic development.

The views scholars hold on the impact that capital inflows will have on the economy can be broadly divided into two types. The first view is that capital inflows have a positive impact on economic development. Agbloyor et al. [29] establish that short-term capital inflows boost economic growth; however, this positive boost is only evident when the financial markets of the inflowing countries are sufficiently strong. Butkiewicz and Yanikkaya [30] argue that long-term capital inflows also have a catalytic effect on economic development, while limiting capital inflows reduces that effect. The second view considers capital inflows' possible negative macroeconomic impact. Lensink and Morrissey [31] argue that capital inflows can only promote smooth economic growth if they remain stable over time (i.e., fluctuations in capital inflows can have a direct negative impact on economic growth). Currently, only the first research view exists in the discourse on marine economy. Capital inflow can directly promote the renewal of various machines and equipment within marine enterprises, as well as the construction of various infrastructures to improve operational efficiency and bring about greater marine economic growth. In addition, the inflow of capital will attract more talents, and the progress of science and technology, enterprise management, and so on are inseparable from the talents. Rashid et al. [12] note that marine economic growth requires adequate marine capital, which reveals the important role of capital investment in marine economic development.

In addition to capital, labor also has an impact on the economy. Boadi et al. [32] posit that the labor force will contribute to economic growth, and low-income countries should focus on upgrading their labor force through education. Alemeu [33] reports that labor also contributes to growth in African regions where economic growth has been unstable. Can [34] expands on previous research and determined that increases in the female labor force following the repeal of laws that discriminate against women also lead to economic growth. However, Balog [35], in analyzing the relationship between the labor force and economic growth in European countries, determined that the labor force does not accelerate economic growth. For the marine economy, van Lottum and van Zanden [13] determined that the input of high-quality labor increases rapid marine economic growth. Radhakrishnan et al. [16] note that the marine fishery industry's significant contribution to economic development is not only dependent on technological advances in fisheries, but is also influenced by labor wages.

Science and technology are the first driving force toward leading development. Pandiloska [36] states that technology is a key factor in promoting economic growth and improving firms' competitiveness in the business world, and that more innovation from technology-intensive firms will lead to more new markets, which will contribute to economic growth. The same holds true for the marine economy. Liang and Choi [17] state that marine technology improvement is an important factor in the growth of China's marine economy, while Kiyong and Cho [14] argue that advances in marine science and technology can provide new growth drivers for marine economic development.

The literature review determined that capital, labor, and science and technology investments are able to promote economic growth. Some scholars have considered resource shortages, but only on one aspect, and have not considered resource constraints in conjunction with the inputs of factors, much less focusing the field on the marine economy. For example, Bringezu [37] notes that countries experiencing natural resource shortages can rely on technological advances to overcome them and promote economic growth. Managi et al. [38] also posit that the impact of technological innovation can fully offset the impact of resource scarcity. Bringezu et al. [39] argue that technology is the basis for increasing resource productivity to break the link between resource consumption and economic growth. These previous findings suggest the possibility that enhancing technological capabilities could promote marine economic growth even under marine resource constraints. However, if so, the impact that capital and labor would have on the marine economy, given these constraints, is unclear. To address these issues, this study classifies marine resources according to their resource industry types, precisely explores the relationship between marine resources and economic growth, and fully considers the interactions between capital, labor, and technology and marine resources, and constructs threshold effect models as threshold variables.

The remainder of the paper is organized as follows. Section 3 describes the construction of the empirical model, variables and data, and statistical analysis methods. Section 4 presents an empirical analysis using a fixed-effects model to test the impact of marine resources on marine economic growth, using capital, labor, and technology as control variables, which are then regressed as threshold variables to further investigate the mechanism of action and change characteristics of the control variables as well as marine resource inputs on the marine economic growth process under the marine resource constraint. Section 5 summarizes relevant findings based on the study's results and proposes relevant policy recommendations to promote marine economic growth.

3. Model, Data, and Variables

We establish the equation for the relationship between marine resource inputs and the impact of marine economic growth, as shown in Equation (1):

$$\ln GOP_{it} = \sigma_{it} + \alpha_1 \ln MR_{it} + \Sigma X_{it} + \theta_{it} + \varepsilon_{it} \tag{1}$$

Considering the possible non-linear relationship between marine resource input and marine economic growth, the squared term of marine resource input is introduced here to reflect it. The specific model is shown in Equation (2):

$$\ln GOP_{it} = \sigma_{it} + \alpha_1 \ln MR_{it} + \alpha_2 \ln MRit^2 + \Sigma X_{it} + \theta_{it} + \varepsilon_{it} \tag{2}$$

GOP is the level of marine economic growth expressed by regional gross marine product. Data were obtained from the Chinese Marine Statistical Yearbook; *MR* is the input of marine resources; *X* is the control variable, including the inputs of marine capital (*MC*), marine-related labor (*ML*), and marine science and technology (*MT*); σ_{it} represents the intercept term; θ_{it} represents the time dummy variable in coastal areas; ε_{it} is the regression disturbance term; and i, t represent province and year, respectively. All variables are logarithmically treated. Each indicator is explained below.

MR represents the amount of marine resource input, which includes living and non-living resources. The paper refers to the classification of environmental assets in the SEEA central framework and the division of the three industries to classify marine resources according to the main industries to which they are applied. The primary industry refers to the industries that produce natural objects. Based on the availability of data, we select the amount of seawater harvesting and mariculture to constitute the primary industry in the ocean. The secondary industry is the processing and manufacturing industry, and we choose marine crude oil production, marine natural gas production, sea salt production, marine chemical production and marine mining production to represent the secondary industry. The tertiary industry mainly refers to transportation, public services and other non-material production sectors, and we choose marine transportation volume to represent them. Please refer to Table 1 for details.

Data were obtained from the Chinese Marine Statistical Yearbook. Different industries involve different types of resources and cannot be summed up directly in an exhaustive manner. The entropy method can exclude the interference of human factors as much as possible, and can also overcome the problems such as difficulties in analysis caused by the small variability of the selected index values, and thus can more scientifically dig out the information implied by the data. Therefore, this paper adopts the entropy value method to synthesize indicators for three types of industrial resource inputs to obtain MR1, MR2 and MR3 in turn, and the main steps are as follows.

(1) Standardization processing. In order to eliminate the influence of data outline quantity, the raw data of each indicator in the evaluation index system are standardized. The data in the evaluation index system are the panel data containing m provinces, n indicators, and T years. The standardization formulas of positive and negative indicators are shown in Equation (3).

Table 1. Marine Resources Classification.

Industry Classification	Resource Statistics
Primary industry (MR1)	Marine fishing production, mariculture production
Secondary industry (MR2)	Marine crude oil, marine natural gas, sea salt, marine chemical, and marine mining production
Tertiary industry (MR3)	Marine transportation volume

$$X_{tij} = \begin{cases} \frac{x_{tij}-\min(x_j)}{\max(x_j)-\min(x_j)} + 10^{-3} \\ \frac{\max(x_j)-x_{tij}}{\max(x_j)-\min(x_j)} + 10^{-3} \end{cases}, \quad (3)$$

where X_{tij} denotes the standardized value ($t = 1, \ldots, T$; $i = 1, \ldots, m$; $j = 1, \ldots, n$); x_{tij} denotes the original value of the jth indicator in province i in year t; $\max(x_j)$ and $\min(x_j)$ are the maximum and minimum values of indicator j in all provinces in all years, respectively.

(2) The indicators are normalized.

$$w_{tij} = X_{tij} / \sum_{t=1}^{T} \sum_{i=1}^{m} X_{tij}, \quad (4)$$

where w_{tij} denotes the share of the jth indicator of the ith province in year t to the sum of the indicators of all provinces in all years.

(3) Calculate the information entropy of the jth indicator.

$$e_j = -(\ln mT)^{-1} \sum_{i=1}^{n} w_{ij} \ln(w_{ij}), \quad (5)$$

where m is the number of provinces in the study sample and T is the time span.

(4) Calculate the coefficient of variation for each indicator.

$$g_j = 1 - e_j. \quad (6)$$

(5) The weights of each indicator were calculated, and the index H_{ti} of the amount of resource input in the three types of industries in 11 coastal provinces and cities in China during 2006–2019 was calculated based on the weights.

$$W_j = g_j / \sum_{j=1}^{n} g_j, \quad (7)$$

$$H_{ti} = \sum_{j=1}^{n} W_j X_{tij}. \quad (8)$$

MC represents the volume of marine capital input measured using the volume of investment in marine fixed assets [40,41]. Data were obtained from the Chinese Statistical Yearbook. Many methods are available to measure the amount of investment in marine fixed assets, and we use the amount of investment in fixed assets within each region to determine it indirectly. The investment in marine capital can provide sufficient physical capital guarantee for scientifically controlling the amount of existing resource development and actively expanding the scale of resource development. Therefore, the prediction coefficient of this indicator is positive.

ML is the amount of marine labor input based on data from the China Marine Statistical Yearbook. The number of sea-related employed persons in each province and city is obtained from 2006–2016 due to the change in data statistical path; the number of employed persons in coastal areas is obtained from 2017–2019 and processed by a logarithm. In the early days of marine development, China had a large marine resource supply and labor force, which could be better utilized for economic development. However, owing to the increasing scarcity of marine resources, a large amount of human input will increase the burden of economic development, thereby leading to wasted resources. In addition, if human input exceeds the demand for marine resources, it will lead to higher development costs and less efficient resource use, which is detrimental to improving the economic contribution of resources. Based on the above analysis, the prognostic coefficient of this indicator cannot be determined.

MT is the amount of marine science and technology input expressed by the total funding income of marine research institutions; data obtained from the China Marine Statistical Yearbook. The level of marine science and technology determines the efficiency of a country's exploitation of marine resources and is an important driving factor of marine economic growth. With increased technology investment, the traditional rough resource development mode is changing, the way resources are utilized is constantly updated, and the efficiency of resource use has greatly improved. However, overexploiting resources will hinder the sustainability of resource input to marine economic growth, especially excessive and disorderly development, which is highly likely to damage the resource environment, such as a decline in or even the extinction of biological resources and reduced quality of tourist resource attractions. Based on the above considerations, the prognostic coefficient for this indicator is also undetermined.

Table 2 shows the results of the descriptive statistical analysis conducted for each of the main variables of the overall sample in the model.

Table 2. Descriptive statistics of the variables.

Variable	Sample Size	Mean	Standard Deviation	Minimum	Maximum	Predicted Coefficient Symbol
LnMGOP	154	8.086621	0.960218	5.706113	9.869186	/
LnMR1	154	15.89831	0.1240218	15.55705	16.10493	+
LnMR2	154	13.09142	1.443139	8.768588	15.40981	+
LnMR3	154	9.466966	0.975403	6.364751	11.33257	+
LnMC	154	9.366622	0.9943723	6.049498	10.98608	+
LnML	154	5.963339	1.144615	4.400603	8.788837	?
LnMT	154	13.19514	1.598125	8.304	15.23491	?

4. Results and Discussion

4.1. Regression Analysis of the Fixed Effects Model of MR and MGOP

We use a fixed-effects model to make a preliminary judgment on the relationship between marine resources (*MR*) and marine economic growth (*MGOP*). Table 3 shows the results of this test. Rˆ2 is the coefficient of determination which indicates the proportion of the variation in Y that can be explained by the variation in X. It is a measure of how closely the regression line fits each observation. When Rˆ2 = 1, it indicates a perfect fit; when Rˆ2 = 0, it indicates that there is no linear relationship between X and Y. The higher the value of Rˆ2, the better the fit. In this paper, Rˆ2 is all close to 1, which indicates a good fit and a linear relationship. F is used to test whether the regression relationship is significant or not. This paper takes $p < 0.10$ as more significant, $p < 0.05$ as significant, and

$p < 0.01$ as very significant. All models in this paper passed the F-test and all regression relationships were significant.

Table 3. Test results of the relationship between marine resources and economic growth (explained variable: marine economic growth).

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
LnMR1	7.555 *** (0.00)			6.525 *** (0.00)		
LnMR1ˆ2				0.043 *** (0.00)		
LnMR2		0.054 ** (0.03)			−0.437 * (0.08)	
LnMR2ˆ2					0.021 ** (0.05)	
LnMR3			0.155 *** (0.00)			0.226 *** (0.00)
LnMR3ˆ2						0.015 *** (0.00)
LnMC	0.009 (0.61)	0.486 *** (0.00)	0.441 *** (0.00)	0.015 (0.21)	0.484 *** (0.00)	0.387 *** (0.00)
LnML	0.014 ** (0.02)	0.086 *** (0.00)	0.073 *** (0.00)	0.006 (0.19)	0.088 *** (0.00)	0.039 ** (0.01)
LnMT	−0.005 (0.47)	0.099 *** (0.00)	0.084 *** (0.00)	−0.015 *** (0.00)	0.099 *** (0.00)	0.031 (0.10)
Cons	−112.128 *** (0.00)	1.013 *** (0.01)	0.952 *** (0.00)	−106.405 *** (0.00)	3.872 ** (0.01)	0.306 (0.31)
Obs	154	154	154	154	154	154
R^2	0.985	0.871	0.874	0.993	0.875	0.908
F	7.58	53.82	52.19	27.12	54.93	74.57
p	0.000	0.000	0.000	0.000	0.000	0.000

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively; *p*-values are in parentheses.

As Table 3 demonstrates, the coefficients of *MR1* and *MGOP* are significantly positive, indicating that an increase in marine resource input in the primary industry can indeed promote marine economic development. Meanwhile, the coefficients of LnMC and LnMT are insignificant, and the coefficient of LnML is significantly positive. This may be due to the fact that the primary industry is mostly resource-dependent with living marine resources, and marine resources have a constraining effect on the growth of marine economy in this industry, and the primary industry does not need the support of capital and technology, etc., and only labor is needed to drive the growth of marine economy. The regression coefficients of *MR3* and *MGOP* are significantly positive, indicating that an increase in marine resource input in the tertiary sector can also promote marine economic development. Over time, the tertiary industry accounts for an increasing proportion of the gross marine product, of which the development of marine transportation is based on resources; thus, the relationship between the two roles is easily apparent. The regression coefficient of *MR2* and *MGOP* is also significantly positive; however, its contribution is smaller than those of the coefficients of primary and tertiary marine resource inputs and marine economic growth. We posit that this is because the growth of the secondary marine economy will be influenced by various factors, with marine resources being only one of the factor inputs, and that the input–output effect may be disturbed by other factors. The control variables *MC*, *ML*, and *MT* showed mostly facilitative effects for *MGOP*.

In addition, we introduce the squared term of marine resources, and the above results show that *MR* and *MGOP* display a U-shaped relationship curve. Thus, regarding factors that lead to change in the marginal growth effect of *MR* on *MGOP*, considering the interaction of factors in economic growth, we defined such influences as the inputs of capital, labor, and technology. Subsequently, we use these three as threshold variables and build a threshold effect model to verify whether the nonlinear effects of the three elements hold.

4.2. Threshold Effect Test for MR and MGOP

In this study, we adopt Hansen's [42] threshold model with marine input capital, sea-related employment, and marine science and technology in coastal areas as threshold variables and conduct threshold tests under the assumptions of single and double thresholds, as shown in Equation (3). The threshold test is employed to verify whether the threshold effect exists and the threshold value is significant, by which a conclusion can be drawn as to whether there is a nonlinear relationship between the variables. Taking the significance test of the single threshold model as an example, the original and alternative hypotheses for the threshold effect are $H_0 : \beta_1 = \beta_2$ and $H_1 : \beta_1 \neq \beta_2$, respectively. The original hypothesis states that no threshold effect is present in the tested model, and that if the results reject this hypothesis, a threshold effect exists. Thus, Equation (9) is composed as follows:

$$\begin{cases} \ln GOP_{xit} = \eta_\iota + \theta_1'(\sigma_{it} + \sum X_{it} + \alpha_1 MR_{xit} \\ \times I(q_{it} \leq \gamma) + \alpha_1 MR_{xit} \times I(q_{it} > \gamma) + \theta_{it} \\ + \varepsilon_{it}) \\ \ln GOP_{xit} = \eta_\iota + \theta_1'(\sigma_{it} + \Sigma X_{it} + \alpha_1 MR_{xit} \\ \times I(q_{it} \leq \gamma_1) + \alpha_1 MR_{xit} \times I(\gamma_1 < q_{it} \leq \gamma_2) \\ + \alpha_1 MR_{xit} \times I(q_{it} > \gamma_2) + \theta_{it} + \varepsilon_{it}) \end{cases} \tag{9}$$

where $I(\cdot)$ represents the schematic function, which takes the value of 0 when the expression in parentheses is false and 1 when the opposite is true. σ_{it} are constants, θ_{it} and ε_{it} and are fixed effects and random perturbation terms, respectively. The threshold value γ divides the sample interval into two or three bins, and each bin is differentiated using the slope value α_x, respectively. φ_x is the impact coefficient of control variables, and X denotes the control variables, including marine capital input, labor input, and marine science and technology input.

Table 4 shows the results of the threshold tests for the existence of the relationship between marine resource inputs and economic growth in China from 2006 to 2019 for capital, labor, and technology. Table 4 reflects the F-values of the threshold tests for each variable and the p-values obtained by repeated sampling of 500 times according to the self-sampling (bootstrap) method.

Table 4. Marine resources and economic growth threshold test.

Explained Variable	Threshold Type	LnMC	LnML	LnMT
LnMR1	Single threshold value	50.69 **	84.19 ***	146.38 ***
	p-value	0.0220	0.0000	0.0000
	Double threshold value	27.64	36.56	29.44 *
	p-value	0.1040	0.1200	0.0620
LnMR2	Single threshold value	7.04	19.70 **	44.16 ***
	p-value	0.6080	0.0300	0.0000
	Double threshold value	9.85	8.90	40.38 ***
	p-value	0.1740	0.4400	0.0000
LnMR3	Single threshold value	4.56	19.63 *	47.13 ***
	p-value	0.8700	0.0620	0.0040
	Double threshold value	7.94	19.17 *	24.65 **
	p-value	0.2900	0.0980	0.0340
Number of bootstrap samples		500	500	500

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively; p-values are in parentheses.

The results in Table 4 show that only *MR1* passes the threshold test when *MC* is used as the threshold variable at a bootstrap count of 500, indicating a lack of threshold effect of capital investment in secondary and tertiary marine resources and marine economic growth. Further, the regression results in Table 5 show that, for marine economic growth, marine capital investment can play a significant promoting role under both secondary and tertiary marine resource inputs.

Table 5. Interval division of the estimation result of the threshold value of marine resources and economic growth.

Variable	lnMC	lnML	lnMT
LnMR1$_{-0}$	LnMC $\leq$ 10.1771	LnML $\leq$ 4.8528	LnMT < 10.0048
	Low-value distribution area of marine capital	Low-value distribution area of the marine labor force	Low-value distribution area of marine technology
LnMR1$_{-1}$	LnMC > 10.1771	LnML > 4.8528	10.0048 $\leq$ LnMT < 11.4468
	High-value distribution area of marine capital	High-value distribution area of the marine labor force	Median distribution area of marine technology
LnMR1$_{-2}$			LnMT > 11.4468
			High-value distribution area of marine technology
LnMR2$_{-0}$		LnML $\leq$ 4.6022	LnMT < 12.1860
		Low-value distribution area of the marine labor force	Low-value distribution area of marine technology
LnMR2$_{-1}$		LnML > 4.6022	12.1860 $\leq$ LnMT < 14.0069
		High-value distribution area of the marine labor force	Median distribution area of marine technology
LnMR2$_{-2}$			LnMT > 14.0069
			High-value distribution area of marine technology
LnMR3$_{-0}$		LnML < 4.0622	LnMT < 12.1860
		Low-value distribution area of the marine labor force	Low-value distribution area of marine technology
LnMR3$_{-1}$		4.0622 $\leq$ LnML < 5.1636	12.1860 $\leq$ LnMT < 14.0069
		Median-value distribution area of the marine labor force	Median distribution area of marine technology
LnMR3$_{-2}$		LnML > 5.1636	LnMT > 14.0069
		High-value distribution area of the marine labor force	High-value distribution area of marine technology

The marine economy cannot be developed without investment in marine capital. The growth of China's marine economy is still in its infancy, and marine resource development is focused on coastal and offshore areas. Backward technology has caused the rough exploitation method to lead to problems such as marine pollution and biological resource decay. Marine capital investment is key to solving these issues. In addition, against the background of seizing the opportunity for marine development and striving to attain the commanding heights of marine development, the renewal of the marine economic growth model, the transformation of the traditional marine industry, and the cultivation of the emerging marine industry also require capital support. Therefore, the present empirical results are consistent with the reality that capital input can always promote economic development and no threshold effect is exerted on either secondary and tertiary marine resource input.

Subsequently, when *ML* is used as the threshold variable, *MR3* only passes the double threshold test, and *MR1* and *MR2* only pass the single threshold test. In contrast, when *MT* is used as the threshold variable, *MR1*, *MR2*, and *MR3* pass the double threshold. To facilitate this study, we divided the intervals according to the threshold estimates, as shown in Table 5.

4.3. Threshold Regression Analysis of MR and MGOP

The results of the threshold test indicate that changes in *MC*, *ML*, and *MT* input levels can have a phase effect on the relationship between *MR* and *MGOP*; however, the degree to which the elements affected and the magnitude of the effect still require further threshold regression to allow conclusions to be drawn. The results of the threshold regression are shown in Table 6.

Table 6. Regression results of thresholds for marine resources and economic growth.

	Marine Resources of the Primary Industry			Marine Resources of the Secondary Industry			Marine Resources of the Tertiary Industry		
Variable	**lnMC**	**lnML**	**lnMT**	**Variable**	**lnML**	**lnMT**	**Variable**	**lnML**	**lnMT**
$LnMR1_{-0}$	7.657 *** (0.00)	7.511 *** (0.00)	7.624 *** (0.00)	$LnMR2_{-0}$	0.086 *** (0.00)	0.058 *** (0.00)	$LnMR3_{-0}$	0.271 *** (0.00)	0.108 ** (0.02)
$LnMR1_{-1}$	7.664 *** (0.00)	7.500 *** (0.00)	7.612 *** (0.00)	$LnMR2_{-1}$	0.050 ** (0.04)	0.031 (0.12)	$LnMR3_{-1}$	0.203 *** (0.00)	0.076 * (0.10)
$LnMR1_{-2}$			7.605 *** (0.00)	$LnMR2_{-2}$		0.050 ** (0.01)	$LnMR3_{-2}$	0.230 *** (0.00)	0.103 ** (0.03)
LnMC	−0.021 (0.19)	0.023 (0.10)	0.020 * (0.09)	LnMC	0.484 *** (0.00)	0.425 *** (0.00)	LnMC	0.390 *** (0.00)	0.410 *** (0.00)
LnML	0.003 (0.61)	0.031 *** (0.00)	0.011 *** (0.00)	LnML	0.114 *** (0.00)	0.090 *** (0.00)	LnML	0.072 *** (0.00)	0.075 *** (0.00)
LnMT	−0.009 (0.14)	−0.001 (0.83)	0.030 *** (0.00)	LnMT	0.105 *** (0.00)	0.145 *** (0.00)	LnMT	0.083 *** (0.00)	0.119 *** (0.00)
C	−113.374 *** (0.00)	−111.564 *** (0.00)	−113.491 *** (0.00)	C	0.799 ** (0.03)	1.048 *** (0.00)	C	0.753 ** (0.01)	1.313 *** (0.00)
R^2	0.989	0.991	0.994	R^2	0.887	0.924	R^2	0.903	0.920
F	10.40 ***	12.00 ***	12.59 ***	F	62.84 ***	92.01 ***	F	54.04 ***	85.96 ***

Note: ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively; t-values are in parentheses.

As presented in Table 6, when *MC* is used as the threshold variable, a single threshold effect is exerted on the *MR–MGOP* relationship for the primary sector only. Regarding the low-value distribution of marine capital, the input of *MC* significantly enhances the effect of *MR*. This enhancement effect is greater when the *MC* input is continuously increased until it enters the high-value distribution area of marine capital. In general, as in the secondary and tertiary sectors, a clear path dependence of marine economic growth on marine capital investment can be observed. None of the control variables are significant, indicating that when capital input is used as the threshold variable, the growth of the marine economy under the primary sector does not require the support of technology and labor.

When *ML* is used as the threshold variable, a single threshold effect is exerted on the relationship between *MR* and *MGOP* for the primary and secondary industries. Regarding the development of the primary and secondary industries of the marine economy, when *ML* is in the low-value distribution area of marine labor, resource input can significantly promote marine economic growth, and when *ML* enters the high-value distribution area of marine labor, the promotion effect becomes relatively smaller but is still statistically significant. Within the appropriate scope, labor input can enable effective exploitation of marine resources and promote marine economic development. However, when labor input is excessive, especially in the form of the influx of low-quality labor, it will cause resource exploitation to become disorderly and barbaric, causing serious environmental damage to and reducing the level of sustainability of economic growth. Nevertheless, excessive labor input will greatly increase the cost of resource utilization and inhibit the growth dynamics of the marine economy. Meanwhile, the coefficients of both *MC* and *MT* are insignificant, which this paper suggests is because the growth of the secondary marine economy can be affected by a variety of factors, weakening the role of other factors when labor input is used as the threshold variable.

In addition, we note that *ML*'s entry into the high-value distribution area of the marine labor force significantly drives the relationship between industries more in the primary industry than in the secondary industry. In analyzing the reasons, we posit that this is mainly because the primary marine industry is still dominated by traditional fishing, which is labor-intensive. Factors such as the backwardness of technical tools and restrictive geographical environment mean that relying on a large number of laborers remains necessary to exploit marine resources. Compared to the primary industry, the development of the secondary industry of the marine economy is mainly based on manufacturing, although the traditional industries are predominant. However, the structure of China's manufacturing industry is undergoing a transformation and upgrades, and compared with the primary industry, labor dependence is reduced. Therefore, when considering the contribution of *ML* to *MR*, we find that the impact of the primary industry is more significant than that of the secondary one. Similarly, the secondary industry will be affected more when labor is over-invested; therefore, the promotion effect of *ML* will become significantly smaller when it enters the high-value distribution area of marine labor.

Further, a double threshold effect is exerted on the relationship between *MR* and *MGOP* in the tertiary industry when *ML* is used as a threshold variable. In the low-value distribution of marine labor, the *ML* input significantly enhances the effect of *MR*. When the *MT* input is continuously increased until it enters the medium-value distribution of marine labor, the enhancement effect will be weakened. However, when it enters the high-value distribution of marine labor, the enhancement effect increases again, although it remains lower than at the initial level. Based on our analysis, we posit that this is because the tertiary industry mainly functions from within the service sector, which is inherently inseparable from the support of labor force. However, the service industry focuses not only on the quantity of labor but also on the quality. When too much labor is imported at once, it is inevitable that low-quality labor will exist, which will impact the growth of the marine economy. When the labor force continues to increase, the market tends to be saturated with the best workers, and a high-quality labor force will further serve the market, which in turn will contribute to marine economic growth. The original research results only tell us that labor input will promote the growth of marine economy. However, due to the current marine resource constraints, our study proves that labor input should be appropriate, and when labor input is excessive, it will instead affect the dynamics of marine economic growth.

When *MT* is used as the threshold variable, a double-threshold effect of scientific and technological inputs on the impact of marine resources on marine economic growth occurs. In the development of the primary industry of the marine economy, when *MT* is in the low-value distribution area of marine science and technology, resource input can promote marine economic growth. When *MT* input is increased until it enters the median-value distribution area of marine science and technology, the enhancement effect is weakened. Further, when it enters the high-value distribution area of marine science and technology, the enhancement effect is further weakened; however, it always displays a significant promotion effect. The primary industry of the marine economy remains dominated by the traditional fishing industry. Although scientific and technological progress will promote marine economy, it still mainly relies on labor, and when investments in science and technology increases, it also consumes capital. To ensure balance between capital inflow and outflow, it is necessary to reduce labor expenditure, which will weaken its promotional role.

Regarding the development of the second and third industries of the marine economy, when *MT* is in the low-value distribution area of marine science and technology, resource input can significantly promote marine economic growth. When *MT* input is increased until it enters the middle-value distribution area of marine science and technology, the promotion effect is weakened. When it enters the high-value distribution area of marine science and technology, the promotion effect increases again, and becomes equal to its initial value. Extensive research and development of new technologies, applied in the field of marine resources, can explore new use values of marine resources, optimize the development mode of marine resources, rationalize the use of marine resources, and improve the use efficiency of resources. Thus, marine resource development in this stage will significantly promote marine economic development. Although technological innovation has increased the strength and depth of resource development, marine resources are finite, and excessive development will gradually weaken the role of technology in driving economic growth, which is not conducive to sustainable economic development. When people realize this, they will focus more on the quality of technology development and its adaptation to all resources along with technological innovation, and in turn, marine resource development will further promote marine economic development. Compared with the results of the original study, we have also made progress in science and technology investment. It is not just a matter of investing in science and technology to maximize the growth of the marine economy, but rather of paying attention to the adaptation of technology to resources and of fully considering the current economic conditions.

Regarding the control variables, we have explained separately for the insignificant cases and for the remaining cases the coefficients are positive and all of them pass the significance test. This is the same result as those of the existing studies, where the inputs of capital, labor and technology are able to promote the growth of the marine economy.

5. Conclusions and Policy Recommendations

In this study, we analyze the relationship between marine resources and economic growth across 11 coastal provinces and cities. Considering the interactions between marine production factors, we posit that marine resources and economic growth do not share a simple linear relationship and may be influenced by other factor inputs. The regression and threshold effect models confirm the validity of the idea that marine resources and economic growth will result in different phases under different levels of marine capital, sea-related labor, and marine science and technology inputs. We conclude the following: The impact of marine resources on economic growth has a single threshold effect of capital input only in the primary industry marine resources. Still, in general, with the increase in capital input, the maritime economy shows a positive development trend. There is a single threshold effect of labor input in the primary and secondary industry marine resources for marine economic growth, and a double threshold effect in the tertiary industry marine resources. With the investment of marine science and technology, the driving result of the development and utilization of marine resources in the first, second and third industries on economic growth generally shows a development law of first large, then small, and then large.

This study's empirical results indicate that the development of the marine economy requires significant capital investment. Currently, there exists a wide capital gap for China's marine development, especially with respect to monetary capital. Financial capital is the main driving force of marine development, and its supporting role is mostly manifested across various levels, such as marine resource development, marine equipment renewal, and marine technology change. Starting from the successful experience of international and domestic capital support for industrial development, based on this study's findings, we propose the establishment of various funding models, such as private investment, credit market, and foreign investment, to provide long-term, stable financial support for developing China's marine resources. Construction funding should be strengthened at all levels and various specific marine funds should be created to meet the varying resource needs of different marine industries. However, to solve the hindrances in the development of financing bottlenecks and constraints, encouraging private capital investment in the marine sector necessitates the employment of various methods, which will require coastal governments at all levels to increase efforts to improve their service environment and approval conditions and provide financial subsidies for key marine development projects to reduce their investment costs. Simultaneously, the establishment of a sound capital market plays an important role in allocating China's marine resources, promoting the development of marine science and technology, optimizing the structure of the marine industry, and preventing financial risks.

In addition, improving workforce quality is crucial. This study's results show that China continues to implement a labor-based approach to marine economic development. China has a large population, a long coastline, and abundant marine resources, which are the root causes for the rapid development of China's marine economy in recent years. However, from a theoretical perspective, excessive labor input will lead to not only a decrease in the efficiency of resource utilization but also an increase in enterprises' production costs, which is detrimental to marine economic development. In considering the ways to address the negative effects of the large workforce on the economy, improving the quality of the workforce and attaching importance to talent training are effective methods for solving this problem. In the development of China's marine industries, especially the emerging marine industry and high-tech-oriented marine industry, the size of their potential depends on training talent. To cultivate marine talent and improve the quality of marine labor force, we must strengthen marine education, improve the quality and structure of the marine labor force, and promote the full employment of the marine labor force. Countermeasures should be taken, including establishing a sound marine education curriculum system from elementary school to university to cultivate professional and technical marine talent, and further improving the continuing education and re-education system for those employed in marine industries to enhance their professionalism, strengthening exchanges between research institutes and marine colleges and universities to promote positive interaction between marine industries and the working population, and actively introducing marine talent from abroad.

Finally, increased investment in marine science and technology is needed. Marine science and technology innovation is the key to promoting marine economic development and transforming the marine economy to one that is conservation-oriented, green, and coordinated. At the beginning of the 21st century, Chinese marine science and technology has made great progress in the context of national marine strategy and internationalization; however, there is still substantial room for development. The results of this paper show that we should not only improve the technology level, but also pay attention to improve the innovation ability of marine science and technology and the matching degree of technology with the available resources so as to promote the development of marine economy to the greatest extent possible. To improve China's marine science and technology innovation capacity, it is first necessary to increase basic investment in science and technology innovation and support the leading role of high-end marine research and development platforms, including establishing locations such as national marine laboratories and engineering research centers. In addition, it is necessary to actively seek government policy support and patent protection. We further suggest actively introducing foreign enterprises to participate in fair competition in the domestic market and promoting China's sea-related enterprises to increase progress in technological innovations, while also further enhancing the transformation rate of China's marine science and technology achievements. Further, we also suggest promoting the integration of government, industry, academia, and research, and encouraging the agglomeration of marine industries to form a complete industrial chain.

Since the neighboring countries have similar marine resources and climate conditions as China, the policy advice in terms of capital investment and science and technology investment is referable. The difference is that China has an abundant labor force, which other countries do not have, so further research is needed on the labor force to promote the development of marine economy. In addition, there are certain shortcomings in this paper. First, this paper does not put different industries into the same model, so it is not possible to compare the size of the impact of different industries on the marine economy under different circumstances, and further investigation is needed. Second, due to the availability of data, we only selected three non-stop threshold variables as control variables. If several more different control variables could be considered, more precise and meaningful results might be obtained.

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