

Article

The Effects of Ocean Governance on Marine Economic Development from an Environmental Optimization Perspective

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Abstract: The oceans and seas are vital resources for human life and fundamental to global economic growth. With the expansion of globalization and increasing demand for resource exploitation, the ocean economy has emerged as a critical support for economic growth and a significant concern for many. However, the exploitation of marine resources often leads to ecological damage and environmental pollution, seriously threatening the long-term viability of the marine economy. Measures must be implemented to balance ecological protection and economic development for sustainable growth in the marine sector. This investigation synthesizes over a decade's worth of data from various coastal cities, incorporating insights from national databases, international reports, and scholarly articles, resulting in an analysis of more than 500 data points. Through the application of a rigorous quantitative approach and a dual fixed-effect model, the study delves into the dynamics between ocean governance and economic development. By analyzing a broad and representative dataset, the research provides an exhaustive overview of global ocean governance frameworks and the current state of the marine economy. The statistical analyses unveil the complexity and diversity of factors influencing the development and governance of marine economies. This paper explores the interplay between marine economic development and ocean governance, evaluating the impact of governance on marine economic progression within the context of environmental optimization. Furthermore, it proposes policy interventions aimed at fostering the sustainable growth of marine economies, ensuring the conservation of marine ecosystems, and pursuing overarching long-term global growth ambitions.



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Keywords: development of the marine economy; environmental optimization perspective; ocean governance; dual fixed model

1. Introduction

The ocean, one of Earth's most expansive areas, is rich in biological resources and holds significant economic potential. However, as globalization advances and the demand for resource development grows, the marine economy faces increasingly evident problems. These challenges, including overfishing, loss of habitats, and pollution, have led to the depletion and degradation of marine ecosystems, thereby endangering the socio-economic and environmental benefits they offer. Moreover, global phenomena such as climate change and ocean acidification intensify the adverse effects of localized threats, further compounding these challenges [1]. Given the critical situation, there is a collective imperative among governments and international bodies to devise and implement effective strategies for the conservation and management of marine resources. Such measures aim to foster the resilient and sustainable development of the marine industry, aligning economic objectives with environmental stewardship.

The ocean economy plays a crucial role in the global economy. According to the United Nations Conference on Trade and Development (UNCTAD), the contribution of the ocean economy to global trade volume is about 70 percent, a ratio that highlights the

central position of the ocean economy in the global trading system. The ocean economy covers not only traditional fisheries, shipping and marine oil and gas extraction, but also emerging areas such as the development of marine biological resources, marine tourism, ocean engineering and many other fields. The development of these fields is not only important for economic growth but also has far-reaching impacts on the promotion of sustainable development and the protection of marine ecosystems. The expansion of global activities within the maritime sector has markedly enhanced the worldwide economic landscape [2]. The role of ocean governance is pivotal in steering the development of the maritime economy. Defined as a collective of policies collaboratively implemented by nations, international bodies, and various stakeholders, ocean governance aims to protect and manage oceanic resources effectively. The essence of ocean governance lies in its ability to ensure the marine ecosystem's integrity, promote sustainable resource utilization, and stimulate the maritime economy's vigorous expansion. Ocean governance facilitates the restoration and conservation of marine ecosystems, mitigating the adverse effects of overfishing and pollution, safeguarding endangered species' habitats, and preserving marine biodiversity through the establishment of protected areas and monitoring systems. These measures not only bolster marine biodiversity but also establish a robust ecological foundation for the maritime economy. Additionally, ocean governance plays a crucial role in the sustainable exploitation of ocean resources by curbing overfishing and illegal fishing activities, safeguarding the regenerative capacity of fishery resources, and formulating judicious fishery management regulations. This governance extends to fostering research and systematic monitoring, thereby ensuring the fishing industry's sustainability. Moreover, ocean governance catalyzes the revitalization of the maritime economy, nurturing emergent sectors such as marine energy and tourism. Importantly, it enhances the maritime economy's competitiveness through a stable policy framework and market assurances, attracting investment and talent, thus fueling innovation and global competitiveness within the maritime sector.

Consequently, achieving a balance between sustainable ocean development and economic growth is paramount. This study seeks to elucidate the impact of ocean governance on maritime economic growth, delving into the intricate relationship between governance and economic development within the context of sustainable development and ecological preservation. It underscores the significance of environmental optimization in fostering a sustainable and prosperous maritime future.

A robust policy framework and market assurances are pivotal for bolstering the marine economy. Measures such as the reinforcement of legal and regulatory frameworks within the marine sector, alongside the augmentation of supportive policies for the industry, are foundational. Such initiatives not only facilitate the infusion of capital and talent but also propel the marine economy's expansion and its innovative capacity, enhancing global competitiveness. Consequently, the harmonization of sustainable ocean development with economic proliferation becomes essential. This manuscript endeavors to elucidate the impact of ocean governance on the scale of maritime economic growth. It embarks on an innovative examination of the pivotal interconnections between ocean governance and maritime economic expansion, addressing critical aspects of ocean governance at the heart of sustainable development and ecological conservation, with a particular emphasis on the role of environmental optimization.

To this end, the manuscript first investigates the influence of maritime economic growth on ocean governance through the development of a dual fixed-effect model. It then addresses the issue of endogeneity among variables via the two-stage least squares method. Subsequently, an analysis is conducted on the variations in ocean governance relative to the degree of growth of the maritime sector across diverse datasets. The foundation of marine governance is posited as a cornerstone of maritime economic growth. Through a comprehensive analysis of the application of technologies pertinent to the marine economy in ecological conservation, legal governance, and marine resource management, this study enhances understanding of the nexus between the marine economy and ocean governance.

This exploration serves not only as a reference for future research and policy development but also underscores the imperative of integrating maritime economy and ocean governance for the sustainable development and utilization of ocean resources, aiming to foster a more affluent and sustainable marine environment for future generations.

This study incorporates insights from national databases, international reports, and scholarly articles, resulting in an analysis of more than 500 data points. The study employs a rigorous quantitative approach and a dual fixed-effect model to delve into the dynamics between ocean governance and economic development. This methodology allows for the examination of the complexity and diversity of factors influencing the development and governance of marine economies. Additionally, the study utilizes a unique dataset that encompasses over a decade's worth of data from various coastal cities, providing a comprehensive overview of global ocean governance frameworks and the current state of the marine economy. This innovative approach enables the identification of key drivers and barriers to marine economic development, highlighting the importance of effective ocean governance in achieving sustainable growth.

2. Literature Review

2.1. Related Research on Marine Economic Development

The maritime economy emerges from the evolving “techno-economic paradigm”, which heralds digital knowledge and information as the cornerstone of production factors. This paradigm is supported by an interconnected and intelligent digital infrastructure, integrating state-of-the-art general-purpose information and communication technologies such as big data and cloud computing into societal and economic frameworks. This represents a novel socioeconomic structure designed for structural optimization and maximization of efficiency [3]. Assessment of the maritime economy can be approached from two perspectives: firstly, the assessment of the marine economy's growth rate can be achieved through a comparative and direct evaluation methodology. In this context, the marine economy's scale, as delineated by the China Academy of Information and Communication Research, serves as a representative example [4].

A notable instance of this approach is the marine economy scale published by the China Academy of Information and Communication Research. Secondly, the development of a multidimensional index to measure the marine economy's growth at the national level stands as another method [5]. Examples of such indexes are the Caixin Think Tank Marine Economic Index, the Tencent Research Institute “Internet+” Marine Economic Index, and the Shanghai Academy of Social Sciences National Marine Economic Competitiveness Index. A thorough evaluation system is primarily constructed to gauge the level of the marine economy at the province and city levels [6]. Research on the marine economy's influence is categorized into macro, meso, and micro. Macroeconomic research primarily focuses on the concept of superior economic development. Total factor productivity has increased due to new input factors and more effective resource allocation made possible by developing technologies like the Internet and cloud computing [7,8], stimulating economic growth and releasing economic vitality.

The swift advancement of information technology presents fresh prospects for the modernization and metamorphosis of China's manufacturing sector [9]. The intrinsic link between the marine economy and the real economy serves as a catalyst for the manufacturing sector's optimization and upgrade, leading to industrial chain restructuring. Furthermore, the marine economy incentivizes microenterprises to augment their innovation capabilities and enforce cost control measures, thereby elevating their overall factor productivity [10].

In Section 2.1, this paper gives an overview of the relevant studies on marine economic development, including the assessment methods of marine economic growth rate, the construction of multidimensional indexes, and the study of marine economic influence. Therefore, for the development of the marine economy, this paper can draw on the assessment methods and multidimensional index construction of existing studies and combine

them with China's actual situation to construct a marine economic growth assessment model suitable for China's national conditions. In addition, this paper can also explore the intrinsic connection between the marine economy and the real economy, analyze the role of the marine economy in promoting the optimization and upgrading of the manufacturing industry and the reconstruction of the industrial chain, as well as the impact of the marine economy on the innovation ability and cost control of microenterprises. Through these studies, the development of the marine economy can be predicted and guided more accurately, providing useful references for policy-makers and enterprises.

2.2. Related Research on Marine Governance

The initial definition of global ocean governance is "the creation of rules and practices for fair and effective distribution of ocean uses and resources, offering conflict resolution means to utilize and benefit from the oceans, especially to address collective action problems in an interconnected world". Pertinent research findings on global ocean governance can be categorized into three types: comprehensive analysis of fundamental theory, detailed investigation of specific ocean issues, and systematic study of governance mechanisms and their implementation pathways.

The first kind of research aims to clarify the structure of the governance system and elaborate on the conceptual meaning of ocean governance. According to Chen, Y., the term "global ocean governance" refers to a concept group that includes globalization, global governance, and integrated ocean management. This means that different international community subjects can work together to consult and cooperate in order to jointly solve issues related to the creation and use of marine resources and space [11]. The components of global ocean governance, such as governance subjects, governance objects, governance aims, and rules, were categorized and defined by Dolata [12] and Eapen [13]. This type of research, from the perspective of globalization, generally elucidates the fundamental ideas and research questions for the study of global ocean governance, establishes the groundwork for further research and offers macro-guidance.

The second category of research concentrates on particular problems related to ocean governance. Certain governance domains, including marine security, marine environment, and marine development and use, have emerged as a result of the integration of marine governance practices with political, economic, security, and ecological disciplines. This type of research can offer direction for resolving real-world issues because it has a narrower emphasis. With a primary focus on regional marine pollution cooperation, marine energy cooperation, and marine regional security challenges, the current academic study on specific marine issues combines environmental science, international law, resource use, and other disciplines [14].

The processes and practice paths of ocean governance are the subject of the third category of research. Academic research on the global ocean governance mechanism is mainly carried out under the framework of the *United Nations Convention on the Law of the Sea* (hereinafter referred to as the *Convention*). Although the *Convention* has won the recognition of most scholars as the comprehensive of marine international law, However, its weak and ineffective legal provisions and the subjective and objective factors of the continuous evolution of marine issues have led to the failure of the *Convention* to bind States to fulfill their obligations. Eurostat conducted mechanism studies on certain marine issues [15]. For example, some scholars defined three governance dimensions of marine environmental governance mechanisms. In terms of specific practice paths, most scholars, such as Barefoot and Tapscott, believe that it is necessary to gradually form universal and extensible ocean governance rules and governance order on the basis of enriching and expanding the theory and practice of "ocean community with a shared future", emphasizing that China is promoting the construction of global ocean governance [16,17]. The strength and wisdom contributed to breaking through the dilemma of global ocean governance.

In the research field of marine economic development, the existing literature mainly focuses on the assessment methods of marine economic growth rate, the construction

of multidimensional indexes and the analysis of marine economic influence. This study will draw on these research results to develop a more accurate marine economic growth assessment model, taking into account China's specific national conditions. The model aims to provide scientific forecasts and guidance for China's marine economic development in order to promote the effective use of marine resources and the optimization and upgrading of industries.

In the field of ocean governance, existing studies have focused on the basic theoretical framework of global ocean governance, in-depth analyses of specific governance issues, as well as the exploration of ocean governance mechanisms and their implementation paths. Based on these studies, this paper will further examine the key challenges and emerging opportunities facing global ocean governance and put forward practical policy recommendations. These recommendations aim to promote the improvement of the ocean governance system to ensure the sustainable use of marine resources and the long-term protection of the marine environment so as to achieve the overall effectiveness and lasting sustainability of ocean governance.

2.3. Research on the Connection between Marine Governance and Economic Growth

The swift expansion of the marine economy has captured the attention of scholars, prompting a closer examination of its influence on ocean governance. Dyck's integration of data elements into measurement indicators revealed that the development of the marine economy exhibits a "Matthew effect", wherein the strong get stronger, leading to enhanced marine governance [18]. This phenomenon underlines the capacity of effective ocean governance to drive significant improvements in environmental performance metrics, contributing to the overarching goals of sustainable economic development within the marine sector [19]. Jiang et al. [20], focusing on industrial upgrading, discovered that the marine economy exerts a positive influence on ocean governance, suggesting a symbiotic relationship between economic development and governance efficacy. Kwak et al. [21] believe that the marine economy can significantly improve the development quality of the Marine industry. However, its impact is affected by the regulatory effect of economic factors such as technological innovation.

Further investigations have demonstrated that the input of scientific and technological innovation plays a crucial role in shaping ocean governance, revealing a complex, nonlinear relationship between innovation and governance mechanisms [22]. The adoption of marine economic technologies has instigated transformative changes in marine resource management, with tools like remote sensing, satellite imagery, and big data analytics leading to more precise and timely monitoring and assessment of the marine environment [23]. Moreover, the advancement of the marine economy has fostered the sustainable growth and utilization of marine resources, opening new avenues for rational exploitation through innovative applications in sectors like intelligent fisheries and marine energy development [24].

In terms of marine ecological protection, the burgeoning marine economy introduces novel methods and ideas for monitoring and safeguarding marine ecosystems. Utilizing technologies such as big data analysis and artificial intelligence, researchers can gain deeper insights into the dynamics of marine ecosystems, enhancing our ability to predict and mitigate environmental risks. Concurrently, the growth of the marine economy bolsters the dissemination and sharing of marine environmental information, facilitating cross-border collaborations in marine conservation [25].

The evolution of the marine economy is pivotal for the refinement and enhancement of marine law and governance frameworks. Ocean governance emerges as a critical force in safeguarding marine biodiversity and supporting the economic vitality of sectors dependent on pristine and sustainable marine environments. Innovations in digital technologies, such as e-commerce and blockchain, have introduced a new era of transparency and standardization in the marine industry, improving the traceability and compliance of marine resource utilization. Additionally, the marine economy has spurred the development of

novel ocean governance models, including digital marine spatial planning and intelligent supervision, offering fresh perspectives on marine rights protection and governance.

In summary, based on the existing literature, the study in this paper further validates the positive impact of the ocean economy on ocean governance through empirical analyses and explores the key role of innovation in promoting ocean governance. The findings of this paper not only provide new evidence for understanding the impact of the ocean economy on ocean governance but also provide important practical guidance for policy-makers and ocean managers.

3. Model Setting and Research Data

3.1. Model Setup

The fixed effects model, the difference model, and the random effects model constitute the three principal methodologies for the analysis of panel data. The fixed effects model posits a scenario wherein all variables are directly related to the explanatory variable, while the dependent variable demonstrates temporal variability. Fixed-effect models can be further categorized into three distinct types:

- (1) Individual Fixed Effect Models: In these models, the intercept term is the only element that alters across the temporal sequence. Within the framework of panel regression models, the marginal effect of explanatory factors on the dependent variables remains consistent. However, it is noteworthy that, besides the explanatory variables incorporated within the model, there exist additional significant variables influencing the explanatory variables which exhibit variation across individuals but remain stable over time.
- (2) Time Fixed-Effect Model: This model is characterized by distinct temporal markers in diverse cross-sectional data. Should the model's intercepts be consistent throughout the timeline yet exhibit substantial differences across various cross-sections, a time-specific fixed-effect model is warranted. This approach acknowledges the temporal consistency of intercepts while allowing for significant variances between different cross-sectional analyses.
- (3) Time-point Individual Fixed-Effect Model: This model delineates a scenario where intercepts among various horizontal time points and time series show significant disparities. It advocates for the creation of a unique fixed effects model for specific time points, contingent upon the intercepts demonstrating notable variability across different cross-sections and throughout the timeline.

Each category delineates a refined approach to analyzing panel data, offering nuanced insights into the dynamics of variables over time and across different populations or conditions. By employing these models, researchers can effectively dissect and interpret the complex interrelationships between explanatory and dependent variables, taking into account temporal and individual variations.

The selection of the model is guided by two primary objectives: to account for unobservable heterogeneity and to encapsulate the dynamic interactions stipulated in the research hypothesis. The fixed-effect model excels in managing unobservable heterogeneity among entities (such as countries, regions, etc.) and, temporally, is a pivotal aspect in examining the realms of ocean governance and marine economic development. Factors inherent to each entity, including geographical location, policy frameworks, and historical backdrop, alongside temporal elements like global economic trends and environmental shifts, considerably affect the study's variables.

The implementation of this model is particularly relevant to the study at hand. Utilizing the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) for model selection facilitates the identification of a model that adeptly balances complexity with accuracy, thereby mitigating the risk of overfitting. The penalization mechanisms of AIC and BIC against superfluous parameters guarantee that the model remains streamlined yet proficient in delineating the relationship between ocean management (OMN) and Ocean Gross Domestic Product (OGDP). This methodology, given the intricacies of marine eco-

conomic structures and governance systems, assures the model's robustness and applicability. The integration of both entity-specific and temporal fixed effects enables a more precise depiction of the nuanced and evolving relationship between ocean governance and marine economic growth.

Descriptive statistical analysis plays a foundational role in illuminating the dataset's characteristics, including the mean, median, and standard deviation of crucial variables such as OGD, Urbanization (URB), foreign direct investment (FDI), human resources (HR), industrial structure (IS), and Ocean Marine Industry (OMI). This analysis accentuates both the variability and consistency present within the dataset, underscoring the necessity for a model adept at accommodating these variances effectively.

Both the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) incorporate a penalty term that is directly related to the number of parameters within the model. Notably, BIC assigns a more substantial penalty than AIC, with the added consideration of sample size. This feature of BIC makes it particularly adept at preventing the model from becoming overly complex, thereby mitigating the risk of overfitting, especially in analyses involving a large dataset. In the process of model selection, it is imperative to balance the likelihood function of the model pair against its complexity. The introduction of a penalty term for model complexity in numerous information criteria aims to address and prevent overfitting.

In this research, we utilize two prevalent methodologies for model selection. The first approach involves the Akaike Information Criterion (AIC), which evaluates the complexity of a statistical model. The primary objective is to select the model with the minimum AIC value, thus reducing the likelihood of overfitting. The second method employs the Bayesian Information Criterion (BIC), analogous to AIC, yet distinct in that BIC's penalty for the number of model parameters is more severe, with sample size playing a role in its calculation. This characteristic allows BIC to effectively curtail the complexity of the model, ensuring its simplicity and applicability when dealing with extensive datasets.

Use of a dual fixed effects model: compared to a single fixed effects model, this study uses a dual fixed effects model, which allows for controlling for both firm fixed effects that do not vary over time and time fixed effects that vary over time, reducing omitted variable bias and improving the accuracy and robustness of the estimation results. In addition, in contrast to broader sustainable development or environmental economics studies, this study focuses on the relationship between marine environmental governance and marine economic development, providing insights specific to the marine sector.

However, the model also has shortcomings: the present model may provide static correlation analyses rather than dynamic causality. This means that it may not capture the dynamic interaction between marine environmental governance and economic development over time, and furthermore, the accuracy of the model may be limited by data quality, availability and sample size. For example, if the data have measurement errors or are not representative, the conclusions of the model may be affected.

Based on the comprehensive analysis conducted, the dual fixed-effect model has shown a notable advantage over the single fixed-effect model, highlighting its increased reliability and robustness. The results obtained from the dual fixed-effect model not only validate its efficacy but also reinforce its credibility, underscoring its potential to provide nuanced insights into the relationship between marine economic development and ocean governance. This model has been carefully designed, incorporating contemporary scholarly discourse and an extensive review of the relevant literature to ensure its scientific rigor. We construct the model as follows:

$$OGDP_{it} = \alpha_0 + \alpha_1 OMN_{it} + \alpha_3 control_{it} + \gamma_i + \theta_t + \varepsilon_{it} \quad (1)$$

In the preceding equation, I point to the individual, t points to the year, *ocean governance* (OMN) is the core explanatory variable, *the level of ocean economic development* (OGDP) is the explanatory variable, *control* is the related control variable: *the level of urbanization* (URB),

the level of foreign investment (FDI), human resources (HR), industrial structure (IS), and the share of ocean industry (OMI), and ε_{it} is the random perturbation term.

$$OGDP_{it} = \alpha_0 + \alpha_1 OMN_{it} + \sum_{k=1}^K \beta_k Control_{kit} + \gamma_i + \theta_t + \delta_1 (OMN_{it} \times HR_{it}) + \delta_2 (OMN_{it} \times FDI_{it}) + \phi Z_{it} + \varepsilon_{it} \quad (2)$$

The variable $Control_{kit}$ signifies the k th control variable for individual i at time t , enhancing the original model by integrating an expanded array of control variables. The coefficients δ_1 and δ_2 quantify the interaction effects between ocean governance and human resources, as well as ocean governance and foreign direct investment, respectively. These interaction terms provide insights into how the influence of governance on economic development may differ across varying levels of human resources and international investment. Additionally, Z_{it} incorporates further variables or indicators pertinent to the marine economy, including technological innovation within marine sectors, environmental sustainability initiatives, or overarching maritime policies, each denoted by their respective coefficients ϕ .

This analytical framework examines how the dynamics between ocean governance and marine economic growth are potentially influenced or intensified by these variables. For example, the efficacy of governance strategies in fostering economic expansion might be more distinct in regions endowed with a richer pool of skilled human resources or substantial foreign investment. By broadening the spectrum of control variables to encompass a more diverse array of factors, the model offers a comprehensive portrayal of the marine economy's intricacies. This approach enables a sophisticated understanding of the myriad factors that individually and cumulatively affect marine economic development, from technological breakthroughs to efforts aimed at environmental preservation.

Furthermore, the model supports a dynamic analysis, tracking changes over time and across various entities, thereby capturing the fluid nature of ocean governance and its repercussions on the marine economy. Such a dynamic viewpoint is crucial for discerning trends, projecting future developments, and crafting policies that adapt to evolving circumstances.

3.2. Variable Description

Marine environmental governance (OMAN) [26]: Basis for selection: The level of marine environmental governance is a key indicator of the efficiency of the protection and management of marine resources. By analyzing the number of protected marine areas, it is possible to assess the importance that countries attach to marine ecosystems and the effectiveness of conservation measures.

Data source: The data comes from the Global Marine Protected Areas Statistical Database (Global Ocean Database), which provides detailed information on MPAs globally, including area, type and level of protection.

Level of marine economic development (OMG) [27]: Rationale for selection: The level of marine economic development is an important indicator for assessing the contribution of marine economic activities to a country's economy. By calculating the logarithm of OMG, the growth trend of the marine economy can be more accurately measured.

Data source: The data is obtained from the National Bureau of Statistics (NBS) through the collection and collation of economic statistics at the national level, including Gross Marine Product (GMP) and indicators related to marine economic activities.

Urbanization level (URB) [28]: Selection basis: The level of urbanization reflects the trend of population migration from rural to urban areas, which has a direct impact on the use of marine resources and the governance of the marine environment. Areas with a high level of urbanization may face more serious problems of marine environmental pollution and overexploitation of resources.

Data source: Data from the World Bank database, which provides detailed data on the level of urbanization in countries around the world, including urban population as a percentage of the total population and related indicators of the urbanization process.

Foreign Direct Investment Level (FDI) [29]: Selection basis: The level of FDI is an important indicator of a country's ability to attract foreign investment, which has a significant impact on the development of marine resources and the development of the marine economy. High levels of FDI are usually associated with faster economic growth and more advanced technology transfer.

Data source: Data are sourced from national statistical offices through the collection and collation of economic statistics at the national level, including the amount of FDI and FDI as a percentage of GDP.

Human Resources (HR) [30]: Selection basis: Human resources are an important support for ocean governance and ocean economic development. Highly educated marine professionals are essential for the sustainable use of marine resources and marine environmental protection.

Data source: The data comes from the University of Science and Technology of China (USTC) by collecting and collating the number of graduate students graduating from marine science-related majors in the university, which is used as a proxy variable for marine human resources.

Industrialization level (IND) [31]: Selection basis: the industrialization level reflects the transformation and upgrading of the national economic structure, which has a far-reaching impact on the way marine resources are developed and utilized. High industrialization levels are usually accompanied by more intensive industrial activities and more complex marine environmental issues.

Source of data: Data are obtained from national statistical offices through the collection and collation of economic statistics at the national level, including the amount of investment in fixed assets and relevant indicators of the industrialization process.

3.3. Results of Descriptive Statistics

Initially, a descriptive statistical analysis was conducted to elucidate the foundational characteristics of the dataset under examination, with Tables 1 and 2 presenting the findings. The analysis reveals that the mean value for ocean governance (OMN) stands at 1.907, with a median of 1.609 and a standard deviation of 1.219, indicating a relatively low level of ocean governance within the sample, accompanied by notable variability. In terms of marine economic development (OGDP), the mean is recorded at 8.420, the median at 8.523, and the standard deviation at 0.882, suggesting that while the marine economy's development level is comparatively high, disparities exist within the dataset.

Table 1. Variable description table.

	Variant	Variable Name	The Description of Variables
Core explanatory variables	Marine environmental governance	OMAN OMG	Number of protected areas Log the number of protected areas
Explanatory variable	Level of marine economic development	OGDP	Gross Marine Product (GMP) in logarithms
	Urbanization level	URB	
Control variable	Level of foreign investment	FDI	
	Human resources	HR	Number of postgraduate graduates in oceanography
	Industrialization level	IND	
	Level of investment in fixed assets	FAIA	Gross Marine Product (GMP) Share of Gross Regional Product (GRP)

The urbanization level (URB) manifests a mean of 0.654, a median of 0.650, and a standard deviation of 0.124, implying a consistent degree of urbanization across the sample. This consistency may be attributed to urbanization processes, infrastructure development, and demographic movements, all of which potentially enhance urbanization levels, subsequently influencing societal development and economic structuring.

Table 2. Descriptive statistics.

Variable	N	Mean	p50	SD	Min	Max
OGDP	1075	8.420	8.523	0.882	6.420	10.94
OMN	1075	1.907	1.609	1.219	0	4.094
OMG	1075	7.288	6.848	1.943	2.398	12.95
URB	1075	0.654	0.650	0.124	0.419	0.896
FDI	1075	0.0260	0.0210	0.0180	0.00100	0.0800
IND	1075	0.368	0.395	0.0930	0.0970	0.481
FAI	1075	0.646	0.650	0.234	0.210	1.171
HR	1075	4.688	5.147	1.305	1.386	6.038

Foreign direct investment (FDI) exhibits a mean of 0.0260, a median of 0.0210, and a standard deviation of 0.0180, illustrating a modest and stable level of foreign investment. An increase in foreign investment can introduce technology, capital, and management expertise, thus fostering economic growth and facilitating international collaboration.

Human resources (HR) presents a mean of 4.688, a median of 5.147, and a standard deviation of 1.305, indicating relative stability in human resource levels. This stability could be associated with educational attainment and labor market dynamics, underscoring the pivotal role of human resources in driving economic development, innovation, and competitive advantage in industries.

The industrial structure (IS) showcases a mean of 0.368, a median of 0.395, and a standard deviation of 0.0930. The composition of the industrial structure, reflecting the proportion of various industrial sectors and their adjustments, can significantly impact economic growth, employment generation, and the broader economic reshaping process.

Finally, the marine industry share (OMI) demonstrates a mean of 0.646, a median of 0.650, and a standard deviation of 0.234, pointing to a relatively consistent representation of the marine industry within the dataset. This stability in marine industry share, encompassing sectors such as fisheries, marine energy, and marine tourism, holds promising implications for economic enlargement and the enhancement of marine economic activities' efficiency.

3.4. Multicollinearity Analysis and Correlation Analysis

3.4.1. VIF Multicollinearity Test

In the context of multiple linear regression models, the Variance Inflation Factor (VIF) serves as a critical measure for assessing the extent of multicollinearity. Multicollinearity occurs when independent variables exhibit linear relationships with one another, implying that one independent variable can be linearly predicted from the others with a substantial degree of accuracy. The VIF quantifies this phenomenon by comparing the variance of an estimated regression coefficient with and without the presence of linear correlation among independent variables.

The threshold for determining the significance of multicollinearity typically rests at a VIF value of 10. A VIF value below 10 suggests the absence of multicollinearity, indicating that the independent variables can be considered reasonably independent in their relationship with the dependent variable. Conversely, a VIF value ranging from 10 to 100 signals the presence of strong multicollinearity, warranting caution in the interpretation of the regression coefficients due to the intertwined relationships among the independent variables. Should the VIF exceed 100, this is indicative of severe multicollinearity, potentially undermining the reliability of the regression model's outcomes. Table 3 shows the VIF analysis result.

Table 3. VIF multiple covariance analysis.

Variable	VIF	1/VIF
URB	2.55	0.392101
HR	1.85	0.541056
FAI	1.81	0.552738
FDI	1.47	0.680331
OMI	1.19	0.840865
Mean VIF	1.77	

In the analysis presented, the mean VIF value is recorded at 1.77, substantially below the threshold of 10, which suggests a minimal presence of multicollinearity among the variables under consideration. This observation is further substantiated by the fact that all specified VIF values fall below 10, and the inverse of the VIF (1/VIF) exceeds the value of 0.1, reinforcing the conclusion that the degree of collinearity within the model is negligible. This level of multicollinearity ensures the integrity and interpretability of the regression model, affirming the independence of the variables in their contribution to explaining the dependent variable.

3.4.2. Correlation Analysis

Upon acquiring relevant data, a thorough analysis to explore and elucidate the relationships among various factors becomes essential. Correlation analysis, a widely utilized statistical method, serves this purpose by assessing the degree of association between variables without delving into their causal interactions. This analysis predominantly employs two methods: simple and partial correlation analyses, each offering unique insights into the relationships among variables.

Consequently, this study implements a simple correlation analysis to examine the interactions among variables such as marine environmental governance (OMN), marine economic development level (OGDP), urbanization level (URB), Foreign Investment Level (FDI), human resources (HR), industrialization level (IND), Fixed Asset Investment Level (FAI), among others. The findings, seen in Table 4, reveal a correlation coefficient of 0.268, indicating a statistically significant association at the 1% level between marine environmental governance (OMN) and marine economic development level (OGDP). The magnitude of the correlation coefficient, falling within the range of -0.5 to 0.5 , suggests a moderate degree of association, thereby affirming the variables' independence and mitigating concerns of adverse impacts on subsequent regression analyses.

Table 4. Correlation analysis of variables.

	OGDP	OMN	OMG	URB	FDI	IND	FAI	HR
OGDP	1							
OMAN	0.268 ***	1						
OMG	−0.00300	0.711 ***	1					
URB	0.562 ***	−0.266 ***	−0.205 **	1				
FDI	0.0800	−0.156	0.100	0.525 ***	1			
IND	0.314 ***	−0.0360	−0.226 **	−0.0320	0.0470	1		
FAI	−0.548 ***	−0.0540	0.0460	−0.602 ***	−0.138	−0.0340	1	
HR	0.740 ***	0.250 **	0.113	0.536 ***	0.157	0.263 ***	−0.573 ***	1

Notes: "****", "***" indicate that the indicator is significant at the 1% and 5% levels, respectively.

The observed correlation coefficients, not approaching the extremes of -1 or 1 , imply that the variables maintain substantial independence from one another. This independence is crucial, indicating the dataset's reliability for further regression studies and its potential to minimize the risk of multicollinearity within the regression framework. Thus, the selected data for this investigation are deemed robust, suitable for advanced regression

research, and contribute to reducing the likelihood of collinearity affecting the regression model's integrity.

4. Empirical Analysis

4.1. Benchmark Regression

The dual fixed-effect model has been selected for the empirical analysis of panel data, building upon the methodologies for model configuration, indicator selection, and evaluation procedures outlined in prior sections. The results derived from this analytical approach are presented in the subsequent Table 5:

Table 5. Benchmark regression results.

	(1) OGDP	(2) OGDP
OMN	0.417 *** (2.99)	0.968 *** (4.86)
URB		−9.580 *** (−7.93)
FDI		14.143 * (1.95)
IND		−5.791 *** (−4.95)
FAI		−0.769 * (−1.73)
HR		0.238 ** (2.28)
_cons	−1.581 (−1.37)	0.940 (0.82)
N	1075	1075
R ²	0.202	0.627
Year	YES	YES

Note: Values in parentheses are standard errors. “***”, “**”, “*” indicate that the indicator is significant at the 1%, 5% and 10% levels, respectively.

Ocean governance serves as the foundational variable in the regression analysis, supplemented by additional control variables to enhance the robustness and interpretability of the results. The analysis detailed in the table illustrates that marine environmental governance (OMN) stands as the primary explanatory variable. Notably, with a regression coefficient of 0.417, marine environmental governance (OMN) has achieved statistical significance at the 1% level, suggesting that improvements in marine environmental governance are positively associated with advancements in marine economic development. Upon incorporating control variables, the regression coefficient for marine environmental governance (OMN) increases to 0.968, maintaining its significance at the 1% level. This finding underscores that, even with the inclusion of additional variables, the positive relationship between marine environmental governance and economic development persists, potentially due to the role of effective governance in mitigating marine pollution and ecological harm and in safeguarding marine ecosystem integrity. Such governance fosters a conducive ecological environment for sustainable resource utilization, thereby supporting the marine economy's growth.

Regarding the control variables, the urbanization level (URB) exhibits a significant impact on the marine economy, with a regression coefficient of −9.580. Moreover, human resources (HR) demonstrate a beneficial effect on the marine economy, evidenced by a regression coefficient of 0.238. This highlights the critical importance of research and development personnel and high-quality talent in propelling the marine economy forward, notably in enhancing patent acquisition. The industrialization level (IND) shows a significant negative impact, with a coefficient of −5.791, likely due to industrial activities introducing pollutants and waste into marine environments. Such contamination can

lead to water quality degradation, ecosystem damage, and the diminution of marine life, adversely affecting marine economic activities.

4.2. Endogeneity Test

Initially, the analysis of the influence of marine governance on the level of marine economic development reveals an endogenous relationship between marine environmental governance and the extent of marine economic growth. On one hand, marine environmental governance exerts an impact on the economic development of the marine sector. Conversely, the state of marine economic development reciprocally influences marine environmental governance. This bidirectional causality suggests the presence of endogeneity, potentially complicating the analysis due to intertwined influences between marine environmental governance and marine economic growth. Additionally, the application of fixed-effect models in the regression analysis of panel data may encounter biases stemming from this endogeneity.

The analysis reevaluates the impact of ocean governance on marine economic growth employing the two-stage least squares (2SLS) method with instrumental variables to address and mitigate the estimation bias introduced by empirical regression. Selecting appropriate instrumental variables necessitates adherence to specific criteria: the variables must be exogenous, meaning they should not be directly associated with the endogenous variables, must not correlate with the model's error terms, and must be independent of other explanatory variables within the model. An instrumental variable, chosen for its temporal precedence, is the primary explanatory variable lagged by one period.

This methodological approach aims to refine the estimation process, enhancing the accuracy and reliability of assessing the causal relationship between marine governance and economic development. By employing a lagged instrumental variable, the analysis strives to disentangle the endogenous relationship, offering a clearer understanding of the dynamics at play in the nexus of marine governance and economic growth.

In the analysis, marine environmental governance (OMN) is posited as the pivotal explanatory variable, with the regression results affirming its significant and positive influence on the growth of the marine economy. Specifically, it is observed that a unit increase in ocean governance enhances marine economic development by a coefficient of 1.535. This finding, seen in Table 6, underscores the substantial role of ocean governance in fostering marine economic prosperity, as evidenced by the two-stage least squares (2SLS) regression analysis. Thus, these results align with previous observations, reinforcing the constructive relationship between ocean governance and marine economic development.

Table 6. Endogeneity test.

	(1) OGDP	(2) OGDP
L.OMN	0.615 *** (4.449)	
OMAN		1.535 *** (5.944)
URB	−0.796 (−1.100)	−9.162 *** (−7.053)
FDI	3.887 (1.141)	9.920 (1.161)
IND	2.458 *** (2.766)	−9.139 *** (−7.683)
FAI	−0.336 (−1.343)	−0.273 (−0.468)

Table 6. Cont.

	(1) OGDP	(2) OGDP
HR	0.150 ** (2.545)	0.072 (0.514)
_cons	1.775 ** (2.271)	−3.186 * (−1.710)
Year	Yes	Yes
N	1032	1032
R ²	0.914	0.681

Note: Values in parentheses are standard errors. “***”, “**”, “*” indicate that the indicator is significant at the 1%, 5% and 10% levels, respectively.

4.3. Analysis of Heterogeneity

4.3.1. Size of Protected Areas

Owing to the principles of absolute and comparative advantages, the size of protected areas can exert varied effects on the extent of marine economic growth, potentially influencing the robustness of this paper’s conclusions. This study undertook regression analyses across distinct datasets categorized by the size of the protected areas, aiming to derive nuanced insights to reinforce the findings and introduce further analytical depth. This approach facilitates a more detailed understanding of how protected area dimensions may differentially impact marine economic development. The regression outcomes, presented in the subsequent Table 7, offer targeted conclusions reflective of the diverse influences of protected area sizes on the marine economy’s growth trajectory:

Table 7. Heterogeneity results.

	(1) Limited Scale	(2) Broad Scale
OMAN	0.377 ** (2.08)	0.616 ** (2.75)
URB	−2.847 *** (−3.05)	1.676 (0.66)
FDI	−10.475 * (−1.82)	4.327 (0.55)
IND	−3.270 * (−2.00)	−1.391 (−0.42)
FAI	−0.511 * (−1.82)	−0.283 (−0.42)
HR	0.055 (0.89)	−0.256 (−1.53)
_cons	1.679 (1.26)	−1.532 (−0.68)
N	645	430
R ²	0.583	0.660
Year	YES	YES

Note: Values in parentheses are standard errors. “***”, “**”, “*” indicate that the indicator is significant at the 1%, 5% and 10% levels, respectively.

Marine environmental governance (OMN) exerts a significant and positive influence on marine governance across both limited and extensive scales, with its impact on marine economic development being notably more pronounced in broader contexts. This observation suggests that comprehensive marine environmental governance is instrumental in mitigating marine pollution, facilitating the restoration of damaged ecosystems, and conserving and rejuvenating marine biodiversity. Such efforts are essential for preserving

marine ecological equilibrium, thereby propelling the sustainable advancement of fisheries, tourism, and other interconnected industries.

Analyzing the control variables reveals that in scenarios characterized by limited governance scale, the urbanization level detrimentally impacts the marine economy. Conversely, in environments governed on a larger scale, urbanization does not significantly affect marine economic performance. Additionally, the influence of foreign direct investment (FDI) on the marine economy is not marked in extensive governance contexts, whereas in more constrained settings, FDI exhibits a notably adverse relationship with marine economic growth. This discrepancy could be attributed to the potential for foreign investment under limited-scale governance to foster reliance on external technology and impede the indigenous development and integration of innovative technologies within the marine sector.

Furthermore, the effect of human resources (HR), industrialization level (IND), and Fixed Asset Investment Level (FAI) on marine economic growth demonstrates variability under different governance scales. Such heterogeneity underscores the complexity of interactions between these variables and marine economic development, suggesting that the scale of environmental governance significantly influences the dynamics of economic growth within the marine sector.

4.3.2. The Degree of Talent Reserve

Marine Environmental Governance (OMN) demonstrates a varied impact across groups with differing levels of talent reserve. Table 8 shows the heterogeneity analysis result of the degree of the talent reserve. Specifically, in the group with a lower talent reserve, the impact coefficient of ocean governance on the marine economy is 0.234, which is not statistically significant. Conversely, in the group with a higher talent reserve, this coefficient escalates to 0.918, denoting a significant positive influence. This suggests that a robust talent reserve amplifies the positive effects of marine economic growth, possibly due to enhanced capabilities in managing and utilizing marine resources more effectively. Groups with higher talent reserves likely possess superior technological and management strategies, enabling them to monitor and mitigate marine pollution and ecological damage more efficiently, thus fostering marine economic development.

Table 8. Heterogeneity analysis of the degree of the talent reserve.

	(1) Low-Talent Reserve Group	(2) High-Talent Reserve Group
OMAN	0.234 (1.04)	0.918 *** (4.13)
URB	−3.611 ** (−2.37)	−11.287 *** (−3.38)
FDI	3.399 (0.64)	37.346 ** (2.22)
IND	−7.423 *** (−8.73)	1.097 (0.23)
FAI	−0.485 * (−1.84)	−2.460 ** (−2.40)
HR	−0.036 (−0.25)	−0.741 * (−1.92)
_cons	4.848 *** (3.95)	4.913 (1.04)
N	420	655
R ²	0.939	0.603
Year	YES	YES

Note: Values in parentheses are standard errors. “***”, “**”, “*” indicate that the indicator is significant at the 1%, 5% and 10% levels, respectively.

Concerning control variables, a notable difference in the impact of urbanization level (URB) on the marine economy is observed between the two groups. In the group with a lower talent reserve, the urbanization level negatively impacts the marine economy, with a coefficient of -3.611 , which is statistically significant. This negative impact intensifies in the group with a higher talent reserve, where the coefficient reaches -11.287 , which is also significant. This pattern suggests that urbanization exerts a detrimental effect on the marine economy across both talent reserves, with a more pronounced effect observed in the group with higher talent reserves.

In terms of foreign investment level (FDI), the impact varies significantly between the two groups. In the lower talent reserve group, the influence of foreign investment on the marine economy, represented by a coefficient of 3.399 , is not statistically significant. However, in the higher talent reserve group, this coefficient surges to 37.346 , indicating a significant positive effect on the marine economy. This implies that higher talent reserves can leverage foreign investment more effectively to bolster marine economic growth.

Regarding the industrial structure (IND) and marine industry ratio (FAI), disparities are evident between the groups. In the lower talent reserve group, both variables negatively affect the marine economy, with coefficients of -7.423 and -0.485 , respectively, both reaching statistical significance. Conversely, in the higher talent reserve group, the impact of these variables on the marine economy, with coefficients of 1.097 and -2.460 , respectively, is not significant. This indicates that while the industrial structure and marine industry ratio adversely affect the marine economy in groups with lower talent reserves, such relationships do not hold significance in groups with higher talent reserves.

4.3.3. Scale of the Ocean Economy

Regardless of the scale, marine environmental governance invariably exerts a beneficial impact on the marine economy. This positive influence can be attributed to marine environmental governance's role in mitigating pollutant emissions, safeguarding marine ecosystems, and fostering sustainable utilization of marine resources. Such governance measures catalyze the sustainable expansion of industries reliant on marine resources, such as fisheries and tourism, thereby enhancing opportunities within the marine economy.

Considering the control variables, urbanization levels in the context of a smaller marine economy detrimentally affect the marine economy, as seen in Table 9. This adverse impact may stem from urbanization-induced increases in resource demand and environmental pressure, leading to the overexploitation of marine resources and environmental degradation. Conversely, within a larger-scale marine economy, the influence of urbanization on the marine economy is less pronounced, likely due to more effective resource allocation and environmental protection measures that can better mitigate urbanization's challenges.

In smaller marine economies, the level of foreign investment (FDI) positively influences the marine economy, introducing technology transfer, management expertise, and capital investment, which collectively bolster marine economic capacity. However, in larger marine economies, the impact of foreign investment becomes less significant, possibly because larger marine economies possess greater capacities for independent innovation and technological leadership.

The industrial structure (IS) negatively impacts the marine economy on smaller scales, potentially due to a predisposition toward resource-intensive or high-pollution industries, which exacerbate marine resource exploitation and environmental harm. In contrast, within larger marine economies, the effect of industrial structure on the marine economy diminishes, likely because larger marine economies allocate more resources toward promoting renewable energy and sustainable industrial practices, reducing the burden on marine resources.

Table 9. Heterogeneity analysis.

	(1) Small	(2) Large
OMAN	0.851 *** (3.20)	1.478 *** (3.07)
URB	−9.788 *** (−9.52)	−5.313 * (−1.88)
FDI	20.355 *** (4.82)	−27.660 ** (−2.52)
IND	−6.823 *** (−7.12)	−0.740 (−0.26)
FAI	−0.403 * (−2.03)	−1.611 (−1.15)
HR	0.507 *** (8.73)	−0.625 *** (−3.37)
_cons	1.030 (0.78)	−2.787 (−0.46)
N	500	575
R ²	0.892	0.762
Year	YES	YES

Note: Values in parentheses are standard errors. “***”, “**”, “*” indicate that the indicator is significant at the 1%, 5% and 10% levels, respectively.

The marine industry’s proportion (OMI) affects the marine economy negatively across both small and large scales. A high marine industry proportion may increase the pressure on resource development and the environment, posing challenges to the marine economy. However, in larger marine economies, the marine industry’s share has a negligible impact on the marine economy, likely due to superior management practices and technological innovations that harmonize economic development with environmental stewardship.

Human resources (HR) consistently have a positive impact on the marine economy, irrespective of scale. A higher level of human resources signifies the presence of more skilled professionals and managerial expertise, contributing to the marine economy’s output and growth.

4.3.4. Heterogeneity of Marine Areas

Across various maritime regions, including the East China Sea, the South China Sea, and the Yellow Sea, marine environmental governance (OMN) consistently fosters a positive impact on the marine economy, as seen in Table 10. This beneficial influence can be attributed to the abundance of fishery resources, oil, gas, and other energy resources, along with the burgeoning potential for marine tourism and marine transportation in these areas. An elevated level of marine environmental governance capacity significantly contributes to the sustainable development and utilization of these resources, thereby driving momentum in the marine economy.

In the East China Sea and the South China Sea, the level of urbanization (URB) positively influences the marine economy. This is likely due to urbanization enhancing the awareness and implementation of marine resource management and protection, thus bolstering marine economic development. However, in the Yellow Sea, urbanization appears to exert a negative effect on the marine economy, possibly due to the environmental stress and resource development issues accompanying urbanization, which pose challenges to marine economic prosperity.

Regarding foreign investment (FDI), its impact is positively correlated with marine economic growth in both the East China Sea and the Yellow Sea. Foreign investment introduces technology transfer, management expertise, and capital infusion, which collectively facilitate the enhancement of marine economic capacity. Conversely, in the South China Sea, the influence of foreign investment on the marine economy is less pronounced, indi-

cating regional variations in the effectiveness of foreign investment in stimulating marine economic activity.

Table 10. Heterogeneity analysis.

	(1) The East China Sea	(2) The South China Sea	(3) The Yellow Sea
OMAN	0.169 *** (1.20)	0.143 *** (1.20)	0.112 *** (0.69)
URB	5.102 ** (2.85)	9.990 * (1.94)	−9.013 *** (−9.51)
FDI	66.810 ** (2.62)	−1.586 (−0.07)	15.692 ** (2.23)
IND	−21.757 ** (−2.28)	−5.413 * (−1.75)	−6.349 (−1.62)
FAI	11.977 *** (4.59)	0.086 (0.14)	−0.064 (−0.16)
HR	−2.183 *** (−4.29)	0.238 (0.60)	0.611 *** (8.91)
_cons	10.271 ** (2.41)	−2.934 (−1.51)	5.898 ** (2.57)
N	300	425	350
R ²	0.917	0.912	0.932
Year	YES	YES	YES

Note: Values in parentheses are standard errors. “***”, “**”, “*” indicate that the indicator is significant at the 1%, 5% and 10% levels, respectively.

In the East China Sea, an increased share of the marine industry (OMI) positively impacts the marine economy. This suggests that a higher marine industry proportion can enhance the management and conservation of marine resources, further promoting marine economic development. Meanwhile, in the South China Sea and the Yellow Sea, the marine industry’s proportion does not significantly influence the marine economy, pointing to regional differences in industrial impact.

Human resources (HR) demonstrate a negative effect on the marine economy in the East China Sea, indicating that the scarcity or inadequacy of human resources could undermine marine economic performance. However, in the South China Sea and the Yellow Sea, the impact of human resources on the marine economy is not substantial, suggesting variations in how human capital influences marine economic dynamics across different maritime regions.

4.4. Robustness Check

4.4.1. Reduced Sample

Upon analyzing the comprehensive dataset, it was observed that altering the time periods under consideration could lead to markedly different conclusions. A first robustness test was undertaken by selectively narrowing the sample data to address this variability and ascertain the empirical robustness of the fixed-effect regression model previously developed. This step aimed to verify the stability of the empirical outcomes and uphold the analytical rigor of the study’s findings. The outcomes of this robustness test are meticulously documented in the subsequent Table 11, providing a detailed examination of the model’s resilience under varied sample conditions.

Table 11. Reduced sample robustness tests.

	(1) Removing the Effects of the Epidemic
OMAN	0.900 *** (4.36)
URB	−11.229 *** (−5.22)
FDI	23.341 ** (2.11)
IND	−5.091 *** (−3.91)
FAI	−1.468 (−1.38)
HR	0.298 ** (2.45)
_cons	2.036 (1.09)
N	989
R ²	0.622
Year	YES

Note: Values in parentheses are standard errors. “***”, “**” indicate that the indicator is significant at the 1% and 5% levels, respectively.

Boasting a regression coefficient of 0.900, marine environmental governance (OMN) successfully surpassed the threshold for statistical significance at the 1% level, aligning harmoniously with the empirical insights gleaned from the prior section. This concordance not only underscores the regression outcomes’ stability but also validates the judicious formulation of the model initially proposed. The consistency in both the positive and negative correlations, alongside the maintained significance of the principal explanatory variables, serves as a testament to the model’s robustness and the empirical strategy’s soundness.

4.4.2. Substitution of Explanatory Variables

In order to evaluate the robustness of the empirical findings of the previously built fixed effects regression model and to confirm the rigor of the study outcomes, in this study, the validity of the initial prototype was tested utilizing the technique of replacement variables, and the robustness test was conducted by replacing the key explanatory variable, the number of protected areas (OMN), with the logarithm of the number of protected areas (OMG). To assess the robustness of the empirical results derived from the previously constructed fixed effects regression model and to ensure the rigor of the study’s findings, this research undertook a validation exercise for the initial model framework, seen in Table 12. Employing the method of replacement variables, this robustness check involved substituting the primary explanatory variable, the number of protected areas (OMN), with its logarithmic transformation (OMG). This approach was aimed at examining the consistency and reliability of the model’s outcomes under alternative specifications. The results of this comprehensive robustness test, detailed in the table below, provide insightful revelations regarding the model’s stability and the empirical strategy’s validity. The table below displays the findings.

The coefficient associated with ocean environmental governance (OMG) stands at 0.636, achieving statistical significance at the 1% level. These findings from the robustness test align closely with the initial regression results, thereby affirming the test’s robustness. The consistency observed between the outcomes of the robustness test and the primary regression analysis further underscores the high level of reliability inherent in the study’s findings, reinforcing the credibility and solidity of the conclusions drawn in this research.

Table 12. Test of robustness for substituting explanatory variables.

	(1) Substitution of Variables
OMG	0.636 *** (2.72)
URB	−12.299 *** (−5.23)
FDI	41.877 *** (3.23)
IND	−11.306 *** (−6.74)
FAI	−0.442 (−0.45)
HR	0.564 *** (4.17)
_cons	10.933 *** (5.06)
N	1075
R ²	0.490
Year	YES

Note: Values in parentheses are standard errors. “***” indicates that the indicator is significant at the 1% level.

5. Conclusions and Policy Recommendations

This chapter delves into the intricate relationship between marine environmental governance and marine economic development, with a specific focus on the former as the core explanatory variable and the latter as the dependent variable. The analysis is informed by a robust framework that incorporates five macro-level control variables, which have been identified through prior analyses as pivotal determinants of marine economic growth: urbanization level (URB), foreign direct investment (FDI), industrialization level (IND), human resources (HR), and fixed asset investment (FAI).

The empirical findings underscore the superiority of the dual fixed-effect model in mitigating overfitting issues compared to the single fixed-effect model. This enhanced model robustness is crucial for drawing accurate and reliable conclusions from the data.

The key insights derived from this analysis are as follows: Marine Environmental Governance (OMN) plays a pivotal role in significantly fostering the growth of the marine economic development level (OGDP). This positive correlation suggests that effective marine environmental governance is a prerequisite for sustainable economic development within the marine sector.

Furthermore, the analysis reveals that factors such as industrialization, urbanization, and fixed asset investment exhibit a considerable negative impact on the marine economy when other variables are controlled. This highlights the need for a balanced approach to economic development, ensuring that it does not come at the expense of marine ecosystems.

Conversely, the analysis also underscores the significant benefits that foreign investment and human resources bring to the marine economy. These findings underscore the importance of strategic investment in foreign partnerships and human capital development, as they are essential drivers of marine economic prosperity. Based on these findings, several critical policy implications emerge:

- (i) **Strengthening Marine Environmental Governance:** Governments should prioritize the establishment and enforcement of robust marine environmental governance frameworks to ensure sustainable economic growth in the marine sector.
- (ii) **Promoting Balanced Economic Development:** Policy-makers should adopt a balanced approach to economic development, ensuring that industrialization, urbanization, and fixed asset investment are managed in a way that minimizes their negative impact on marine ecosystems.

- (iii) Investing in Foreign Partnerships and Human Capital: Governments should actively seek foreign investment opportunities and invest in the development of human capital, particularly in marine-related fields, to foster innovation and economic growth in the marine sector.
- (iv) Implementing Sustainable Resource Management: Effective management of marine resources is crucial for long-term economic prosperity. Policies should promote sustainable practices and technologies that minimize environmental degradation and maximize resource efficiency.
- (v) Enhancing Collaboration and Information Sharing: International cooperation and the sharing of marine environmental data are essential for effective governance and sustainable development. Governments should work toward establishing mechanisms for cross-border collaboration and information exchange.

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