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Beyond the Ecological Boundary: A Quasi-Natural Experiment on the Impact of National Marine Parks on Eco-Efficiency in Coastal Cities

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Abstract: National marine parks (NMPs) are a crucial form of marine protected areas that serve an essential function in safeguarding marine ecosystems and the related inland urban ecosystems. Though 30 coastal cities in China have established NMPs, little is known about the ecological benefits national marine parks contribute to surrounding areas. This study takes China's coastal cities as an example and employs a multi-period DID model to investigate how eco-efficiency responds to the establishment of national marine parks, based on panel data from 2003 to 2020. The results show that the establishment of NMPs contributed to a 3.87% enhancement in the eco-efficiency of coastal cities. This finding remains robust after a series of robustness tests such as PSM-DID. In addition, significant heterogeneities are captured, with NMPs exhibiting a more substantial enhancement effect for cities along the East China Sea and South China Sea. NMPs with a large area increased the eco-efficiency of coastal cities by 5.18%, but small-area NMPs failed the significance test. A mechanism analysis further reveals that NMPs could improve the eco-efficiency of coastal cities by optimizing the industrial structure, enlivening the local economy, and inhibiting sewage pollution behaviors. This study provides evidence of the impact of NMPs on local eco-efficiency in developing countries.

Keywords: national marine park; China's coastal cities; eco-efficiency; multi-period DID

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1. Introduction

Coastal cities have long been interconnected with the dynamic marine ecosystems surrounding them, as significant hubs of human settlement and economic activity [1–3]. Coastal regions rely on marine resources, with residents depending on the ocean for economic activities, commercial transactions, and communal interactions [4]. However, the unsustainable exploitation of marine resources [5] and the pollution of manufacturing and living areas in coastal cities present a range of challenges for the effective execution of marine conservation efforts [6–8]. In response, implementing marine protected areas has been recognized as a crucial conservation approach to ensure the healthy operation of marine ecosystems and the adjacent terrestrial environments [9,10].

Ecosystems in coastal zones exhibit interconnectivity. The environmental implications of a national marine park could exceed its delimited boundaries and exert profound impacts on the ocean and adjacent coastal areas. NMPs are responsible for protecting the sea and land–sea interface zones. These places, where fishing and tourism are allowed sparingly, are classified as limited development zones, so tourism within national marine parks is extraordinarily cautious. In addition, NMPs can act as "ecological corridors", facilitating the exchange of organisms, nutrients, and energy among the designated protected areas and the neighboring coastal land [11]. These intricate relationships profoundly affect the ecological variation of coastal cities [12], thereby necessitating the integration of the ecological benefits of NMPs and coastal cities into a unified research framework.

The eastern coastline cities of China are the most developed regions, characterized by numerous mega-cities, and their concentrated economic operations have caused a decline in China's offshore ecosystem [13]. The main purpose of establishing NMPs is to safeguard the health of the littoral, island, and marine ecosystems, and to develop a healthy ecological network in coastal regions. According to related governmental documents in China, namely the National Marine Main Functional Area Plan, Management Measures for Marine Special Protected Areas, National Marine Functional Zoning (2011–2020), and the General Programme for the Establishment of National Park Systems, it is evident that NMPs are categorized as a portion of Marine Specially Protected Areas (MSPAs). China's NMPs can be divided into two categories: ecological conservation areas and rational use areas. The ecological conservation area is a core region with very stringent limits on social activities, and even scientific study requires prior application; the rational use area can retain an operational ecological fishing area, which also serves as a destination for eco-tourism. Overall, the ecological attributes of marine parks are more prominent in China.

National marine parks have a variety of positive and negative impacts on coastal areas. Much of the previous research on NMPs has focused on two areas: the effects of NMPs on marine ecology, and the effects of NMPs on coastal residents. Cockerell, L. et al. [14] highlighted the importance of national marine parks as crucial protections for coastal ecological security, emphasizing their capacity for improving the resilience and well-being of coastal urban ecosystems. Campbell, S. and Edgar, G. [15] noted that NMPs can maintain the abundance and diversity of previously targeted fish populations. McKenna, M. et al. [16] had similar conclusions, and they pointed out that the NMP can halt and possibly reverse declines in local fish stock abundance and productivity. According to Denny, C. and Babcock, R. [17], there should be stringent limitations on productive endeavors within the NMP region, including a complete ban on all fishing activities. However, the closure of the core area of the NMP may cause partial transfer of marine exploitation activities to adjacent sea areas [18], and may also generate conflicts among various stakeholders [19].

Studies on the economic impacts of NMPs are divergent. Tadjuddah, M. et al. [20] argued that NMPs can deliver ecologically valuable services and simultaneously offer sustainable livelihood opportunities for coastal communities. Similarly, Davis, G et al. [21] maintained that NMPs contribute to the economic well-being of local communities through tourism. However, sprawling development plans and inadequate enforcement of environmental regulations in NMPs may marginalize local citizens in terms of decision-making processes and compromise their rights [22]. Elliott, G. et al. [23] revealed that the management plan implemented for Wakatobi Marine Park in eastern Indonesia failed to consider the needs and interests of the local population adequately. In any case, the construction of national marine parks must be in the general public's best interests [24,25], focusing preserving vital marine ecosystems while considering the appropriate utilization of resources for recreational activities, scientific investigations, and educational purposes [26].

Urban eco-efficiency seeks to integrate sustainable development concepts into all facets of city planning, with the objective of minimizing adverse environmental effects while simultaneously promoting economic advancement and societal welfare. The notion is increasingly recognized as a significant paradigm for evaluating urban ecosystems. Marzluff, J. et al. [27] examined the correlation amongst urban ecosystems, with a particular emphasis on the necessity of incorporating natural elements into urban areas to enhance ecological efficiency and facilitate sustainable urban development. Lin, J. et al. [28] proposed a new method to measure sustainability based on urban eco-efficiency, which compares the relative sustainability state of different regions at different times. The factors impacting urban eco-efficiency have also been extensively discussed in several studies: Walker, R. et al. [29] conducted a comprehensive review of nutrients, water, and energy in urban systems to determine the factors contributing to enhanced eco-efficiency. Bleischwitz, R. and Hennicke, P. [30] investigated the regulatory policies for eco-efficiency. Other concerning factors include technological innovation [31], urban planning and design [32], urban greening [33], and environmental policy [34].

Although several studies have examined the ecological benefits of NMPs, there is currently a lack of investigation into the impact of NMPs on the ecology of coastal cities. This casts doubt on whether NMPs can be used as a comprehensive tool that benefits coastal areas. The quantitative evaluation of environmental effects in national maritime parks is constrained by the complexity of the marine ecosystem and the diversity of human activities. Furthermore, there is a significant gap in the research on China's NMPs. In China's practice, implementing NMPs has encountered multiple challenges, including the fact that certain coastal regions prioritize their demands over the protection of the ocean, have inadequate supervision, and consider canceling established protected areas in favor of economic development. These factors demonstrate that it is more practical to scientifically identify the impact of China's NMPs on eco-efficiency. This study aims to investigate the impact of NMPs on the eco-efficiency of Chinese coastal towns by treating the establishment of NMPs as a "quasi-natural experiment." The DID model was employed to evaluate the ecological effects of NMPs based on panel data from 53 coastal cities in China from 2003 to 2020.

The potential contributions of this study are as follows: (1) This study is the first to use econometric analysis to investigate how NMPs affect urban eco-efficiency, which provides a supplementary examination of the effects of NMPs. (2) The calculation of urban eco-efficiency was conducted using the SBM model. Afterwards, a rigorous empirical analysis was performed using the multi-period DID model to investigate the relationship between NMPs and urban eco-efficiency. To ensure the findings' reliability, a series of robustness and heterogeneity tests were performed to identify the causal relationship more rigorously. (3) The mechanism of NMP's effect on coastal cities' eco-efficiency is explored from three perspectives, thereby offering valuable theoretical and empirical insights that contribute to the advancement of NMPs and marine eco-protected areas.

2. Mechanism Analysis and Research Hypotheses

The establishment of NMPs necessitates the procurement of a portion of the fisheries' land and the prohibition of other associated fishery production activities. Thus, fishermen will experience a loss of traditional fishing areas, leading to increased expenses associated with fishing operations and diminished quantities of catches. If the fishermen encounter inadequate alternative sources of income, a portion of them may be compelled to transition from their customary fishing areas to engage in activities within the secondary or tertiary sectors [35,36]. This will significantly influence the ratio of production factors, such as labor force and capital, among sectors.

Furthermore, NMPs could offer specifically allocated areas for tourism-related endeavors. Tourism could provide substantial job opportunities for fishermen, enabling them to remain involved in various fishery-related occupations. A majority of NMPs have been shown to create significant visitor attraction and sustained economic advantages that well surpass their benefits in terms of fisheries [37,38]. The tourism industry plays a substantial role in promoting the diversification and advanced development of coastal industries, facilitating the positive expansion of all three sectors and enhancing the ecological efficiency of coastal cities.

Hypothesis 1. *NMPs could improve eco-efficiency in coastal cities through the mediating effect of industrial structure optimization.*

The living conditions of indigenous populations residing in protected marine areas are typically in a poor general state. This may be attributed to several constraints, including inadequate transportation infrastructure, restricted access to information, and restricted availability of fishing grounds. NMPs have the potential to enhance the economic well-being of people in the local community by leveraging sustainable fisheries and the tertiary sector, while concurrently fostering the generation of job possibilities [39]. Through the strategic utilization of various resource elements across NMPs, it becomes feasible to unleash the economic potential of the area, leading to a more substantial enhancement of the livelihoods of coastal fishermen and fostering economic prosperity around the coastal area [40].

Furthermore, implementing NMPs requires an adequate allocation of dedicated financial resources. It is necessary to compensate indigenous people for the opportunity costs they face when they give up their traditional mode of production. Additionally, creating ecological tourism programs in NMPs requires the mobilization of increased social capital to effectively complement the park's development. This could potentially promote a novel form of collaboration between the government and social capital, expand avenues for financial support, and invigorate the local economy.

Hypothesis 2. *NMPs could improve eco-efficiency in coastal cities through the mediating effect of activating the local economy.*

In contrast to land-based national parks, marine environments exhibit greater complexity and fluidity. Further, the boundary between land and sea ecosystems lacks distinct and rigid limits. In the context of China, there is an ongoing issue of excessive discharges originating from direct sources of sea pollution. These discharges, stemming from industrial, residential, and combination sources, have a detrimental effect on the overall health of the seas. China has been grappling with persistent issues of direct sea discharge pollution and excessive sewage discharge into the sea, and industrial, domestic, and combined discharges pose great challenges to the health of marine life along the coastal zone. China's 457 direct sources of marine pollution released 750,199,000 tons of sewage in 2022 [10]. Only 30.4% of the 230 state-controlled river sections that discharged into the ocean and were examined had water quality within categories I to II, which is not encouraging.

NMPs can function as a barrier, effectively inhibiting the transmission of inland wastewater contaminants into the marine ecosystem. Firstly, NMPs have the potential to effectively mitigate the concentration of detrimental elements within the seawater. This is achieved via the imposition of regulations that strictly limit sewage and wastewater discharge to NMPs in coastal areas, as well as the imposition of limitations on industrial and agricultural operations in proximity to NMPs. Furthermore, most NMPs function as crucial habitats that should ideally be safeguarded from human activity in order to preserve the stability of water quality and ecological health. Additionally, stable ecosystems in the NMPs could help to uphold the integrity of the food chain, which contributes to a reduction in organism mortality and the accumulation of metabolites, thereby reducing the risk of eutrophication in water bodies. In summary, NMPs can enhance eco-efficiency by curbing discharge behaviors and alleviating environmental stress in coastal areas.

Hypothesis 3. *NMPs could improve eco-efficiency in coastal cities through the mediating effect of the suppression of pollution behaviors.*

3. Methodology

3.1. Study Area

The study area of this paper is the eastern coastal cities of mainland China. Due to incomplete data for some cities in Hainan Province, the final study object was 53 cities in 11 coastal provinces, as shown in Figure 1. In 2011, China established the first batch of national marine parks in six cities, including Lianyungang and Xiamen. Forty-two more national marine parks were established by five batches in the following six years, with a total area of about 519,024 hectares. We used ArcGIS 10.8 software to obtain the geometric center of each NMP surface area based on latitude and longitude, and labelled them in Figure 1.

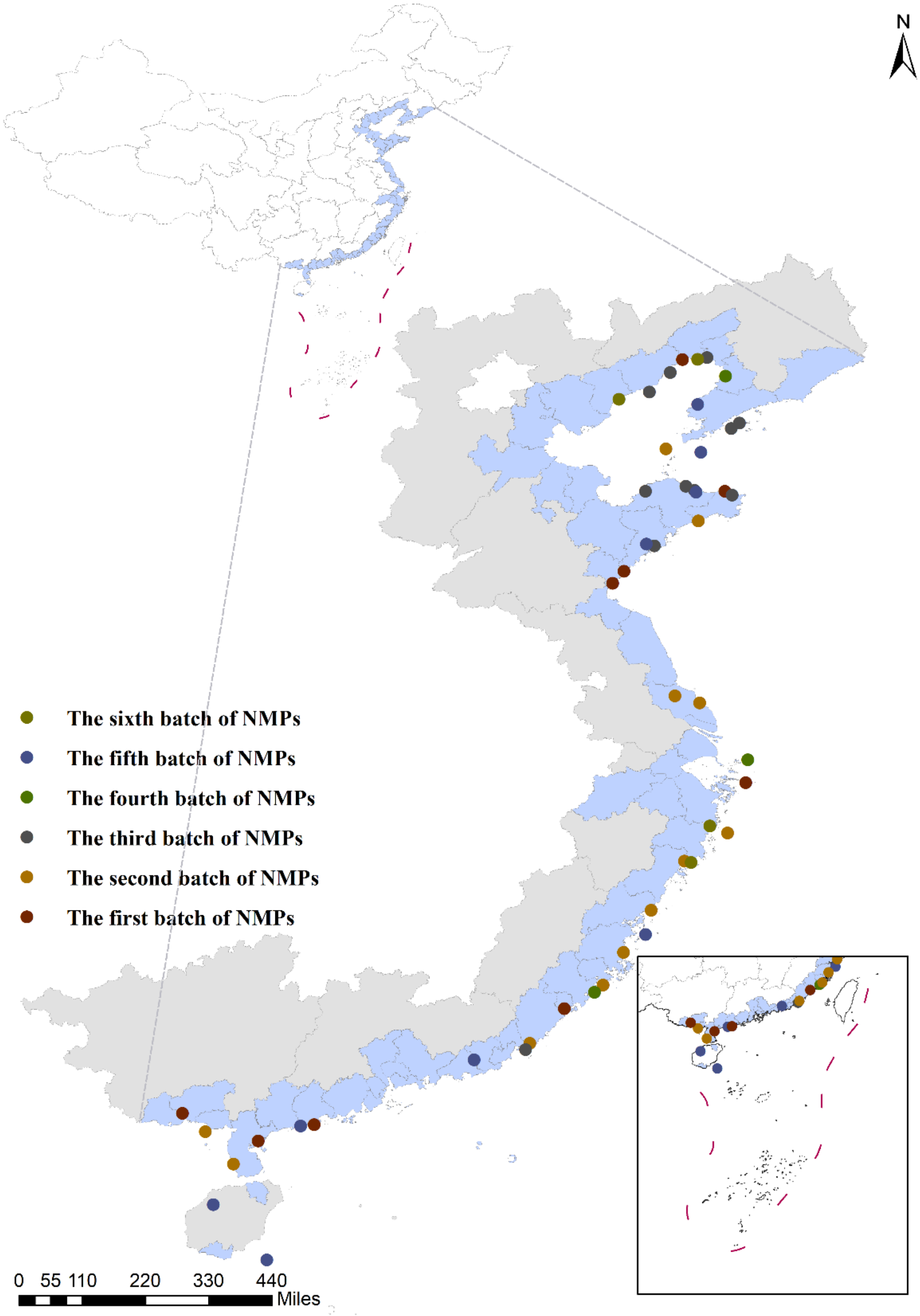

Figure 1. Spatial distribution and establishment batches of NMPs in coastal cities of China. Note: The base map is the 2022 Chinese standard map; the review number is GS (2022) 1873; and there are no changes to the base map.

3.2. Model Setting

The difference-in-differences (DID) model is primarily employed to evaluate the impact of policies by treating policy implementation as a "natural experiment". One notable advantage of DID is that it can mitigate the endogeneity caused by "selection bias".

NMPs built in batches have the benefit of being quasi-natural experiments for identifying how they affect the eco-efficiency of coastal cities. Thus, the empirical analyses conducted in this study employ a time-varying DID, the formula for which is as follows:

$$Y_{it} = \alpha + \theta Treat_i \times Post_t + \beta Controls_{it} + \mu_i + \lambda_t + \xi_{it} \quad (1)$$

where the explanatory variable Y_{it} is the eco-efficiency of coastal city i in year t. $Treat_i$ is a dummy variable that takes the value of 1 (treatment group) if coastal city i sets up an NMP within the sample period, and 0 (control group) otherwise. $Post_t$ is also a dummy variable that takes the value of 1 when an NMP establishment event occurs in a coastal city, and 0 otherwise. The product of the above two dummy variables serves as the core explanatory variable of this study. $Controls_{it}$ is a group of control variables that possibly affect ecological efficiency, μ_i is the city fixed effect, λ_t is the year fixed effect, and ξ_{it} is the residual term. θ is the most critical coefficient; if θ is significantly greater than 0, establishing NMP can effectively improve the eco-efficiency of coastal cities.

Robustness testing is imperative in order to ensure the validity and dependability of baseline regression results of Equation (1). A series of robustness tests including parallel trend tests, PSM-DID, placebo tests, excluding other interfering policies, extreme samples, and outliers will be conducted in this study to mitigate potential sources of bias or confounding. A prerequisite of the multi-period DID model is that the parallel trend assumption is satisfied. Thus, the initial step in the robustness tests entails conducting a parallel trend test.

3.3. Measuring Eco-Efficiency of Coastal Cities

The dependent variable of this research is the eco-efficiency of coastal cities in China. The primary objective of eco-efficiency is to maximize economic output while minimizing the negative environmental impact by effectively allocating resources. Therefore, a scientific and reasonable characterization of eco-efficiency requires a systematic consideration of input and output indicators, and the selection of indicators needs to accurately capture the connection among alterations in resource inputs, economic growth, and environmental pollution. Input indicators were selected as follows. (1) Capital investment: government capital investment is the essential guarantee for the city to adopt sustainable development measures, so we selected the capital stock of coastal cities to represent the capital input indicator; (2) employment: the total employment serves as an indicator of the availability of a skilled workforce inside the city, which is a reliable indicator of the city's capacity to recognize and address environmental issues; (3) urban construction land: the support of land resources is crucial for urban growth, and decisions in urban land planning have a significant role in the ecological advancement of cities. Thus, we used the amount of urban built-up land area to denote the land factor input; finally, (4) energy consumption: energy is a fundamental resource for urban operations and manufacturing, and its use is intricately linked to the environmental consequences of urban areas. Energy consumption is therefore a crucial input indicator that must be considered. The urban gross domestic product (GDP) is the desired output. Incorporating insights from [41,42], it is crucial to consider SO_2 emissions, dust emissions, and wastewater discharge as undesired outputs, which could avoid the anomalous behavior of a single undesired output and further enhance the model's accuracy. The input and output indicators selected for this study are shown in Table 1.

Data envelopment analysis (DEA) is a methodology used to evaluate the relative efficiency among decision-making units (DMUs) with multiple inputs and multiple outputs [43]. However, the traditional DEA model lacks the inclusion of an undesired output in its efficiency measurement. Tone, K. [44,45] proposed the slacks-based measurement (SBM) model with undesired outputs, which addresses the limitations of the traditional DEA model. When faced with multiple DMUs with efficiency values 1, it is difficult to distinguish the difference among effective DMUs in the SBM model. The super-efficiency DEA model introduced by Andersen, P. and Petersen, N. [46] allows comparisons among efficient DMUs. The super-efficiency SBM model, which combines the advantages of both the super-efficiency model and the SBM model, estimates the value of the DMU in a more precise way. This study employed the super-efficiency SBM model to assess the eco-efficiency of 53 coastal cities in China from 2003 to 2020, the formula for which is as follows:

$$\rho^* = \frac{1 - \frac{1}{m}\sum_{i=1}^{m} \frac{S_i^-}{x_{i0}}}{1 + \frac{1}{S_1+S_2}\left(\sum_{r=1}^{S_1} \frac{S_r^g}{y_{r0}^g} + \sum_{r=1}^{S_2} \frac{S_r^b}{y_{r0}^b}\right)} \tag{2}$$

$$s.t.\begin{cases} X_0 = X\lambda + S^- \\ y_0^g = Y^g\lambda - S^g \\ y_0^b = Y^b\lambda + S^b \\ S^- \geq 0,\ S^g \geq 0,\ S^b \geq 0, \lambda \geq 0 \end{cases} \tag{3}$$

where ρ^* is the objective function, that is, the efficiency value sought. Each coastal city can choose m different input and output modes, including S_1 desired outputs and S_2 undesired outputs; y^g and y^b are the output vectors of S_1 and S_2, respectively; S_r^g and S_r^b denote the projected values of inputs and outputs of the evaluated units; y_{r0}^g and y_{r0}^b indicate the corresponding original values; S^-, S^g, and S^b denote slack variables for inputs, desired outputs, and undesired outputs, respectively; and λ is the vector of weights.

Table 1. Index system of ecological efficiency of coastal cities.

Norm	Composition of Indicators	Expressions and Units
Input indicators		
	Capital stock	Fixed assets investment stock (10,000 CNY)
	Energy consumption	Annual electricity consumption (10,000 kwh)
	Urban construction land	Area of urban construction land (square kilometers)
	Employee	Persons employed in urban units at year-end (10,000 persons)
Undesired output indicators		
	SO_2 emission	Volume of sulphur dioxide emissions (ton)
	Dust emission	Volume of industrial soot/dust emissions (ton)
	Wastewater discharge	Volume of industrial waste water discharged (10,000 tons)
Desired output indicators		
	GDP	Annual real regional GDP (billion CNY)

Note: The capital stock is measured using the perpetual inventory method and is calculated as follows: $K_t = I_t + K_{t-1}(1-\delta)$, K_t denotes the capital stock in period t, I_t denotes the capital input, and δ is the depreciation rate. Referring to the treatment of Zhang, J. et al. [47], the economic depreciation rate of fixed assets in coastal cities is set at 9.6%. To minimize errors arising from inflation, all incomes are reduced by the consumer price index.

The MaxDEA Ultra 9.0 software was used to measure the efficiency value of Chinese coastal cities. Figure 2 illustrates the spatial and temporal characteristics of the eco-efficiency of Chinese coastal cities in the years 2003, 2012, and 2020, which indicates that the cities along the East China Seas have higher eco-efficiency as a whole, cities located along the Yellow Sea demonstrate relatively lower levels of eco-efficiency, and individual cities improved in 2020. Heterogeneity analysis is an essential step due to the distinct properties of various water regions.

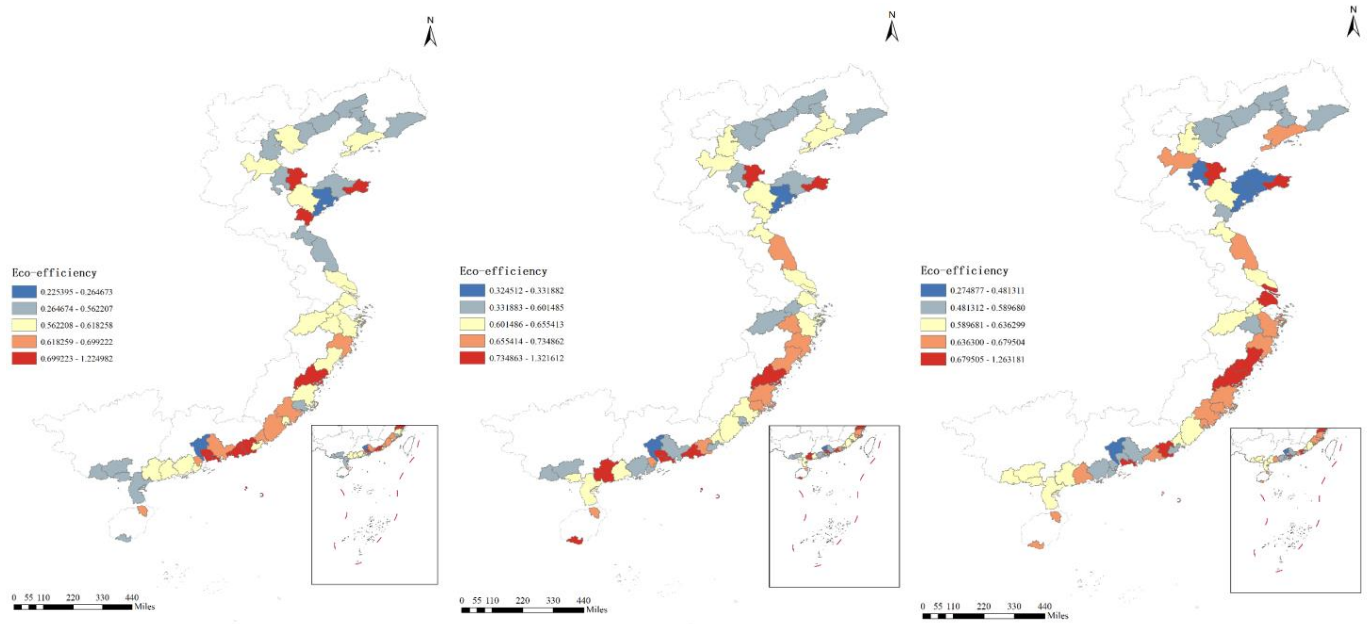

Figure 2. Spatial and temporal distribution of eco-efficiency in Chinese coastal cities; the graphs represent 2003 (**left**), 2012 (**middle**), and 2020 (**right**), respectively. Note: The base map is the 2022 Chinese standard map; the review number is GS (2022) 1873.

3.4. Data and Variable Selections

3.4.1. Mediating Variables

Based on the mechanism analysis above, the mediating variables selected for our study are as follows: (1) Optimize the industrial structure (*lnindus*). The NMPs ' influence on the economic sectors of coastal cities is mainly reflected in the tertiary industry. Consequently, the variable representing this effect is expressed by the ratio of value contributed by the tertiary sector to the GDP. (2) Enliven the local economy (*light*). Night-time light data could accurately depict human production intensity and life footprints, and has apparent advantages in describing economic development [48,49]. In this study, DMSP/OLS steady night-time light data of Chinese coastal cities are utilized to characterize the variable of economic performance to reflect the intensity of economic activity more objectively. (3) Inhibit sewage pollution behaviors (*inh*). The strict constraints NMPs imposed on human behaviors could bring immediate ecological advantages for coastal cities. This mediating variable is represented by the average concentration of inorganic nitrogen in seawater near the shore of coastal cities.

3.4.2. Control Variables

Referring to previous studies of [31,33], combined with the typical characteristics of urban eco-efficiency and data availability, the following control variables were included: (1) Economic development (*lnpgdp*), expressed as the per capita GDP of each coastal city. (2) Financial support (*lnfin*), measured by the ratio of local fiscal expenditure to GDP. (3) Foreign investment (*lnfdi*), measured by the ratio of foreign direct investment to GDP. (4) Research investment (*lntech*), represented by science expenditure in each coastal city. (5) Environmental regulation (*lnreg*), which is represented by the green coverage rate of completed areas in coastal cities. Descriptive statistics of the variables are shown in Table 2.

Table 2. Descriptive statistics of variables.

Variable	Obs	Mean	Std. Dev.	Min	Max
y	954	0.682	0.202	0.225	1.329
lnpgdp	954	5.540	3.654	0.464	20.35
lnfin	954	14.04	1.376	10.56	18.09
lntech	953	10.13	2.114	3.989	15.53
lnreg	954	3.659	0.196	2.570	4.227
lnfdi	953	0.642	1.140	−4.993	3.626
light	954	25.02	19.26	5.585	98.42
inh	848	0.302	0.304	0.00438	2.271
lnindus	954	12.68	0.616	10.49	14.27

3.4.3. Data Sources

Based on the availability of coastal city data, the sample data were selected from the panel data of 53 coastal cities in China from 2003 to 2020. The original data for this study were obtained from the China City Statistical Yearbook, China Urban Construction Statistical Yearbook, and the China Statistical Yearbook on Environmental, Bulletin on the State of the Marine Ecosystems in China, as well as official statistical data such as government work reports of coastal cities. Missing data were supplemented by interpolation.

4. Results and Discussion

4.1. Baseline Results

Estimation of the multi-period DID model was conducted using Stata 17.0 software in this study. The regression results for the impact of NMPs on urban eco-efficiency are displayed in Table 3. It can be seen that the establishment of NMPs significantly improves the eco-efficiency of coastal cities after taking into account the time-fixed effect and city-fixed effect, and it remained significant after adding the control variable. The regression coefficient of $treat \times post$ indicates that the implementation of NMPs led to a substantial rise of approximately 3.87% in the eco-efficiency of cities.

Table 3. Baseline regression results.

	M1	M2
$treat \times post$	0.0320 **	0.0387 ***
	(0.0153)	(0.0149)
lnpgdp		0.0215 ***
		(0.00370)
lnfin		−0.0521 ***
		(0.0167)
lntech		0.00640
		(0.00883)
lnreg		0.0696 **
		(0.0270)
lnfdi		−0.00189
		(0.00641)
City effect	Yes	Yes
Year effect	Yes	Yes
Observations	954	954
R-squared	0.294	0.453

Note: Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The significance degree of the M2 model containing the control variable was enhanced, proving the rationality of selecting the control variable. The regression coefficients of *lnpgdp* and *lnreg* were all significantly positive, which indicates that economic expansion and environmental regulation in coastal cities can promote eco-efficiency. China's coastal cities are highly active zones of economic activity due to their strategic locations and business-friendly policies. These regions are also home to centers of technological innovation and financial centers, which could stimulate investments in sustainable technologies and promote resource efficiency. Furthermore, economic development can facilitate the allocation of resources towards environmental preservation and restoration efforts. The impact of environmental regulation on urban ecology is indeed a complex and contested issue [50]. Environmental regulation not only curbs the negative impacts of economic activity, but also fosters the transition of coastal cities towards a less resource-intensive and more eco-efficient state by encouraging sustainable practices. This finding is in line with previous studies [51,52].

The financial support (*lnfin*) factor exhibited a statistically significant negative relationship, suggesting that certain coastal regions tend to allocate fiscal resources toward projects that have high returns but are not ecologically friendly. Historically, a pronounced emphasis on rapid economic growth, often at the expense of environmental considerations, has driven local governments in these cities to prioritize GDP expansion and infrastructure development over sustainable practices. Moreover, local governments, although offered financial incentives and support, typically prioritize cost-effective production and exhibit a greater dependence on existing economic models and established interests, thus limiting the transition towards a more ecological model in coastal cities. The allocation of funds to support green technological innovation is therefore crucial to improving the eco-efficiency of coastal cities [53]. The variables of foreign investment (*lnfdi*) and research investment (*lntech*) failed the statistical significance test.

4.2. Robustness Tests

4.2.1. Parallel Trend Test

A prerequisite for the unbiased estimation results of the DID model is that the parallel trend assumption is satisfied between the treatment group and the control group; i.e., before the establishment of NMPs, the ecological efficiency of the treatment group and the control group should have the same trend of change. We use the event study method proposed by Jacobson, L. et al. [54] to conduct a parallel trend test and construct the following model:

$$Y_{it} = \alpha + \mu_i + \lambda_t + \sum_{k=-4}^{4} \theta_k D_{it}^k + \beta Controls_{it} + \xi_{it} \quad (4)$$

The NMPs were established to include five years, 2011, 2012, 2014, 2016, and 2017, covering a long period before and after the event. Therefore, we shrank the time dummy variables for parallel trends by selecting the first four periods and the last four periods of the event to experiment.

D_{it}^k is a set of dummy variables that takes the value of 1 if a coastal city i establishes an NMP in year t, and 0 otherwise. The symbol meanings of other variables are the same as those in Formula (1). θ_k is the parameter to be concerned with; when $k < 0$, θ_k is not significant, and the parallel trend test is satisfied.

As can be seen in Figure 3, the coefficient estimates for the periods before the implementation of NMPs were not significant, indicating that the parallel trend assumption was satisfied. In the four periods after the event, the dummy variables' coefficients were greater than 0, which provides adequate evidence of the effectiveness of establishing NMPs. Notably, θ_k became substantial in the second year, indicating that there may have been a lag effect within the experimental group of coastal cities. Establishing a National Marine Park is a multifaceted undertaking that generally does not result in instant enhancements in ecological efficiency. The effort requires a transitional period encompassing numerous important processes such as strategic planning, monitoring implementation, ecological restoration, and community involvement. While ecological effects may not be immediate, NMPs' long-term health benefits in coastal cities make them a valuable endeavor.

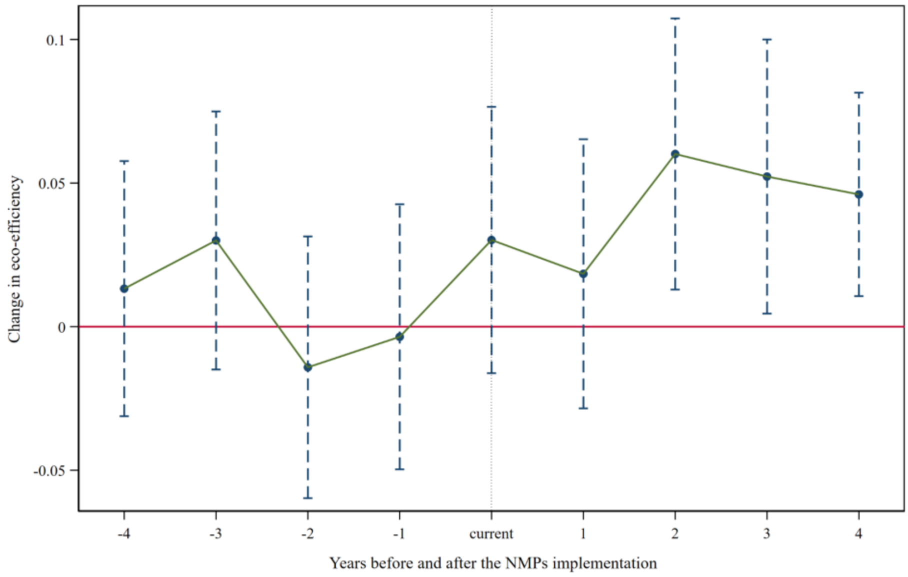

Figure 3. Parallel trend test. Note: Solid dots indicate the estimated coefficients θ_k of Equation (4), and dashed lines are the upper and lower 95 percent confidence intervals corresponding to robust standard errors.

4.2.2. Placebo Test

Drawing on the work of Cai, X. et al. [55], this study conducted a placebo test that involved randomly selecting the year of the NMPs shock (randomizing the time of the establishment of NMPs) and the experimental group (randomizing the experimental group). According to Figure 4, most autosampling estimates (1000 samples in total) were smaller than the actual estimate (0.0387). The autosampling estimates were centered around 0 and approximately followed a normal distribution, indicating that establishing the NMPs had no significant effect on the randomly selected experimental groups and verifying the robustness of the core results.

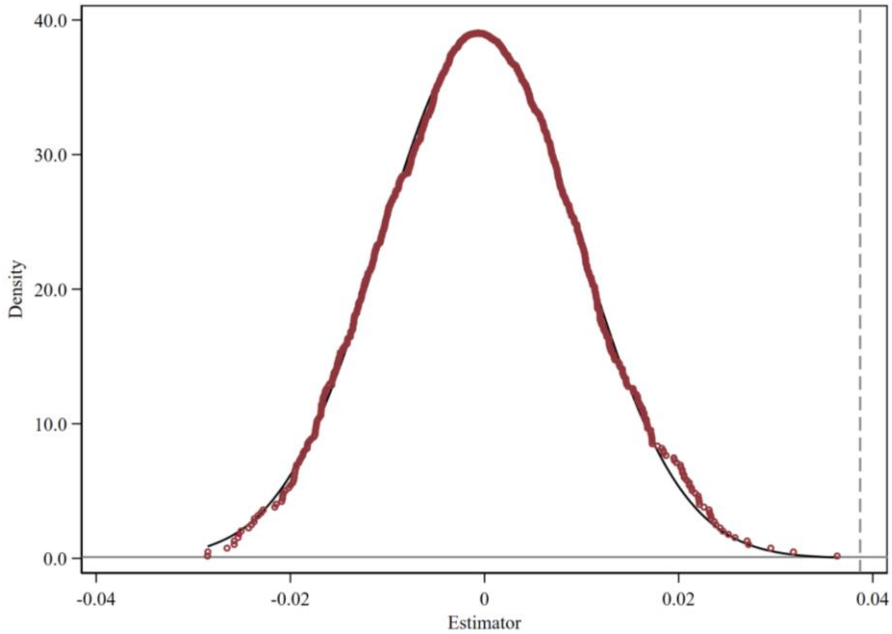

Figure 4. Placebo test. Note: The curve is the kernel density distribution of the estimated value; the hollow red dots are the associated p-values; and the dashed line is the estimated value of the $treat \times post$ (0.0387) in M2.

4.2.3. PSM-DID

The propensity score matching the DID (PSM-DID) approach was employed for robustness tests to enhance the reliability of baseline regression results. PSM can minimize the problem of selectivity bias and confounding bias through the selection of treatment and control groups. We used the nearest-neighbor matching method to match the samples based on the 1:1 no put-back. Then, the control variable was used as a covariate, the grouping dummy variable was used as an explanatory variable to perform Logit regression to obtain propensity matching scores, and the coastal city with the closest score was used as a control group.

Figure 5 illustrates the results of the matching balance test, which indicate that four control variables exhibit considerable disparities before and after matching. After propensity score matching, the differences among the four control variables became insignificant, meaning robust matching results.

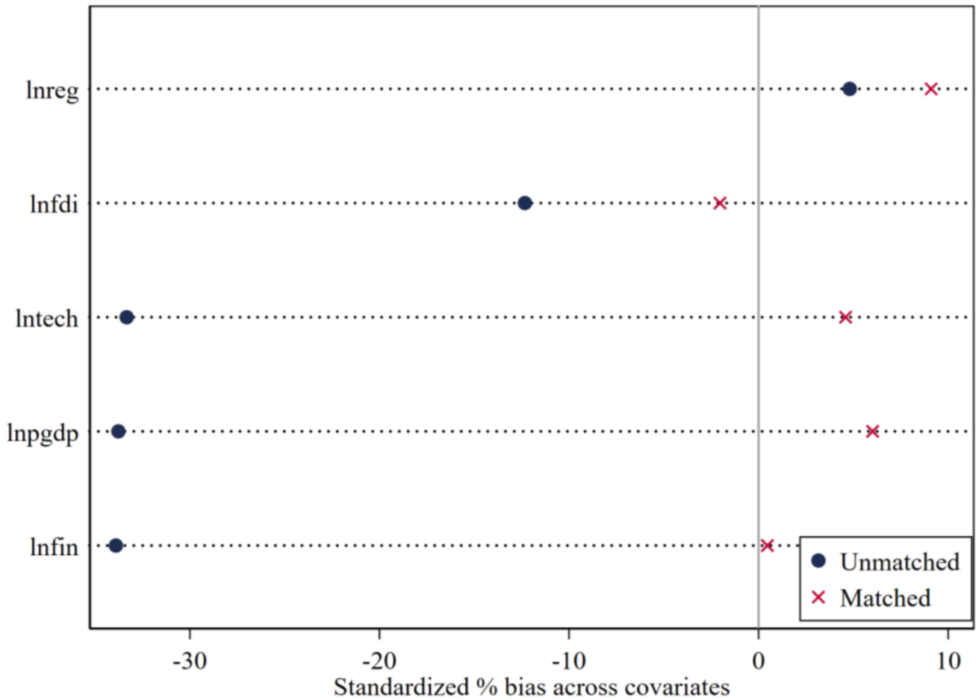

Figure 5. Matching balance test.

Next, DID regression was conducted on the matched samples, and the estimation results are shown in column M3 of Table 4. The coefficient of $treat \times post$ was significantly positive at the 1% level. It did not differ much from the baseline regression results, supporting the PSM-DID method's feasibility and the baseline results' robustness.

4.2.4. Other Robustness Tests

Excluding other interfering policies: Since the establishment of marine protected areas (MPAs) in some coastal cities in China happened as early as 1990, certain MPAs and NMPs may have boundary overlaps that interfere, which might cause the influence of the NMPs to be overestimated. This study excludes cities with MPAs, and re-tests the remaining sample using Equation (1). The results are presented in M4 of Table 4, and reveal that the coefficients of the explanatory variables are still significantly positive.

Table 4. PSM-DID and other robustness test results.

	M3 PSM-DID	M4 Excluding Other Policies	M5 Excluding Mega-Cities	M6 Eliminating Outliers
treat × *post*	0.0416 ***	0.0332 *	0.0515 ***	0.0371 **
	(2.7467)	(0.0188)	(0.0156)	(0.0147)
Constant	−0.1430	−0.637	−0.353	0.402 *
	(−0.5326)	(0.555)	(0.359)	(0.240)
Control variables	Yes	Yes	Yes	Yes
City effect	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes
R-squared	0.4431	0.252	0.435	0.345

Note: Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Excluding mega-cities: Mega-cities like Shanghai and Guangzhou have shown superior levels of economic development compared to other coastal cities. Moreover, these cities have distinct advantages in terms of resources and technology. Hence, it is necessary to eliminate cities with a permanent population greater than 10 million. The result was presented in M5 of Table 4, showing that the result remained robust.

Eliminating outliers. The sample variables were subjected to a 5% reduction of the upper and lower tails to eliminate the interference of outliers. M6 in Table 4 shows that the results are still robust after the shrinkage treatment.

The effect of NMPs on eco-efficiency in coastal cities remains significant and positive after the above series of robustness tests. This suggests that the study effectively addressed potential sources of bias or confounding factors that might undermine the validity of the multi-period DID analysis.

4.3. Heterogeneity Analysis

China has four primary maritime regions: the Yellow Sea, the Bohai Sea, the East China Sea, and the South China Sea. These areas exhibit notable variations in their geographical features, marine ecosystems, and distribution of resources. Consequently, the impacts of NMPs may show heterogeneity across various marine regions. In this study, coastal cities were categorized into four groups according to the sea areas, and the grouping regression results are shown in columns M7 to M10 of Table 5.

Table 5. Results of heterogeneity analysis.

	M7 Yellow Sea	M8 Bohai Sea	M9 East China Sea	M10 South China Sea	M11 Large-Area	M12 Small-Area
Treat × *Post*	−0.0451	0.00150	0.0631 ***	0.135 ***	0.0518 **	0.00257
	(0.0410)	(0.0238)	(0.0241)	(0.0385)	(0.0242)	(0.0305)
Constant	0.321	−0.162	0.742 **	−0.725	−1.255 **	−0.446
	(0.919)	(0.445)	(0.305)	(0.709)	(0.625)	(0.499)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
City effect	Yes	Yes	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.207	0.327	0.487	0.403	0.379	0.156

Note: Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The coefficient of *Treat* × *Post* shows that the influence of NMPs on the East China Seas and South China Seas remains statistically significant. The cities along these two seas exhibit an outstanding level of economic advancement and marketization, so that the implementation of the NMPs can be facilitated and ensured by favorable conditions. These two regions have a more balanced mix of industries, including cleaner and more environmentally friendly sectors [56]. Consequently, these coastal cities tend to possess enhanced ecological diversity and distinctive ecosystems, thereby facilitating the establishment and advancement of marine national parks.

The Bohai Sea regression results were positive, but no longer statistically significant. One potential explanation for this result is that the cities along the Bohai Sea may be more dependent on traditional industries and have a higher reliance on traditional sectors, which limits the contribution of NMPs to urban eco-efficiency. The Yellow Sea's waters are surrounded by many resource-intensive cities, resulting in the NMP not being a positive contributor. The performance of these two regions is consistent with previous studies [57]; the cities still experience the issue of eco-efficiency losses resulting from disparities in urban scale structure and industrial structure. These challenges make it harder to protect and restore natural habitats, potentially undermining the effectiveness of NMPs.

Large-area NMPs are better able to concentrate on systematicity and accomplish their ecological target, since they have a wider geographic reach and a more extensive biological network; small-area NMPs are relatively isolated and have weaker long-term ecological benefits than large areas. Consequently, we conducted separate experiments for cities with NMPs greater than 300 square kilometers and less than 100 square kilometers. The results are presented in M11 and M12 of Table 5, indicating that large-area NMPs significantly affect the eco-efficiency of coastal cities, and the effects were increased compared to M2. The small-area NMPs failed the test of significance. This is in line with Edgar, G. et al.'s study, which concluded that large areas contributed to increases in fish biomass, prompting MPAs to reach their greater potential [58].

Large marine reserves provide a more extensive and more varied habitat area, which can support a greater diversity of species and ecological processes. This concept is grounded in the theory of island biogeography proposed by MacArthur, R. and Wilson, E. [59], which posits that larger islands (or reserves) generally have more species due to reduced extinction and immigration rates. In the context of NMPs, large reserves provide ample space for ecological connectivity, encompassing various habitats and ecological niches, facilitating the movement of species between land and sea, and enhancing ecosystem diversity throughout the coastal zone. In contrast, smaller reserves often cannot maintain such connectivity. In addition, large NMPs more readily positively impact coastal cities through economies of scale, making it more cost-effective to implement and monitor regulations. Smaller areas may face higher per-unit costs and limited resources, potentially leading to less effective management.

4.4. Mechanisms Test Results

This study employed the causal step method proposed by Baron, R. M. and Kenny, D. A. [60] to examine the mediating effect. The steps are as follows: the first step involves using the mediator variable as the explained variable, and treating *treat* × *post* as the core explanatory variable to examine the impact of NMPs implementation on the intermediary variable; the second step involves using the mediator and *treat* × *post* variables as the core explanatory variable, taking eco-efficiency as the explained variable to examine the impact of mediator variables on the eco-efficiency of coastal cities, for which the following formula is used:

$$M_{it} = \alpha_1 + \theta_1 Treat_i \times Post_t + \beta_1 Controls_{it} + \mu_i + \lambda_t + \xi_{it} \tag{5}$$

$$Y_{it} = \alpha_2 + \gamma M_{it} + \theta_2 Treat_i \times Post_t + \beta_2 Controls_{it} + \mu_i + \lambda_t + \xi_{it} \tag{6}$$

M_{it} denotes the mediating variables, which specifically include optimizing the industrial structure (*lnindus*), enlivening the local economy (*light*), and inhibiting sewage pollution behaviors (*inh*). The model focuses on the coefficients of θ_1 and γ, and estimation results are shown in Table 6.

Table 6. Mechanism test results.

	M13 *light*	M14 *y*	M15 *Inh*	M16 *y*	M17 *lnindus*	M18 *y*
light/inh/lnindus		0.0658 *		0.00411		0.198 ***
		(0.0456)		(0.0458)		(0.0248)
Treat × *Post*	0.411 ***	0.0360 **	−0.0243 *	0.0286 **	0.0617 ***	0.0265 *
	(0.110)	(0.0150)	(0.0132)	(0.0141)	(0.0195)	(0.0144)
Constant	20.36 ***	0.194	0.866 ***	0.0194	9.474 ***	−1.550 ***
	(1.620)	(0.237)	(0.261)	(0.282)	(0.288)	(0.316)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
City effect	Yes	Yes	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.740	0.355	0.082	0.146	0.910	0.411

Note: Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Columns M13 and M14 in Table 6 show an analysis of whether the NMPs can achieve eco-efficiency by influencing the enlivening of the local economy. The coefficient of *Treat* × *Post* was 0.411, which passed the test at the 1% significance level, indicating that establishing NMPs can promote the economic development of the area in which they are situated. The coefficient of *Treat* × *Post* was 0.0360, lower than the M2 coefficient without the mediating variable. This suggests that the NMPs can improve the eco-efficiency of coastal cities by boosting the local economy, and therefore Hypothesis 1 can be verified. The empirical findings underscore the significance of establishing NMPs in the context of regional economic development. The rise in new types of fishing and tourism and related services, driven by the presence of NMPs, generates a demand for jobs. The resulting expansion of employment opportunities can mitigate unemployment and boost local incomes, therefore augmenting the overall economic welfare of the coastal region. In addition, NMPs serve as ecological assets that entice environmentally conscious capital. This attraction of environmentally focused capital has the potential to enhance the breadth and structure of local economies. It might strengthen the resilience and sustainability of coastal city economies, ultimately leading to improved eco-efficiency.

The coefficient of *Treat* × *Post* of M15 was significantly negative, suggesting that establishing NMPs could effectively curb sewage pollution. It is worth noting that γ coefficients were insignificant when θ_1 is significant in M16, so we used Sobel and Bootstrap methods to verify further whether the mediating effect exists. Experimentally, the statistical value of the Sobel test is greater than the critical value of -1.33, and the mediation effect accounts for 6.68%; in addition, after conducting 1000 bootstrap tests, the 95% confidence interval of the *lninh* variable was [−0.1260, −0.0410], which does not contain 0. Thus, it suggests that the mediation effect does exist. Hypothesis 2 was thereby proven. NMPs serve as protective barriers against harmful discharging behaviors, including industrial pollution, wastewater discharge, and sediment runoff. These reserves typically have stringent regulations to safeguard water quality and ecosystem health, which can mitigate the adverse environmental effects of discharging activities. Further, the regulatory framework within NMPs incentivizes the adoption of clean and sustainable technologies, fostering eco-friendly industrial practices. The rigorous enforcement and monitoring system contributed to the harmonious coexistence of city growth and marine protection, providing a pathway to eco-efficiency in coastal cities.

M17 and M18 in Table 6 are the regression results utilizing industrial structure optimization as the transmission mechanism. In M17, the regression coefficient of NMPs on *lnindus* was significantly positive at the 1% statistical level, suggesting that NMPs can stimulate and advance the tertiary sector effectively. The results of M18 reveal that NMPs can enhance the eco-efficiency of coastal cities by optimizing the industrial structure, which is consistent with the expectation and supports Hypothesis 3. The tertiary industry can diversify the local economy, reducing dependence on a single industry and thereby enhancing coastal cities' overall stability and sustainability [61]. NMPs are highly attractive for eco-tourism, luring tourists seeking recreational and educational activities connected to coastal ecosystems. These activities further promote the tertiary sector by generating demand for services such as accommodation, catering, conference facilities, and transportation. This factor of the tertiary sector not only contributes to ecological efficiency in coastal cities, but also enhances the resilience of economies by promoting sustainable practices.

5. Conclusions

NMPs assume a significant role in facilitating the sustainable development of coastal regions by serving as an effective tool for ecological preservation. Nevertheless, previous research has neglected to examine the ecological impacts of NMPs on their locations using econometric approaches. This study considers the establishment of NMPs a "quasi-natural experiment". The initial step involves conducting a qualitative analysis of the interaction and influencing mechanism between NMPs and the eco-efficiency of coastal cities. Subsequently, this study uses the multi-period DID model to examine the effectiveness of NMPs in enhancing the eco-efficiency of coastal cities, utilizing panel data from 53 Chinese coastal cities from 2003 to 2020. Additionally, this study conducts various robustness and heterogeneity tests to ensure the reliability and validity of the findings. Based on the research above, this study draws the following main findings. (1) It has been discovered that the implementation of NMPs resulted in a significant rise of 3.87% in the eco-efficiency of coastal cities in China. This result remains robust after the parallel trend test, placebo test, PSM-DID, and exclusion of other policy interferences and outliers. (2) The examination of mechanisms reveals that NMPs contribute to improving eco-efficiency in coastal cities by energizing the local economy, optimizing the industrial structure, and suppressing sewage pollution. (3) There is heterogeneity in the impact of NMPs on the eco-efficiency of coastal cities, and its promoting effect is more significant in the East China Sea, the South China Sea, and cities with large areas of NMPs. The South China Sea coastal regions had a significant 13.5% increase in ecological efficiency following the establishment of NMPs, which had the most significant effect. Coastal cities' eco-efficiency increased by 5.18% as a result of implementing large-area NMPs. However, NMPs with an area of less than 100 km^2 failed the significance test.

This study's conclusions have the following implications for policies for advancing NMP implementation and enhancing the eco-efficiency of coastal cities. The construction of NMPs must be undertaken carefully, considering the specific requirements and priorities of local development. The effective carrying out of the ecological function of NMPs depends on the scientific design, efficient administration, and collaboration among diverse stakeholders. It is recommended that the government assumes a more proactive role in the design, management, implementation, cooperation, education, monitoring, and assessment of NMPs. This way, optimizing human welfare in neighboring regions using NMPs can be achieved while preserving the marine ecosystem's equilibrium. The tourism development strategy for NMPs should embrace a small-scale, multi-restricted, and sustainable approach. It is imperative to prioritize ecosystem protection while providing the public with limited opportunities for leisure and recreational activities. It is crucial to emphasize that the entire touring process must be subject to stringent regulations. In most instances, large-area NMPs demonstrate a greater capacity to maintain the integrity of marine ecosystems. Nevertheless, there are fewer large-area NMPs in China, and a dispersed and blocky distribution characterizes the existing NMPs. Hence, expanding the area of specific adjacent NMPs is feasible to establish linkages among smaller-area NMPs. Alternatively, further NMPs with large-area and more comprehensive biological networks may be necessary.

Some of the restrictions of this study may serve as motivation for further investigation. In future research endeavors, it is necessary to incorporate a broader range of indicators that relate to oceans and fisheries and give more significant thought to how NMPs may affect marine eco-efficiency. Furthermore, in future investigations, we intend to examine the impacts of NMPs on coastal communities and fishermen, using more thorough approaches to enhance the depth and breadth of NMP-related research.

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