Research on the Supply Efficiency of Marine Ecological Products in the Yangtze River Delta Costal Urban Agglomerations Based on DEA-Tobit Model

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Abstract: In this research, we choose the coastal cities in the Yangtze River Delta as the subjects of study, including Shanghai, Lianyungang, Yancheng, Nantong, Jiaxing, Ningbo, Zhoushan, Taizhou, and Wenzhou, nine cities in total. With marine ecological products as the starting point and the supply efficiency of marine ecological products in each city as the subjects of research, and after collecting a quantity of data and by constructing the efficiency analyzing modes, we analyze the supply efficiency of those cities with the involved supplying service, cultural service, and value of regulating service as the output, and the operation of related authorities as the input of marine ecological products. Meanwhile, combining with the outside factors affecting the supply efficiency, we explore and identify the existing problems of marine ecology products in this region, such as the unreasonable supply structure, regional development imbalance, marine environment quality degrading, etc., and present the corresponding solutions and rationalization proposal for the existing problems, thus providing a new thought for promoting the development of the Yangtze River Delta, especially for marine activities.

Keywords: marine ecological products; supply efficiency; the Yangtze River Delta; countermeasures and proposals

1. Introduction

Ecological products are products and services provided by the ecosystem for human society to use and consume [1,2]. At present, the shortage of ecological products has become one of the main bottlenecks restricting China’s economic and social development. Since the government of China proposed to enhance the production capacity of ecological products in 2012, the research on the supply of ecological products has gradually increased thereby [3,4]. The ocean is an important basis for supporting the Earth’s life system. As the main ecosystem type on Earth, the marine ecosystem not only provides the material basis and natural conditions for human survival and development, but also has the function of maintaining the ecosystem structure, ecological process, and regional ecological environment. Therefore, as an important part of ecological products, marine ecological products are an important basis for protecting marine ecosystems and improving public ecological well-being. It is of great practical significance to study their supply in the context of further promoting the construction of ecological civilization in China.

At present, the research on marine ecological products mainly focuses on the definition and function of connotation [5,6], value realization path and development mechanism [7–9], value evaluation, and accounting of products and services [10–12], etc., but efficiency analysis, an important factor affecting the effectiveness of its supply [13], has not attracted enough attention. On the other hand, there is a large number of studies on the eco-environmental efficiency of ocean and other natural resources, mainly focusing on the following three aspects:
(1) Research methods. At present, the methods of measuring eco-environmental efficiency mainly develop from single to multiple nonlinear regression methods [14–16], which better reflects the dynamic relationship and response degree between eco-environmental efficiency and its influencing factors over time. For example, Quariguasi et al. (2009) developed an ecological topology method based on Pareto optimization to evaluate eco-environmental efficiency [17].

(2) Research perspective, from national scope to micro urban agglomeration research [18–21]. According to the theory of sustainable development, this starts from the need to discuss the measurement and evaluation of eco-environmental efficiency in terms of social development by constructing an evaluation index system and putting forward some suggestions for the development of urban agglomerations, which solves the problem that early research had no strong policy guidance for specific cities.

(3) Research content. Based on the improvement of the DEA model, this involves comprehensively analyzing eco-environmental efficiency and its spatial-temporal distribution characteristics in the coal industry, agriculture, industry, tourism, steel industry, and other fields, as well as the influencing factors of eco-environmental efficiency [22–24]. Among them, the DEA model is widely used as an effective method of efficiency evaluation because it has the advantages of fewer indexes and complete original information. However, Song et al. (2018) believed that the effectiveness of the model was difficult to guarantee due to the subjective characteristics of the direction vector, so a ray slack-based measure (RSBM) model was proposed [25].

The Yangtze River Delta is rich in marine resources and part of the marine economy. The research on the supply efficiency of marine ecological products in coastal cities is helpful to promote the high-quality development of the region. Based on the reality of the Yangtze River Delta region according to the panel data of each coastal city from 2009 to 2018, the calculation method of marine ecosystem service value, and input indicators such as policy formulation and investment of marine ecological products in the region, this study comprehensively analyzes and judges the supply efficiency of marine ecological products in the region, discovers the existing problems on this basis, and puts forward countermeasures and suggestions for improvement. The research results can enrich the theoretical content of marine ecological products and provide references for promoting the development of the Yangtze River Delta region at a higher level.

2. Materials and Methods

2.1. Study Area

There are 9 coastal cities in this area, including Shanghai (SH), Lianyungang (LYG), Yancheng (YC), and Nantong (NT) in Jiangsu Province, and Jiaxing (JX), Ningbo (NB), Zhoushan (ZS), Taizhou (TZ), and Wenzhou (WZ) in Zhejiang Province. The scope of the research area involved in this research included coastal cities with offshore areas and jurisdictional sea areas. That is to say, many of the 9 coastal cities mentioned above are actually ones that only have a district or a county close to the sea. Due to the late development of marine economy and industry and the defects in marine statistics, the research with counties as units would be severely affected by data deficiency or no data. These problems were inevitable, so the research unit was based on cities at the prefecture level and above. Hangzhou and Shaoxing are also coastal cities, but they were not included in the scope of this research since the yearbook and other data indicate that they do not have jurisdictional sea areas. Currently, the jurisdictional sea areas of coastal cities were determined gradually from land to sea in accordance with the actual demand of ocean development and utilization, but the extension did not exceed the offshore areas of the Bohai Sea, the Yellow Sea, the East China Sea, or the South China Sea [26]. Therefore, this research was conducted by taking the offshore areas as the research scope.
2.2. Index System

2.2.1. Input and Output Indicators of Supply Efficiency

The government is the largest provider of the input to the supply of marine ecological products, maintaining and guaranteeing the entire supply process with its strong leadership. The government’s acts involving oceans have become the key to determining the supply efficiency of marine ecological products and dominate its development trend. Today, marine ecological products lack market regulation, which makes the government have the basic function of providing ecological products with the attributes of public products. As a result, in current marine fields, the Chinese government provides many inputs for marine ecological products such as facility construction, policy recommendations, project investment, and management services. Therefore, the selection of investment indicators in this paper is based on the government’s acts in relevant marine fields.

The research focuses on the output of supply efficiency from the perspective of marine ecosystem services, and gives marine ecological products value by combining the value connotation of marine ecological products with corresponding value accounting. Moreover, based on a summary of the relevant research results at home and abroad, the research maximizes the content of marine ecological products and includes other relevant fishery products, marine industrial products, marine cultural research, and corresponding soft power into the marine ecological product value system (Table 1).

Table 1. Measurement indices of input–output efficiency of marine ecological products in coastal urban agglomerations.

| Comments | Indicator Type | First-Level Indicators | Secondary Indicators |
|----------|----------------|------------------------|----------------------|
| Supply efficiency of marine ecological products | Input indicator | Input of labor key factors | Number of marine policy recommendations |
| | | Input of capital key factors | Investment in marine environmental protection and treatment |
| | | | Investment in ocean-related projects |
| | | | Investment in daily operation and management |
| | | | Number of ecological restoration projects |
| Output indicators | Supply service value | Food supply | Raw material supply |
| | | | Genetic resource supply |
| | Cultural service value | Tourism and entertainment | Spiritual culture |
| | | | Scientific research |
| | Regulative service value | Climate regulation | Gas regulation |
| | | | Wastewater disposal |
| | | | Interference regulation |
| | | | Biological control |

2.2.2. Factors Affecting Supply Efficiency

While developing and utilizing marine resources, human beings destroy the ecological environment and bring tremendous pressure to marine environmental protection, leading to marine resource environments having external characteristics and the losses caused by environmental pollution being shared by other members [27]. From an economic point of view, this is also the cause of ecological and environmental problems. The development of industry is critical to the promotion of marine economy, and the supply of ecological products is also affected by environmental factors. Hence, only by paying attention to primary problems can we solve the marine ecological and environmental problems so as to ensure the marine ecological balance and achieve sustainable development. In this paper, the indicators for the factors influencing supply, as shown in Table 2, were set up
by combining existing scholars’ research on marine environmental pollution and damage problems that occur during the supply of marine ecological products, referring to the existing indicators for the assessment of the impact of human activities on marine resources and the environment, taking into account the actual marine development in the Yangtze River Delta, and following the principles of science, goal orientation, and data availability.

Table 2. Summary of environmental impact factors of supply efficiency.

| Items | Evaluation Indicator | Units       |
|-------|----------------------|-------------|
| 1     | Wastewater discharge | 10,000 tons |
| 2     | Industrial exhaust emissions | 100,000,000 m³ |
| 3     | Amount of wastewater directly discharged into oceans | 10,000 tons |
| 4     | Marine fishing output | Tons        |
| 5     | Mariculture area     | Hectares    |
| 6     | Mariculture output   | Tons        |
| 7     | Amount of dumped solid waste | Tons |
| 8     | Reclamation area     | Hectares    |

2.3. Methods

2.3.1. Calculation of Marine Ecological Products Value

The definition and calculation method of output indicators are shown in Appendix A: Table A1.

2.3.2. Data Envelopment Analysis (DEA) Model

To analyze the supply efficiency of marine ecological products in the Yangtze River Delta, the DEA model was adopted. The calculation method is to use pure technical efficiency (PTE) to multiply scale efficiency (SE) [28]. The equation is as follows.

$$ TE = PTE \times SE $$  

where TE is technical efficiency, representing the level of achieving the maximum output or the minimum input to reach a preset output. PTE is pure technical efficiency, which characterizes the efficiency excluding scale factors. SE is the scale efficiency, which characterizes the extent to which economies of scale are exerted in comparison with scale effective points.

The model has also been widely used abroad for analyzing the efficiency of public goods supply in a variety of fields [29]. In this research, the supply, culture, and regulative service value of marine ecological products in coastal cities in the Yangtze River Delta were taken as output aspects, and the government’s acts as input aspects. As a more mature method for efficiency analysis, the DEA model is effective for analyzing the technical efficiency, pure efficiency, and scale efficiency of each city, thereby finding out the problems existing between cities. Therefore, it is very appropriate for evaluating the supply efficiency of marine ecological products in the Yangtze River Delta.

2.3.3. Tobit Regression Model

This analysis method, first proposed by the economist Tobit as a form of restricted dependent variable regression in 1958, can be completed by calculating the values of the dependent variables under certain constraints [30]. It is also a model analysis method for sample selection. In this research, the model was constructed by taking the factors affecting the supply of marine ecological products as explanatory variables and the comprehensive technical efficiency of each city in the supply process as an explained variable.

$$ TE_i = \alpha_0 + \alpha_1X_1 + \alpha_2X_2 + \alpha_3X_3 + \alpha_4X_4 + \alpha_5X_5 + \alpha_6X_6 + \alpha_7X_7 + \alpha_8X_8 + \nu_i $$  

where $TE_i$ represents the regional comprehensive technical efficiency of Shanghai, Lianyungang, Yancheng, Nantong, Jiaxing, Ningbo, Zhoushan, Taizhou, and Wenzhou; $\alpha_0$
is a constant term and $\alpha$ is an estimated coefficient; $X_{(1-8)}$ represent wastewater discharge (10,000 tons), industrial exhaust emission (100 million cubic meters), direct discharge of wastewater into the sea (10,000 tons), marine fishing output (tons), mariculture area (hectares), marine aquaculture output (tons), amount of dumped solid waste (tons), and reclamation area (hectares), respectively; and $\upsilon_i$ is random error.

2.4. Data Source

This research involved plenty of indicator data, which were difficult to collect due to the wide range. They were mainly from the following sources:

1. “China Statistical Yearbook,” “China Ocean Yearbook,” “China Ocean Statistical Yearbook,” “China Fishery Yearbook,” “China Fishery Statistical Yearbook,” “Shanghai Statistical Yearbook,” “Jiangsu Statistical Yearbook,” “Zhejiang Statistical Yearbook,” and statistical yearbooks of relevant cities within the research scope.

2. “China Marine Economic Statistics Bulletin,” “China Marine Environment Bulletin,” “China Marine Disaster Bulletin,” “China Marine Ecological Environment Status Bulletin,” “China Offshore Area Environmental Quality Bulletin,” “Shanghai Marine Environmental Quality Bulletin,” “Zhejiang Marine Environment Bulletin,” “Zhejiang Fishery Water Environmental Quality Bulletin,” “Jiangsu Province Offshore Area Environment Quality Bulletin,” and government bulletins involving the cities within the research scope.

3. Public information through relevant government information websites, such as the websites of the Ministry of Finance of the provinces and cities, the websites of the Department of Natural Resources, the websites of the Department of Ecology and Environment, and the websites of the State Oceanic Administration.

4. Data organization and collection through relevant network databases, HowNet data, library network databases, and newspaper information searches.

5. The results obtained from a remote sensing data product, Ocean Productivity (www.science.oregonstate.edu/ocean.productivity/), were regarded as relevant regulation data. The product has been widely adopted by a large number of related studies for a long time.

In addition, the data sample interval was 2009–2018, and the data frequency was by years. The deadline for the public data collection was 2018, and the relevant data of 2019 and 2020 will be released in the second half of 2021. Furthermore, marine fishing output was excluded since the research scope focused on offshore areas.

3. Results

3.1. Analysis of Supply Efficiency

The indicator data related to the supply output and input of marine ecological products in the nine cities with offshore waters in the Yangtze River Delta were sorted out to obtain the average value of the relevant data from 2009 to 2018, as shown in Table 3.

| City | SH  | LYG | YC  | NT  | JX  | NB  | ZS  | TZ  | WZ  |
|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| SS   | 51.93 | 54.87 | 55.85 | 83.75 | 30.4 | 118.68 | 193.93 | 188.29 | 80.64 |
| CS   | 1017.12 | 32.47 | 67.87 | 80.23 | 78.23 | 168.93 | 432.75 | 79.57 | 101.43 |
| RS   | 295.66 | 207.01 | 471.31 | 251.99 | 111.28 | 270.86 | 599.65 | 193.53 | 195.55 |
| NMPR | 40 | 21 | 23 | 32 | 29 | 45 | 54 | 45 | 50 |
| IMEPT| 4.36 | 1.69 | 1.97 | 5.01 | 4.68 | 5.32 | 6.1 | 5.72 | 5.06 |
| IMP  | 55.5 | 19.41 | 20.71 | 27.53 | 26.03 | 45.19 | 38.47 | 39.88 | 37.65 |
| DIOM | 29.17 | 2.44 | 2.91 | 4.8 | 4.02 | 6.24 | 4.16 | 3.86 | 3.65 |
| NERP | 28 | 14 | 19 | 28 | 23 | 30 | 24 | 21 | 18 |

Note: Units: supply of services (SS) ($\times$100 million CNY), cultural services (CS) ($\times$100 million CNY), regulative services (RS) ($\times$100 million CNY), number of marine policy recommendations (NMPR), investment in marine environmental protection and treatment (IMEPT) ($\times$100 million CNY), investment in marine projects (IMP) ($\times$100 million CNY), daily investment in operation and management (DIOM) ($\times$100 million CNY), number of ecological restoration projects (NERP).
DEA model analysis software was applied to calculate the technical efficiency, pure technical efficiency, and scale efficiency of marine ecological products in the offshore waters of 9 cities in the Yangtze River Delta region, and the output results are shown in Table 4.

### Table 4. Output data results.

| City | Pure Technical Efficiency | Scale Efficiency | Comprehensive Technical Efficiency |
|------|---------------------------|-----------------|-----------------------------------|
| SH   | 1.00                      | 1.00            | 1.00                              |
| LYG  | 0.85                      | 0.92            | 0.78                              |
| YC   | 0.87                      | 0.86            | 0.75                              |
| NT   | 1.00                      | 1.00            | 1.00                              |
| JX   | 0.93                      | 0.91            | 0.85                              |
| NB   | 1.00                      | 1.00            | 1.00                              |
| ZS   | 0.86                      | 0.91            | 0.78                              |
| TZ   | 1.00                      | 0.89            | 0.89                              |

3.1.1. Analysis on the Pure Technical Efficiency of the Supply of Marine Ecological Products

Pure technical efficiency is a kind of production efficiency affected by technology, management, and other influencing factors and reflects the degree of inefficiency in the supply of marine ecological products, namely, the effective degree of marine ecological product supply under certain scales. Values less than 1 represent invalid pure technical efficiency. It can be seen in Table 5 that the pure technical efficiency of Lianyungang, Yancheng, Jiaxing, and Taizhou was invalid, indicating that these cities had insufficient technical support or financial expenditures in the supply of marine ecological products. Consequently, it is necessary to give more financial support to the above four cities and provide corresponding technical guarantees in production to improve pure technical efficiency, thereby reversing the current situation of the invalid pure technical efficiency.

### Table 5. Regression analysis results of the influencing factors in cities.

| City | Variable Name | X1 | X2 | X3 | X4 | X5 | X6 | X7 | X8 |
|------|----------------|----|----|----|----|----|----|----|----|
| SH   | Coefficient   | -2.12 | -1.01 | -0.62 | - | - | - | -0.021 | -0.012 |
|      | Significance level | 0.045 ** | 0.21 | 0.067 | - | - | - | 0.19 | 0.31 |
| LYG  | Coefficient   | -2.23 | -1.09 | -0.54 | 0.021 | 0.12 | 0.018 | -0.011 | -0.011 |
|      | Significance level | 0.042 ** | 0.29 | 0.069 | 0.022 ** | 0.081 ** | 0.009 *** | 0.18 | 0.33 |
| YC   | Coefficient   | -2.31 | -1.23 | -0.34 | 0.034 | 0.18 | 0.017 | - | - |
|      | Significance level | 0.039 ** | 0.23 | 0.058 | 0.026 ** | 0.08 * | 0.003 *** | - | - |
| NT   | Coefficient   | -2.28 | -1.62 | -0.36 | 0.046 | 0.13 | 0.012 | - | - |
|      | Significance level | 0.021 ** | 0.31 | 0.049 ** | 0.029 ** | 0.078 * | 0.005 *** | - | - |
| JX   | Coefficient   | -3.12 | -1.63 | -0.24 | 0.021 | 0.17 | 0.019 | -0.017 | -0.017 |
|      | Significance level | 0.051 * | 0.34 | 0.071 | 0.024 ** | 0.072 * | 0.006 *** | 0.19 | 0.39 |
| NB   | Coefficient   | -3.03 | -1.98 | -0.35 | 0.039 | 0.18 | 0.011 | -0.018 | -0.021 |
|      | Significance level | 0.055 * | 0.39 | 0.073 | 0.021 ** | 0.073 * | 0.001 ** | 0.16 | 0.33 |
| ZS   | Coefficient   | -3.01 | -1.35 | -0.21 | 0.019 | 0.17 | 0.019 | -0.015 | -0.022 |
|      | Significance level | 0.013 ** | 0.31 | 0.059 | 0.029 ** | 0.084 * | 0.012 ** | 0.18 | 0.35 |
| TZ   | Coefficient   | -2.98 | -1.21 | -0.29 | 0.018 | 0.15 | 0.012 | -0.016 | -0.014 |
|      | Significance level | 0.016 ** | 0.29 | 0.052 | 0.031 ** | 0.082 * | 0.009 *** | 0.12 | 0.34 |
| WZ   | Coefficient   | -2.01 | -1.72 | -0.26 | 0.011 | 0.21 | 0.014 | -0.016 | -0.017 |
|      | Significance level | 0.014 ** | 0.27 | 0.043 | 0.032 ** | 0.069 * | 0.011 ** | 0.14 | 0.31 |

(Note: ***, **, and * are significant at 1%, 5%, and 10%, respectively).

3.1.2. Analysis on the Scale Efficiency of the Supply of Marine Ecological Products

There is a certain gap between the current and the optimal production scales. The efficiency of measuring differences in the scales of decision-making units is called scale efficiency. The smaller the scale efficiency value is, the worse the production scale will
be. Conversely, the closer the value gets to 1, the closer the production scale comes to the optimal, and the more ideally formed the production scale is. Figure 1 shows that the cities that reached the best production scale were Shanghai, Nantong, Ningbo, and Zhoushan, and the ones that did not include Lianyungang, Yancheng, Jiaxing, Taizhou, and Wenzhou. In view of the above situation, the cities with optimal production scales lower than 1 and the ones with invalid pure technical efficiency were basically the same. It can be seen more obviously that the production scale efficiency of marine ecological products was closely correlated with the technical means and financial investment adopted by the locals to deal with such products. In addition, the pure technical efficiency of Wenzhou was 1, but its scale efficiency was smaller than 1, which resulted in invalid comprehensive technical efficiency. The reason for this situation may be that Wenzhou did not make sufficient efforts in the supply scale of marine ecological products. Its small supply scale and unreasonable structure of the scale supply caused the failure to reach the optimal supply scale. In order to solve the above problems, Weihenziou can take measures to expand the scale of supply and increase corresponding investment, and optimize and adjust the structure of the supply scale of marine ecological products to solve its problem of invalid scale efficiency.

In addition, the four cities, including Lianyungang, Yancheng, Jiaxing, and Taizhou, all faced the problems of invalid pure technical efficiency and poor scale efficiency. However, it was found after careful observation that the pure technical efficiency and scale efficiency of Yancheng and Jiaxing were smaller than 1, but their pure technical efficiency was greater than scale efficiency, which indicates that only by expanding the scale of supply under the premise of further ensuring existing technologies and financial investment could the two cities change the existing comprehensive supply efficiency, thereby realizing valid comprehensive supply efficiency. The other cities, Lianyungang and Taizhou, had greater scale efficiency than pure technical efficiency, indicating that speeding up the improvement of production technologies was a top priority when the cities had problems in scale efficiency and pure technical efficiency. The local governments can support corresponding technical work by increasing fiscal expenditures while optimizing the supply scale and structure to solve the current problems.

![Figure 1](image-url)

**Figure 1.** Development results of pure technology, scale, and comprehensive technical efficiency of cities.

3.1.3. Analysis on the Comprehensive Technical Efficiency of the Supply of Marine Ecological Products

The comprehensive technical efficiency, evidently, is measurement and evaluation based on the analysis on the comprehensive level and ability of a decision-making unit. This comprehensive ability covers the abilities of resource utilization efficiency, resource allocation, resource deployment, and comprehensive use of resources. As shown in Table 5,
the values of Lianyungang, Yancheng, Jiaxing, Taizhou, and Wenzhou were less than 1, indicating that these cities had no comprehensive technical efficiency, and also had problems in relation to pure technical efficiency and scale efficiency. The above data reveals that the cities with invalid comprehensive technical efficiency overlapped with the ones whose production scale was not optimal, which further proves that comprehensive technical efficiency is largely affected by the scale of production. That is to say, large-scale production will help to improve the efficiency of regional marine ecological product supply. For example, Wenzhou had valid pure technical efficiency, but its non-optimal production scale led to invalid comprehensive technical efficiency, which further illustrates the importance of scale efficiency to improve comprehensive technical efficiency.

3.2. Analysis of Supply of Comprehensive Technical Efficiency

Based on the analysis on the development trend chart of comprehensive technical efficiency in the past 10 years, it was found that the Shanghai’s indicator remained valid, indicating that Shanghai, as the core of China’s economic development areas, had powerful economic strength and momentum for development, including the marine field. Three cities, including Nantong, Ningbo, and Zhoushan, achieved valid comprehensive technical efficiency in the supply of marine ecological products in 2013 and 2015, respectively, and their development also showed an upward trend year by year before they achieved valid technical efficiency, which indicates that the scales of production and the application of production technologies fulfilled the actual demand of local development and boosted the improvement of the overall technical efficiency (Figure 2). Additionally, the implementation of a series of policies on marine economic development stimulated the potential of marine economic development. Jiaxing just realized valid comprehensive technical efficiency in 2018, and its technical efficiency presented an upward trend year by year during the previous 10-year development, which indicates that Jiaxing, in recent years, seized the opportunity of the integrated development of the Yangtze River Delta region to accelerate its development by taking advantage of it, and achieved valid technical efficiency in the end. The overall technical efficiency of the supply of marine ecological products in Lianyungang and Taizhou remained unstable, indicating that the development direction was still uncertain, so it is necessary to optimize the production technologies, scale structure, supply mode, policies, and systems related to the supply of marine ecological products in a timely manner and regulate them appropriately in order to ensure that the supply of marine ecological products develops in the right direction.

![Figure 2. Development trend of the comprehensive technical efficiency of cities.](image-url)

More attention needs to be paid to Yancheng and Wenzhou, whose comprehensive technical efficiency declined in 2018, leading to the originally valid technical efficiency.
becoming invalid, which indicates that problems emerged in the supply technologies, financial investment, scale development model, and supply scale structure of marine ecological products in the two cities in 2018. If they attach no importance to these problems and do not improve them, the development levels of the two cities will continue to decline. Relevant government sectors should quickly find the root cause of the problems and explore a model and path suitable for the development of the region by regulating the scale of supply, improving existing production technologies, broadening the vision of development, optimizing development ideas, and diversifying development paths. The comprehensive technical efficiency in the marine ecological product supply is expected to get back on track and achieve positive development in the future.

3.3. Influencing Factors for the Variations in Supply Efficiency

Software was applied to perform regression analysis on the data of the influencing factors of each city and the comprehensive technical efficiency of their supply from 2009 to 2018, and the results of the Tobit regression analysis are shown in Table 5.

3.3.1. The Discharge of Wastewater and Its Direct Discharge into the Sea Play a Negative Role in Improving the Overall Technical Efficiency of the Regional Marine Ecological Product Supply

Environmental pollution is largely related to the discharge of substandard water, so it is in the marine field. Mankind’s dependence on water resources has become stronger with the continuous development of industry and living standards. Economic development stimulates the exploitation and utilization of water resources. However, in the case of a constant environmental carrying capacity, the development of environmental protection facilities and the capabilities of wastewater reclamation and treatment cannot fulfill the actual demand of wastewater discharge. As a consequence, regarding wastewater mainly produced in the terrestrial environment, in addition to the recycled or collected part, most is discharged into rivers and lakes, and flows into the sea through surface runoff, thus generating an extensive impact on the regional marine environment.

3.3.2. Marine Fishing Output and Mariculture Area and Output Play a Positive Role in Improving the Overall Technical Efficiency of the Regional Marine Ecological Product Supply

The abovementioned content expounds that food supply is one aspect of the supply of marine ecological products. Marine fishing and mariculture are the main methods of food provision. The output items of ecological product supply are increased by strengthening the impact of food supply on marine ecological products so that efficiency is improved to a certain extent. The marine fishing and mariculture involved in this research were limited in offshore waters. Nevertheless, according to the collection and statistics of other sources such as yearbooks, it was found that fishing and mariculture in offshore waters were prohibited in some regions, such as Shanghai. On the other hand, the increase in mariculture area also plays a certain role in driving the large-scale development of marine ecological products, and reduces the possibility of wastewater being discharged directly into the sea. Mariculture occupies a large area of the sea, enhancing the influence degree of scale and the scale efficiency of supply.

3.3.3. The Amount of Dumped Solid Waste, the Area of Reclamation, and the Amount of Industrial Exhaust Emissions Have No Significant Effect

In recent years, countries with territorial waters have strictly controlled activities that occupy the utilization area of marine resources, such as dumped solid waste and sea reclamation. On the basis of original development, they further lower the impact of marine development activities, restore the original ecological appearance of the ocean, and legislate against illegal operations. All the above actions have achieved a prominent effect. Sea reclamation and other aspects pose a slight impact on the marine environment due to restrictions from relevant policies. On the other hand, China has formulated strict control
standards for industrial exhaust emissions and implemented real-time monitoring and tracking for a series of emissions facilities such as elevated sources through online systems to ensure that the emissions composition and composition also meet the corresponding national standards. Thus, they have little impact on a marine ecosystem with a large area and self-purification abilities.

3.3.4. The Indicators of Influencing Factors in Some Cities Are Unstable

According to data statistics and analysis, it was found that the discharge of wastewater and the direct discharge of wastewater into the sea mostly showed a downward trend or undulated in a fixed value in the five cities of Shanghai, Nantong, Ningbo, Zhoushan, and Jiaxing in recent years, presenting a lack of stability. There was a year-by-year increase in the output and area of the marine aquaculture and the marine fishing output, but the driving role of the comprehensive technical efficiency of the regional marine ecological product supply remained to be improved further. However, on the contrary, the data of the negative indicators of environmental impact, such as wastewater discharge, increased during a certain period in the four cities of Lianyungang, Yancheng, Taizhou, and Wenzhou, and the marine fishing and aquaculture indicators, which should have taken a catalytic role, generated a smaller driving force. Additionally, the environmental protection policies and investment failed to form a significant growth trend, resulting in fluctuations and even stagnation or regression in the supply efficiency of local marine ecological products.

4. Discussion

4.1. Supply Problems

4.1.1. Unbalanced Regional Supply Development

With the development of marine economy in the new era, plenty of research has been conducted on how to enrich the multi-channel and multi-field development of the marine field. In recent years, marine ecological products, as a new research aspect, have aroused more and more attention. Unbalanced development in the supply efficiency of marine ecological products have appeared in the Yangtze River Delta region, of which Shanghai, Nantong, Jiaxing, Ningbo, and Zhoushan gained the fastest development. It was intimately related to their locations in the core area of the Yangtze River Delta, since these cities could accelerate the development of marine ecological product supply by virtue of the powerful economic influence from international cities such as Shanghai. In spite of lying in the planning scope of the Yangtze River Delta region, Lianyungang, Yancheng, Taizhou, and Wenzhou obtained little driving effect due to their locations farther from the economic core circle. Accordingly, it is necessary for the local governments to proactively approach the core circle when formulating policies and carrying out cooperation related to the maritime field in order to obtain more powerful support and stimulation, thereby attaining more convenience and benefits brought by integrated development.

4.1.2. Unreasonable Supply Structure

The supply of marine ecological products in the Yangtze River Delta has been developing in recent years, but there are some unreasonable points in the supply structure of the cities. It is possible for Yancheng and Wenzhou to face problems such as off-tracking supply and imbalanced structure. The government is the largest investor in the supply of marine ecological products, so the method and direction of its investment is critical. Most government investment targets key areas such as basic projects, but more importance should be attached to science and technologies as well as culture and service. Scientific research and the introduction of advanced production concepts and technologies should be relied on to resolve the current problems of inadequate technical support and scientific research in the supply process. The intrinsic soft power ought to be utilized to use intrinsic soft power to boost the supply structure to advance in a more reasonable direction.
4.1.3. Inadequate Regulation of Supply Mode

The status quo of the supply and development of marine ecological products in nine cities in the Yangtze River Delta reveals that the supply modes of many areas are outdated. With the high-quality development of the economy, it is indispensable for the marine field to build high-quality development models. Although cities in various regions have regulated their models in a timely fashion in view of their own location advantages, the problems of late and inadequate regulation still exist. Today, large-scale development takes a pivotal position in improving the supply efficiency of marine ecological products. The growing supply scale can gear up the improvement of the scale efficiency, and motivate people to put more energy into it and enhance support for supply.

4.1.4. Marine Environmental Issues Remains to Be Further Improved

Environmental pollution caused by human production behaviors during development has been aggravated, with overall marine development moving forward. The emergence of marine environmental problems brings more uncertain factors for the entire supply process of marine ecological products and heightens the possibility of environmental risk outbreak. For example, the discharge of wastewater worsens seawater quality and imposes pressure and challenges for normal production and life in the marine field. Local governments have attached great importance to environmental protection in recent years and increased investment in environmental conservation, but the addition of more and more production behaviors and methods have made the coastal areas of the Yangtze River Delta take on more risk of being polluted. Water quality in the field of aquaculture exceeded the standards to varying degrees, which reduced the supply efficiency and brought a series of pressure to the environment. The environmental statuses of the cities were different. In addition to reducing the damage of related influencing factors, how to further stimulate the promotion effect is also the key to continuing development.

4.1.5. Insufficient Market Guidance and Unsound Policies and Regulations

At present, the supply input methods of marine ecological products are mostly formed under the guidance of the government, and lack market guidance. Social participation is insufficient in the supply process of marine ecological products. The lack of social forces and private capital makes it fail to form a situation of co-governance and sharing. In addition, the lack of policy orientation in some areas leads to deviations from the direction of the supply process. Furthermore, despite rich marine policies and regulations, only a small part of them are related to the supply of marine ecological products, which may be because this field is still in the initial stages. The unsound policies and regulations result in unclear quality standards, accountability systems, and management responsibilities of the supplied products in the supply process, making it impossible to carry out unified quality assessment and standard identification. In the meantime, the lack of considerations of safety in the supply process and the regulatory gaps leads to a series of problems.

4.2. Policy Suggestion

4.2.1. Adjust Supply Methods and Optimize Supply Structure

Methods suitable for supply development in the region should be explored by combining with the location advantages in response to the development status quo of the supply efficiency of marine ecological products in cities in the Yangtze River Delta region. Shanghai, Jiaxing, Ningbo, Nantong, and Zhoushan should seize the advantages of the core economic circle of the Yangtze River Delta and grasp the good supply effect achieved at this stage to further enrich supply channels and content, thus maintaining the current good status. In spite of the current fluctuating supply efficiency, Lianyungang, Yancheng, Taizhou, and Wenzhou should continue to enhance the transformation of the supply mode of marine ecological products, reorganize the supply structure, and integrate the focus and characteristics of regional development while enriching the supply content. Moreover, they also need to continuously increase investment in traditional supply and output, adjust the
production methods of the marine food supply such as fishery timing, as well as regulate production ideas, create production methods, and take the path of sustainable development in view of the different types of seafood in these areas.

4.2.2. Establish and Improve the Legal and Regulatory System Related to Supply

Laws and regulations involving the oceans are relatively complete, covering articles for protection, governance, rewards, and punishments, but the legal system for the supply of marine ecological products is still being improved. As the region with the fastest economic development in China, the Yangtze River Delta encounters the most new problems in the continuous development of various fields. New issues often do not have relevant laws or regulations for direct reference, so it is imperative to improve regional laws and regulations. The key to restricting personnel in this industry to carry out normal production is to establish laws to abide by when dealing with the supply of marine ecological products. Lots of cities sit in the Yangtze River Delta, so problems such as inadequate supply supervision and untimely disposal are more likely to occur.

4.2.3. Enrich and Improve the Existing Supply Mode

The supply mode of marine ecological products in the Yangtze River Delta region plays a huge role in the current supply process. It is unknown whether this role will maintain a promoting effect with the development of the economy and the enrichment of ideas. In other words, only by constant innovation and improvement can the existing production model adapt to the development rhythm of today. Large-scale development plays a more and more significant role in daily production, and the implementation of expanding production scale in the marine field will also play a role in further improving supply efficiency. The ocean is a system that is extremely susceptible to environmental factors. In the era when everyone is advocating low-carbon actions, it is a good option to apply a low-carbon production model to the supply of marine ecological products. The supply mode can be gradually shifted in the direction of low carbon. The application of a dual-cycle production model must be accelerated. As the consumption of resources is lowered, the internal production model should be transformed in a timely manner to realize the transformation and upgrading of the production model towards intensification and drive the development of model construction.

4.2.4. Strengthen the Protection, Governance, and Restoration of the Marine Ecological Environment

The marine environment has become an important factor influencing economic development. Especially for the marine economy, the development of relevant economic activities relies on the ocean, and also has an inseparable relationship with the marine environment. The quality of the marine ecological environment, as a central axis of economic development, controls the speed and rhythm of high-quality economic progress. The governance, restoration, and protection of the marine environment require participation of everyone to form an environmental governance pattern featuring joint construction, governance, and sharing. Covering a large sea area, the Yangtze River Delta region requires much manpower, and numerous materials and funds in the links and processes involved in environmental protection and governance. As a key force leading environmental governance and protection, the government should increase corresponding subsidies and investment in all links to upgrade and optimize the marine environmental protection system. In order to improve the supply capacity of regional marine ecological products, the government can also formulate active taxation policies related to environment conservation, such as providing tax relief or government subsidies to relevant organizations and individuals involved in marine ecological environmental protection and governance, and giving tax incentives and support to some marine ecological restoration projects.
4.2.5. Harmoniously Promote the Continuous Development of Regional Supply Levels

The cities in the region have uneven supply and development of marine ecological products, so only by strengthening communication and cooperation between these cities can the synergetic development of regional integration be achieved. Among the nine coastal cities in the Yangtze River Delta, Yancheng and Lianyungang can strengthen exchanges and cooperation with Nantong on the supply of marine ecological products to enrich development methods and improve development efficiency. Wenzhou and Taizhou can learn from Ningbo and Jiaxing about how to constantly promote the improvement of supply efficiency. It is critical to establish and improve a communication and collaboration system on the premise of taking into account the normal interests of each city so as to achieve a good synergetic effect within the region. The coastal cities in the region should keep in step with the development trends of the times, combine their own geographic advantages and resources, vigorously explore the supply of unique advantages suitable for the development of the region, and position themselves accurately. Moreover, they should summarize and plan for a system that constitutes the supply of regional ecological products, explore efficient supply channels and methods suitable for their long-term development, and maintain sustainable development by stabilizing growth and regulating structure. Finally, it is necessary to deepen the cooperation of coastal cities in protecting their marine ecological environment, and carry out experience exchanges and technical discussions on marine environmental problems encountered in the development of these areas.

4.2.6. Optimize Financial Investment and Improve Government Financing Capacity

People’s dependence on the ocean is becoming stronger with the continuous exploit and use of it. Therefore, regarding the supply of marine ecological products, the government must strive to promote ecological products with public attributes to be known and used by more people. Regarding the fiscal expenditure, the government must expand the proportion of funds for products, increase the utilization rate of funds, raise funds through multiple channels, and encourage the entry of more types of funds. The improvement of the multi-channel and multi-subject participation mechanism of the marine ecological product supply can effectively increase the utilization rate of the regional economy, thereby upgrading the efficiency of supply. On the other hand, the government should strengthen the infrastructure construction for the supply of marine ecological products, and reduce unnecessary investment while increasing technological content and levels to prevent investment waste and increase the capital conversion and utilization rates.

5. Conclusions

The development level of the supply efficiency of marine ecological products in the Yangtze River Delta plays a very important role in improving the development process of the regional marine economy. As an emerging aspect of marine economic development in recent years, marine ecological products have attracted more and more attention. This paper calculated the marine ecosystem service value of coastal urban agglomerations in the Yangtze River Delta from 2009 to 2018. The DEA-Tobit model was used to further analyze the supply efficiency of marine ecological products and its influencing factors. The main conclusions are as follows:

1. There were certain problems in varying degrees in the supply efficiency of marine ecological products in all nine coastal cities in the Yangtze River Delta. The problems focused on uneven development of regional supply, unreasonable supply structure, inadequate regulation of the supply mode, marine environmental problems needing further improvement, insufficient market guidance, and unsound policies and regulations.

2. In the supply process of marine ecological products, the unbalanced development among different regions should be considered, which plays an important role in improving the supply efficiency.
3. Furthermore, the supply efficiency of regional marine ecological products can be enhanced by regulating the supply mode and optimizing the supply structure, establishing and improving the laws and regulations system related to the supply, enriching and upgrading the existing supply mode, strengthening the restoration of marine ecological environmental protection, coordinating the continuous development of regional supply levels, and optimizing financial investment and government financing capabilities in order to provide paths and ideas for the development of the Yangtze River Delta region, especially in the marine field.

4. Only by practically improving the efficiency of supply, earnestly implementing and executing related solutions and development paths, and enhancing the understanding of the supply problem of marine ecological products can the supply level of marine ecological products in the Yangtze River Delta region be effectively promoted, the regional marine economy development be accelerated, and a harmonious coexistence and development pattern of economic development and environment be formed.

There are some research limitations in this paper. First, due to the limitation of data integrity and availability, in this paper, only data from 10 consecutive years were used for analysis, which is relatively short.

Second, in this paper, the calculation model and formula of the value of marine ecosystem services was simple, and fewer factors were considered (for example, the non-use values were basically not considered). At the same time, considering the same kind of ecosystem services in a different social and economic environment would show different values, so the final calculated results could not reflect the level of all real values.

Third, this paper mainly considered the impact of human behaviors on the supply efficiency of marine ecological products, but did not take into account the interaction between cities, thus making it difficult for the results to reflect all situations.

With the vigorous development of the marine economy as well as the continuous improvement of the statistical indicators and data, in a later study, the data of coastal provinces in the Yangtze River Delta should be considered, the time span should be longer, and all kinds of factors that influence the supply efficiency of marine ecological products should be explored by using comprehensive panel data, which will be the key direction of future research.

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Appendix A

Table A1. Calculation of marine ecological product value.

| First-Level Indicator       | Secondary Indicators           | Calculation Method                                                                 | Definition                                                                                                                                 |
|-----------------------------|--------------------------------|-----------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|
| Food supply                 | Supply value of mariculture =  | Supply value of mariculture output \(\times\) unit price for sale;                 | Refers to all kinds of food directly provided to humans, including fish, shrimps, shellfish, crabs, and seaweed, that are obtained through marine aquaculture and fishing. |
|                             | mariculture output \(\times\)  |                                                    |                                                                                                                                           |
|                             | unit price for sale;           |                                                    |                                                                                                                                           |
|                             | Marine fishing supply value =  | Marine fishing amount \(\times\) unit price for sales                              |                                                                                                                                           |
|                             | marine fishing amount \(\times\) |                                                    |                                                                                                                                           |
| Supply service value        | Sea salt supply value = sea salt | Sea salt output \(\times\) unit price for sale;                                    | Refers to the raw materials and biochemical substances used for production indirectly provided for humans, including food, daily necessities, decorations, fuels, medicines, etc. Based on the development of the marine industry in the coastal cities of the Yangtze River Delta, the indicators include sea salt, marine biomedical materials, offshore wind power, low-quality kelp sold as raw materials, and dried shells sold on nursery substratum. |
|                             | output \(\times\) unit price for sale; |                                                    |                                                                                                                                           |
|                             | Supply value of marine biomedical materials = (local marine economic output value/national marine economic gross output value) \(\times\) national marine biological medicine output value; |                                                                                                                                           |
|                             | Offshore wind supply value =   | total offshore wind power generation \(\times\) 12 h/day \(\times\) 365 days \(\times\) feed-in tariff; |                                                                                                                                           |
|                             | total offshore wind power      |                                                    |                                                                                                                                           |
|                             | generation \(\times\) 12 h/day |                                                    |                                                                                                                                           |
|                             | \(\times\) 365 days \(\times\)  |                                                    |                                                                                                                                           |
|                             | feed-in tariff;                |                                                    |                                                                                                                                           |
|                             | Supply value of low-quality kelp | output of low-quality kelp \(\times\) unit price for sale;                        |                                                                                                                                           |
|                             | kelp \(\times\) unit price for sale; |                                                    |                                                                                                                                           |
|                             | Dry shell supply value =       | shellfish output \(\times\) (total dry shell weight \(\div\) total wet shell weight) \(\times\) unit price for sale [31,32]. |                                                                                                                                           |
|                             | shellfish output \(\times\)    |                                                    |                                                                                                                                           |
|                             | (total dry shell weight \(\div\) |                                                    |                                                                                                                                           |
|                             | total wet shell weight) \(\times\) |                                                    |                                                                                                                                           |
|                             | unit price for sale            |                                                    |                                                                                                                                           |
| Raw material supply         | Genetic resource supply value  | Genetic resource supply value = sea area \(\times\) the value of genetic resources provided by per unit area of the marine ecosystem | Refers to the genes and genetic information contained in marine organisms that can be exploited and utilized by humans [33]. |
|                             |                                    |                                                    |                                                                                                                                           |
| Cultural service value      | Tourism and entertainment value = | (local marine economic output value/national marine economic output value) \(\times\) national coastal tourism output value | Refers to the direct commercial value, which comes from the unique landscape formed by coastal zones and the marine ecosystem or the aesthetic development characteristics. |
|                             | (local marine economic output   |                                                    |                                                                                                                                           |
|                             | value/national marine economic  |                                                    |                                                                                                                                           |
|                             | output value) \(\times\) national marine economic output value |                                                    |                                                                                                                                           |
|                             | output value                   |                                                    |                                                                                                                                           |
|                             | spiritual cultural value =      | sea area \(\times\) spiritual cultural value provided by per unit area of the marine ecosystem | Refers to the contribution value of satisfying human spiritual demand and artistic creation.                                             |
|                             | spiritual cultural value        |                                                    |                                                                                                                                           |
|                             | provided by per unit area of    |                                                    |                                                                                                                                           |
|                             | the marine ecosystem            |                                                    |                                                                                                                                           |
|                             | Scientific research value = the | the number of regional marine research papers \(\times\) funds invested in each paper | Refers to scientific research activities produced and attracted by oceans to enhance human understanding of the natural world.          |
|                             | number of regional marine       |                                                    |                                                                                                                                           |
|                             | research papers \(\times\) funds |                                                    |                                                                                                                                           |
|                             | invested in each paper          |                                                    |                                                                                                                                           |
Table A1. Cont.

| First-Level Indicator          | Secondary Indicators         | Calculation Method                                                                 | Definition                                                                                   |
|-------------------------------|------------------------------|------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| Regulative service value      |                              | Based on the primary productivity of offshore waters, it is calculated by combining the average value of afforestation cost and carbon tax (650 CNY/t) with the area of the waters | Refers to the absorption and fixation of carbon dioxide by the marine ecosystem, which play a role in regulating climate. |
| Gas regulation                |                              | According to the principle of photosynthesis, 2.667 g of oxygen are released for every gram of carbon fixed in the ocean. First, the primary productivity in the offshore waters is used to determine the amount of oxygen released, and the result is multiplied by the average value of afforestation costs and industrial oxygen production costs (376.45 CNY/t). | Refers to gases beneficial to human survival released by the marine ecosystem (mainly oxygen), which help to stabilize the composition of the atmosphere and benefit the survival and development of various organisms, including humans. |
| Wastewater disposal           |                              | The ocean absorbs carbon, nitrogen, and phosphorus in a ratio of 106:16:1, based on which the amount of fixed nitrogen and phosphorus elements can be calculated [34]. Then it is calculated with the cost of wastewater treatment in China (nitrogen is 1500 CNY/t, and phosphorus is 2500 CNY/t). | Refers to the process in which the marine ecosystem uses its own purification function to incorporate and purify pollutants, mainly for nitrogen and phosphorus elements [35]. |
| Interference regulation       |                              | Sea area × the value of disturbance regulation provided by the unit area of the marine ecosystem | Refers to the effects of absorption and mitigation of a certain range of vibrations generated by the marine ecosystem on the environment. |
| Biological control            |                              | Sea area × the value of biological control provided by the unit area of the marine ecosystem | Refers to the use of marine ecosystems to control harmful organisms and reduce losses caused by them. |

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