2. Spatial Patterns of Ocean Economic Efficiency and Their Influencing Factors in Chinese Coastal Regions

Xin ZHAO[1]
Yong PENG[1]
Yuemei XUE[1]
Shun YUAN[2]

Abstract

Since the Chinese government's ocean power strategy was launched in 2011, the ocean economy plays an increasingly important role in the Chinese national economy. This paper uses stochastic frontier analysis (SFA) and spatial econometric methods to measure ocean economic efficiency and analyze the distribution characteristics, spatial effects, and its influencing factors. Panel data for 11 coastal regions in China covering the 2007-2013 period are employed to illustrate the advantage of the method. The results show that the ocean economic efficiency of most coastal regions is at medium or high levels, and the longitudinal changes in spatial distribution of 11 coastal regions remain relatively stable. Furthermore, the efficiency of coastal regions has positive spatial correlation and spatial agglomeration, where a spatial spillover effect exists between adjacent regions due to geographical distance. The results also present the significant positive influences on the efficiency of ocean economy are regional openness, scientific research and regional ocean economic development.

Keywords: ocean economic efficiency; spatial patterns; stochastic frontier analysis; spatial panel model

JEL Classification: O47, C51

1. Introduction

Since 2003, when the National Ocean Economic Development Plan was promulgated, China's ocean economy has sustained its rapid development. In 2015, the gross ocean

[1] *School of Economics, Ocean University of China, Qingdao, Shandong, People's Republic of China.*

[2] *School of Ocean and Atmospheric Science, Ocean University of China, Qingdao, Shandong, People's Republic of China.*

product has been up to 9.6% of the total GDP, ocean economy has become a new growth point in China's economy. While the ocean economy is developing rapidly in the coastal regions, contradictions among ocean economic, ecological, and social development have become more and more prominent, which is not conducive to the sustainable development of the ocean economy. Therefore, assessing economic efficiency reasonably and identifying its key influences are vital issues for maintaining the sustainable development of the ocean economy at this stage.

Many studies have paid great attention to measurements of economic efficiency based on the approach initiated by Farrell (1957). More and more scholars have begun to explore economic efficiency, with economic efficiency evaluation and spatial correlation recognition being their main research focuses. Ramilan (2011) used the two-stage data envelopment analysis (DEA) to analyze the environmental and economic efficiency of New Zealand's agricultural industry. Aparicio (2015) used the standard and non-homothetic DEA model to analyze the USA's regional economic efficiency; finding that the non-homothetic DEA result was superior to that of standard DEA, he also decomposed economic efficiency into technical efficiency and allocative efficiency. Tao (2016) measured China's provincial green economic efficiency based on a non-separable input-output SBM approach, which is the evolution of DEA. Hailu (2015) used stochastic frontier analysis (SFA) to investigate the technical efficiency of manufacturing firms in Ethiopia. Ji (2012) and Song (2013) evaluated regional economic efficiency in China based on the SFA model and panel data. Glass (2016) developed a spatial autoregressive stochastic frontier model for panel data based on SFA and used it to study the asymmetric directional spillover effect of economic efficiency; then he applied the model to analyze the economic efficiency of European countries. Qian (2013) estimated the green economic efficiency of China's provinces using the SBM model in DEA efficiency models; he went on to use the Tobit panel model to examine the determinants of China's green economic efficiency. Liu (2012) estimated China's economic efficiency using the Malmquist index model and analyzed the spatial distribution and its causal factors among the east, middle, west, and northeast regions. Lv (2009) first estimated China's economic efficiency using the DEA model, then used spatial measurement techniques to analyze spatial correlations of regional economic efficiency.

From the point of view of ocean economy, a few researchers have begun to focus on the issue of ocean economic efficiency, building upon the economic efficiency research described in the previous paragraph. Some scholars have investigated economic efficiency in a single marine sector, such as fisheries, sea transport, or marine-based strategic emerging industries. For example, Maravelias (2008) analyzed the economic efficiency of fisheries in the Mediterranean Sea using the DEA model, and Jamnia (2015) used the SFA model to estimate the technical efficiency of fishing vessels operating in the Chabahar region of Iran. Cullinane (2006) estimated the efficiency of the sea transport industry in 30 major ports around the world using both the DEA and SFA models, and concluded that the results from the SFA model were relatively more robust than those from the DEA model. Odeck (2012) used the DEA and SFA models to evaluate the mean technical efficiency of European seaports, and then compared the two models. Yuan (2014) evaluated the efficiency of marine strategic emerging industries based on the Malmquist index method used in the DEA models, and then structurally decomposed its overall regional differences. In addition, some scholars have paid attention to global ocean economic efficiency, focusing on regional differences, cyclical changes in ocean economic efficiency, and influencing factors. In general, the major evaluation method is the DEA model, while the primary method for identifying influential factors is the panel model. Fan (2011), Zhao (2015), and Zhao (2016) all used the DEA model to evaluate ocean economic efficiency and analyze its regional differences and cyclical changes. Furthermore, Wu (2015) and Ding (2015) each used the DEA model to evaluate ocean economic efficiency, and then they analyzed its influencing factors using the panel model and Tobit panel model, respectively.

The above literature on national economic efficiency provides references for studying ocean economic efficiency. The popular method, *i.e.*, the DEA model, a non-parameter estimation method has achieved many significant results for the national economy. However, since the ocean economy is emerging in China, it has own characters based on energy and environment. Hence, it is necessary for us to explore new method analyze the economic efficiency of ocean economy. Furthermore, in identifying ocean economic efficiency factors, most research using the common panel model hardly notices the spillover effects and spatial correlation between adjacent regions. In other words, most research ignores the "first law of geography." Therefore, in order to identify the spatial patterns of ocean economic efficiency and the factors that influence it, this paper uses the SFA model and spatial econometric methods to measure ocean economic efficiency and to analyze its distribution characteristics, spatial effects, and factors. The panel data used herein to describe the economic efficiency of China's 11 coastal regions covers the period from 2007 to 2013. Compared to the disadvantages of existing research, the contributions of this paper are following. Firstly, in order to reduce the estimating bias for ocean economic efficiency, the paper uses the SFA model for measurements, considering the impact of both input factors and random factors. Secondly, different from the traditional econometric assumptions for which interregional economic variables are independent, this paper uses spatial econometrics and incorporates spatial distance weighting. It not only identifies the relevant factors, but also verifies the possible existence of spatial effects.

The remainder of this paper is organized as follows. In section 2, we present the methodology and data used in this paper, encompassing the SFA model and spatial panel model. In section3, we present the spatial patterns of ocean economic efficiency. Section 4 provides the factors that influence the ocean economic efficiency. Conclusions are drawn in Section 5.

2. Methodology and Data

2.1 The SFA Model

The key to constructing a SFA model is selecting a rational production function. Compared with the relative simple Cobb-Douglas production function, the transcendental logarithmic production function not only ignores technology-neutral and fixed output elasticity assumptions, but also fits the stable relationship between inputs and outputs of time variables; these factors make it more suitable for panel data. Based on the findings of Battese (1992), we selected the SFA model using the transcendental logarithmic production function. The specific form is shown in Formula (1):

$$\ln Y_{it}=\beta_0+\beta_1\ln L_{it}+\beta_2\ln K_{it}+\frac{1}{2}\beta_{12}\ln L_{it}\ln K_{it}+\frac{1}{2}\beta_{11}(\ln L_{it})^2+\frac{1}{2}\beta_{22}(\ln K_{it})^2$$
$$+\beta_{t1}t\ln L_{it}+\beta_{t2}t\ln K_{it}+\beta_t t+\frac{1}{2}\beta_{tt}t^2+\nu_{it}-\mu_{it} \tag{1}$$

$$\mu_{it}=\mu_i\exp[\eta(t-T)] \tag{2}$$

where: Y_{it} represents the outputs of units i in period t ; L_{it} and K_{it} represent the labor and capital inputs, respectively, of units i in period t; t represents the time trend of technological change; β is a coefficient of the variables; and ν_{it} is the random error and obeys the normal distribution of $N(0,\sigma^2)$. Mutually independent from ν_{it}, μ_{it} represents non-negative random variables and expresses the technical factors and invalid assumptions in a given structure. In Formula (2), μ_i represents non-negative random variables and obeys the normal distribution of $N(0,\sigma^2)$, while η is a parameter indicating the change rate of technical efficiency, which must be estimated.

The maximum likelihood method can be used to estimate the parameter coefficients in Formula (1) and identify the technical efficiency. Based on the method used by Yu(2015) to calculate urban economic efficiency, the efficiency of China's coastal ocean economy can be obtained using the following formula (3) :

$$TFP_{it}=TE_{it}\exp(\beta_0+\beta_t t)$$
$$TE_{it}=\exp(-\mu_{it}) \tag{3}$$

where: TFP_{it} represents the total factor productivity, which measures the ocean economic efficiency; TE_{it} represents the technical efficiency of are i in t period; and $\exp(\beta_0+\beta_t t)$ represents the frontier technical level in t period.

2.2 The Spatial Panel Model

Spatial panel models mainly include the spatial lag model (SLM) and spatial error model (SEM). Anselin (1994) used the LM test to compare the Lagrange multiplier (LM value) and robust Lagrange multiplier (robust-LM value) of the two models in order to analyze their applicability. If the LM value of the SLM is more significant than that of the SEM, and the robust-LM value of the SLM is significant while the robust-LM of the SEM is not significant, then the SLM should be selected. If the opposite conditions are true, the SEM should be selected.

Taking into account the likely spatial effect on the ocean economic efficiency in China's coastal areas, and building on Fischer’s (2009) research into the spatial panel model, this paper establishes the spatial panel model for China's coastal ocean economic efficiency:

$$\ln TFP_{it} = \rho \sum_{j=1}^{N} W_{ij} \ln TFP_{it} + \beta X_{it} + \alpha_i + \nu_i + \varepsilon_{it}$$

$$\varepsilon_{it} = \lambda \sum_{j=1}^{N} W_{it} \varepsilon_{it} + \mu_{it} \tag{4}$$

where: TFP_{it} represents the ocean economic efficiency of *i* districts in period t; X_{it} represents the control variables, which demonstrate the influence factors of regional ocean economic efficiency; α_i , ν_i , and ε_{it} represent the regional effect, time effect, and stochastic disturbance term respectively. ρ and λ represent, respectively, the spatial lag and spatial error coefficients, which are the main parameters used to measure the spatial effect. The parameter ρ reflects how a change to a variable in a certain region can affect its adjacent regions. λ reflects how a change to a variable in an adjacent can affect this region. If $\rho=0$, the model is the SEM; if $\lambda=0$, the model is the SLM; and W_{it} represents the spatial weights matrix.

2.3 Data and Variables

2.3.1 The SFA Model Variable Selection

The variables in Formula (1) include labor input and capital input. This paper uses employment related to the sea and marine capital stock to represent labor input and capital input, respectively. Because statistics describing the domestic capital stock of the marine areas are not available, we use the following formula based on research into estimating marine capital stock published by He (2014):

Marine capital stock = (coastal GOP / coastal GDP) *coastal capital stock
(5)

The formula (5) outlines methods for estimating coastal capital stock using the perpetual inventory method, based on Zhang's (2004) formula:

$$K_t = (1-\delta) K_{t-1} + I_t / P_t \tag{6}$$

where: K_t is the capital stock in period *t;* δ is the depreciation rate, which is set at $\delta=9.6\%$; I_t is the total fixed capital formation for the coastal regions and cities during period *t;* and P_t is the fixed asset price index during period *t.* Referring to the initial capital stock provided by Zhang Jun, it calculates the yearly nominal capital stock represented by the current price. Then it uses the fixed assets price index to calculate the actual capital stock based on 2007.

In order to eliminate the dimensionally different variables and avoid heteroscedasticity, all data used in the model must be processed with logarithmic function. In this paper, data on regional employment related to the sea and regional GOP are derived from the China Marine Statistical Yearbook (2008-2014), while the regional GDP, total fixed capital formation, and fixed assets price index are drawn from the China Statistical Yearbook for various years (2008-2014).

2.3.2 Spatial Panel Model Variable Selection

The variables in Formula (4) include ocean economic efficiency, the spatial weights matrix, and control variables. Based on the work of Dai (2015), this paper uses the reciprocal distance between provincial capital cities in two provinces to construct the spatial weights matrix.

Scholars have not yet formed a unified framework to identify the factors that influence ocean economic efficiency. Unquestionably, scholars consider regional openness, industrial structure, and personnel structure to be the most influential factors (2015). In general, a higher degree of openness not only draws a great deal of capital, but also brings more advanced production technology and management concepts; these factors all have positive effects on ocean economic efficiency. Furthermore, a reasonable industrial structure is key to improving ocean economic efficiency. Because the tertiary industry is low in power consumption and high in added value, it plays a stronger role in boosting ocean economic efficiency. Therefore, a reasonable marine industrial structure involves gradually transferring primary and secondary industries to tertiary industry status. In addition to these variables, labor represents a main factor in production activities. High-quality labor and a high proportion of talented personnel increase labor productivity and create higher labor value; these changes play a positive role in promoting ocean economic efficiency. In addition, many scholars have researched the impact of financial development on the ocean economy (2012), concluding that financial development plays an important role by uniting all parties' capital in order to promote marine economic activities and accelerate the mobility of each production factor. In fact, some scholars regard scientific research and marine economic development as the primary factors influencing ocean economic efficiency (2015). In theory, a higher level of scientific research leads to higher productivity, which has a positive effect on economic efficiency. The level of marine economic development is mainly reflected in the economic growth created by labor, capital, and other input factors. It can represent a solid foundation for the regional ocean economy and help to promote positive effects on industrial structure, the policy environment, and other non-input factors.

In summary, this paper uses regional openness (OP), industrial structure (IS), professional structure (PS), financial development level (FI), technological level (TI), and marine economic development lever (ML) as the control variables in Formula (4); these terms represent the main factors influencing ocean economic efficiency. Regional openness is expressed by the regional import and export volume as a proportion of GDP. Industrial structure is represented by the proportion of GOP accounted for by regional marine tertiary industries. Professional structure is expressed by regional the number of students who majoring in marine fields. Financial development level is expressed by the proportion of the regional yearly increase in deposits and loans accounted for GDP, while ocean economic development level is expressed by the regional GOP/GDP. Technological level is expressed by the number of research subjects in regional marine scientific research institutions.

Index data comes from the China Statistical Yearbook (2008-2014), the China Marine Statistical Yearbook (2008-2014), and the China Financial Yearbook (2008-2014). In addition, monetary data involved in the model has been adjusted based on monetary values from 2007. To eliminate the dimensionality of different variables, all data used in the model must be processed using logarithms.

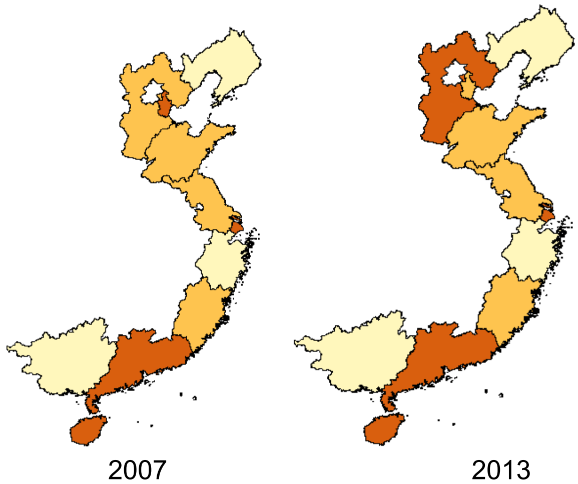
3. Spatial Patterns of Ocean Economic Efficiency

This study used the Frontier 4.1 software and Formula (3) to measure China's coastal ocean economic efficiency. To comprehensively test economic efficiency in spatial, this paper analyzes spatial patterns from two perspectives: spatial distribution and spatial effect.

3.1 Spatial Distribution of Ocean Economic Efficiency

To clarify the spatial distribution of and variations in coastal ocean economic efficiency, this study used GeoDa software to divide areas into three levels based on ocean economic efficiency: low, medium, and high. This study also used 2007 and 2013 as examples to analyze separately.

Figure 1.
Spatial Distribution of Coastal Ocean Economic Efficiency in 2007 and 2013



As shown in Figure 1, coastal ocean economic efficiency values in Liaoning, Zhejiang, and Guangxi provinces were at low levels in 2007. Median-value areas included Hebei, Shandong, Jiangsu, and Fujian provinces, while high-value areas were Tianjin, Shanghai, Guangdong, and Hainan provinces. In 2013, Hebei province replaced Tianjin as a high-value area, and Tianjin fell into the median-value area; no significant changes occurred in other provinces and cities. Judging by the grade distribution, the ocean economy of Shanghai, Guangdong, and Hainan have been in good condition and have relied on rapidly-emerging marine industries in recent years. In contrast, Tianjin, Hebei, Shandong, and Jiangsu represent traditional maritime provinces, with ocean economic efficiency levels that are high as compared to areas characterized by emerging marine industries; however, the relatively extensive mode of economic development in these areas has its disadvantages. In Liaoning, Zhejiang, and Guangxi, due to factors related to location and resources, marine economic development has weakened gradually and lowered efficiency. Overall, the majority of coastal regions and cities in China, accounting for more than two-thirds of the coastal areas, have high levels of ocean economic efficiency that did not change significantly during the study period. Furthermore, the spatial distribution remained relatively stable.

3.2 Spatial Effects of Ocean Economic Efficiency

3.2.1 Spatial Correlation Analysis

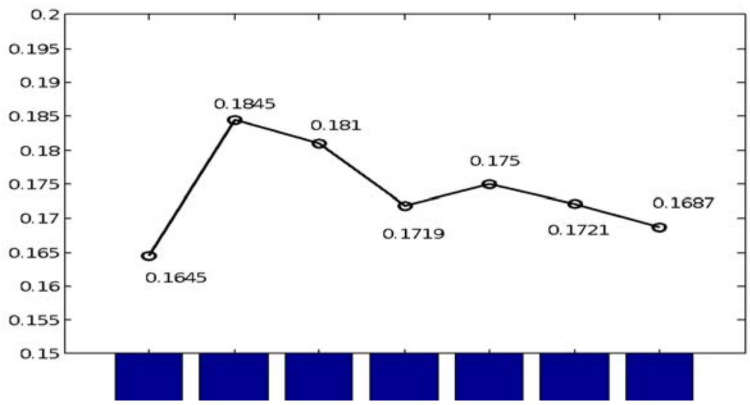
This study used the Moran's I (Moran index) test to inspect spatial correlations and specify whether there is spatial effect across coastal areas in China. Moran's I values lie within the range of [-1, 1]. If the value exceeds 0, ocean economic efficiency between the coastal areas has a positive spatial correlation, also known as a spatial agglomeration; values less than 0 represent a negative correlation between coastal areas.

Based on coastal ocean economic efficiency values in China, results from the Moran's I tests for 2007 and 2013 are shown in Figure 2.

During 2007 and 2013, the Moran's I values for coastal ocean economic efficiency were positive and significant at a 10% significance level, indicating a significant positive spatial correlation. Influenced by similar spatial characteristics, other regions demonstrated a spatial agglomeration phenomenon rather than a random state; this finding conforms to "the first law of geography" as it applies to coastal ocean economic efficiency in China. However, after reaching a maximum value of 0.1852 in 2008, the ocean economic efficiency fluctuated downward, and the degree of spatial agglomeration diminished. After ocean economic efficiency consolidated to a certain extent due to the external economic effects caused by factors such as rising production prices and intense market competition, the ocean economic efficiency began to show spatial rejection.

Figure 2

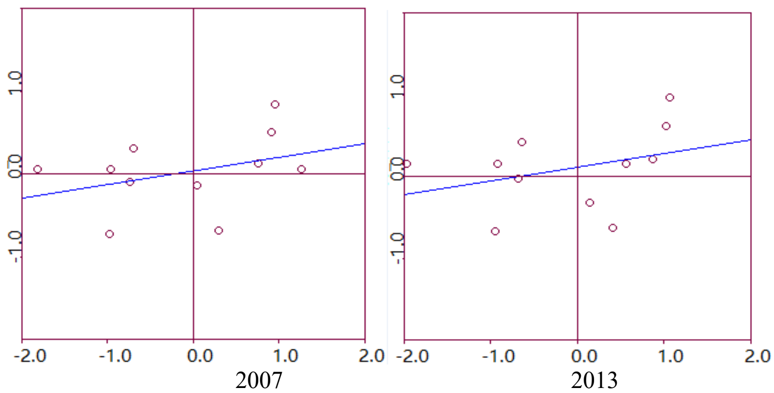
Moran's I Trends in Coastal Ocean Economic Efficiency during 2007 and 2013



Although the Moran's I findings can judge the spatial correlation degree of coastal ocean economic efficiency globally, the test fails to identify spatial correlation patterns between coastal areas; therefore, a scatter plot of Moran's I is required for further assessment. The scatter plot has ocean economic efficiency and lag in ocean economic efficiency as its axes, and it is divided into four quadrants that represent the following spatial correlation patterns: "high-high," "low-high," "low-low," and "high-low". By examining Moran's I scatter plots for 2007 and 2013, this paper illuminates the spatial correlation patterns of ocean economic efficiency in China's coastal regions and cities.

As shown in Figure 3, the coastal areas whose ocean economic efficiency values in 2007 and 2013 lie in the first quadrant are Guangdong, Hebei, Tianjin, and Shanghai; these areas have a "high- high" spatial correlation pattern, indicating high ocean economic efficiency and proximity to other provinces with high economic efficiency. This pattern consists of "high-high" areas that are spatially concentrated and improve together. The second quadrant includes Liaoning, Fujian, and Hainan. These areas represent a "low-high" space association mode, in which two province with lower ocean economic efficiency are surrounded by provinces with higher ocean economic efficiency, creating a negative spatial correlation. The marine economic efficiencies of Zhejiang and Guangxi provinces are located in the third quadrant, and they represent a "low-low" mode. These two provinces have lower ocean economic efficiency and are surrounded by other low-efficiency provinces, producing a negative impact on one another in space. The marine economic efficiencies of Jiangsu and Shandong provinces lie in the fourth quadrant, indicating the "high-low" spatial correlation mode. In this mode, a province with higher ocean economic efficiency is surrounded by lower-efficiency provinces. Overall, the spatial association patterns of coastal ocean economic efficiency did not change significantly from 2007 to 2013, basically consistent with their spatial distribution.

Figure 3.
Moran's I Scatter Plot of Ocean Economic Efficiency Values of Coastal Regions in 2007 and 2013



3.2.2 Spatial Spillover Effect Analysis

To clarify whether ocean economic efficiency in coastal areas of China exhibits a spatial spillover effect, this study used the Matlab software and maximum likelihood estimation method to estimate the parameters of spatial panel model. Table 1 shows the descriptive statistics for each variable. The Hausman test value is 1.3456, which is not significant; therefore, it is necessary to choose a spatial random effect panel model for interpretation, with the regression results shown in Table 2.

Table 2 shows that the spatial lag coefficient ρ is 0.932, while the spatial error coefficient λ is 0.969. Both values are significant at a 1% significance level, indicating a significant impact of spatial distance on coastal ocean economic efficiency, as well as a significant spatial spillover effect of ocean economic efficiency across coastal areas.

Table 1

Descriptive Statistics for Each Variable

	Average Value	Median Value	Standard Deviation	Minimum Value	Maximum Value
LnTFP	-0.0984	-0.0025	0.5951	-1.5755	0.8542
LnOP	3.7341	3.7162	0.7589	2.4631	5.1483
LnIS	3.8346	3.8501	0.1593	3.4436	4.1463
LnPS	-0.7081	-0.6036	0.8157	-3.2853	0.9120
LnFI	3.6469	3.6183	0.3719	2.8401	4.6945
LnTL	5.9071	6.2841	1.3239	3.1354	7.6916
LnOL	4.1545	4.2626	0.7309	2.4849	5.3981

These findings mean that a change in ocean economic efficiency in a given area has a positive spatial spillover effect on ocean economic efficiency in adjacent areas. At the same time, changes in the ocean economic efficiency in adjacent areas also create a positive spatial spillover effect on the ocean economic efficiency in the targeted area.

Table 2

Spatial Panel Regression Results

	Spatial lag random effects panel model			Spatial error random effects panel model		
	Estimated Value	t-Value	Prob.Value	Estimated value	T-Value	Prob.Value
intercept	-1.4085***	-2.8887	0.0038	-1.3170***	-2.8499	0.0043
lnOP	0.1162 ***	2.6004	0.0093	0.1645***	3.1920	0.0014
lnIS	0.0581	0.5362	0.5917	-0.0236	-0.2475	0.8044
lnPS	0.0104	0.6224	.5336	0.0045	0.2252	0.8218
lnFI	0.0176	0.8642	.3874	0.0471	1.4435	0.1488
lnTI	0.0482**	2.1248	0.0336	0.0492***	2.4689	0.0135
lnML	0.1248***	2.7388	0.0061	0.0710	1.5462	0.1220
	0.9329***	56.9514	0.0000	-	-	-
	-	-	-	0.9695***	116.1499	0.0000
	0.8950			.9055		
Log-likelihood	83.7429			85.2980		

Note: The symbols "**" and "***" indicate that the finding is significant at the 5% and 1% significance levels, respectively.

The spatial spillover effect exists because the constant improvement in China's market economy and reforms to the household registration system cause protectionist barriers to collapse and market information asymmetry to weaken gradually; in addition, regional liquidity continuously increases for elements of the ocean economy such as capital, manpower, and technology. At the same time, as a result of economic activity related to externalities and public goods, a region that adapts to marine economic development and increases public goods or services produces positive externalities in adjacent areas. Similarly, public goods or services in adjacent areas also generate positive externalities in the targeted region.

4. Analysis of Factors Affecting the Ocean Economic Efficiency

In conjunction with the Hausman Test, the random effects model is useful for testing marine spatial economic efficiency. In order to choose between the spatial error model and spatial lagged model, we must use the LM Test for spatial econometric models. As shown in Table 3, the LM value (LM-SLM) and the robust LM value (Robust-LM-SLM) are 169.45 and 152.59, respectively, in the spatial lag model; all findings are significant at a 1% level. In the spatial error model, the LM value (LM-SEM) and the robust LM value (robust LM-SEM) are 57.50 and 40.64, respectively, at a 1% significance level; these results are less than the LM-SLM and robust-LM-SLM. Therefore, this paper uses the spatial lag regression model to explain the factors affecting ocean economic efficiency.

Table 3

The LM Test of Spatial Econometric Model

Index	Statistics	Prob. Value
LM- SLM	169.4545	0.000
Robust LM-SLM	152.5955	0.000
LM- SEM	57.5025	0.000
Robust LM-SEM	40.6435	0.000

Based on the data in Table 2, the regression results of the spatial lag model and the random effects panel show the following:

(1) The parameter for regional openness is 0.1162, passing a T-test at a 1% significance level. This result indicates that regional openness has a significant positive impact on ocean economic efficiency; specifically, ocean economic efficiency is expected to increase by 0.1162 units when the regional openness increases by 1 unit. This finding also means that regional openness is a key factor contributing to ocean economic efficiency. Furthermore, coastal regions represent the frontier areas for reform and opening up, and they have made full use of regional advantages to introduce external advanced elements and management concepts, improving local ocean economic efficiency.

(2) Industrial structure has a positive impact on ocean economic efficiency, but it does not pass the significance test. This finding shows that the development model is still investment-driven, and that the secondary industries dominate. Against this background, the service-oriented tertiary marine industries have a weak impact on ocean economic efficiency; in other words, tertiary industries do not have an obvious feedback effect on the ocean economic efficiency. Based on the concept of "the belt

and the road," the coastal regions should make full use of their location and industrial advantages to promote optimization of marine industrial structures, thereby promoting the development of tertiary industries.

(3) The estimated parameter value for professional structure is 0.0104, which is not significant; this finding indicates that talent resources do not obviously improve the local ocean economic efficiency. Marine economic activity should be supported strongly by maritime professionals, but marine human capital has two shortcomings in China: asymmetry between supply and demand, and a mismatch between professional settings and realistic demands. As a result, under the existing training model, the marine professionals cannot play their roles effectively. Therefore, it is important to increase the training of marine professionals and explore training strategies that can improve the ocean economic efficiency.

(4) The regression coefficient for financial development is positive, but it does not pass the significance test. This finding indicates that financial development neither effectively promotes the development of ocean economy nor has a significant impact on the ocean economic efficiency. The supporting function of finance in ocean economy is mainly reflected in the scale effect and intensive effect. The scale effect refers to funds from banks and other financial intermediaries, and the intensive effect refers to capital allocation efficiency . At present, the financial supporting function has a relatively weak influence on the development of ocean economy, indicating that large-scale capital does not flow to ocean economy. Capital flow began relatively late and involves high risks. Furthermore, financial intermediaries provide poor direct support to marine economic activities, and capital utilization efficiency is low. In summary, ocean economy lack effective financial support, especially in terms of the capital support scale and the allocation efficiency of financial intermediation.

(5) The parameter for technological level is 0.0482, which achieves a 5% significance level. This finding indicates that in order to boosting economic efficiency, marine technology requires both a high level and faster application capabilities. Empirical results show that coastal regions have strong technology and application abilities, such that marine science and technology play an obvious positive role in boosting ocean economic efficiency. Furthermore, this finding confirms that improvements in ocean economic efficiency should not be separated from the scientific and technological progress.

(6) The regional ocean economy development level has a strong, significant, positive impact on ocean economic efficiency. Specifically, ocean economic efficiency increases by 0.1248 units when the regional marine economic development level increases by 1 unit. This finding indicates good development, meaning that the region can provide strong accumulation of human resources and capital. Furthermore, the region is highly efficient in allocating resources in terms of non-input factors such as industrial distribution, policy environment optimization, and technological transformation. Therefore, under the current situation, maintaining a high level of overall regional economic development is a key factor for improving ocean economic efficiency.

5. Conclusions

This study used stochastic frontier analysis (SFA) and panel data to measure ocean economic efficiency in China's 11 coastal regions between 2007 and 2013. Using Moran's I test, this paper analyzed spatial patterns from the two perspectives of spatial distribution and spatial effects in order to identify spatial correlations between ocean economic efficiency and its associated mode. Using the spatial panel model, we identified spatial spillover effects and other key influencing factors. The results demonstrate the following. Firstly, in terms of spatial distribution, coastal areas are generally characterized by high levels of ocean economic efficiency, and longitudinal changes are relative stable in their spatial distribution. Secondly, in terms of spatial effects, overall coastal ocean economic efficiency has a positive spatial correlation and spatial agglomeration. The spatial correlation model did not indicate obvious changes in regional ocean economic efficiency. The "high-high" model regions are Guangdong, Hebei, Tianjin, and Shanghai; the "low-high" model regions are Liaoning, Fujian, and Hainan; the "low-low" model regions are Zhejiang and Guangxi; and the "high-low" model regions are Jiangsu and Shandong. Obvious spatial spillover effects exist, affected significantly by geographical distance. Thirdly, regional openness, the marine technological level, and the regional marine economic development level represent factors with significant positive impact on ocean economic efficiency. In contrast, industrial structure, professional structure, and regional financial development have little significant impact on ocean economic efficiency.

Acknowledgements

This work is supported by the National Science Foundation of China (No. 71471105; 71373247), Research Fund (No. 15ZDB171) and Taishan Scholar Program.

References

Farrell, M.J., 1957. The measurement of productive efficiency. *Journal of the Royal Statistical Society. Series A (General)*, 120(3), pp.253-290.

Ramilan, T. Scrimgeour, F. and Marsh, D., 2011. Analysis of environmental and economic efficiency using a farm population micro-simulation model. *Mathematics and Computers in Simulation*, 81(7), pp.1344-1352.

Aparicio, J. Pastor, J.T. and Zofio, J.L., 2015. How to properly decompose economic efficiency using technical and allocative criteria with non-homothetic DEA Technologies. *European Journal of Operational Research*, 240(3), pp.882-891.

Tao, X. Wang, P. and Zhu, B., 2016. Provincial green economic efficiency of China: A non-separable input-output SBM approach. *Applied Energy*, 171, pp.58-66.

Hailu, K.B. and Tanaka, M.A., 2015. A "true" random effects stochastic frontier analysis for technical efficiency and heterogeneity: Evidence from manufacturing firms in Ethiopia. *Economic Modelling*, 50, pp.179-192.

Zhiying, J., 2012. Evaluation of economic efficiency of coastal regions in China based on stochastic frontier analysis. *East China Economic Management*, 9, pp.63-66.

Changqing, S. Zilun, L. and Fang Ma., 2013. Analysis on regional differences and convergence of China's economic growth technical efficiency. *Urban Problems*, 6, pp.46-51.

Glass, A.J. Kenjegalieva, K. and Sickles, R.C., 2016. A spatial autoregressive stochastic frontier model for panel data with asymmetric efficiency spillovers. *Journal of Econometrics*, 190(2), pp.289-300.

Zhegming, Q. and Xiaochen, L., 2013. Regional differences in China's green economic efficiency and their determinants. *China Population, Resources and Environment*, 7, pp.104-109.

Jianguo, L. *et al.*, 2012. Spatial distribution and its affecting factors of economy efficiency and total factor productivity in China: 1990-2009. *Acta Geographica Sinica*, 8, pp.1069-1084.

Bingyang, L. and Danlin Y., 2009. Improving economic efficiency within the framework of China's tiered development model: An analysis from a spatial perspective. *Social Sciences in China*, 6, pp.60-72, 205-206.

Maravelias, C.D. and Tsitsika, E.V., 2008. Economic efficiency analysis and fleet capacity assessment in Mediterranean fisheries. *Fisheries Research*, 93(1), pp.85-91.

Jamnia, A.R. Mazloumzadeh, S.M. and Keikha, A.A., 2015. Estimate the technical efficiency of fishing vessels operating in Chabahar region, Southern Iran. *Journal of the Saudi Society of Agricultural Sciences*, 14(1), pp.26-32.

Cullinane, K. et al., 2006. The technical efficiency of container ports: comparing data envelopment analysis and stochastic frontier analysis. *Transportation Research Part A: Policy and Practice*, 40(4), pp.354-374.

Odeck, J. and Bråthen, S., 2012. A meta-analysis of DEA and SFA studies of the technical efficiency of seaports: A comparison of fixed and random-effects regression models. *Transportation Research Part A: Policy and Practice*, 46(10), pp.1574-1585.

Qingmin, Y. and Dong F., 2014. The regional difference analysis and production efficiency research of marine strategic emerging industry of China. *Soft Science*, 12, pp.42-45, 64.

Fei, F. Caizhi, S. and Yaoguang, S., 2011. An empirical study on the ocean economic efficiency of coastal cities in the Bohai rim economic circle. *Statistics & Decision*, 6, pp.119-123.

Xin, Z. and Kaiying, G., 2015. Efficiency analysis and evaluation of marine economy in coastal areas based on the GRA-DEA mixed model. *Marine Economy*, 5, pp.5-10.

Lin, Z. et al., 2016. An evaluation of Chinese marine economy efficiency based on SBM and Malmquist productivity indexes. *Resources Science*, (3), pp.461-475.

Shujuan, W. Shaoyu L. and Jianhua X., 2015. On the evaluation of Chinese marine economy green efficiency and its acting factors. *Journal of Industrial Technological Economics*, 11, pp.105-112.

Lili, D. Lin, Z. and Guangshun, H., 2015. Measurement and influencing factors of green total factor productivity of marine economy in China. *Forum on Science and Technology in China*, 2, pp.72-78.

Battese, G.E. and Coelli, T.J., 1992 *Frontier production functions, technical efficiency and panel data: with application to paddy farmers in India*. Springer Netherlands.

Binbin, Y. Hongxiang, Y. and Gang, J., 2015. Can industrial agglomeration improve regional economic efficiency? Based on the spatial econometric analysis of China's urban data. *Journal of Zhongnan University of Economics and Law*, 3, pp.121-130.

Anselin, L., 1995. Local indicators of spatial association-LISA. *Geographical Analysis*, 27(2), pp.93-115.

Fischer, M.M. Scherngell, T. and Reismann, M., 2009. Knowledge spillovers and total factor productivity: Evidence using a spatial panel data model.*Geographical Analysis*, 41(2), pp.204-220.

Guangshun, H. Lili, D. and Weiling S., 2014. *Theory, method and practice of marine economic analysis and evaluation*. Beijing: Ocean Press,

Jun, Z. Guiying, W. and Peng, J., 2004. The Estimation of China's provincial capital stock: 1952-2000. *Economic Research Journal*, 10, pp.35-44.

Bin, D. Gang, J. and Mingfang, H., 2015, Analysis on temporal and spatial evolution of marine science and technology total factor productivity and its influencing factors in Chinese coastal areas. *Geographical Research*, 2, pp.328-340.

Wenzhen, Y. and Xianfu, L., 2012. Analysis of the impact of financial structure on the marine economy in China. *Science & Technology Economy Market*, 7, pp.26-28.