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Chinese Marine Economy Development: Dynamic Evolution and Spatial Difference

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Abstract: This study focuses on China's coastal area and its marine economic development. Applying the information diffusion method, the study establishes a kernel density function and its decomposition using a marine economic per capita as the index of the model to depict the dynamic evolution law and the internal influential factors of the Chinese marine economy during 1996–2013. The relative development rate was introduced to analyze the spatial differences in the marine economy's development. In this way, space and time dimensions fully characterized the evolution of the Chinese marine economy. Additionally, the influence of growth and inequality in the process of its development can be analyzed. The study shows that the Chinese marine economy as a whole has been growing, and regional marine economic development is relatively coordinated. In addition, the marine economy began to develop even more rapidly after 2004. There are three factors affecting the dynamic evolution of China's marine economy: first, the most influential mean effect, followed by, second, the variance effect, and third, the least influential residual effect. The biggest influence on the dynamic evolution of the marine economy is the improvement of the development level of the marine economy in the coastal area. Meanwhile, due to the existence of inequality, provinces at higher development levels are more dispersed. Furthermore, the existence of the residual effect weakens the influence of the mean effect, and the influence on the dynamic evolution of the marine economy continuously increases. In the analysis of the influencing factors of the evolution and spatial difference of marine economic development, the level of opening to the outside world, the level of investment in fixed assets and the industrial structure have a positive role in promoting economic development. However, capital investment in scientific human research has a negative correlation with economic development, and does not pass the significant test. The difference in regional development levels and development speed is also very apparent; namely, the provinces with higher development levels generally displayed faster development speeds while those with lower development levels showed slower development speeds across the four periods analyzed.

Keywords: information diffusion; kernel density function decomposition; marine economic output per capita; coastal area

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1 Introduction

Oceans play an important role in supporting human well-being, specifically in terms of climate regulation and economic activities such as food production (Zhang et al., 2002; 2004; Di et al., 2007; Morrissey et al., 2011; Halpern et al., 2012). With large-scale development and utilization of land resources, people have begun to pay attention to marine resources and their potential economic value as well as to promote development of the marine economy (Zhao et al., 2014). Human activities in the ocean and coastal areas are expanding at an unprecedented scale (Böhnke-Henrichs et al., 2013; Stojanovic and Farmer, 2013). With the development of the

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marine economy, the position and function of the ocean in the national economy is becoming more and more important. Since the latter half of the last century, people have paid more attention to marine resources and the marine economy (Song et al., 2013; Zheng, 2015). Qualitative and quantitative analysis of the marine economy have been carried out in different countries (Kildow and McIlgorm, 2010; Foley et al., 2014; Park and Kildow, 2014; Fernández-Macho et al., 2016). In addition, the legislation, policies, and strategies related to the world's marine and coastal zones have increased significantly (Clarke, 2006; Vivero and Mateos, 2012; Zheng, 2012; Surís-Regueiroet al., 2013; Ye et al., 2013), promoting the development of marine resources and the marine economy.

Since the reform and opening up, Chinese coastal provinces have gradually become the most dynamic regions in China owing to their favorable geographic position and national policy. Since 2000, especially, the status of the marine economy in the overall national economy has been increasing, becoming the new growth point of the Chinese economy (Luan, 2004). In fact, the Chinese gross ocean product (GOP) has increased nearly 19 times over the last decades, from 2.86×10^{11} yuan (RMB) in 1996 to 5.43×10^{12} yuan (RMB) in 2013. Moreover, in 2013, GOP accounted for 9.5% of China's gross domestic product (GDP), an increase of 7.6% over the previous year. Because China's coastal provinces are dispersed geographically around the country, such regional characteristics as their natural resources, social and economic conditions, and levels of science and technology differ significantly. Along with the exploitation of marine resources and the formation of marine economic regions, regional economic differences are becoming increasingly significant (Zhang et al., 2011). Theoretically, modest marine economic differences can be conducive to a comparative regional advantage and can promote the rapid development of the marine economy. However, overly unbalanced economies are not conducive to the sustainable development of the regions (Wu and Wei, 2008). Therefore, it is necessary to study the evolutionary characteristics of the marine economy and the differences between regions should be placed on the research agenda.

In recent years, the regional differences in the marine economy have been a concern of many scholars and related research on this topic has become increasingly rich. These studies cover marine economic development and regional differences, including regional differences in spatial and temporal characteristics (Wang, 2012; Di et al., 2013), the exploration of inherent mechanisms (Han and Xu, 2008; Zhang et al., 2010), and comprehensive strength difference evaluations (Gao et al., 2015). The coefficient of variation (Lin and Han, 2014; Zhang et al., 2015), Gini coefficient (Rozelle and Boisvert, 1995), and the Theil index (Kanbur and Zhang, 1999; Fujita and Hu, 2001; Han and Xu, 2008) are commonly applied in most studies. Currently, the trend is to utilize these methods comprehensively (Di et al., 2013). These methods are easy to understand and compare, but they can only be used to reflect the unilateral characteristics of the marine economy. Therefore, it has been difficult to measure the overall distribution of the marine economy accurately. Moreover, by constructing marine production, employment, and specialization, for example, as specific indicators (Morrissey and O'Donoghue, 2012; Colgan, 2013; Morrissey, 2014), or from a specific analysis point (Jiang et al., 2014), some scholars have identified the development of the marine economy gap between regions. Existing research methods indicating the law of the dynamic evolution of the marine economy in time variation are still insufficient. And there is relatively little research on the evolution of the marine economy over time. Based on the kernel density function and its two-effect decomposition model, Sun and Li (2015) studied the dynamic evolution law and the spatial difference of the marine economy development in China. However, their decomposition of the kernel density function was not complete; the spatial differences of the coastal provinces were not analyzed in detail and no internal reasons were provided for the differences in space.

Based on previous studies, this study takes the research further. There is relatively little research on the evolution of the marine economy over time. The dynamic evolution law of Chinese marine economy development during the sample years is described by a visual density distribution map over time in this study. In addition, this study for the first time decomposes a kernel density function of the marine economy into three factors. Furthermore, the three internal mechanisms that influence the annual distribution difference in the marine economy are identified and the impact extent of the three factors on the distribution of the marine economy is determined. This study adds explanatory variables to provide reasons for the evolution and spatial difference of the marine economy behind the three factors. This study not only shows the process of marine economic development and spatial phenomenon, but also links the cause and mechanism of explanatory variables to explain the process and spatial distribution patterns, giving this study rich theoretical depth and practical explanation. Second, a relative development rate is introduced. Therefore, for the first time, from the two aspects of the development level and development speed, this study analyzes regional differences in detail alongside proposals to reduce such regional differences effectively. The impact of growth and the inequality in the evolution of the marine economy in the process of its development is analyzed from the angles of both time and space.

This study provides significant information and insights to grasp China's marine economy situation accurately, understand the internal mechanism driving the development trends, formulate scientific development policy for the marine economy, and promote the coordinated, sustainable development of the marine economy.

2 Materials and Methods

2.1 Study area

The Chinese coastal provinces from north to south are Liaoning, Hebei, Tianjin, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Guangxi, and Hainan (Fig. 1a), covering the Circum-Boha, Yangtze River Delta, and Pearl River Delta regions. As data are unavailable, Taiwan Province, Hong Kong, and Macao special administrative regions were excluded from the study areas. The Chinese sea area is vast and the coastal area is rich in marine resources. The total length of the coastline is about 32 000 km, of which the mainland coastline is 18 000 km and island coastlines are 14 000 km. Rich marine resources compensate for the shortage of land, providing an important guarantee for the development of the marine economy (Zhang, 2000; Sun and Zhao, 2011). With the continuous development of marine resources, the scale of the marine economy has been expanding (Fig. 1b); however, the gap between marine regions is becoming increasingly marked and the absolute gap (i.e., the gap between the maximum and minimum GOP of coastal areas in each year) continues to expand (Table 1).

2.2 Methodology

2.2.1 Kernel density estimation

As a method, the kernel density estimation (Rosenblatt, 1956; Parzen, 1962; Kumar and Russell, 2002; Massaro et al., 2013) is used in probability theory to estimate an unknown kernel function and is a non-parametric processing method. Kernel density estimation can estimate probability density directly from the data, without relying on any assumption about the form of the data's distribution. It is a method use to study data distribution characteristics from the data sample itself. By using kernel density estimation in this study, we can observe the position, stretch, and mode characteristics of the marine economy's distribution to obtain an intuitive and clear description of it overall. The kernel density estimation parameters can be set arbitrarily, and the distribution

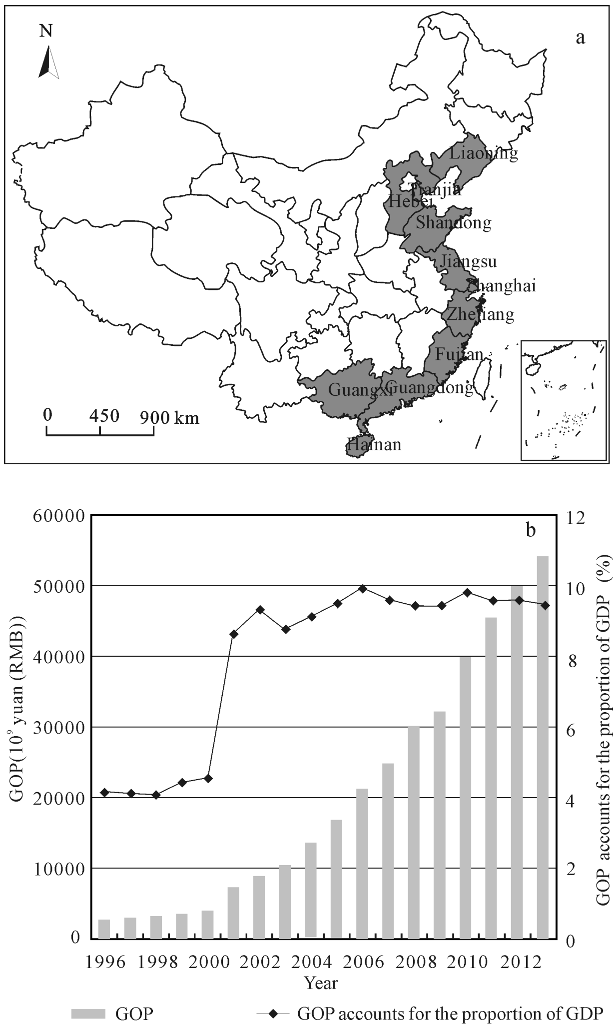

Fig. 1 Basic status of coastal provinces in China. a. Coastal regions of China; b. GOP and the change of GOP in GDP from 1996 to 2013

Table 1 Marine economy differences in coastal provinces

Coastal provinces	GOP of coastal areas accounting for the proportion of total GOP (%)		GOP of coastal areas accounting for the proportion of economy in the region (%)		GOP of coastal areas (10^9 yuan (RMB))		Added value of major marine industries (10^9 yuan (RMB))		Annual average increasing rate of GOP (%)
	1996	2013	1996	2013	1996	2013	1996	2013	1996–2013
Liaoning	7.38	6.89	6.57	13.82	207.52	3741.9	80.26	1857.2	6.81
Hebei	1.94	3.21	1.58	6.15	54.5	1741.8	26.28	851.6	6.58
Tianjin	3.96	8.38	10.11	31.69	111.4	4554.1	56.8	2235.2	5.78
Shandong	18.26	17.85	8.62	17.73	513.74	9696.2	280.05	4232.7	7.7
Jiangsu	4.43	9.06	2.08	8.32	124.61	4921.2	66.13	2054.9	6.58
Shanghai	11.98	11.61	11.61	29.19	336.85	6305.7	68.36	2335.3	7.42
Zhejiang	10.24	9.68	6.95	14	288.16	5257.9	116.36	2078.2	7.22
Fujian	9.49	9.26	10.24	23.11	266.87	5028	116.68	2091.4	7.18
Guangdong	28.09	20.78	12.12	18.15	790.13	11283.6	215.93	4040.3	7.98
Guangxi	2.71	1.66	4.07	6.26	76.14	899.4	39.68	461.9	5.33
Hainan	1.53	1.63	11.04	28.08	43.02	883.5	20.19	442.5	5.29

of the explanatory variables and the explained variables are limited only marginally. Kernel density estimation is used mainly used to describe economic distribution by the kernel function, which retains the original dynamic information of the observed value of continuous income when constructing the transition-probability matrix. There is no need to limit the data generation process with Markov properties. The basic principles of the kernel density estimation method are as follows.

In this study, it was assumed that X_1, X_2,…, X_n obey the same distribution and their kernel function $f(x)$ is unknown. It was necessary to estimate the kernel function $f(x)$ through the sample. The empirical distribution function of the sample is

$$F(x) = \frac{1}{n}\{X_1, X_2, ..., X_n\} \tag{1}$$

In this study, the kernel function is uniform and the function was estimated as

$$\begin{aligned} f_h(x) &= \frac{[F_n(x+h_n)] - F_n(x-h_n)}{2h} \\ &= \int_{x-h_n}^{x+h_n} \frac{1}{h} K(\frac{t-x}{h_n}) \mathrm{d}F_n(t) \\ &= \frac{1}{nh_n}\sum_{i=1}^{n} K(\frac{x-x_i}{h_n}) \end{aligned} \tag{2}$$

where $K(x)$ represents kernel function and h represents window width or a smoothing parameter.

2.2.2 *Information diffusion*

A large quantity of sample data is needed in the application of kernel density estimation (Poluektov, 2015). In this study, 18 years of data from coastal area were used, which is a rather small sample. In order to make up for the lack of information, the information diffusion approach was used to deal with the data. Information diffusion (Zhang et al., 2009) is a kind of fuzzy mathematics method and that does require the assumption that the distribution of the parameters has been estimated in advance. In addition, even when information is insufficient, the results can be analyzed as accurately as possible. When a given sample is not complete, it will diffuse the information of the single sample to all points of a designated area, thereby maximizing the useful information and making up for the lack of information. According to the characteristics of the evolution of the marine economy, this study used the non-linear normal information diffusion function (Huang, 2005; Sun et al., 2014) to construct the membership function. The principle is as follows.

Assuming that the index domain of the study is U, $U = \{u_1, u_2, …, u_n\}$, u_i represents a certain value in the field and n represents the number of values in the domain. Setting an index sequence and assuming the single observation sample is y_j, $y_j=\{y_1, y_2…, y_m\}$, m represents sample numbers. Information about the single-valued observation samples y_j is diffused to all points in the domain U. Thus, the information diffusion estimation is

$$f_j(u_i) = \frac{1}{h\sqrt{2\pi}} \exp\left[-\frac{(y_j - u_i)^2}{2h^2}\right] \tag{3}$$

where $i = 1, 2, 3\ldots, n$; $j = 1, 2, 3,\ldots, m$, $f_j(u_i)$ represents the amount of information about the observation sample value, which is diffused from y_j to u_i, u_i represents the value of the domain, m represents sample numbers of evaluation indicators, and h represents the diffusion coefficient. h can be determined according to the minimum and maximum value of samples in the sample set and sample numbers m. Because $f_j(u_i)$ is the same as the form of the normal distribution function, it is also called a normal diffusion function. In order to estimate a probability kernel function using normal diffusion, $f_j\left(\frac{x - x_i}{\Delta f_j}\right)$ was taken as the $f_j(u_i)$ and then, the following formula was obtained:

$$\hat{f}_h(x) = \frac{1}{nh\sqrt{2\pi}} \sum_{i=1}^{n} \exp\left(-\frac{(x - x_i)^2}{2h^2}\right) \tag{4}$$

$\hat{f}_h(x)$ represents the normal diffusion estimation of the sample $f_h(x)$. h represents the window width of the normal diffusion function, and the calculation formula is

$$h = \begin{cases} 0.8146(b-a)\ldots\ldots\ldots\ldots\ldots n = 5 \\ 0.5690(b-a)\ldots\ldots\ldots\ldots\ldots n = 6 \\ 0.4560(b-a)\ldots\ldots\ldots\ldots\ldots n = 7 \\ 0.3860(b-a)\ldots\ldots\ldots\ldots\ldots n = 8 \\ 0.3362(b-a)\ldots\ldots\ldots\ldots\ldots n = 9 \\ 0.2986(b-a)\ldots\ldots\ldots\ldots\ldots n = 10 \\ 2.6851(b-a)/(m-1)\ldots\ldots n \geq 11 \end{cases} \tag{5}$$

where $a = \min_{1 \leq i \leq n}\{x_i\}$ and $b = \max_{1 \leq i \leq n}\{x_i\}$.

When n is greater than or equal to 11, then the effective root number is 0.9330 and the adjustment coefficient is 2.6851. h represents the assumed simple coefficient based on the average distance. The normal diffusion estimation that uses h is called the simple diffusion estimation. Roughly speaking, for small samples, the error of the simple normal diffusion estimation is 38% less than that of the soft histogram estimation (Huang, 2012).

2.2.3 Kernel density function decomposition

Kernel density function estimation can reflect the overall changes in the distribution of the marine economy, but it does not identify which factors benefit the development of the marine economy. In order to analyze the internal mechanism for the changes in marine economic development and to determine the impact extent of various factors on the distribution of the marine economy, this study used the method of kernel density function decomposition (Jenkins and van Kerm, 2005; Liu et al., 2009; An et al., 2012) and the relevant indices were decomposed. By describing the dynamics of the provincial marine economy kernel density function during the base period and the reporting period, we investigated the reasons for inter-annual changes in the marine economy. The step is as follows.

$$\Delta f(x) = f_{t_1}(x) - f_{t_0}(x) \tag{6}$$

where t_1 and t_0 represent the year of the reporting period and that of the base period, respectively. $f_{t_1}(x)$ and $f_{t_0}(x)$ represent the result of the kernel density function estimation in the reporting period and in the base period, respectively. $\Delta f(x)$ represents the density difference at the same economic level of the reporting period and base period.

A better characterization of marine economic growth in the density function should be capable of observing three kinds of distribution characteristics at the same time (Cowell et al., 1996), that is, the position, stretch, and modes of the marine economic development distribution (Burkhauser and Rovba, 2005). Then, an intuitive and clear description of the overall distribution of the marine economy can be observed. Thus, the changes of the distribution kernel density function can be divided into three parts. The first is the shift of the density function, which is also called the mean effect. This occurs under the assumption that the stretch and modes of the density function remain unchanged and the density function changes only along the mean income level. The position of the whole curve reflects the development level and the changes of the marine economy in coastal areas. If the density function moves to the right, it indicates that the overall level of the marine economy improved. The second part is the stretch of the density function, which is also called the variance effect. This occurs under the assumption that the mean and basic modes are the same and only the distribution variance changes. The stretch reflects the inequality of economic development between coastal provinces. If the distribution extends to both sides, the variance is enlarged, indicating that inequality in the marine economy increases. The third part is the deformation of the density function, which is called the residual effect. It is assumed that the mean and variance remain unchanged and only the distribution pattern is deformed. As the residual effect is related to a complex two-order transformation and reflects the existence of heterogeneous groups, it usually presents as an irregular shape.

Through the analysis of the factual function (Jenkins and van Kerm, 2005), the change of the density function was divided into three parts:

$$\Delta f(x) = CD_1(x) + CD_2(x) + CD_3(x) \tag{7}$$

where $CD_1(x)$,$CD_2(x)$, and $CD_3(x)$ represent the shift, stretch, and modes of the graph under the density function, respectively, which are under the control of the other two unchanged factors.

Assume that the kernel density function in t period is $f_t(x, \mu, h_t)$. μ_t represents the mean value of the function in t period, h_t represents the window width of the function variance in t period, and then, $f_{t0}(x, \mu_{t0}, h_{t0})$ and $f_{t1}(x, \mu_{t1}, h_{t1})$ represent the density function of the base and reporting periods, respectively. An anti-factual function $\xi_{t1}(x, \mu_{t1}, h_{t0})$ was constructed, which incorporates the mean change. μ_{t1} represents the mean value of the reporting period and h_{t0} represents the variance of the base period.

The expression of the mean effect is

$$CD_1(x) = \eta[\zeta_{t_1}(x, \mu_{t_1}, h_{t_0}) - f_{t_0}(x)] + (1-\eta) [\zeta_{t_1}(x, \mu_{t1}, h_{t_1}) - \zeta_{t_1}(x, \mu_{t_0}, h_{t_1})] \tag{8}$$

In the same way, an anti-factual function that incorporates variance $\xi_{t1}(x, \mu_{t1}, h_{t0})$ was constructed, and the expression of the variance effect is

$$CD_2(x) = \eta[\zeta_{t_1}(x, \mu_{t_1}, h_{t_1}) - \zeta_{t_1}(x, \mu_{t_1}, h_{t_0})] + (1-\eta) [\zeta_{t_1}(x, \mu_{t_0}, h_{t_1}) - f_{t_0}(x)] \tag{9}$$

When decomposing the residual effect, an anti-factual function $\xi_{t1}(x, \mu_{t1}, h_{t1})$ was constructed, and the expression of the residual effect is

$$CD_3(x) = f_{t_1}(x) - \zeta_{t_1}(x, \mu_{t_1}, h_{t_1}) \tag{10}$$

In summary, the kernel density function is expressed as

$$\Delta f(x) = \eta\left[\zeta_{t_1}(x, \mu_{t_1}, h_{t_0}) - f_{t_0}(x)\right] + (1-\eta)\left[\zeta_{t_1}(x, \mu_{t_1}, h_{t_1}) - \zeta_{t_1}(x, \mu_{t_0}, h_{t_1})\right] + \eta\left[\zeta_{t_1}(x, \mu_{t_1}, h_{t_1}) - \zeta_{t_1}(x, \mu_{t_1}, h_{t_0})\right] + (1-\eta)\left[\zeta_{t_1}(x, \mu_{t_0}, h_{t_1}) - f_{t_0}(x)\right] + f_{t_1}(x) - \zeta_{t_1}(x, \mu_{t_1}, h_{t_1}) \tag{11}$$

The value of η determines the different decomposition order, $\eta \in [0,1]$, where the value of η has no effect on the final decomposition. In this study, η=1, that is, the mean effect is decomposed, the variance effect follows, and the remainder is the residual effect.

2.2.4 Regression analysis

This study divided the driving factors of marine economic evolution into three factors, revealing the direction and extent of the impact of these factors. The evolution characteristics and influencing factors of marine economic development are demonstrated from the time dimension. In order to find out the specific relevant points behind the three factors that influence the development of the marine economy, and to provide a theoretical basis for the Chinese government to develop a more targeted marine economic development strategy, regression analysis was used to explain the reason for and mechanism of the process and the spatial distribution pattern of the marine economy with the explanatory variables. This study used STATA (Su et al., 2013; Zhao et al., 2016) software to analyze the representative factors that might affect the evolution of the marine economy based on the regression analysis method. The dependent variable is per capita marine output value. With reference to the relevant literature, the explanatory variables are per capita fixed assets investment (X1), human capital investment in marine scientific research (X2), total export-import volume (X3), and the tertiary marine industry output value accounting for the proportion of GOP (X4), which represent investment level, marine scientific research human capital investment level, the level of regional opening up, and the level of marine industrial structure, respectively.

2.2.5 Relative development rate

The relative development rate (Nich) (Ouyang, 1993; Wu and Wei, 2008) can reflect the relative development speed of each area and can indirectly reflect the marine economic development level of the regions. In this study, the relative development rate was used to calculate the marine economic development of the 11 regions in four time periods and to reflect spatial differentiation characteristics of marine economic development.

The formula is:

$$Nich = \frac{y_{2_i} - y_{1_i}}{y_2 - y_1} \tag{12}$$

where y_{1_i} and y_{2_i} represent marine economic output per capita in region i in the base and reporting periods, respectively. y_2 and y_1 represent marine economic output per capita of all coastal provinces in the reporting and base periods, respectively.

2.3 Data sources and processing

The marine economy is the summation of various types of industrial activities for developing, utilizing, and protecting oceans as well as associated activities (Liu, 2012). The statistical scope of the Chinese marine economy includes the marine industry and marine-related industries (Jiang et al., 2014). The collection of marine data at the provincial scale began in 1996 (Sun et al., 2015). Hence, in this study, we chose 11 coastal provinces and cities in China during 1996–2013 for the research investigation. Marine data are extracted from the China Marine Statistical Yearbook (State Oceanic Administration of China, 2014) and China Statistical Yearbook (National Bureau of Statistics of China, 2014). Considering comparability and accuracy, the relevant index data over 18 years were processed and divided into four periods with cut-off points of 1996, 2000, 2004, 2008 and 2013. The indicator reflecting the level of marine economic development is usually marine production; however, total marine production is affected by the regional population. Marine economic output (Han and Xu, 2008) per capita is a relative index that can more accurately reflect the marine economy in coastal areas. Thus, in this study, marine economic per capita which is divided by resident population (Di et al., 2013; Zhang et al., 2015) is the index used. The distribution of kernel density in each year was calculated based on the indicator of the logarithm obtained on marine economic output per capita. We used the logarithm obtained on marine economic output per capita due to the large amount of data and the data after the logarithm being more normally distributed.

3 Results and Discussion

3.1 Dynamic evolution analysis

Fig. 2 shows the distribution of the kernel density function of Chinese marine output per capita and reflects the dynamic evolution of the marine economy. The following information is pertinent.

The overall shape (Fig. 2a) shows a single-peak distribution pattern for marine output per capita of Chinese coastal provinces. There is no double or multi-peak phenomenon and no obvious polarization phenomenon. Overall, the development of the marine economy was relatively harmonious in the coastal areas. There is a trend to the right of the whole density curve of 1996–2013. This shows that the total GOP of China's coastal area has been continuously increasing year by year. In addition, Fig. 2a shows that the kurtosis value continuously moved to the right, and the corresponding peak density rose. This indicates that the medium level of marine economic development in the region was increasing and moving toward high levels. The curve began to show a slight right skewness in 2004, showing that the marine economy began to develop even more rapidly after 2004. This is closely related to the national marine economic development plan outline, which established guidelines and targets for developing the marine economy.

The intersections of the annual density difference curve and the horizontal line (Fig. 2b) is regarded as the low and high demarcation points of marine economic output per capita. The intersection and density curve moved to the right and the area on the right side of the intersection was enlarged, indicating that coastal provinces with low and medium development levels moved continuously in the direction of high levels of development, and thus, the cut-off points continued to move to the right and the coastal provinces at high development levels gradually increased. By gradually paying attention to the development of the marine economy and by introducing advanced technology, coastal provinces at relatively low levels of marine economic development grew significantly and promoted the overall development level.

3.2 Kernel density decomposition analysis

The provincial marine economy distribution density

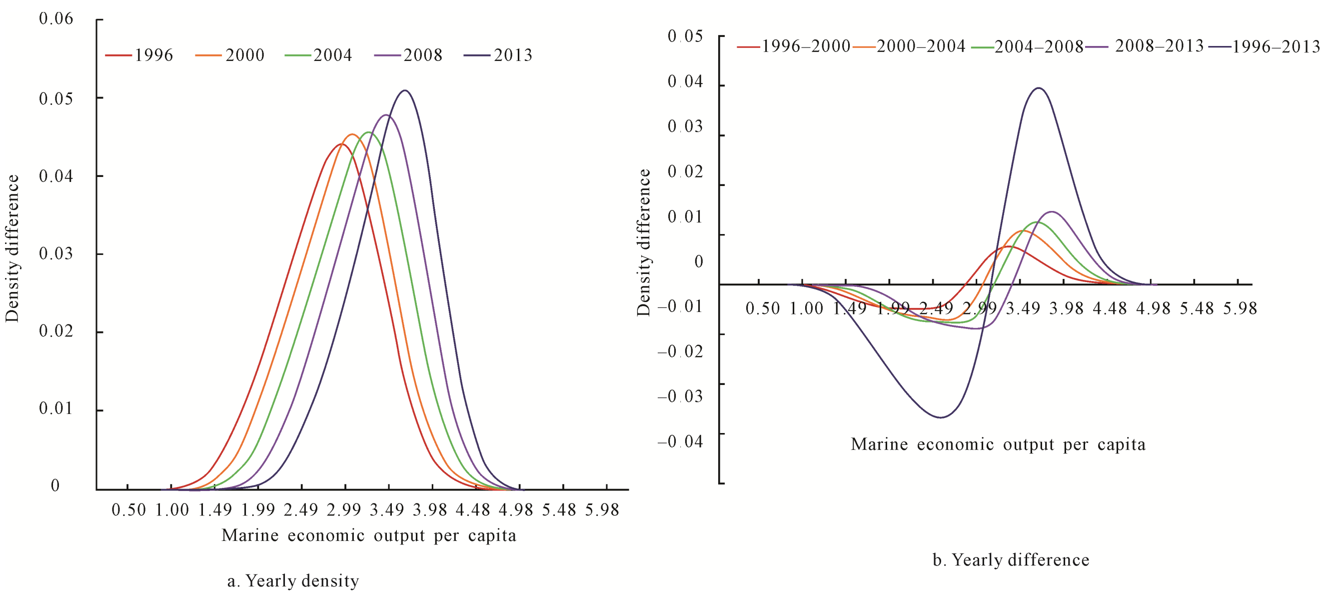

Fig. 2 Distribution density of marine economic output per capita and density difference in coastal area

function showed only the overall changes of economic conditions. Further application of kernel density decomposition is needed to determine which factors caused the evolution pattern of marine economic development and how each factor influenced the ocean economy growth. Using the factor decomposition method, the distribution density curve of the marine economic annual difference was decomposed, divided into mean effect, variance effect, and residual effect. From the decomposition diagram of the density function, the relative position of the decomposition curve and horizontal line determined whether the effect was positive or negative. If the decomposition curve was above the horizontal line, the decomposition curve was in the same direction as the total difference curve and the contribution of the decomposition curve was positive. By contrast, if the decomposition curve was below the horizontal line, the decomposition curve was opposite to the direction of the change of the total difference, and then, the contribution of the decomposition curve was negative. If the decomposition curve coincided with the horizontal line, the contribution of the decomposition curve was 0. The relative distance between the decomposition curve and the horizontal line determined the degree of influence. If the decomposition curve was farther away from the horizontal line, or the area between the decomposition curve and the horizontal line was larger, then this decomposition effect made a greater contribution to the overall difference curve, and vice versa. The distribution function of the total difference of marine output per capita was decomposed into 1996–2000, 2000–2004, 2004–2008, and 2008–2013. In order to compare the influencing degree of the three effects, different vertical coordinates were used (Fig. 4 and Fig. 5). The results are as follows.

First, the change in direction of the mean effect (Fig. 3) is basically the same as the annual distribution difference curve (Fig. 2b). This accounted for the largest proportion of the total effect of distribution differences, indicating that the biggest influence on the dynamic evolution of the marine economy is the improvement of the development level of the marine economy in the coastal area. The left side of the intersection of the horizontal line and the mean effect curve can be regarded as low marine economic development levels. The right side of the intersection can be regarded as high marine economic development levels. In Fig. 3, it can be observed that the density distribution of high levels of marine economic output per capita shows an upward trend. The density curve and cut-off point continuously moved to the right. Because of the rapid development of the marine economy in some coastal provinces, the density distribution flowed from low marine economy development levels to high marine economy development levels, promoting the improvement of the overall marine economy.

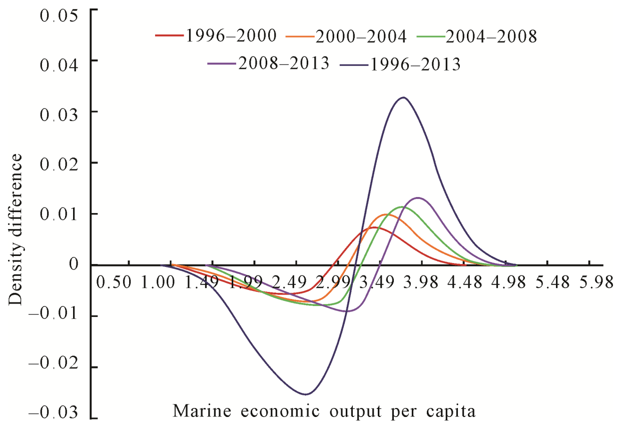

Fig. 3 Decomposition effect of density difference of marine output per capita—mean effect

Second, the influencing factor of second-most importance is the variance effect. The variance effect reflects the degree of differentiation of the whole marine economic density difference. Fig. 4 shows that the variance effect is mainly reflected as negative effects on low levels of marine output per capita and positive effects on high levels. Moreover, the positive effects are far greater than the negative effects. The left side of the second intersection of the horizontal line and the variance effect, the curve and the annual difference curve performed in the same direction, indicating that the existence of inequality concentrates density in the low and middle level provinces. However, the right side showed the opposite, indicating that the variance effect reduced the density of overall distribution of density differences of provinces at higher development levels. Additionally, due to the existence of inequality, provinces at higher development levels were more dispersed. Of note, in order to compare the degree of the three effects directly, we used two kinds of vertical coordinates in the variance effect and residual effect. Computation results showed that the influencing degree of the variance effect was less than that of the mean variance effect.

Third, the effect of the residual effect was the lowest. This indicates that the distribution modes in different years changed due to heterogeneity. Although the residual effect occupied a certain position in the whole distribution difference, its influence was relatively small and of lowest importance. As observed from Fig. 5, the residual effects were both positive and negative at low and high levels of marine economic development. In the four time periods of 1996–2013, the residual effect curve moved farther and farther away from the horizontal coordinate and the influence of the density difference curve grew bigger and bigger. The existence of the residual effect weakened the influence of the mean effect, which can not be ignored in the whole distribution curve.

3.3 Analysis of factors affecting development of the marine economy

Table 2 shows that the coefficient of marine scientific research personnel was negative, which is consistent with the conclusion of Su et al. (2013). In marine economic activities, although the number of marine scientific studies continues to increase, the research cannot be better applied to the development of the marine economy, as there are few scientific and technological

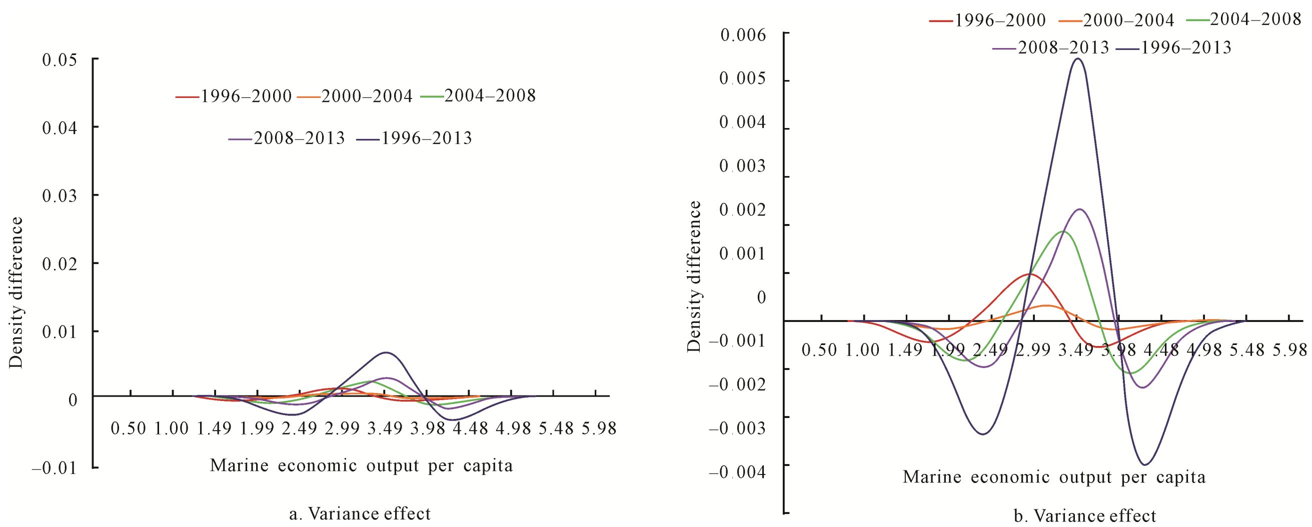

Fig. 4 Effects of decomposition of density difference of marine output per capita—variance effects (under different vertical coordinates)

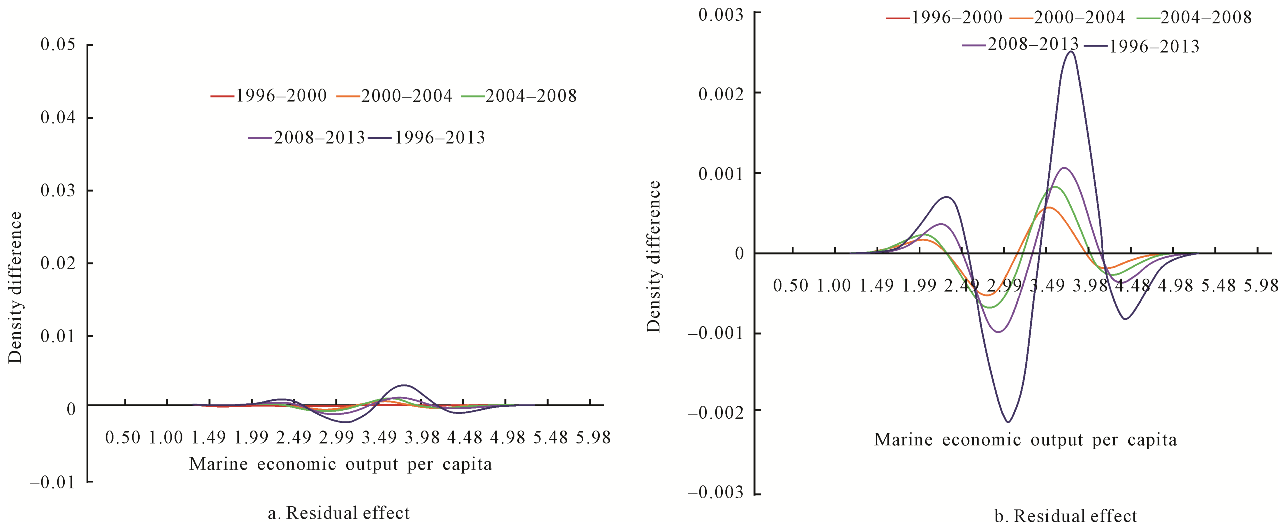

Fig. 5 Effects of decomposition of density difference of marine output per capita—residual effects (under different vertical coordinates)

Table 2 Regression results of influencing factors of marine economy dynamic evolution

Coefficient	*SE*	*z*	*P*>|*z*|	*Y*
*X*1	0.1456555	0.0521656	2.79	0.005
*X*2	−0.034364	0.0433174	-0.79	0.428
*X*3	0.3218535	0.0486001	6.62	0.000
*X*4	0.4065093	0.1798664	2.26	0.024
Cons	2.924448	0.3246269	9.01	0.000

Notes: *X*1 *means* per capita fixed assets investment, *X*2 means human capital investment in marine scientific research, *X*3 means total export-import volume, *X*4 means the third industry output value accounted for the proportion of gross domestic product, cons means constant

achievements. In addition, more scientific research personnel represent an increase in fiscal expenditure. This implies that the technological progress of the marine economy did not come from endogenous technological innovation, but to a large extent from the imitation of foreign technology (Zhao et al., 2016). In addition, the number of marine scientific research personnel did not pass the significance test, implying that a large number of inputs of human, material, and financial resources did not bring huge scientific and technological progress or increase the output of the ocean.

Regional investment level, opening level, and industrial structure have positive effects on the development of the marine economy. The industrial structure has played a significant role in promoting the development of the marine economy. By opening to the outside world, the coastal area has introduced foreign capital and foreign advanced technology to promote the rapid development of the marine economy. In addition, the level of investment in a region reflects the government's policy aims, which obviously promote the development of the local marine economy. Therefore, in the future, China should increase national policy support for the marine economy and improve the level of investment to develop lagging areas of the marine economy. Because of ocean transportation and coastal tourism within the marine economy, tertiary industries can directly use the marine space, which has a strong intervention effect and a high economic effect. In recent years, coastal provinces have been listed as one of the leading industries of coastal tourism development, promoting the development of the marine tertiary industry and the marine economy. The marine industry structure, investment level, degree of opening to the outside world, among other factors, promote the development and evolution of the marine economy in the coastal area, and leads to the existence of differences of the marine economy in the coastal area.

3.4 Spatial difference analysis

The Gini coefficient (Dalton,1920) of per capita marine production value in the coastal provinces was calculated for 1996–2013, and the results showed that the marine economic disparity between regions was decreasing, from 0.4193 in 1996 to 0.3564 in 2013 (Table 3), indicating that the gap was reasonable (Cheng et al, 2016). The regional marine economic development level can be measured from the two aspects of development scale and development speed (He et al, 2014). In order to further investigate the spatial difference of marine economic development in coastal area, this study introduced an index of the relative development rate, *Nich*, and calculated the relative development rate of coastal provinces in the four periods: 1996–2000, 2000–2004, 2004–2008, and 2008–2013. We divided the characteristics of the *Nich* values into two: faster and slower development speeds. If the value of *Nich* was greater than 1, meaning, faster development, the average marine economic development speed of the area would have been faster than that of all coastal provinces. If the value of *Nich* was less than 1, meaning, slower development, the average marine economic development speed of the are would have been slower than all coastal provinces.

As observed from Table 4, provinces with faster development rates during 1996–2013 were Tianjin, Shandong, Shanghai, Fujian, and Guangdong. The development rates of Hebei, Jiangsu, Guangxi, and Hainan provinces were lower than the coastal area average. In 1996–2000, the relative development rate in Guangdong was at a slower level, but after 2000, its relative development rate was at a faster level. In addition, development speeds of Liaoning moved from a lower rate to a faster one during 2008–2013. However, Zhejiang is the only province that moved from a faster development rate to a lower one during 2008–2013. Fig. 6 shows that the marine economy development level was significantly different within the coastal areas and their relative development rates were relatively large. Among them, the marine economic development levels of Tianjin, Shandong, Shanghai, Zhejiang, Fujian, and Guangdong were relatively strong and the Liaoning, Hebei, Jiangsu, Guangxi, and Hainan provinces were relatively weak. The Shanghai, Guangdong, and Tianjin marine economies are in the leading positions with high marine economic development levels and fast development speeds. The reasons for this are that, on the one hand, at the beginning of the reform and opening up, the Pearl River Delta was the first to implement special policies in economic activities, foreign investment was concentrated in the southeast coastal areas, and the level of foreign investment in Guangdong province was higher. With the continuous progress in the reform and development, foreign investment to the coastal area gradually spread to the north, coupled with the great potential of Shanghai to build an international economic, trade, financial and shipping center to attract foreign investment. Shanghai was the main recipient of foreign investment, and has developed an export-oriented economy, and thus, its marine economic foundations were relatively stronger. On the other hand, the reason for the leading positions of Shanghai, Guangdong, and Tianjin was their high levels of marine science and technology. Shanghai and Guangdong form one regional growth pole with strong driving effects on the regions, and the role of agglomeration has led to the expansion of regional spatial differences and non-equilibrium (Han and Xu, 2008). There was a large gap between Guangxi, Hebei, and the other provinces in terms of marine resources, economic conditions, and the level of marine science and technology, resulting in weak marine economies with slow development speed in Guangxi and Hebei. Their tertiary marine industry development levels and the degree of opening to the outside world are low and have slow development speeds. The government should give more policy and financial support to Hebei and Guangxi provinces. These provinces should, based on their own advantages, constantly change their mode of economic development, improve the level of opening up to the outside world, and introduce foreign capital and advanced science and technology to enhance their levels of marine economic development. The total marine economy output value in Hainan is also low, but due to its smaller population, its per capita marine output is relatively high. However, its marine economic development foundation is weak, and its marine science and technology level is low. Nonetheless, in recent years, the development speed of its marine economy has increased. The Hainan coastal resources and coastal tourism resources should be further strengthened in the future, the development of the tertiary marine industry should be promoted, and the upgrading of the industrial structure should be promoted in order to enhance the development of the marine economy. The marine economy of Liaoning developed faster than the national average in 2008–2013. Since the development planning of the marine economy in Liaoning province in the 11th Five-Year Plan and the development planning of Liaoning coastal economic belt, along with other polices that have been put in place, competitive advantage of the marine industry has been promoted. With this, the development speed of the marine economy has improved, showing great potential for the future. Zhejiang has the

Table 3 Gini coefficient of per capita marine production value in the coastal provinces in 1996–2013

Year	1996	1998	2000	2002	2004	2006	2008	2010	2012	2013
Gini coefficient	0.4193	0.4232	0.4144	0.4120	0.4089	0.3971	0.3844	0.3674	0.3594	0.3564

Table 4 Comparison of relative development rate of coastal areas

	1996–2000	2000–2004	2004–2008	2008–2013
Faster development (*Nich*>1)	Tianjin (2.17) Shandong (1.19) Shanghai (3.56) Zhejiang (1.14) Fujian (1.71)	Tianjin (2.46) Shandong (1.14) Shanghai (2.81) Zhejiang (1.18) Fujian (1.23) Guangdong (1.73)	Tianjin (2.03) Shandong (1.20) Shanghai (2.15) Zhejiang (1.05) Fujian (1.47) Guangdong (1.52)	Liaoning (1.04) Tianjin (2.33) Shandong (1.23) Shanghai (1.70) Fujian (1.76) Guangdong (1.35)
Slower development (*Nich*<1)	Liaoning (0.82) Hebei (0.17) Jiangsu (0.37) Guangdong (0.96) Guangxi (0.23) Hainan (0.71)	Liaoning (0.79) Hebei (0.13) Jiangsu (0.34) Guangxi (0.22) Hainan (0.71)	Liaoning (0.91) Hebei (0.14) Jiangsu (0.36) Guangxi (0.30) Hainan (0.76)	Hebei (0.14) Jiangsu (0.39) Zhejiang (0.91) Guangxi (0.39) Hainan (0.93)

longest coastline in China, with rich biological, mineral, and coastal tourism resources, better marine resource endowment and marine economic strength. However, in recent years, due to the constraints of the level of marine science and technology, the speed of the development of its marine economy has slowed. In the future, it should take full advantage of its resources, improve its level of marine science and technology, and break the development bottleneck, thereby enhancing its speed of development.

Therefore, the regional economic development levels and development speeds of the marine economy in the coastal areas differ. In summary, the provinces with higher development levels generally display faster development speeds. On the other hand, the provinces with lower development levels show lower development speeds across the four periods. The marine economic gap among regions will continue to exist in the future. Therefore, there is a need to coordinate marine economic development among regions.

4 Conclusions

Based on the information diffusion method, this study used the kernel density function estimation method to depict marine economic development and evolution in a time dimension in China of the past few decades, thereby contributing to the previous literature, which lacked analysis of the time dimension. In addition, the distribution of the marine economy was for the first time decomposed by three factors to analyze the internal mechanism influencing this distribution. In addition, explanatory variables were added for the quantitative analysis of the internal mechanism behind the three factors, providing a theoretical basis for the Chinese government to develop a more targeted marine economic development strategy. Furthermore, the spatial differences in the marine economy were analyzed using a relative development rate within the space dimension. In the two dimensions of time and space, this study reflects the trends of development and evolution of the marine economy and the internal mechanism. The main conclusions are as follows.

1) The total marine economy of China's coastal area has been increasing continuously year by year. Marine economic development levels among coastal provinces are relatively coordinated. Coastal provinces with low development levels moved continuously in the direction of medium and high development levels and the marine economy began to develop even more rapidly after 2004. 2) The dominant effect on the dynamic evolution of the marine economy was the mean effect, followed by the variance effect, while the residual effect was weakest. The biggest influence on the dynamic evolution of the marine economy was the improvement of the development level of the marine economy in the coastal area. Meanwhile, due to the existence of inequality, provinces at higher development levels were more dispersed. Furthermore, the existence of the residual effect weakened the influence of the mean effect, and the

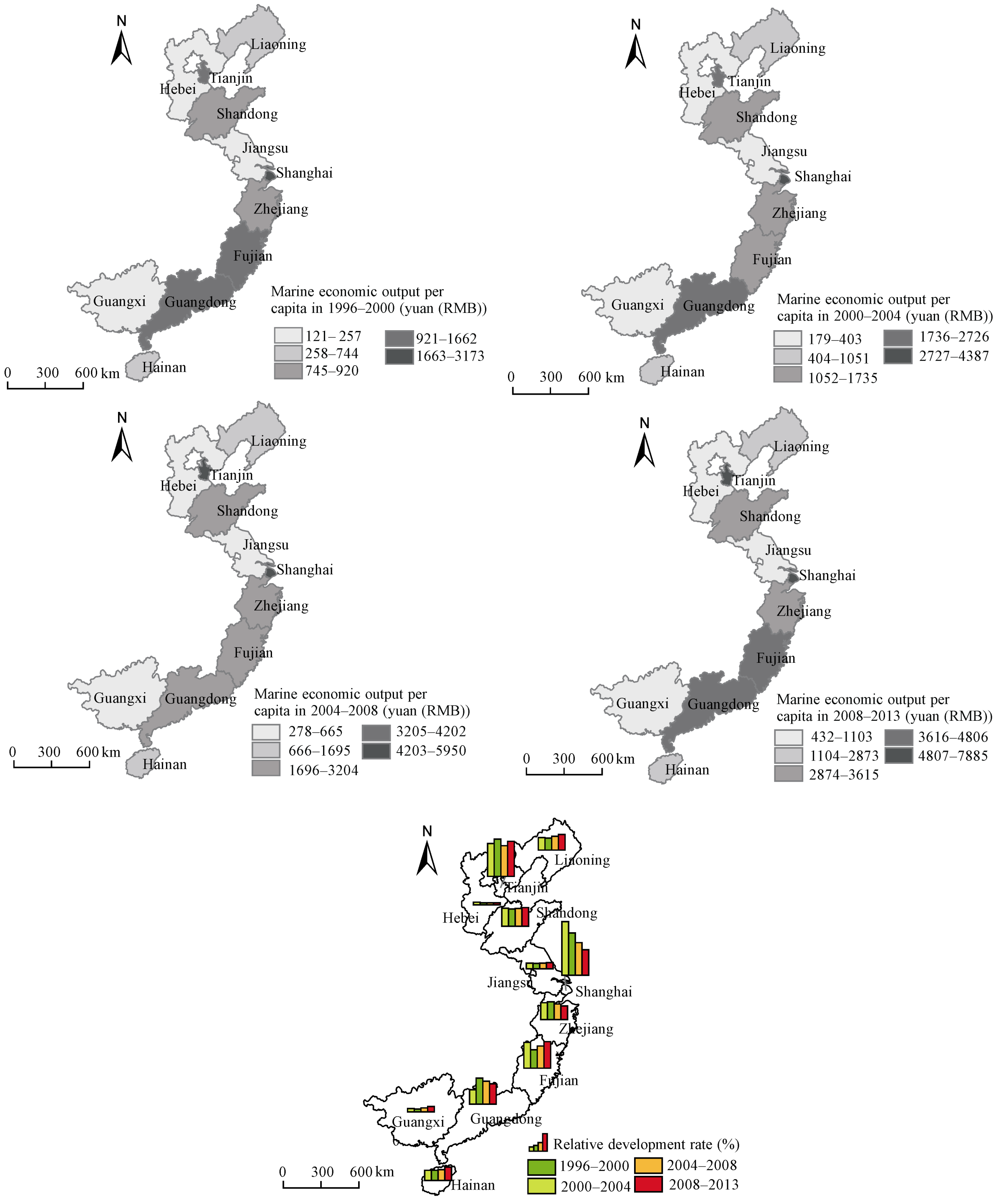

Fig. 6 Marine economic output per capita and relative development rate in coastal area

influence on the dynamic evolution of the marine economy continuously increased. 3) The level of opening to the outside world, the level of investment in fixed assets, and the industrial structure played positive roles in promoting the development of the marine economy. However, capital investment in scientific human research was negativly correlated with economic development, and did not pass the significance test, implying that a large number of inputs of human, material, and financial resources did not bring huge scientific and technological progress or increase the output of the ocean. 4) Because of differences among the provinces, such as the level of opening up to the outside world, the level of investment in fixed assets, and the industrial structure, there are significant differences in the development levels and relative development speeds of the coastal area. The provinces with higher development levels generally displayed faster development speeds while those with lower development levels showed lower development speeds across the four periods, indicating that marine economic gap among coastal provinces will continue to exist in the future.

The results of this study suggest that the Chinese government should develop reasonable scientific policies to promote coordinated and sustainable development of the marine economy. Different parts of the coastal area should improve their level of regional opening, introduce foreign capital technology, and improve their level of investment in fixed assets. At the same time, they should make significant efforts to develop the tertiary marine industry and to improve the scientific and technological innovation capability of marine human resources to enhance the level of marine science and technology.

References

An Kang, Han Zhaozhou, Shu Xiaohui, 2012. Dynamic distribution analysis of province economic coordination development in China. *Inquiry Into Economic Issues*, (1): 20–25. (in Chinese)

Böhnke-Henrichs A, Baulcomb C, Koss R et al., 2013. Typology and indicators of ecosystem services for marine spatial planning and management. *Journal of Environmental Management*, 130: 135–145. doi: 10.1016/j.jenvman.2013.08.027

Burkhauser R V, Rovba L, 2005. Income inequality in the 1990s: comparing the United States, Great Britain and Germany. *The Japanese Journal of Social Security Policy*, 4(1): 1–16.

Cheng Chao, Tong Shaoyu, Peng Haiying et al., 2016. Ecological carrying capacity of water resources in the central Yunnan urban agglomeration area. *Resources Science*, 38(8): 1561–1571. (in Chinese)

Clarke A C, 2006. Towards a future maritime policy for the Union: a European vision for the oceans and seas. Brussels: European Commission.

Colgan C S, 2013. The ocean economy of the United States: measurement, distribution, & trends. *Ocean & Coastal Management*, 71: 334–343. doi: 10.1016/j.ocecoaman.2012.08.018

Cowell, F A, Jenkins S P, Litchfield J A, 1996. The changing shape of the UK income distribution: kernel density estimates. In: Hills J R. *New Inequalities: the Changing Distribution of Income and Wealth in the United Kingdom*. Cambridge: Cambridge University Press.

Dalton H, 1920. The measurement of the inequality of incomes. *The Economic Journal*, 30(119): 348–361. doi: 10.2307/2223525

Di Qianbin, Han Zenglin, Liu Guichun et al., 2007. Carrying capacity of marine region in Liaoning Province. *Chinese Geographical Science*, 17(3): 229–235. doi: 10.1007/s11769-007-0229-0

Di Qianbin, Liu Xinxin, Cao Ke, 2013. Spatial and temportal disparities of marine economic development and dynamic changes in China. *Scientia Geographica Sinica*, 33(12): 1413–1420. (in Chinese)

Fernández-Macho J, González P, Virto J, 2016. An index to assess maritime importance in the European Atlantic economy. *Marine Policy*, 64: 72–81. doi: 10.1016/j.marpol.2015.11.011

Foley N S, Corless R, Escapa M et al., 2014. Developing a comparative marine socio-economic framework for the European Atlantic area. *Journal of Ocean and Coastal Economics*, 2014(1): 3.

Fujita M, Hu D P, 2001. Regional disparity in China 1985-1994: the effects of globalization and economic liberalization. *The Annals of Regional Science*, 35(1): 3–37. doi: 10.1007/s00168 0000020

Gao Yuan, Han Zenglin, Yang Jun et al., 2015. Spatial Agglomeration of Marine Industries and Region Coordinated Development in China. *Scientia Geographica Sinica*, 35(8): 946–951. (in Chinese)

Halpern B S, Longo C, Hardy D et al., 2012. An index to assess the health and benefits of the global ocean. *Nature*, 488(7413): 615–620. doi: 10.1038/nature11397

Han Zenglin, Xu Xu, 2008. Analysis on regional disparities of mairine economy and evolvement course in China. *Geographical Research*, 27(3): 613–622. (in Chinese)

He Guangshun, Ding Lili, Song Weiling, 2014. *Theory, Method and Practice of Marine Economic Analysis and Evaluation*. Beijing: Ocean Press, 135–140. (in Chinese)

Huang Chongfu, 2005. *Risk Assessment of Natural Disaster: Theory & Practice*. Beijing: Science Press, 80–98. (in Chinese)

Huang Chongfu, 2012. *Risk Analysis and Management of Natural Disasters*. Beijing: Science Press. (in Chinese)

Jenkins S P, van Kerm P, 2005. Accounting for income distribution trends: a density function decomposition approach. *The Journal of Economic Inequality*, 3(1): 43–61. doi: 10.1007/s 10888-004-8309-1

Jiang X Z, Liu T Y, Su C W, 2014. China′ s marine economy and regional development. *Marine Policy*, 50: 227–237. doi: 10. 1016/j.marpol.2014.06.008

Kanbur R, Zhang X B, 1999. Which regional inequality? The evolution of rural-urban and inland–coastal inequality in China from 1983 to 1995. *Journal of Comparative Economics*, 27(4): 686–701. doi: 10.1006/jcec.1999.1612

Kildow J T, McIlgorm A, 2010. The importance of estimating the contribution of the oceans to national economies. *Marine Policy*, 34(3): 367–374. doi: 10.1016/j.marpol.2009.08.006

Kumar S, Russell R R, 2002. Technological change, technological catch-up, and capital deepening: relative contributions to growth and convergence. *The American Economic Review*, 92(3): 527–548.

Lin Cunzhuang, Han Limin, 2014. Research about the disparities of the development of marine economy about coastal provinces in China. *Chinese Fisheries Economics*, 32(4): 67–73. (in Chinese)

Liu Jing, Zhang Chewei, Mao Xuefeng, 2009. The dynamic changes of the income distribution in China from 1991 to 2006: a decomposition analysis based on kernel density function. *World Economy*, (10): 3–13. (in Chinese)

Liu R Z, 2012. *Regional Oceanography of China Seas-Marine Economic*. Beijing: Ocean Press, 3–8. (in Chinese)

Luan Weixin, 2004. “Bottleneck” and countermeasure of high-technologization of marine industry in China. *Chinese Geographical Science*, 14(1): 15–20. doi: 10.1007/s11769-004-0003-5

Massaro F, D'Abrusco R, Paggi A, et al, 2013. Unveiling the nature of the unidentified gamma-ray sources. V. Analysis of the radio candidates with the kernel density estimation. *The Astrophysical Journal Supplement Series*, 209(1): 10. doi: 10.1088/0067-0049/209/1/10

Morrissey K, 2014. Using secondary data to examine economic trends in a subset of sectors in the English marine economy: 2003-2011. *Marine Policy*, 50: 135–141. doi: 10.1016/j.marpol.2014.05.018

Morrissey K, O’Donoghue C, Hynes S, 2011. Quantifying the value of multi-sectoral marine commercial activity in Ireland. *Marine Policy*, 35(5): 721–727. doi: 10.1016/j.marpol.2011.02.013

Morrissey K, O’Donoghue C, 2012. The Irish marine economy and regional development. *Marine Policy*, 36(2): 358–364. doi: 10.1016/j.marpol.2011.06.011

National Bureau of Statistics of China, 1996-2014. *China Statistical Yearbook*. Beijing: China Statistics Press. (in Chinese)

Ouyang Nanjiang, 1993. Economic restructuring and regional disparities in Guangdong province. *Acta Geographica Sinica*, 48(3): 204–217. (in Chinese)

Park K S, Kildow J T, 2014. The estimation of the ocean economy and coastal economy in south Korea. Monterey, USA: Center for the Blue Economy in Monterey Institute of International Studies.

Parzen E, 1962. On estimation of a probability density function and mode. *The Annals of Mathematical Statistics*, 33(3): 1065–1076. doi: 10.1214/aoms/1177704472

Poluektov A, 2015. Kernel density estimation of a multidimensional efficiency profile. *Journal of Instrumentation*, 10(2): P02011. doi: 10.1088/1748-0221/10/02/P02011

Rosenblatt M, 1956. Remarks on some nonparametric estimates of a density function. *The Annals of Mathematical Statistics*, 27(3): 832–837. doi: 10.1214/aoms/1177728190

Rozelle S, Boisvert R N, 1995. Control in a dynamic village economy: the reforms and unbalanced development in China's rural economy. *Journal of Development Economics*, 46(2): 233–252. doi: 10.1016/0304-3878(94)00060-P

Song W L, He G S, McIlgorm A, 2013. From behind the Great Wall: the development of statistics on the marine economy in China. *Marine Policy*, 39: 120–127. doi: 10.1016/j.marpol.2012.09.006

State Oceanic Administration People’s Republic of China, 1996-2014. *China Marine Statistical Yearbook*. Beijing: China Ocean Press. (in Chinese)

Stojanovic T A, Farmer C J Q, 2013. The development of world oceans & coasts and concepts of sustainability. *Marine Policy*, 42: 157–165. doi: 10.1016/j.marpol.2013.02.005

Su Weihua, Wang Long, Li Wei, 2013. The factor research of total factor productivity of marine economy in China-based on spatial panel data model. *Collected Essays on Finance and Economics*, (3): 9–13. (in Chinese)

Sun Caizhi, Yu Guanghua, Wang Zeyu et al., 2014. Marine carrying capacity assessment and spatio-temporal analysis in the Bohai Sea Ring Area, China. *Scientia Geographica Sinica*, 34(5): 513–521. (in Chinese)

Sun Caizhi, Li Xin, 2015. Dynamic evolution analysis of China’s marine economy development based on kernel density estimation. *Economic Geography*, 35(1): 96–103. (in Chinese)

Sun Caizhi, Zhang Kunling, Zou Wei et al., 2015. Assessment and evolution of the sustainable development ability of human-ocean systems in coastal regions of China. *Sustainability*, 7(8): 10399–10427. doi: 10.3390/su70810399

Sun Jiting, Zhao Yujie, 2011. The mechanism of land-sea coordination in the development of China's marine economy. *Social Sciences in Guangdong*, (5): 41–47. (in Chinese)

Surís-Regueiro J C, Garza-Gil M D, Varela-Lafuente M M, 2013. Marine economy: a proposal for its definition in the European Union. *Marine Policy*, 42: 111–124. doi: 10.1016/j.marpol.2013.02.010

Vivero J L S D, Mateos J C R, 2012. The Spanish approach to marine spatial planning. Marine Strategy Framework Directive vs. EU integrated maritime policy. *Marine Policy*, 36(1): 18–27. doi: 10.1016/j.marpol.2011.03.002

Wang Shuang, 2012. Analysis of China’s marine economic regional characteristics and development countermeasures for these regions. *Economic Geography*, 32(6): 80–84. (in Chinese)

Wu Kang, Wei Yuchun, 2008. The measure and analysis of regional development equilibrium of Jiangsu province since 1990s. *Progress in Geography*, 27(1): 64–74. doi: 10.11820/dlkxjz.2008.01.009 (in Chinese)

Ye Xiangdong, Ye Dongna, Chen Sizeng, 2013. *Strategic Planning and Practice of Modern Ocean*. Beijing: Publishing House of Electronics Industry, 25–83. (in Chinese)

Zhang Lijuan, Li Wenliang, Zhang Dongyou, 2009. Meteorological disaster risk assessment method based on information diffusion theory. *Scientia Geographica Sinica*, 29(2): 250–254. (in Chinese)

Zhang Yaoguang, 2000. A preliminary approach to the regionalization of the marine comprehensive economic region in

Liaoning Province. *Chinese Geographical Science*, 10(4): 356–365. doi: 10.1007/s11769-000-0051-4

Zhang Yaoguang, Dong Lijing, Li Chunping, 2002. Approach to the regionalization of agricultural-pasturalization around changshan islands in northern yellow sea. *Chinese Geographical Science*, 12(3): 218–225. doi: 10.1007/s11769-002-0005-0

Zhang Yaoguang, Dong Lijing, Yang Jun et al., 2004. Sustainable development of marine economy in China. *Chinese Geographical Science*, 14(4): 308–313. doi: 10.1007/s11769-004-0033-z

Zhang Yaoguang, Han Zenglin, Liu Kai et al., 2010. Analysis of regional differences of marine economy and use structure of coastal zone: a case study of Liaoning Province. *Geographical Research*, 29(1): 24–34. (in Chinese)

Zhang Yaoguang, Liu Kai, Liu Guichun et al., 2011. Quantitative analysis of the spatial and temporal differences between the regional systems of marine economy in Liaoning province. *Resources Science*, 33(5) 863–870. (in Chinese)

Zhang Yaoguang, Wang Guoli, Liu Kai et al., 2015. A study on the characteristics of regional differentiation in China's marine economy and demarcation of marine economic areas. *Economic Geography*, 35(9): 87–95.

Zhao Lin, Zhang Yushuo, Jiao Xinying et al., 2016. An evaluation of Chinese marine economy efficiency based on SBM and Malmquist productivity indexes. *Resources Scie*nce, 38(3): 461–475. (in Chinese)

Zhao R, Hynes S, He G S, 2014. Defining and quantifying China's ocean economy. *Marine Policy*, 43: 164–173. doi: 10.1016/j.marpol.2013.05.008

Zheng Guibin, 2012. The construction of blue economic zone and the planning for the coordinated development of land and ocean. *Marine Economy*, 2(6): 31–34. (in Chinese)

Zheng Y, 2015. The static and dynamic evaluation on ocean environment performance for Chinese coastal cities. *Journal of Coastal Research*, 73: 660–664. doi: 10.2112/SI73-114.1