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Study on Spatial-temporal Pattern and Influencing Factors of Coupling Coordination between Ecological Environment and Regional Economy under High-quality Development: A Case Study of the Yangtze River Economic Belt in China

Yuzhen Li, Pengzhen Yu*, Feiyu Zhu

School of Management, Chongqing University of Technology, Chongqing 400054, China

*fuccboi_wnl666@163.com

Abstract

Studying the relationship between ecological environment and economy (EERE) development in the Yangtze River Economic Belt (YREB) is the realistic requirement to realize the modern economic system in the region, and is of great significance for promoting the high-quality development (H-QD) of China's economy. In this study, a comprehensive evaluation index system of EERE from the perspective of H-QD was constructed. Besides, the entropy method, the coupling coordination model and the Tobit model were adopted to explore the H-QD, spatial-temporal coupling relationship and influencing factors of EERE of 11 provinces and municipalities in the YREB in the period 2008-2018. The results show that temporally, the coupling coordination degree (CCD) between EERE in the region rises in fluctuations. Spatially, the CCD is high in the lower reaches and low in upper reaches, but the spatial gap gradually narrows with the passage of time. Among the influencing factors, GDP growth rate and other factors have an inhibitory effect on the CCD, while technology market turnover, fiscal expenditure and total import and export volume exert a promoting effect on it. On this basis, some countermeasures and suggestions are put forward to enhance the coordinated development of EERE.

Keywords

High-quality Development; Coupling Coordination Degree; Yangtze River Economic Belt; Ecological Environment.

1. Introduction

Since 1960s, ecological resources on the earth have shown signs of decline with increasing human activities, and the living environment of human beings has been deteriorating [1]. Environmental problems such as ecological imbalance and soil erosion have aroused widespread concern of scholars at home and abroad. Governments all over the world are implementing policies to promote the coordination of EERE development.

Since the reform and opening up, China's economic development has made remarkable achievements, but these achievements are at the expense of serious environmental pollution and waste of resources. Extensive economic growth has a growing negative impact on the ecological environment; especially, environmental pollution and ecological destruction continue to restrict the process of economic development. Under the background of increasingly serious ecological degradation and environmental pollution, the way to change this situation is to realize the sustainable development of EERE, that is, to realize the goal of CCD of EERE. The quantitative evaluation of the CCD between EERE development can provide relevant theoretical basis for the realization of this goal, which contributes to continuously

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adjusting the direction and mode of coordinated development between EERE according to the change of CCD and provides guarantee for the sustainable development of EERE.

Since the 19th National Congress of the Communist Party of China, China's economy has changed from a high-speed growth stage to a H-QD stage. High-quality economic development not only pursues the speed but pays more attention to the quality [2]. It is aimed at the coordinated development between EERE. The paper chooses the YREB as the research object, because it has considerable development potential and remarkable international strength and influence. However, the YREB also has problems such as unbalanced regional development and environmental pollution, striving to fulfill the arduous task of EERE development in a coordinated manner. Therefore, scientifically evaluating the EERE development status of the YREB, and studying the regional differences and coordination level of the development status of provinces and municipalities are the inevitable requirements for exploring the path of H-QD of EERE with Yangtze River characteristics [3].

The research on EERE H-QD can objectively reveal the internal relationship between EERE development, and boasts important reference value for developing regional H-QD strategy. The study aims to evaluate the CCD between EERE H-QD in the region, analyze factors affecting the CCD. Thus, on the basis of economics and ecology, this study took the YREB as the research object, evaluated the coupling coordination between EERE H-QD in this region, and provided countermeasures and suggestions for its sustainable development.

2. Literature Review

The relationship between EERE development is a research hotspot concerning ecological economics. Since the 1970s, foreign scholars have studied the conditions for the coordinated development of EERE in the light of the economic growth theory. Solow [4] and Stiglitz [5] introduced ecological environment as a variable into the neoclassical growth model to analyze the way of developing and utilizing natural resources, but the research results lack certain rationality because technical progress is not taken into consideration. In the 1990s, with the development of the endogenous economic growth theory, Gradus and Smulder[6] began to add environmental pollution to the endogenous economic growth model, trying to coordinate the development of economy and environment under limited natural resources.

In addition, experts have also carried out evaluation research on the relationship between EERE. The environmental Kuznets curve (EKC) [7]: the ecological problems caused by economic growth must be solved by economic growth itself.In addition, Caviglia-Harris et al. also applied the EKC to judgment of the coupling state between economic systems and environmental systems in different regions. At the same time, the green Solow model put forward the interaction between EERE growth. With respect to EERE comprehensive effects, ecological protection usually brings ecological benefits to local communities rather than causes more burden [8]. Nevertheless, it must be noted that, because of the complexity and integrity of the system, using only a single index to analyze the relationship between EERE is insufficient and has many drawbacks. Instead, it is necessary to use comprehensive indexes for further study. Therefore, some scholars have studied the coordinated relationship between EERE system by borrowing the concepts of coupling coordinated development degree from physics. Most of the researches on coupling coordination between EERE development at home and abroad focused on theories, methods and evaluation models, and their research fields involved watersheds, cities, etc. [9]. Meanwhile, the relationship among resources, EERE was considered , such as environmental pollution and economic development [10], ecological environment and socialization [11], economic resources and environment (ERE) [12].In terms of methods, it is necessary to combine various methods due to the comprehensiveness and complexity of the coupling coordinated development of EERE. With the construction of H-QD index system in

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China, The research focused on the theory and model of quantitative evaluation, and many methods have been widely used in the coupling of EERE, such as ecological value estimation [13], the grey model, the ecological footprint method [14].

Generally speaking, research on the relationship between economic development has a certain foundation, but there are also obvious shortcomings: First, the existing economic index system is mainly based on indexes such as total amount and growth rate, without considering the connotation and inherent requirements of H-QD. In recent years, people have begun to think about the relationship between EERE development from a new perspective. Most of the existing studies involve the correlation between EERE development, focusing on evaluating the CCD level of EERE, while the studies on the spatial-temporal coupling and coordination between them are relatively few. In this paper, the CCD model is adopted to analyze the characteristics of EERE H-QD in time and space, which is of great significance to social and economic development and ecological civilization construction.

In this study, an evaluation system of EERE H-QD was established, and the entropy method of time variables, the CCD model and spatial autocorrelation analysis were added in this system. Furthermore, the spatial-temporal changes of EERE development level and CCD in provinces and municipalities in the YREB were discussed. Besides, the influencing factors of CCD were empirically analyzed by the Tobit model.

3. Methods and Data

3.1. Research Methods

3.1.1. Constructing Index System

On the basis of analyzing the connotation and characteristics of EERE H-QD in the YREB, an index system of EERE H-QD in the YREB, including 5 second-level indexes and 24 third-level indexes, is constructed in five development dimensions, namely innovation, coordination, green, openness and sharing (Table 1).

Table 1. Index system of EERE H-QD in the YREB

	First-level index	Second-level index	Third-level index	Attribute	Weight
Ecology	Green development	Pollution discharge	Sulfur dioxide emissions (tons)	-	0.0182
			Total industrial wastewater discharge (ten thousand tons)	-	0.0196
		Environmental governance	Comprehensive utilization rate of industrial solid waste (%)	+	0.0338
			Harmless treatment rate of domestic garbage (%)	+	0.0091
		Environmental protection	Proportion of environmental protection investment to GDP	+	0.0465
		Green environment	Green coverage rate of built-up area (%)	+	0.0119
		Ecological construction	Per capita park green area (person/m^2)	+	0.0241

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			Forest coverage rate (%)	+	0.0221
			Proportion of protected area to total land area (%)	+	0.0565
Economy	Innovation and development	Innovation output	Proportion of technology market turnover to GDP	+	0.0762
		Innovation investment	R&D funds of industrial enterprises above designated size (ten thousand yuan)	+	0.0918
	Coordinated development	Urban-rural coordination	Urbanization rate (%)	+	0.0253
		Industrial coordination	Proportion of secondary and tertiary industries	-	0.0209
		Development speed	GDP growth rate (%)	+	0.0284
	Openning development	Opening effect	Total import and export volume (ten thousand dollars)	+	0.1312
			Foreign exchange income from tourism (ten thousand dollars)	+	0.0767
		Opening degree	Number of inbound tourists (ten thousand)	+	0.0643
	Shared development	People's life	Expenditure on Social Security and Employment/General Budget Expenditure	+	0.0189
			Proportion of fiscal expenditure to GDP	+	0.0483
			Total investment in fixed assets of the whole society (100 million yuan)	+	0.0471
			Registered urban unemployment rate (%)	-	0.0227
		Public service	Number of hospital beds per 10,000 people	+	0.0334
			Medical and health expenditure (100 million yuan)	+	0.0373
			education expenditure (100 million yuan)	+	0.0357

This study adopts to the entropy method to measure the H-QD level of the YREB and the development and changes in five dimensions were calculated.

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3.1.2. CCD Model

Because coupling cannot fully reflect the overall coordination of the composite system, the coordination development level is introduced on the basis of coupling to form a coupling coordination model [15]. The equation is:

$$D = \sqrt{C \times T}$$
$$T = \alpha Q_1 + \beta Q_2 \quad (1)$$

where D is the CCD; T is the comprehensive coordination index; C is the coupling degree between EERE H-QD; Q_1 and Q_2 are the H-QD levels of EERE, respectively; α and B are the undetermined coefficients, and α + β = 1. Considering that EERE are equally important in this study, the values of both α and β are 0.5.

On the basis of calculating the CCD between EERE development of provinces and municipalities in the YREB in the period 2008-2018, considering their actual development, the coordinated development stages are classified according to the C value: maladjusted recession [0, 0.4], transformation development [0.4, 0.6) and coordinated development [0.6, 1]. (Table 2).

Table 2. Division of coupling coordination stages

Coordinated development stage	Coordination level	Type of CCD
Maladjusted recession	[0, 0.20)	Serious maladjustment (SM)
0 ≤ D(t) < 0.4	[0.20, 0.40)	Moderate maladjustment (MM)
Transformation development	[0.40, 0.50)	Verge of imbalance (VI)
0.4 ≤ D(t) < 0.6	[0.50, 0.60)	Primary coordination (PC)
Coordinated development	[0.60, 0.80)	Moderate coordination (MC)
0.6 ≤ D(t) < 1.0	[0.80, 1.00]	High coordination (HC)

3.1.3. Spatial Autocorrelation

Generally, the global Moran index is adopted to measure the spatial correlation of sample areas. The calculation equation is:

$$\mathrm{I} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(x_i - \bar{x})(X_j - \bar{x})}{S^2 \sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}} \quad (2)$$

3.1.4. Tobit Model

Tobit model reflecting the relationship between them is established to carry out regression analysis on the factors influencing the CCD between EERE H-QD in the YREB in the period 2008-2018. The basic expression is:

$$Y_{it}^* = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \varepsilon_{it}$$
$$Y_{it} = \begin{cases} Y_{it}^*, & Y_{it}^* < 1 \\ 1, & Y_{it}^* \geq 1 \end{cases} \quad (3)$$

where Y_{it} and Y_{it}^* are the observed variable and latent variable in the Tobit model respectively; X_1, X_2, X_3, X_4, X_5 and X_6 are Fiscal expenditure, Economic development level, Industrial structure, Urbanization level, Scientific and technological development level, Level of opening to the outside world, six influencing factors respectively; $\beta_1, \beta_2, \beta_3, \beta_4, \beta_5$ and β_6 are the coefficients of six independent variables in the model, and their values reflect the internal

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relationship between the influencing factors and the CCD between EERE H-QD in the YREB; ε_{it} is a random disturbance term in the model.

3.2. Research Object and Data Source

The YREB includes 11 provinces in eastern, central and western China, covering an area of about 2.05 million m2 and accounting for more than 40% of China's population and economy. It is a key field of China's economic development and environmental protection.

The research object of this study is 11 provinces and municipalities in the YREB. The data come from 2008-2018 China Science and Technology Statistical Yearbook, China Environment Statistical Yearbook, China Urban Statistical Yearbook, Statistical Yearbooks of corresponding provinces and municipalities, etc.

4. Results and Analysis

4.1. Temporal-spatial Evolution of Ecology and Economy H-QD in the YREB

4.1.1. Temporal Evolution of H-QD

Based on the entropy method, the ecology and economy H-QD levels of provinces and municipalities in the YREB in the period 2008-2018 were calculated, and the samples were divided into two stages with 2013 as the boundary (Figs. 1 and 2)

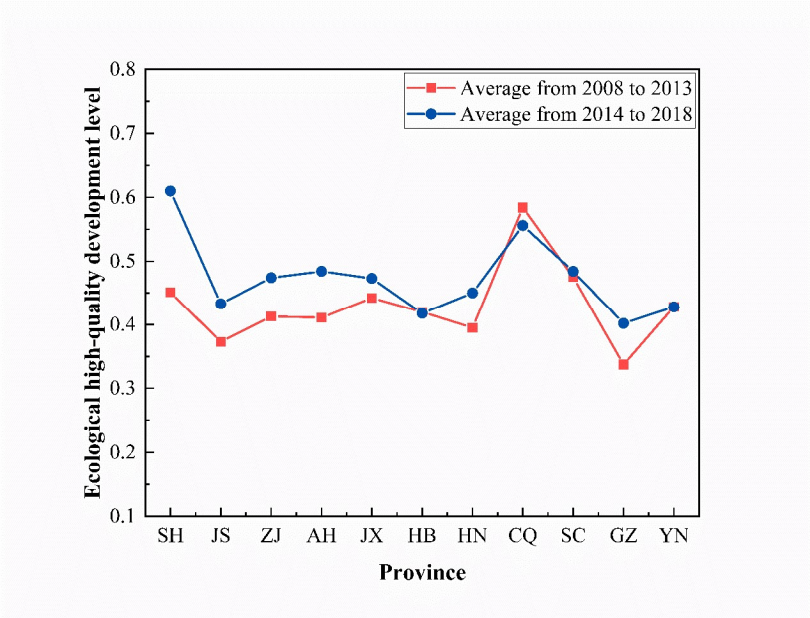

Fig. 1 Ecology H-QD level in the YREB

As presented in Fig. 1, the ecology H-QD level in the YREB in the period 2008-2018 basically fluctuates. During 2008-2013, the average value of ecology H-QD level of various provinces and municipalities is 0.430, and the standard deviation is 0.058. The value of Shanghai in the lower reaches of the YREB is obviously higher than the average value. The reason is that it has obvious location advantages, and as a first-tier city, it leads the whole country in environmental governance and ecological construction. Meanwhile, the value of Chongqing in the middle reaches is also obviously higher than the average value for the following reasons. First, it enjoys obvious policy advantages of being a municipality directly under the central government; second, located at the intersection of the main stream and tributaries of the YREB, it boasts complex topography and rich ecological resources, its forest coverage rate being in the forefront among provinces and municipalities in the YREB. During 2014-2018, the average

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value of ecology H-QD is 0.474, 10.2% higher than the previous stage. The standard deviation is 0.056, which decreases compared with the previous stage, indicating that the gap between ecology H-QD levels of provinces and municipalities in the YREB is narrowing.

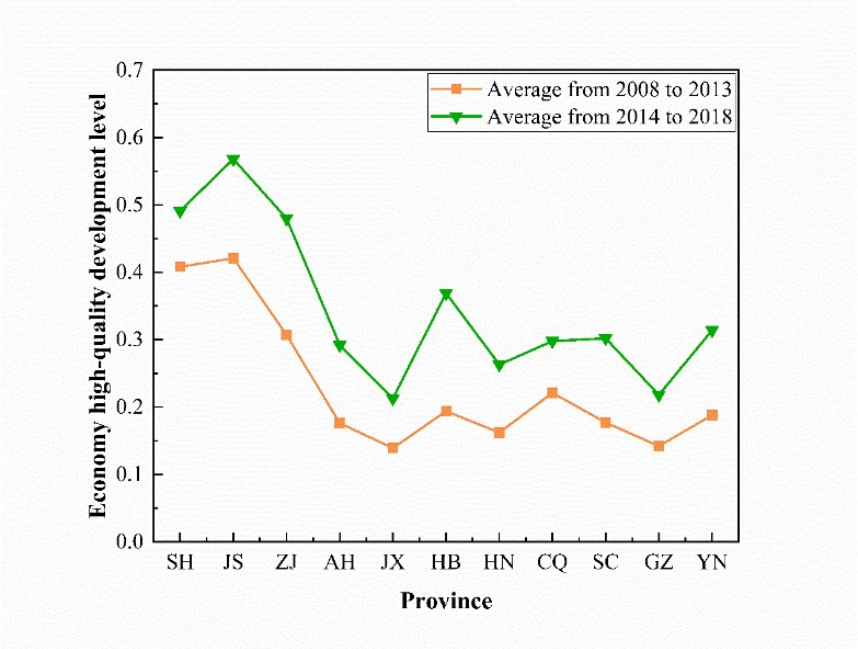

Fig. 2 Economy H-QD level in the YREB

As displayed in Fig. 2, the economy H-QD level in the YREB shows an upward trend overall, but the development speeds of different provinces and municipalities differ. During 2008-2013, the average value of economy H-QD level of various provinces and municipalities is 0.231, and the standard deviation is 0.093. The levels of Shanghai, Zhejiang and Jiangsu are higher than the average. Meanwhile, during 2014-2018, the average value of economy H-QD level of various provinces and municipalities is 0.346, 49.8% higher than the previous stage. The standard deviation is 0.107, which increases compared with the previous stage, suggesting that the gap between economy H-QD levels of provinces and municipalities in the YREB is widening in these years. Besides, compared with the previous stage, Hubei is added into the list of provinces and municipalities whose levels ate higher than the average.

Generally speaking, in the first stage of the research period, due to the weak foundation, both ecological environment protection and economic development lagged behind. Economic development in various regions focused on the growth of quantity, and investment was still the main driving force for economic growth. In particular, the middle and upper reaches pursued economic scale growth and ignored innovation for a long term, leading to industrial structure imbalance and environmental pollution. In this stage, the ecological protection and economic development levels were far lower than the average levels of the YREB. Compared with the first stage, since 2013, the economy of provinces and municipalities in the YREB has grown steadily, and investment has no longer been the incentive of economic development. All regions have begun to focus on the quality of economic development, shifting their priority from speed to efficiency, and the benefits of H-QD are obvious. However, in recent years, the comprehensive level of ecological environment development fluctuates violently. Thereby, the YREB still needs to strengthen the governance and construction of ecological environment and continuously improve the stability of ecological environment development.

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4.1.2. Spatial Distribution of H-QD

In this paper, the high-quality EERE H-QD levels of the YREB in 2008, 2013 and 2018 were selected for spatial evolution analysis. In order to evaluate and compare the EERE system under different time scales, according to the mathematical multiple relationship (the fixed standard method), the study took 75%, 100% and 125% of the ecology H-QD level and 50%, 100% and 150% of the economy H-QD level as the classification criteria. With these criteria, the four types of ecological environment level are high ecological environment (HEE) (>125%), slightly high ecological environment (SHEE) (100%-125%), moderate ecological environment (MEE) (75%-100%) and low ecological environment (LEE) (< 75%), and the four types of urbanization level are high urbanization (HU) (>150%), slightly high urbanization (SHU) (100%-150%), moderate urbanization (MU) (50%-100%) and low urbanization (LU) (<50%). Visual analysis on the calculation results is exhibited in Fig. 3.

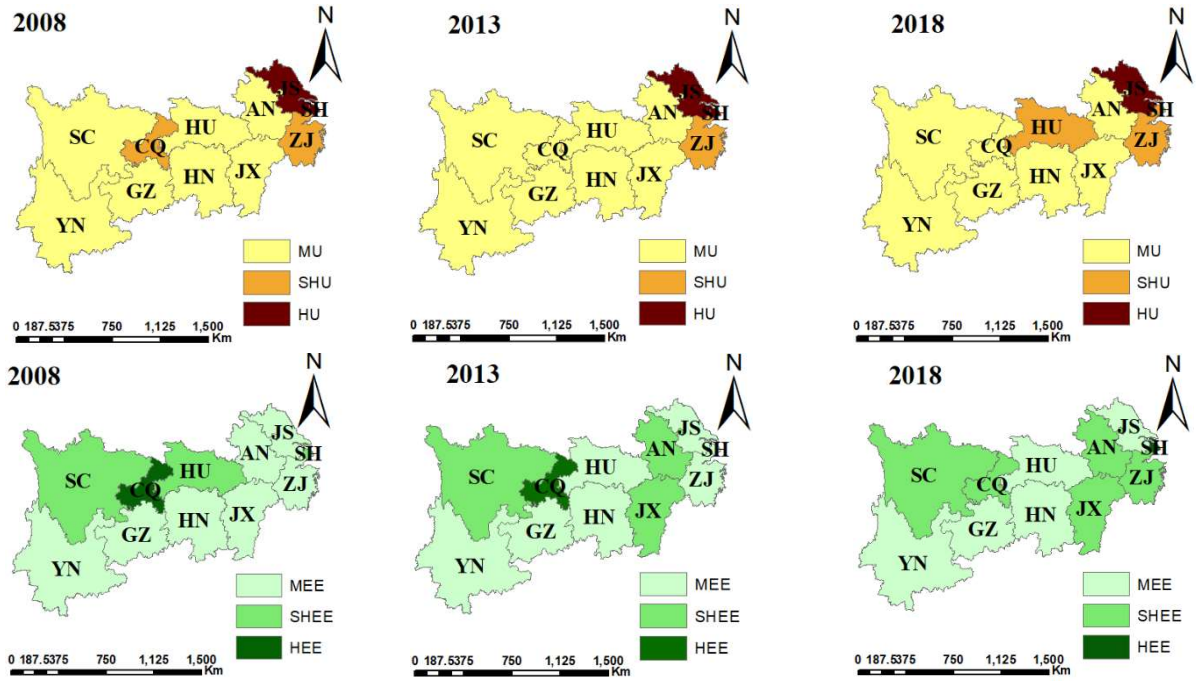

Fig. 3 Spatial distribution of EERE development in the YREB

As illustrated in Fig. 3, in 2008, Shanghai and Jiangsu in the lower reaches are in high urbanization; Zhejiang and Chongqing, slightly high urbanization; and other areas, moderate urbanization. Meanwhile, Chongqing corresponds to high ecological environment; Sichuan, Hubei and Shanghai, slightly high ecological environment; and the rest areas, moderate ecological environment. In 2013, the spatial pattern changes insignificantly. Shanghai and Jiangsu are still in high urbanization, but Chongqing changes from slightly high urbanization to moderate urbanization. Provinces and municipalities with slight high ecological environment changes from Shanghai and Hubei to Jiangxi and Anhui, and the rest remain unchanged. In 2018, Jiangsu is the only province in high urbanization; Hubei is a newly added province in slightly high urbanization; and the list of provinces and municipalities in moderate urbanization remains stable with little change. Besides, Shanghai is added to the list of provinces and municipalities with high ecological environment; Chongqing and Zhejiang are added to the provinces and municipalities with slightly high ecological environment; and the rest remain unchanged.

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4.2. Spatial-temporal Analysis on CCD between EERE H-QD

4.2.1. Temporal Evolution of CCD

Based on the CCD model, the CCD between EERE H-QD of provinces and municipalities in the YREB in the period 2008-2018 was calculated (Table 3).

Table 3. CCD in the YREB in the period 2008-2018

Year	Shanghai	Jiangsu	Zhejiang	Anhui	Jiangxi	Hubei	Hunan	Chongqing	Sichuan	Guizhou	Yunnan	Average
2008	0.640	0.595	0.555	0.474	0.453	0.496	0.472	0.573	0.493	0.424	0.479	0.514
2009	0.634	0.585	0.558	0.488	0.465	0.515	0.488	0.568	0.513	0.437	0.505	0.523
2010	0.655	0.618	0.583	0.495	0.495	0.527	0.514	0.596	0.524	0.445	0.516	0.543
2011	0.659	0.643	0.602	0.519	0.509	0.525	0.498	0.608	0.551	0.482	0.534	0.557
2012	0.673	0.660	0.627	0.541	0.517	0.545	0.510	0.609	0.564	0.495	0.558	0.573
2013	0.665	0.663	0.642	0.584	0.540	0.582	0.530	0.634	0.575	0.516	0.591	0.593
2014	0.710	0.672	0.660	0.574	0.546	0.605	0.541	0.632	0.583	0.523	0.590	0.603
2015	0.715	0.686	0.681	0.592	0.554	0.616	0.563	0.630	0.595	0.529	0.598	0.614
2016	0.748	0.701	0.701	0.620	0.554	0.627	0.587	0.637	0.611	0.535	0.599	0.629
2017	0.752	0.719	0.714	0.633	0.567	0.637	0.610	0.638	0.632	0.549	0.608	0.642
2018	0.773	0.740	0.696	0.644	0.592	0.645	0.627	0.650	0.665	0.581	0.626	0.658

As can be observed from Table 3, from the perspective of average value, the CCD between EERE H-QD in the YREB increases year by year, from 0.514 in 2008 to 0.658 in 2018. As the CCD steps from primary coordination to moderate coordination, the level of coupling coordination has been rising. From the perspective of provinces and municipalities, the CCDs of Shanghai, Jiangsu and Zhejiang are relatively high, probably because they are located in the eastern coastal areas of China. Their obvious regional advantages endow them with high levels of economic development and opening up, perfect urban environmental protection infrastructure and mature ecological governance system. In addition, although the CCDs of Guizhou and Jiangxi increase steadily year by year, they are still in the middle and late section of primary coordination by 2018. These provinces should take measures to improve the CCD between EERE H-QD to prevent falling into an unbalanced state.

4.2.2. Spatial Evolution of CCD

In this paper, based on the CCD data between EERE H-QD in the YREB in 2008, 2013 and 2018, the spatial evolution of CCD was analyzed with the aid of ArcGIS10.2 for spatial visualization (Fig. 4).

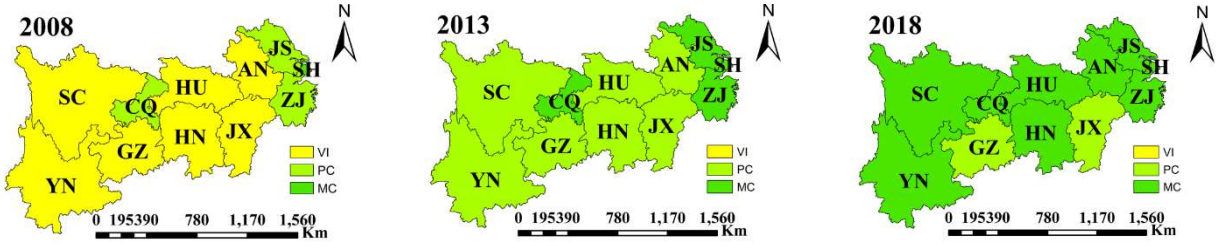

Fig. 4 Spatial evolution of CCD in the YREB

Fig. 4 reveals that great spatial difference exists in the CCD between EERE H-QD in the YREB, but the difference gradually shrinks with the passage of time. In 2008, among the provinces and municipality in the lower reaches, Shanghai, Jiangsu and Zhejiang are in modern coordination and primary coordination; among those in the middle and upper reaches, only Chongqing is in primary coordination, while Anhui, Jiangxi, Guizhou, Hubei, Hunan, Yunnan and Sichuan are in verge of imbalance. Since 2013, the two provinces and one municipality in the lower reaches have entered moderate coordination, so has Chongqing, and all other provinces are no longer

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in verge of imbalance, maintaining stability while seeking progress on the whole. By 2018, the YREB as a whole is in modern coordination, except Jiangxi and Guizhou which are still in primary coordination. Such a result demonstrates that the spatial difference in CCD of the YREB is gradually narrowing, showing a balanced development trend.

4.3. Spatial Correlation Analysis

In this paper, ArcGIS10.2 was adopted to test the significance of global autocorrelation of CCD between EERE H-QD in the YREB in the period 2008-2018 (Table 4), and the change of Moran's I value was depicted (Fig. 5).

Table 4. Global autocorrelation index of CCD in the YREB

Year	Moran's I	Z	P
2008	0.237	1.815	0.070
2009	0.294	2.050	0.040
2010	0.294	2.020	0.043
2011	0.361	2.300	0.021
2012	0.416	2.583	0.010
2013	0.343	2.200	0.028
2014	0.395	2.510	0.012
2015	0.447	2.770	0.006
2016	0.478	2.977	0.003
2017	0.491	3.030	0.002
2018	0.468	3.002	0.003

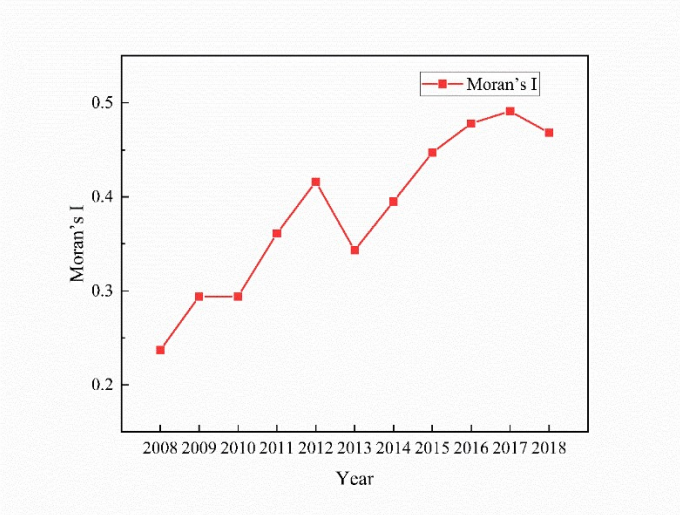

Fig. 5 Global Moran's I of the YREB in the period 2008-2018

From Fig. 5, it can be found that the Moran's I value of EERE H-QD in the YREB in the period 2008-2018 ranges from 0.237 to 0.495. Since 2008, it is significant at least at the level of 5%, which indicates that the CCD between the two is positively correlated spatially and shows concentrated spatial distribution. Temporally, the overall Moran's I value increases in fluctuations from 0.237 in 2008 to 0.495 in 2018. Specifically, the overall Moran's I value grows rapidly after 2008. This phenomenon can be explained as follows: after the financial crisis in

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2008, the government implemented fiscal policies to stimulate economic growth, which led to the rapid development of related industries and thereby resulted in a surge of CCDs of various provinces and municipalities. And with the withdrawal of financial support in 2012, the economic effect weakened. After 2014, it was clearly proposed to build the YREB as a coordinated development zone of interaction, cooperation and cooperation among the East, the Central and the West. Driven by the policies, the cooperation among provinces and municipalities in the YREB was strengthened, which promoted the inter-regional flow of EERE resources, alleviated the regional gap of CCD and enhanced the spatial agglomeration effect day by day.

4.4. Influencing Factors Analysis of CCD

Based on the Tobit model, the significance of factors influencing the CCD between EERE H-QD in the YREB was tested using Stata12.0. The results are listed in Table 5.

Table 5. Regression results of the Tobit model

Variable	Coefficient	T	P
Proportion of technology market turnover to GDP	1.8830***	3.69	0.000
Urbanization rate	0.0005	0.88	0.378
Proportion of secondary and tertiary industries	-0.0008*	-1.79	0.076
GDP growth rate	-0.0073***	-6.30	0.000
Proportion of environmental protection investment to GDP	0.0519	1.22	0.223
Total import and export volume	0.0451***	10.38	0.000
Proportion of fiscal expenditure to GDP	0.207***	7.38	0.000
L-likelihood	272.414		

Note: *, ** and *** represent significance levels of 10%, 5% and 1%, respectively.

Based on the regression results of the main influencing factors in Table 4, the specific analysis is as follows.

(1) The results show that more investment in the science and technology market corresponds to a higher level of science and technology development and thus promotes the development of high-tech industries. Meanwhile, it will ensure economic growth and improve the ability and efficiency of ecological environment governance, ultimately improving the CCD.

(2) The urbanization rate has no significant effect on the CCD in the YREB. The reason may be that China's urbanization has not yet popularized adequately, and the impact of urbanization rate on CCD in the YREB remains uncertain. Therefore, its effect is insignificant in the initial stage of urbanization development in China.

(3) The impact of the proportion of secondary and tertiary industries on CCD is negative at the significance level of 10%. However, the middle and upper reaches, which account for a large proportion in the whole YREB, hold a solid heavy industry foundation (such as Guizhou and Sichuan). The secondary industry is still an important pillar of economy in the middle and upper reaches. It negatively affects the CCD and weakens the positive effect between the industrial structure and the ecological environment development in the lower reaches to a certain extent. Hence, it has a significant negative correlation with CCD.

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(4) The impact of GDP growth rate on CCD is negative at the significance level of 1%. As GDP growth and economic development become faster, the gap between EERE development levels will widen, which inhibits the CCD to a certain extent.

(5) The impact of total import and export volume on CCD is positive at a significance level of 1%. When a region is closely connected with other parts of the world, it can promote the sound development of EERE in the region while introducing foreign advanced technology. Therefore, this index has positive effect on CCD.

(6) The impact of proportion of fiscal expenditure to GDP on CCD is positive at the significance level of 1%. The higher the proportion of fiscal expenditure, the higher the proportion of funds used to protect the environment, which is more conducive to improving the ecological environment and facilitating regional economic resource allocation, thus promoting the coupling coordinated development of the two.

5. Conclusion and suggestions

5.1. Conclusion

In this study, the EERE H-QD levels, their coupling relationship and influencing factors of YREB in the period 2008-2018 were discussed. The following main conclusions were drawn:

(1) According to the analysis on temporal-spatial changes of H-QD in the YREB in 2008, 2013 and 2018, in terms of economic development, spatially, the provinces and municipalities in high urbanization are basically unchanged; those in slightly high urbanization and moderate urbanization are relatively stable; and no provinces and municipalities are in low urbanization. The ecological development aspect is generally stable. Specifically, slightly high ecological environment and moderate ecological environment are dominant. From 2008 to 2018, the ecology H-QD level of YREB rises, and the inter-provincial difference narrows. Meanwhile, the economy H-QD level achieves fruitful results, showing a gradual spatial development pattern.

(2) From the temporal perspective, the CCD between EERE H-QD in the YREB increases in fluctuations from 2008 to 2018, and the overall CCD changes from verge of imbalance to moderate coordination. As for the spatial structure, great differences exist in the CCD between the two. However, with the passage of time, the spatial difference gradually shrinks; the trend of balanced development appears; and EERE basically realize overall coordinated development. In addition, Moran's I index shows that the CCD between EERE H-QD in the YREB is significant correlated, which is indicative of an obvious spatial aggregation effect and a remarkable development trend.

(3) The CCD between EERE H-QD in the YREB is affected by many factors to varying degrees. Tobit regression analysis reveals that the effect of urbanization is unobvious; technology market turnover, fiscal expenditure and total import and export volume can promote the CCD, while GDP growth rate and the proportion of secondary and tertiary industries will inhibit the CCD.

5.2. Suggestions

Coordinated development of EERE is the foundation of H-QD. The YREB should strengthen the CCD between EERE H-QD for the purpose of enhancing the CCD of the two. The suggestions are as follows:

(1) In terms of CCD between EERE H-QD, an obvious spatial gap exists in the YREB. Strengthening regional cooperation and exchanges is an effective way to narrow the gap. Therefore, the YREB should make full use of the links among municipalities, stimulate the linked development of the whole region, and realize the inter-regional flow of talents, capital and technology, so as to narrow the gap and change the unbalanced development situation. To be specific, the provinces and municipality in the lower reaches should take the Yangtze River

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Delta as the core and stimulate the development of the surrounding. While the provinces in the upper reaches improve the EERE H-QD level through policies and capital inclination, Hubei, Sichuan and Chongqing should be made as central provinces and municipality leading the ecology and economy H-QD in the middle and upper reaches. By this way, they will guide high-quality industries to create new development opportunities, drive the development in the middle and upper reaches, narrow the gap with the lower reaches, and promote the overall development of the YREB.

(2) The CCD between EERE H-QD of YREB grows steadily, but it is still dominated by primary and moderate coordination. In recent years, the ecological environment development in the YREB generally lags behind the economic development, and the economic development is relatively detaches from ecological environment protection. Therefore, while developing the economy, provinces and municipalities in the YREB should implement the concept of ecology priority and green development, and realize the coordinated promotion of EERE development.

(3) The empirical results show that science and technology development level, fiscal expenditure and opening to the outside world are important means to improve CCD. Hence, the YREB should make full use of its geographical location and policy advantages, vigorously develop shipping, open up foreign trade channels, strive to raise the level of opening up, and facilitate the linked development of internal and external economic cycles, so as to form a new pattern of opening up to the outside world. Moreover, in the hope of injecting new impetus into the development of ecological environment protection and economic construction, it should increase investment in science and technology, attract high-caliber talents, stimulate scientific research enthusiasm, and promote the upgrading of industrial structure. Besides, government departments should increase financial investment in ecological environment, fully integrate ecological resources on the basis of protecting ecological environment, and promote the process of ecological industrialization, actively exploring the CCD of EERE under the background of the new era.

Credit Authorship Contribution Statement

Yuzhen Li: supervision, writing-review & editing. Pengzhen Yu: data curation, supervision, writing-original draft, writing-review & editing, methodology. Feiyu Zhu: supervision, visualization, writing-review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

The authors do not have permission to share data.

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