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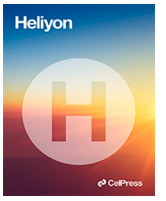

Research article

A comparative analysis of the levels and drivers of regional coordinated development in the Yangtze River Economic Belt and Yellow River Basin, China

Xiaolin Yang *, Zengwei Feng, Yiyan Chen, Xiangyang Xu

School of Emergency Management, Henan Polytechnic University, Jiaozuo, China

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ABSTRACT

Positioned in the era of the transformation of China's primary social contradictions, this study delves into the new connotations of regional coordinated development(RCD) from the perspective of "factors" coordination within the region and constructs an RCD evaluation system from five subsystems of regional economic coordination(REC), urban-rural coordination(URC), economic and social coordination(EASC), resource and environmental coordination(RAEC), and material and spiritual civilization coordination(MASCC). Then, the Entropy weight-TOPSIS model is used to evaluate the RCD levels of the 19 provinces located in the Yangtze River Economic Belt(YREB) and Yellow River Basin(YRB) from 2010 to 2019, and the two-way fixed-effects model is employed to illustrate the driving mechanisms of various influencing factors on the RCD in YRB and YREB. The results show that:(1)the RCD levels of YRB and YREB show a fluctuating upward trend during 2010 and 2019, however, both regions have low RCD levels, as seen by the mean RCD indices for YREB and YRB, which are only 0.433 and 0.309, respectively. (2) The RCD level of YREB is higher than that of YEB. In 2019, the "coordinated" provinces in YRB and YREB account for 37.50% and 81.82% of the total number of provinces in the basins, respectively, the "uncoordinated" and "low coordinated" provinces all located in YRB. (3) The RCD of YRB and YREB is significantly improved by REC, URC and RAEC, but not significantly positively by MASCC or EASC, and insufficient development of MASCC is the main contradiction limiting the increase in the RCD level of YRB, while the low level of EASC has become the main obstacle limiting the RCD of YREB. (4)Finally, based on the varying impact degrees and directions of different influencing factors on the RCD in YRB and YREB, the recommendations to promote RCD are proposed.

1. Introduction

China's swift economic growth since the reform and opening-up elevated it to the position of the world's second-largest economy and reshaped the pattern of world economic growth. However, the long-term excessive pursuit of high-speed economic growth has led to a series of problems such as disparity in regional development, vicious regional competition, over-consumption of resources, and serious deterioration of regional ecosystems, especially in China, where the total growth of regional GDP has long been the main variable in the performance assessment, and local governments are engaged in economic growth strategies in order to increase the

* Corresponding author.
E-mail addresses: yxl@hpu.edu.cn (X. Yang), zengwei970215@163.com (Z. Feng), yocttf_yiyan@163.com (Y. Chen), xxy77@hpu.edu.cn (X. Xu).

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proportion of regional GDP, resulting in a one-way development of "economic growth without regard to social development" [1,2] and the problem of "inadequate, uncoordinated and unbalanced regional development" has become the biggest shackle for China's high-quality development [3]. In 2017, China's General Secretary Xi Jinping pointed out that "as socialism with Chinese characteristics has entered a new era, the principal contradiction facing Chinese society has evolved. What we now face is the contradiction between unbalanced and inadequate development and the people's ever-growing needs for a better life" [4]. The transformation of the main social contradictions in the new era has given a new contemporary connotation to regional coordinated development(RCD), which should not only realize the continuous convergence of the economic gaps between regions, but also realize the coordinated development between social, economic, environmental and other multi-dimensional elements within the region, so as to better satisfy the pubilc's expanding demands for a better life [3]. In response to the major social contradictions in China, the coordinated development of among different developmental factors within the region will be an important direction for the future high-quality development(HQD) of China.

Since 2012, promoting the HQD of the Yangtze River Economic Belt(YREB) and the Yellow River Basin(YRB) has successively become China's national strategy, creating a new situation of RCD in China. YREB and YRB span 19 provincial-level units in the three major regions of eastern, central and western China, and the basins cover about 53.33% of China's national territory, with 66.84% of the country's total population and 66.62% of China's GDP in 2020 [5]. As China's most important watershed economic zones and coordinated development zones, YRB and YREB have systematic consistency and reference pathways in terms of institutional reforms, ecological protection, and economic development [6]. Furthermore, the RCD of YREB and YRB is not only a crucial vehicle for realizing China's national RCD strategy, but also an anchor for building a new pattern of RCD in China. Therefore, assessing the RCD levels of YREB and YRB and the driving mechanisms of influencing factors are of great theoretical and practical significance in facilitating the formulation of RCD policies for YREB and YRB.

2. Literature review

2.1. Research on RCD

Since the proposal of a sustainable development strategy by the United Nations Commission on Environment and Development in 1987 [7], RCD has emerged as a crucial issue for sustainable development [8–10]. Current research on RCD primarily focuses on the following three aspects:

(1) The connotation of RCD. The theory of RCD has its roots in regional development theories such as Agricultural Location Theory [11] and Central Place Theory [12,13]. These theories, rooted in economics and geography, impart a diverse perspective to the theory of RCD. Therefore, scholars mostly focused on RCD from the perspective of economics. For instance, Qin and Jiang(2011) defined RCD as an evolutionary process of economic relationships between regions, characterized by the convergence of economic development gaps and sustained overall economic efficiency growth [14]. Liu and Hao(2023) argued that RCD aims for common development among regions, seeking relative economic balance and dynamic coordination through rational division of labor in the process of uneven economic growth in regions [15]. Wang et al.(2023) posited that RCD is a model that controls development gaps between regions within reasonable and moderate bounds, achieving equalization of economic development opportunities through mutual complementarity and shared development [8]. Building upon economic development, scholars have gradually introduced non-economic factors such as social progress, ecological protection, and public services, further expanding the connotations of RCD. This emphasizes that RCD not only involves reducing economic disparities between regions, but also entails the organic combination and coordination of institutions, society, population, environment, and resources among regions [16]. It is evident that there is currently some divergence in the understanding of the connotations of RCD. However, its essence is consistently emphasized as the reduction of development gaps between regions during the developmental process.

(2) Measurement of the RCD Level. Due to varying interpretations of the connotations of RCD among scholars, a consistent system for measuring the RCD level has not yet been established. The previous studies predominantly adopt an economic perspective, emphasizing the reduction of economic disparities between geographic regions. Core indicators such as GDP and per capita GDP are often employed, utilizing methods such as the Gini coefficient and Theil index to reflect economic gaps between regions. These measures are then used as the basis for assessing the RCD level. For instance, Gao and Ke(2020) used per capita GDP data and employed the Gini coefficient and population-weighted coefficient of variation to study the dynamic evolution of economic development gaps among different provinces in China [17]. Tirado et al. (2016) utilized population-weighted Gini coefficient and Theil index of per capita GDP to assess the changing RCD levels in various regions of Spain from 1860 to 2010 [18]. As increasing economic disparities between regions give rise to various social problems, regional coordinated development has become an important goal in the country's social governance. Consequently, in recent years, research on RCD has shifted from an economic perspective to a managerial perspective. The dimensions of regional coordination have also expanded from the single dimension of regional economic disparities to multiple dimensions, including education, population, technology, and the environment [3]. Scholars are inclined to develop a comprehensive index system to assess the RCD levels. For example, Yao and Men(2020) evaluated the coordinated development levels of economic development, technological innovation, and technological talents between different regions in China using the coupling degree model [19]. Zhang et al. (2020) established an RCD evaluation framework from five aspects, namely, ecological environment, people's livelihood, infrastructure, public services, and economic development, and utilized the coefficient of variation, the Theil index, and the σ coefficient localized coordinated

development measurement method to study the RCD levels of 30 provinces in China [2]. Guo et al.(2021) constructed an RCD assessment system from the dimensions of economic system, social system, infrastructure, and ecological environment, and utilized the Gini coefficient method to reveal the discrepancies in the RCD level and the reasons of the differences in the provinces in China [20]. Although the analysis of the measurement of RCD levels has shifted from measuring economic development gaps to measuring gaps in measuring gaps in the level of integrated economic, social and environmental development, the essence remains the measuring of development gaps between regions.

(3) Influencing factors for RCD. The unequal and unbalanced development of different regions can be attributed to variations in infrastructure, technological applications, environment and natural features, etc. [21]. As research on RCD has progressed, many scholars have attempted to delve into the influencing factors of RCD from different dimensions, often emphasizing qualitative research. For example, Gao and Li (2016) and Li et al.(2021) discussed the influence of industrial industry transfer on RCD by taking industry transfer as a research perspective, explaining the endogenous and exogenous mechanisms of industrial transfer to promote regional coordinated development [22,23]. Zhang(2019) explored the impact of industrial structure upgrading on RCD and analyzed its mechanism [24]. Wang et al. (2017) argued that the spatial spillover effect of technological innovation is a strong driving force to improve RCD, and put forward the mode and path for technological innovation to promote RCD [25].

2.2. Research on RCD of YRB and YREB

The Yellow and Yangtze rivers are the mother rivers of China, and scholars have been particularly interested in the development of these two river basins, and a great deal of research has been done on the management of water-soil hazards [26–28], the responses of climate change [29,30], the value of ecosystem services [31,32], medical care, common prosperity, education, and other livelihood problems [33,34],etc. Recently, the issue of HQD in YREB and YRB has gradually gained more attention among scholars [27], who have focused on policies and development paths of the basins' HQD [35,36], and assessment of the level of HQD of the basins economy, industry, agriculture, etc. [37–39]. In the context of the RCD of YREB and YRB, the existing literature is relatively scarce. The limited studies available primarily focus on regional disparities within YREB and YRB, particularly in areas such as agricultural efficiency [40], the levels of HQD [27,41], technological innovation efficiency [42], resource utilization efficiency [43] and green growth efficiency [44].

The literature review shows that the current relevant researches have greatly enriched the connotations, level measurement and influencing factors of RCD and have also improved the methodological system of RCD research. However, the following limitations still exist: (1)RCD includes not only the convergence of the development gaps in economic, social and environmental factors between regional subjects, but also the coordinated development of all factors such as economy, society and environment within the region, while the existing studies mostly understand the RCD from the perspective of interregional differences, neglecting the issue of coordinated development among "factors", such as economic, social and environmental factors, within the region. (2)At present, the analysis of influencing factors on RCD mostly discusses the influencing mechanism of a certain factor on RCD, such as industry transfer, industry structure, and national strategy, etc., and most of them are based on qualitative research. (3)YREB and YRB jointly carry national strategies such as the West Development Strategy and the Belt and Road Strategy, therefore, the coordinated development of YRB and YREB is a microcosm of the coordinated development of China and an important direction for the HQD of YREB and YRB. However, there is a lack of comparative studies on the RCD of YREB and YRB from the perspective of factors coordination within the region, especially studies on the driving mechanisms of different factors on the RCD are rare.

Based on the above, the study focuses on factors coordination of the 19 provinces within YREB and YRB. Positioned in the context of the era characterized by the transformation of China's primary social contradictions, the research delves into the new connotation of RCD from the perspective of the coordinated development among internal factors within the region. Furthermore, based on the thorough analysis of factors coordination connotation, an RCD evaluation system is constructed. The study provides a comprehensive investigation of the RCD characteristics of the 19 provinces in the two basins from 2010 to 2019. Additionally, the research utilizes a panel regression method to examine the driving mechanisms of influencing factors on the RCD levels.

This study makes the following key contributions: (1) this study explores the issue of RCD from the coordinated development among internal regional factors. This departure from previous approaches, which mainly measured RCD issues from the perspective of inter-regional coordination, enriches the connotations of RCD. Moreover, it provides new insights and focal points for constructing a new pattern of RCD in China. (2)The previous studies mainly employed methods such as the Gini coefficient and Theil index to compare the development gaps between regions and measure the RCD level. This study, however, delves into the new connotations of RCD from the perspective of the coordination of internal regional factors and constructs an RCD evaluation system based on the objective weighting method, i.e. the Entropy weight-TOPSIS model. Additionally, the paper conducts quantitative analysis of the driving mechanism of RCD through a panel regression model, which can better reveal the impact and direction of different influencing factors on the RCD of YRB and YREB. It also provides a reference point for future policies formulation and adjustment in the coordinated development of these regions. (3)Through the comparative analysis of the RCD levels in YREB and YRB, this paper can better reveal the strengths and weaknesses of the RCD in these two regions. Consequently, it facilitates the promotion of inter-regional development between the two basins, helps narrow the north-south gap, and provides a reference basis for cultivating a new pattern of RCD in contemporary China.

3. Study Area and methodology

3.1. Study Area

In order to better understanding the differences in the levels of RCD and their driving mechanisms in YREB and YRB, 19 provinces in YREB and YRB are taken as the research targets(Fig. 1). YREB includes 11 provinces, including Sichuan, Anhui, Shanghai, Zhejiang, Jiangxi, Jiangsu, Hunan, Hubei, Chongqing, Yunnan and Guizhou, and YRB includes eight provinces, including Qinghai, Shandong, Shanxi, Gansu, Shaanxi, Ningxia, Inner Mongolia and Henan.

3.2. Research framework

This paper is carried out in four steps to investigate the spatial-temporal characteristics of the RCD levels and to identify the driving mechanisms of influencing factors on the RCD levels in YRB and YREB(Fig. 2). Firstly, we begin from the analysis of new connotation of RCD and reveal the components of the system of RCD from the perspective of factors coordination within the region. Secondly, according to the in-depth analysis of the connotation of RCD, the assessment system of RCD is constructed from five dimensions and the regional coordinated development evaluation model is established with assistant of Entropy weight-TOPSIS method. Thirdly, from 2010 to 2019, the 19 provinces' RCD indices in YRB and YREB are calculated, and the driving mechanisms of influencing factors on the levels of RCD in YRB and YREB are explored with the help of two-way fixed effects model. Finally, combined with the findings of the driving mechanisms of different influencing factors on the RCD in YRB and YREB, we proposed the recommendations to improve the RCD levels in YRB and YREB.

3.3. The connotation of RCD and the construction of the index system

In the past, scholars have mostly measured the RCD levels by assessing the disparity between geographic regions from the perspective of economics. With the expansion of research on the coordinated regional development, scholars generally agree that the coordinated regional development system is a complex system containing multiple subsystems. And scholars mostly believe that economy, society and environment are the core elements of a coordinated regional development system, and multiple interdependent and interactive relationships exist among them, which in turn promote and restrict each other. For example, the economy subsystem provides material support for both the ecological environment and the society subsystems, the environment subsystem provides the various resources and conditions for the economy and society subsystems, and the society subsystem provides various powers and services for the economy and environment subsystems. Meanwhile, the development of economic and social systems can also put enormous pressure on the ecological environment. Thus, the most important element of regional coordinated development of is to fulfill coordinated development among social, economic and environmental factors. In 2019, China's General Secretary Xi Jinping elaborated on the new connotation of RCD in the new era in his article *Deeply Understand of the New Development Philosophy*, from the aspects of promoting coordinated regional economic development, coordinated urban-rural development, coordinated economic and social development, coordinated development of material and spiritual civilization, and integrated development of economic and

Fig. 1. Study area.

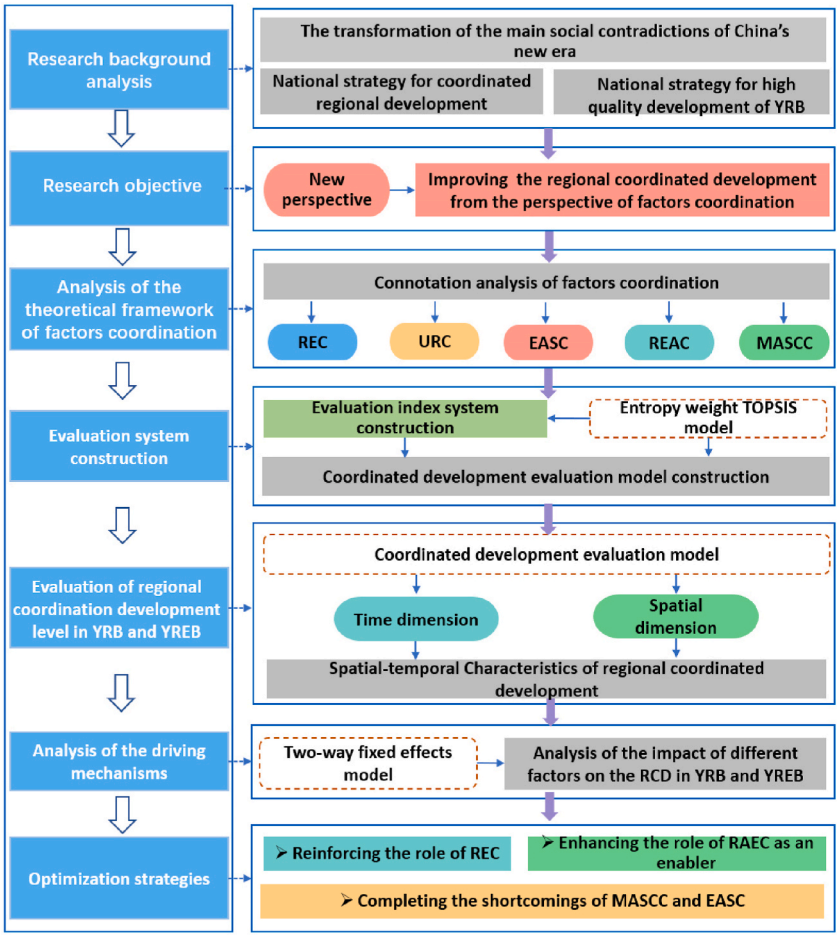

Fig. 2. Research framework.

national defence construction [45], which has pointed out the direction for the construction of an RCD pattern in China in the future. In view of this, this study, on the basis of previous studies and in conjunction with Xi's elaboration on the connotation of RCD in the new era, establishes a RCD evaluation index system including 5 subsystem layers, 13 elemental layers, and 18 indicator layers around regional economic coordination(REC), urban-rural coordination(URC), economic and social coordination(EASC), resource and

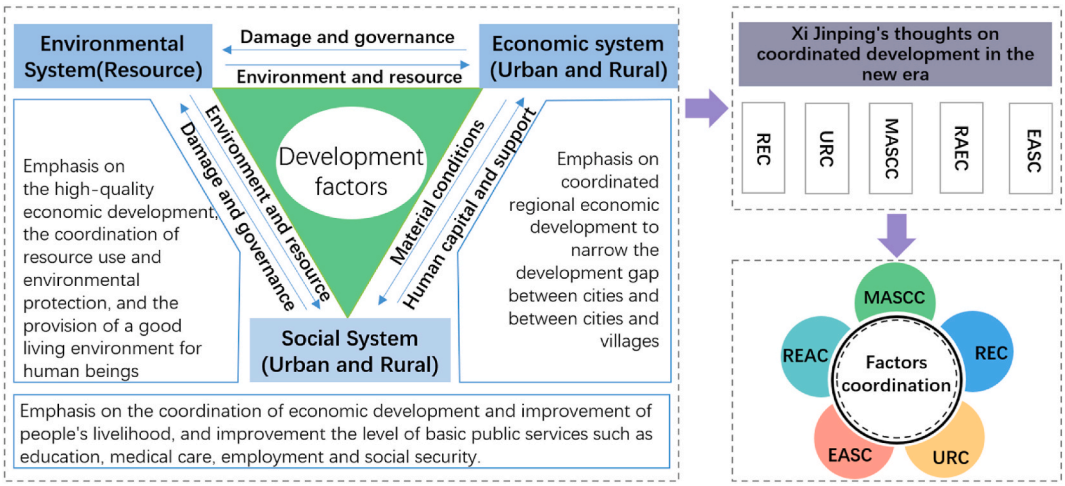

Fig. 3. The theoretical analysis framework of RCD from the perspective of "factors" coordination.

environmental coordination(RAEC), material and spiritual civilization coordination(MASCC), and economic and defense construction coordination(EDCC) (data on EDCC are difficult to obtain and will not be analyzed in this paper) (Fig. 3, Table 1):

(1) Regional economic coordination(REC). REC is the basis and core element of RCD, the core meaning of which is to adjust the industrial structure of smaller-scale units within the region according to their respective resource endowment conditions, so as to complement each other's strengths and develop in a staggered manner, and gradually upgrade the economic structure, so that innovative development and open development will become the primary driving force and the only way for their economic development, and promote a trend change in the economic growth model. And the concrete manifestation of regional economic coordination is the continuous convergence of the interregional economic gaps and the directional reversal of the divergent trend of regional economic growth.
(2) Urban-rural coordination(URC). The core essence of URC is to achieve balanced income and equal quality of life for rural and urban dwellers, accelerate the upgrading and transformation of the industrial structure in rural areas, enhance the integrated urban-rural development level and narrow the development gaps. Therefore, this paper establishes two elemental level indicators, including the level of integrated urban-rural development, the level of urban-rural income.
(3) Economic and social coordination(EASC). The ultimate aim of high-quality development is to make economic growth better promote people's well-being [46], focusing on solving the contradiction of insufficient supply of basic public services such as education, medical care, and social security, realizing a reasonable allocation of public service resources and improving the level of equalization of basic public service quality. Therefore, this paper establishes three elemental level indicators, including education level, medical care level and infrastructure level.
(4) Resource and environmental coordination(RAEC). All along, China's long-term rapid economic growth has mainly relied on high input, high consumption and high emission factor-driven and input-driven, which not only easily causes serious overload of resources and energy, but also leads to increasingly prominent environmental pollution problems. The realization of RAEC requires innovation in economic development models, with green development as the core philosophy. Firstly, it involves a transformation of development patterns, a shift in growth momentum, and a re-evaluation of the priority order for creating and acquiring economic value [47]. Secondly, it necessitates the reduction of resource and energy consumption in the process of economic growth, along with minimizing the generation and emission of environmental pollutants. Meanwhile, emphasizing ecological civilization construction serves as a focal point, complemented by increased investment in environmental governance.

Table 1
Evaluation index system.

Subsystem Layers	Element Layers	Indicator Layers	Units	Properties	Weight		
					2010	2014	2019
REC	Economic level difference	Coefficient of variation of GDP per capita by city	–	+	0.0267	0.0178	0.0193
	Economic structural difference	Coefficient of variation of the share of tertiary industry in GDP by city	–	+	0.0028	0.0024	0.0012
	Economic power difference	Coefficient of variation in the number of patents per 10,000 people by city	–	+	0.1644	0.1146	0.0765
	Economic openness difference	Coefficient of variation of the share of total exports and imports in GDP by city	–	+	0.1618	0.1282	0.1083
		Percentage of airport employees per 10,000 people	%	+	0.1743	0.1522	0.1674
URC	Urban-rural integration level	Urbanization rate	%	+	0.0072	0.0044	0.0025
	Urban-rural income level	Urban to rural income ratio	%	–	0.0034	0.0023	0.0022
EASC	Education level	Public finance expenditure on education per capita	yuan	+	0.0098	0.0065	0.0060
	Medical care level	Public budget expenditure on health per capita	yuan	+	0.0110	0.0052	0.0087
	Infrastructure level	Parkland area per capita	m^2	+	0.0299	0.0219	0.0167
RAEC	Resource consumption level	Unit energy intensity	standard coal/yuan	–	0.0194	0.0252	0.0484
		Unit water consumption intensity	m^3 / million	–	0.0347	0.0290	0.0370
	Environmental pollution level	Industrial SO_2 emission intensity	t/million yuan	–	0.0531	0.0598	0.0994
		Industrial solid waste emission intensity	t/yuan	–	0.0613	0.1222	0.1774
	Environmental governance level	Investment in environmental governance as a proportion of GDP	%	+	0.0648	0.0911	0.0454
		$PM_{2.5}$ concentration	$\mu g/m^3$	–	0.0113	0.0119	0.0064
MASCC	Cultural industries development level	Cultural services revenue as a share of GDP	%	+	0.0912	0.1430	0.1260
		Number of cultural industry institutions above 10,000 persons in size	pcs	+	0.0730	0.0624	0.0511

Note: In the column Properties, "+" means the index is positive and "-" means the index is negative.

(5) Material and spiritual civilization coordination(MASCC). The core content of common prosperity is a high degree of unity between the value of material interests and the value of spiritual needs. And in parallel with economic development, we need to keep providing more public cultural goods and services to satisfy people's growing spiritual needs. Therefore, this paper establishes one elemental indicator, namely the cultural industries development level.

3.4. Measuring the RCD levels

At present, the common methods of multi-index comprehensive evaluation can be divided into two categories: subjective assessment method (Delphi method, AHP method, etc.) and objective assessment method (Entropy weight method, Entropy weight-TOPSIS model, etc.) [48]. Compared with the subjective assessment method, the objective evaluation method can automatically determine the weighting coefficients mainly through the variation of each indicator in the indicator as a whole and the degree of influence on other indicators, which could reduce the interference of artificial factors and have stronger objectivity. Thus, it can reflect the differences between the evaluation objects more effectively. The Entropy weight-TOPSIS model is a comprehensive assessment method that incorporates the Entropy weight method and TOPSIS method. The Entropy weight method is a kind of objective assignment method, whose biggest effect is to reduce the bias brought by subjective assignment. TOPSIS method is a kind of multi-objective decision analysis method, especially suitable for the comparative study of multiple programs and objects, from which to find out the best program or the object with the strongest competitiveness. This study adopts the Entropy weight-TOPSIS model to calculate the RCD level of the 19 studied provinces, which uses the Entropy weight method to determine the weights of different index first, and then the TOPSIS model to rank the objects. The model can well assess the difference of RCD levels of YRB and YREB and the contribution of the subsystems. The method of calculation is as follows.

3.4.1. Construct the original matrix

Assuming that there are n assessment units and m assessment index, and x_{ij} represents the value of the i-th index of the j-th assessment unit, among which, $i \in [1,m]$, $j \in [1,n]$, the assessment raw data matrix can be constructed (Eq. (1)).

$$A = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \tag{1}$$

3.4.2. Index weights are determined as follows

1. Determine the ratio r_{ij} of the i-th index in the j-th cell, see Eq. (2).

$$r_{ij} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}} \tag{2}$$

2. Calculate of entropy values for each index, see Eq. (3).

$$e_i = -\frac{\sum_{j=1}^{n} r_{ij} \times ln\, r_{ij}}{ln\, n} \tag{3}$$

where e_i is the entropy value of the i-th index, see Eq. (4).

3. Calculate of weight for each index.

$$w_i = \frac{1 - e_i}{\sum_{i=1}^{m} (1 - e_i)} \tag{4}$$

where w_i is the weight of the i-th index.

3.4.3. Data standardisation

As there are positive and negative index in the assessment index system, Eq. (5) and Eq. (6) are adopted to standardize original data of positive index and negative index, respectively. So as to obtain the standardized data matrix $B = (x_{ij}^{'})_{m\times n}$.

$$x_{ij}^{'} = \frac{x_{ij} - min\,(x_{ij})}{max(x_{ij}) - min\,(x_{ij})} \tag{5}$$

$$x_{ij}^{'} = \frac{max(x_{ij}) - x_{ij}}{max(x_{ij}) - min\ (x_{ij})} \tag{6}$$

3.4.4. Construct a weighted decision matrix (WDM)

Equation (7) is used to construct a weighted decision matrix V, and the weight vector matrix W is adapted the weights of each indicator w_i.

$$V = B \times W = \left[v_{ij}\right]_{m \times n} \tag{7}$$

3.4.5. Determine the ideal solutions

Determine the positive ideal solution V^+ and the negative ideal solution V^- for each index (Eq. (8) and Eq. (9)).

$$V^+ = \left\{max\ v_{ij} \middle| i = 1, 2, \ldots, n\right\} = \left\{V_1^+\ ,\ V_2^+, \ldots, V_n^+\right\} \tag{8}$$

$$V^- = \left\{min\ v_{ij} \middle| i = 1, 2, \ldots, n\right\} = \left\{V_1^-, V_2^-, \ldots, V_n^-\right\} \tag{9}$$

3.4.6. Calculate the distances

Eq. (10) and Eq. (11) are used to calculate the distances D_j^+ and D_j^- for each assessment vector to V^+ and V^-, respectively.

$$D_j^+ = \sqrt{\sum_{i=1}^{n} \left(V_i^+ - V_{ij}\right)^2} \tag{10}$$

$$D_j^- = \sqrt{\sum_{i=1}^{n} \left(V_i^- - V_{ij}\right)^2} \tag{11}$$

3.4.7. Calculate the nearness degree

Eq. (12) is used to calculate the Nearness Degree T_j, i.e. the factor coordination development index of different evaluation units or the development index of the five subsystems.

$$T_j = \frac{D_j^-}{D_j^+ + D_j^-} \tag{12}$$

3.5. Analysis of the driving mechanisms of RCD: a panel regression model

In order to reveal the driving mechanisms of different influencing factors on RCD of 19 provinces in YRB and YREB, and based on the measurement of the RCD levels in both basins from 2010 to 2019, this paper establishes a panel regression model to explain the RCD of YRB and YREB during the period of 2010–2019 with the RCD index as the explained variable and REC, URC, EASC, RAEC, and MASCC as the explanatory variables. The panel regression model constructed is as follows.

$$RCD_{it} = \beta_0 + \beta_1 REC_{it} + \beta_2 URC_{it} + \beta_3 EASC_{it} + \beta_4 RAEC_{it} + \beta_5 MASCC_{it} + \varepsilon_{it} \tag{15}$$

Where RCD_{it} is the factors coordination development index for province i in period t; REC_{it}, URC_{it}, $EASC_{it}$, $RAEC_{it}$ and $MASCC_{it}$ are the development index of REC, URC, EASC, RAEC and MASCC of province i in period t respectively; β is the regression coefficient for the

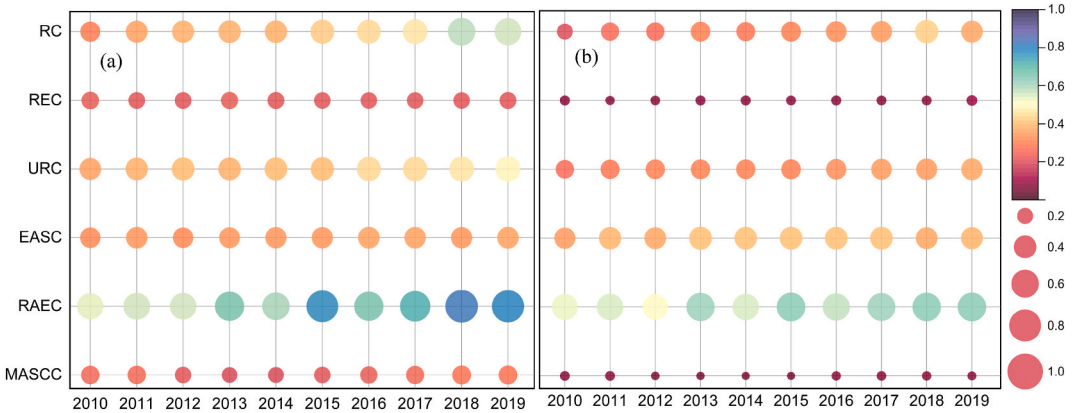

Fig. 4. Trends in the temporal dynamics of the RCD Indices. (a)YRB, (b)YREB.

different variables and ε_{it} is the random errorterm.

3.6. Data sources and processing

The worldwide outbreak of the COVID-19 had a great negative impact on China's economy, especially in 2020–2021, when the severe epidemic led to anomalies and distortions in various indicators of China's economic and social development. In order to better assess the RCD levels of YRB and YREB, this study mainly chooses the 10-year period from 2010 to 2019 prior to the outbreak of the New Crown Epidemic as the time period for the study. The 2011–2020 *China Energy Statistical Yearbook*, the 2011–2020 *China Statistical Yearbook*, and the statistical yearbooks of the 19 provincial units are the primary sources of the data in this paper. Data processing and mapping was mainly done with the help of Microsoft Excel 2018, Stata and ArcGIS 10.8.

4. Results

4.1. Temporal dynamics of the RCD index of YRB and YREB

Fig. 4 displays the temporal trends of the average values of the RCD indices and the five sub-system indices for YRB (Fig. 4a) and YREB (Fig. 4b) for each provincial unit from 2010 to 2019. The results show that the RCD indices of YREB and YRB during the study period ranged from 0.311 to 0.582 and from 0.199 to 0.419, with average values of 0.433 and 0.309, respectively, and the RCD indices of both showed a fluctuating upward trend. From the five subsystems, (1)the RAEC indices in YRB and YREB ranged from 0.528 to 0.644 and from 0.525 to 0.827, respectively, and the indices showed a fluctuating upward trend during the 10 years. (2)The URC indices of YREB and YRB also demonstrated a steady upward trend from 2010 to 2019, with the URC index of YRB rising from 0.263 in 2010 to 0.367 in 2019, and the URC index of YREB rising from 0.366 in 2010 to 0.483 in 2019. (3)The trend of REC indices in YRB and YREB during 2010–2019 is not obvious and the overall level is low, with multi-year averages of 0.078 and 0.066, respectively. (4) Similarly, the MASCC indices in YRB and YREB showed a less obvious pronounced trend and a low overall level during the period 2010–2019, with multi-year averages of 0.221 and 0.239 respectively. (5) Additionally, the EASC indices in YRB and YREB during 2010–2019 ranged from 0.352 to 0.407 and from 0.323 to 0.362 respectively, suggesting that the level of EASC in both regions did not improve significantly during the 10 years.

4.2. Spatial distribution patterns of the RCD levels of YRB and YREB

To better analyse the spatial pattern of RCD levels in YRB and YREB, this paper selects cross-sectional data of the RCD indices for the 19 provinces in 2010, 2014 and 2019 to carry out the spatial distribution pattern analysis. As the comprehensive index of RCD of 19 provinces in 2010, 2014 and 2019 ranged from 0.110 to 0.920, with a mean (Mean) of 0.353 and a standard deviation (SD) of 0.165. Therefore, drawing on the study of Wei and Li(2018) [4], based on the mean and SD of the RCD index, the provinces with the index greater than Mean + 0.5SD, i.e. greater than 0.436, are classified as "coordinated"; the provinces with Mean < RCD index < Mean + 0.5SD, i.e. 0.353 < RCD index<0.436, are classified as "improved"; the provinces with Mean-0.5SD < RCD index < Mean, i.e. 0.271 < RCD index <0.353, are classified as "low coordinated"; the provinces with RCD index < Mean-0.5SD, i.e. less than 0.271, are classified as "uncoordinated".

The results show (Fig. 5) that:(1) in 2010, only three provinces had "coordinated" indices greater than 0.436, namely Shanghai (0.843), Zhejiang(0.509) and Jiangsu(0.477), and only one provincial unit had a "low coordinated" index between 0.271 and 0.353, namely Shandong(0.278), while the remaining 15 provinces were "incoordination". (2)In 2014, there were still three "coordinated" provinces with RCD indices greater than 0.436, namely Shanghai(0.749), Zhejiang(0.494) and Jiangsu(0.442), and two "improved" provinces with the indices between 0.353 and 0.436, namely Chongqing(0.367) and Shandong(0.356). The only "uncoordinated"

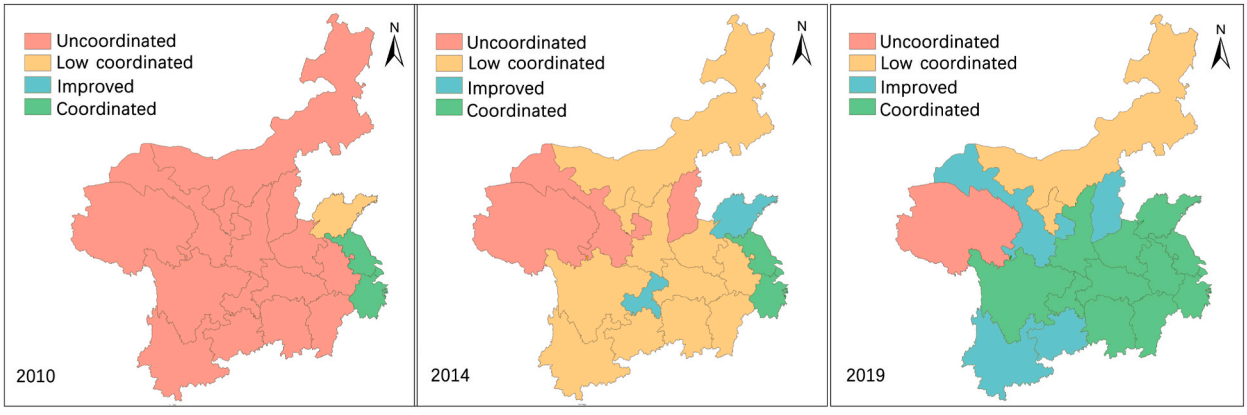

Fig. 5. Spatial distribution patterns of RCD levels in 2010, 2014 and 2019. a:2010, b:2014; c:2019.

provinces with the indices of less than 0.271 include Gansu(0.262), Shanxi(0.228) and Qinghai(0.154), while the remaining 11 provinces are all "low coordinated" provinces. (3)In 2019, there were 12 "coordinated" provinces with RCD indices greater than 0.436, such as Shanghai(0.920), Zhejiang(0.591) and Jiangsu(0.532) etc., while the "improved" provinces with indices between 0.353 and 0.436 include Guizhou(0.408), Yunnan(0.407), Gansu(0.390) and Shanxi(0.362). The "low coordinated" provinces include Inner Mongolia(0.326) and Ningxia(0.341), while the only uncoordinated province is Qinghai(0.144).

The spatial patterns of the development levels of the five subsystems in 2010, 2014 and 2019 are showed in Fig. 6. (1)In terms of the REC, Shanghai, Zhejiang and Jiangsu ranked the top three in the REC indices, with multi-year average values of 0.870, 0.434 and 0.398, respectively, indicating that the economic development gap between cities within them is relatively small, while the REC indices of other provinces are generally low, with multi-year average values ranging from 0.025 to 0.180, and the REC indices of Anhui, Jiangxi, Chongqing, Yunnan, Henan and Shandong are on an upward trend, while all other provinces are on a downward trend to varying degrees. (2)In terms of the URC, the URC indices of Shanghai and Gansu decreased from 2010 to 2019, while the rest of the provinces showed varying degrees of increase; Shanghai, Jiangsu and Zhejiang had higher URC indices, with multi-year averages of 0.944, 0.612 and 0.626 respectively, while Gansu, Yunnan and Guizhou have relatively lower ones, with multi-year averages of 0.042, 0.082 and 0.040 respectively. (3)In terms of the EASC, the indices for Shanghai, Zhejiang, Jiangsu, Hunan, Yunnan and Shaanxi are on the decline, while the rest of the provinces are on the rise. And spatially, Shanghai, Chongqing and Ningxia having the higher indices, with multi-year averages of 0.887, 0.703 and 0.778 respectively, while Henan, Yunnan, Sichuan and Guizhou have lower indices, with multi-year averages of less than 0.200. (4)In terms of the RAEC, the indices of the system are generally high, with all provinces, except Qinghai, Gansu and Ningxia, showing an increasing trend. (5)In terms of the MASCC, the indices of the system are generally low, except for Shanghai, which is high.

5. Analysis of the driving mechanisms for the RCD of YRB and YREB

5.1. Descriptive analysis of variables and unit root test

Table 2 presents the descriptive statistical results for each variable. It can be seen that the mean and median values of each variable are relatively similar. The skewness is close to 0, suggesting that the variables tend to show a Gaussian distribution.

Fig. 7 shows the correlation between the explained variable and each explanatory variable. The results show that there is a certain linear relationship between the RCD index and the indices REC, URC, EASC, the RAEC, and MASCC, with the R^2 values of 0.6444, 0.6063, 0.1954, 0.4579 and 0.6211, respectively, see Fig. 7a-e.

Besides, to avoid spurious regression affecting the test results, this paper first chose ADF test, LCC test and IPS test to conduct unit root tests on the six variables: RCD, REC, URC, EASC, RAEC, MASCC, in the 19 provinces from 2010 to 2019. Table 3 shows that the variables passed the stability test of the unit root, indicating that the panel data of all variables could be estimated by the panel regression model.

5.2. Estimation of the panel regression model

Panel regression models generally include random effects models(REM), fixed effects models(FEM) and mixed effects models (MEM) [2]. In this paper, the optimal model will be determined by Hausman test and F-test, and Table 3 shows the regression results. In addition, the study added different effect controls such as individual random effect, individual fixed effect, time random effect, time fixed effect and two-way fixed effect in the process of analysis. First of all, the results of F-test suggest that the results of FEM are better than that of the MEM, and then the results of Hausmann's test show that the results of FEM are better than that of the REM, so this paper should choose the FEM for analysis. Furthermore, the F-test results show that the results of the two-way fixed effects model (two-way FEM) are better than those of the individual fixed-effects model and the time fixed-effects model, so the two-way FEM is

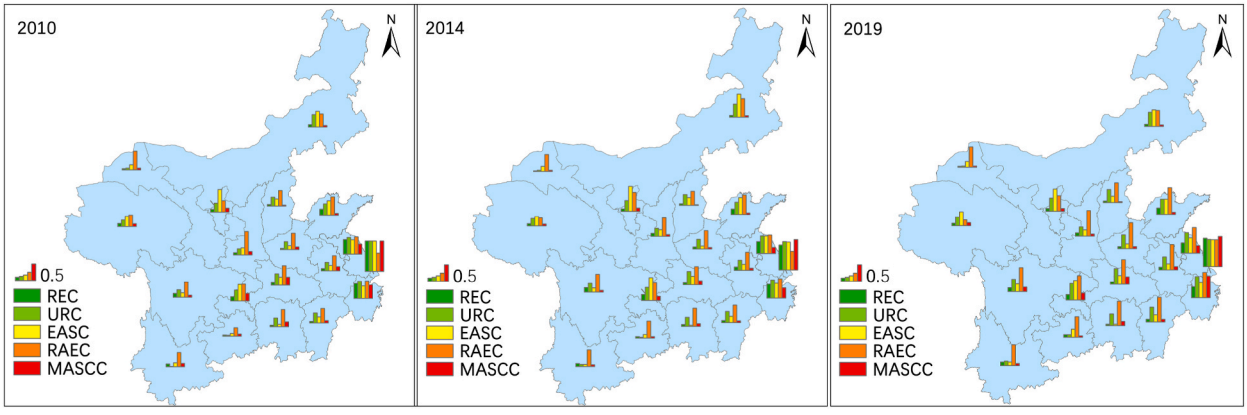

Fig. 6. Spatial distribution pattern of development level of subsystems in 2010, 2014 and 2019. a:2010, b:2014; c:2019.

Table 2
The descriptive statistics of the variables.

Variable	Mean	Median	Std.Dev	Min	Max	Range	Skewness	Kurtosis
RCD	0.378	0.342	0.157	0.094	0.920	0.826	0.616	2.063
REC	0.161	0.184	0.202	0.016	0.997	0.980	0.557	3.113
URC	0.375	0.372	0.211	0.010	1.000	0.990	0.649	2.024
EASC	0.363	0.298	0.249	0.035	1.000	0.965	0.753	2.419
RAEC	0.646	0.662	0.160	0.090	0.919	0.829	−0.847	3.771
MASCC	0.164	0.186	0.225	0.023	1.000	0.977	0.892	4.647

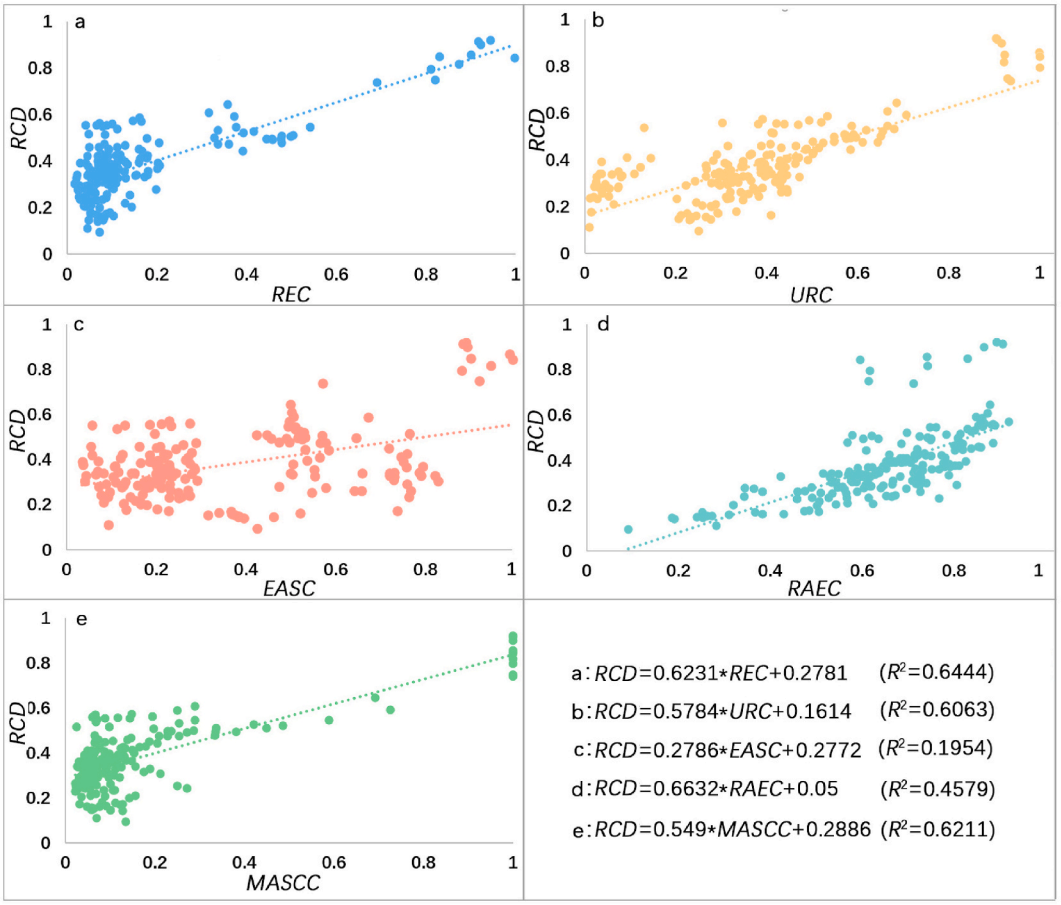

Fig. 7. The correlation between the explained variable and each explanatory variable. a: REC, b:URC, c:EASC, d:RAEC, e:MASCC.

Table 3
Unit root test.

Variables	RC	REC	URC	EASC	RAEC	MASCC
ADF test	35.815	79.353***	101.543***	13.001	68.591***	18.902
LLC test	−9.349 ***	−6.209***	−10.956***	−6.677***	−12.129***	−3.860***
IPS test	−4.074***	−1.277* *	−1.506	0.859*	−5.673***	1.498***
Stability	Stable	Stable	Stable	Stable	Stable	Stable

Note: Significant at the 1%, 5%, and 10% levels of significance are indicated by the symbols ***, **, and *, and the same is as below.

the optimal panel regression model in this paper. Therefore, this paper adopts the estimation results of two-way FEM to discuss the impact of various factors on the RCD of YRB and YREB. The estimation results of the two-way FEM(Table 4) show that the regression coefficients of REC, URC, and RAEC are 0.593, 0.398, and 0.363, respectively, and all the variables pass the significance test at the 1% level, which suggests that REC, URC, and RAEC have significantly improved the RCD in both regions. And the RCD index will increase

Table 4
Results of the panel regression analysis.

Explanatory variables	Individual REM	Individual FEM	Time REM	Time FEM	Two-way FEM
REC	0.295*** (5.16)	0.519*** (5.38)	0.477*** (13.78)	0.396*** (13.51)	0.593***(9.82)
URC	0.122***(2.84)	1.016*** (13.27)	0.070**(2.20)	0.010 (0.52)	0.398*** (6.12)
EASC	−0.025 (−0.96)	−0.076 (−1.18)	−0.036*(-1.89)	−0.011 (−0.93)	−0.082*(-2.12)
RAEC	0.463***(15.66)	0.359*** (12.25)	0.387*** (19.26)	0.409***(23.86)	0.363***(16.98)
MASCC	0.146***(2.95)	−0.032 (−0.44)	0.043 (1.43)	0.140***(5.61)	0.008 (0.17)
Constant	−0.029 (−1.53)	−0.285***(-8.55)	−0.042***(-3.29)	0.028***(2.61)	−0.133***(-5.09)
R^2		0.809		0.963	0.940
F-test		F = 11.41,P = 0.00		F = 52.43,P = 0.00	F = 177.23,P = 0.00
Hausman Test	chi2 = 178.84,P = 0.00		chi2 = 67.79,P = 0.00		

by 0.593%, 0.398% and 0.363% for every 1% increase in the REC, URC, and RAEC indices. The regression coefficient of MASCC is 0.008, but it fails the test of significance, indicating that MASCC has a positive effect on RCD, but the effect is not obvious. The regression coefficient of EASC is −0.082 and passes the 10% significance test, suggesting that the EASC of YRB and YREB is not fully consistent with the direction of the overall RCD of the regions.

5.3. Heterogeneity analysis of YRB and YREB

The heterogeneous regression analysis results of different factors on the driving mechanisms of the RCD in YRB and YREB are shown in Table 5. It can be seen that: (1)the regression coefficients of REC and RAEC on YRB and YREB are 0.478, 0.666 and 0.425, 0.370, respectively, and all of them pass the test of significance at least at the 5% level, indicating that both REC and RAEC have a positive influence on the RCD in both regions. (2)The regression coefficient of URC in YREB is 0.656 and passes the 1% significance test, while the regression coefficient in YRB is −0.078, but fails to pass the significance test, suggesting that URC has significantly improved the RCD of YREB, while it has hindered the RCD of YRB, but the impact is not significant. (3)The regression coefficient of EASC on YRB and YREB are −0.082 and −0.146 respectively, indicating that EASC has a negative impact on the RCD of both basins. This indicates that the level of public facilities and infrastructure allocation lags behind the level of regional economic growth, and this phenomenon is more obvious in YREB. (4)The regression coefficient of MASCC in YRB is −0.653 and passes the 1% significance test, suggesting that MASCC has significant hindered the RCD of in both basins, whereas the regression coefficient of MASCC in YREB is 0.036, suggesting that a marginally significant beneficial impact of MASCC on YREB's RCD.

6. Discussion

6.1. Comparison of RCD levels in YRB and YREB

At the beginning of the China's reform and opening-up, China implemented the policy of "unbalanced development", and gradually formed an unbalanced economic and geographic pattern of macroeconomics in which "the South is strong and the North is weak, and the East is high and the West is low", and the problem of uncoordinated and unbalanced regional economic development has become increasingly prominent. After the year 2000, with the implementation of the strategic initiatives such as the Western Development, the revitalization of the Northeast, especially since 2012, strategies such as the "Belt and Road" initiative and the ecological protection and high-quality development strategy in YREB and YRB have been implemented, resulting in a continuous narrowing of the regional economic gaps in China [2]. However, it is essential to recognize that the long-term pursuit of rapid economic growth at the expense of single-dimensional social development has imposed numerous constraints on China's RCD. Issues such as unbalanced urban-rural development, low levels of basic public services, and serious environmental pollution have become increasingly prominent. In this context, China's General Secretary Xi Jinping noted in 2017 that "what we now face is the contradiction between unbalanced and inadequate development and the people's ever-growing needs for a better life" [4]. This signifies that the connotation of RCD in China has extended from the traditional narrowing of economic disparities between regions to the realization of comprehensive coordinated development within regions, including the reduction of regional disparities, urban-rural coordination, economic and social coordination, and resources and the environment coordination. The RCD of YRB and YREB plays a crucial role in reducing the developmental disparity between northern and southern China, while striving for integrated economic, social, and environmental development in the new era [15].

Table 5
Results of heterogeneity analysis of YRB and YREB.

Explanatory variables	REC	URC	EASC	RAEC	MASCC	Constant	R^2	F test	F-statistic
YRB	0.478** (2.46)	−0.078 (−0.71)	−0.082 (−1.23)	0.425*** (14.95)	−0.653*** (−3.90)	0.035 (0.91)	0.954	F = 8.29,P = 0.00	85.25
YREB	0.666*** (11.19)	0.656*** (9.03)	−0.146*** (−3.38)	0.370*** (10.49)	0.036 (0.77)	−0.247*** (−6.56)	0.962	F = 15.74, P = 0.00	153.6

This study reveals that the mean values of the RCD indices for YRB and YREB in 2010–2019 are 0.309 and 0.433, respectively. It is evident that, on one hand, the RCD level in YREB is obviously superior to that in YRB. In 2019, the "coordinated" provinces accounted for 37.50% and 81.82% of the total provinces in YRB and YREB, respectively. This result is consistent with previous studies on the resource and environment [49], economic development [50], and green development efficiency [44] in YRB and YREB. On the other hand, based on the classification criteria for the RCD levels proposed by Bai et al.(2018) [51], as of 2019, among the "coordinated" provinces, only Shanghai has reached the level of high-quality coordination(the RCD index greater than 0.9), while the RCD index of other provinces is less than 0.6, indicating a basic coordination level. This suggests that due to the long-term pursuit of a traditional extensive economic growth model, there is much space for future improvement, as the overall level of RCD in YREB and YRB is not high. Meanwhile, it can be seen that the RCD indices of the two basins both exhibit a fluctuating upward trend. The number of "coordinated" provinces increased from three in 2010 to 12 in 2019, and the number of "uncoordinated" provinces decreased from 15 in 2010 to one in 2019. The decreasing number of "uncoordinated" provinces and the increasing number of the "coordinated" provinces indicate that as a series of national strategies such as ecological civilization construction and poverty alleviation have been put on the agenda, the RCD levels in both basins have shown consistent enhancement over time. This is consistent with the research findings of Jiang et al. (2021) on the level of HQD of YRB [52].

6.2. Contribution of the RCD subsystems

In terms of the various subsystems of RCD, the mean values of REC, URC, EASC, RAEC, and MASCC indices of YRB and YREB from 2010 to 2019 are 0.078, 0.311, 0.386, 0.596, 0.066, and 0.221, 0.421, 0.347, 0.667, 0.239, suggesting that the contributions of five subsystem to the RCD varies obviously. Further analysis reveals:

(1) REC. Shanghai, Zhejiang, and Jiangsu exhibit higher REC levels in YREB, with the indices of 0.870, 0.434, and 0.398 from 2010 to 2019, respectively. In contrast, Shandong stands out as the province with the highest REC level in YRB, with the REC index of only 0.180 over the same period. This suggests that the REC level in YREB is superior to that in YRB, aligning with the findings of Yang and Duan(2023) [53]. Meanwhile, the overall REC levels in both basins are still somewhat low. This indicates significant economic development disparities among cities between the provinces of both basins. Of particular note are the substantial economic gaps between provincial capital cities and other prefecture-level cities. For example, in Shandong Province and Henan Province, which are more economically developed provinces in YRB, the average GDP of the capital cities of Shandong Province and Henan Province in 2021 is 2.93 and 4.75 times the average GDP of their prefecture-level cities, respectively.

(2) URC. The URC indices are 0.421 and 0.311 for YREB and YRB, respectively, indicating that the URC level in YREB is still higher than that in YRB. Among them, Shanghai, Zhejiang and Jiangsu are the provinces with the highest URC levels in YRB and YREB. This observation aligns with the recognition of Zhejiang Province by China as a crucial foundation and advantage for constructing a demonstration area for HQD and common prosperity [54]. However, the URC levels of the provinces such as Yunnan, Gansu, and Guizhou, located in the upstream regions of YRB or YREB are significantly lower compared to other provinces, with multi-year URC indices of 0.082, 0.042 and 0.040 respectively. These provinces are often characterized as areas with a mix of multiple ethnic groups, regions facing poverty, and ecologically vulnerable areas [55]. The significant disparities in urban-rural development and the relatively low level of urbanization in these provinces severely constrain the improvement of their coordinated development. Fortunately, there has been an overall upward trend in the URC indices in YRB or YREB from 2010 to 2019. This trend indicates that comprehensive urban-rural development and integrated development have achieved certain success in various provinces, and the urban-rural gaps has been narrowed gradually, which is basically in line with the results of the study on China's urban-rural integrated development(URID) level by Jia et al.(2022) [56], who found that China's URID level has had an obvious upward trend.

(3) EASC. The final purpose of economic growth is to ensure that the economic fruits better benefit the welfare of the populace, continually enhancing the equality in the quality of basic public services like employment, education, and medical care [57]. However, the results of this study reveal that the EASC indices in YRB and YREB are 0.386 and 0.346, respectively. Furthermore, the results indicate that in provinces with lower economic development levels, such as Ningxia, Chongqing, and Inner Mongolia, the EASC indices are relatively higher, measuring 0.7780, 0.703, and 0.655, respectively. Conversely, in provinces with higher economic development levels, such as Jiangsu and Zhejiang, the EASC indices are relatively lower, measuring 0.535 and 0.487, respectively. This suggests a noticeable divergence effect between economic development and the supply of basic public services in YRB or YREB. This phenomenon may be attributed to the excessive pursuit of GDP growth during regional development, neglecting the allocation and supply of resources for basic public services [2]. Therefore, enhancing the level of basic public services and improving the people's livelihoods and welfare are crucial aspects of future RCD [58].

(4) RAEC. The RAEC indices of YRB or YREB shows an upward trend, suggesting that the level of green development of both basins is upgraded, and the quality of ecological environment is constantly improving. Specifically, the level of resource consumption has been decreasing [59], environmental governance investment has been increasing [60], and the environmental quality has been improving [61]. It also shows that under the development concept of "common protection", the two basins are pursuing greener and low-carbon economic development models, which is also consistent with the conclusions of the study by Liu et al. (2023) [44]. However, it is worth noting that in the provincial units such as Qinghai, Gansu, and Ningxia in the upper and middle reaches of YRB are experiencing a downward trend in RAEC indices and the gap between these provinces and others is widening continuously. This trend may be attributed to the fact that these regions are generally in the early stages of industrialization and most of the industries are still traditional, such as chemical, metallurgical, power, and building materials

industries, primarily relying on energy and raw materials [62]. Additionally, amid the background of the inland transfer of national industries, these provinces are undertaking industries that are often characterized as "high pollution, high investment, and high consumption" of mid-to-low-end industries from developed eastern regions [63]. The escalating environmental pressure is consistent with the conclusions of studies such as those by Zhong et al.(2020) [64], which suggests that a certain pollution refuge effect exists in the middle and upper reaches of the Yellow River.

(5) MASCC. Increasing the supply of public cultural services to continuously satisfy the people's ever-growing spiritual needs is an important destination for economic development. However, this study reveals that the MASCC levels of YRB or YREB is generally low, with an average over the years of only 0.067 and 0.239, respectively. This may be due to the fact that the longstanding focus on economic growth in China, with insufficient investment in spiritual civilization construction, leading to a lag in the development of spiritual civilization compared to material civilization. In recent years, Shanghai has placed significant emphasis on the construction of the public cultural services system, accurately grasping the spiritual needs of the masses. Through continuous enhancement of its public cultural service supply capacity, Shanghai has positioned itself as the city with the highest MASCC level in both basins. This has resulted in a substantial disparity in the MASCC level between Shanghai and other provinces. In 2022, the cultural and creative industry in Shanghai contributed to approximately 13% of the city's total GDP, with a per capita output of 1.7 million yuan for individuals employed in the cultural and creative sector. This figure significantly exceeds the national average. Therefore, in the future, the provinces within YRB or YREB should continuously strengthen the construction of spiritual civilization. It is essential to adhere to a people-centered approach, emphasize the bidirectional efforts of demand-driven supply and supply-led demand, and enhance the high-level and high-quality supply capacity of public cultural products and services.

6.3. Driving mechanisms for the RCD of YRB and YREB

The regression analysis show that REC has the largest positive effect on the RCD of YRB and YREB, and for every 1% increase in the REC index, the RCD indices of the both basins will be increased by 0.666% and 0.478%, respectively. This indicates that the RCD of the both basins falls under the category of economically driven coordinated development. Henceforth, it is imperative to consider REC as a key lever for promoting RCD within the basins, which can be achieved by narrowing the economic development disparities among cities to foster RCD.

The explanatory variable RAEC also contributes significantly to the RCD of YRB and YREB. Specifically, for every 1% increase in the RAEC index, the RCD index of the both basins will increase by 0.425% and 0.363%, respectively. This observation underscores the attainment of phased victories in the recent pollution control efforts within YRB and YREB. Therefore, in the future, YRB and YREB should further take ecological protection as the lifeline of the basins' HQD, accelerate the upgrading and adjustment of the industry, and actively explore the development path of green, low-carbon, and circular economy according to the basic conditions of their respective economic development and the characteristics of their resource endowments [65]. Simultaneously, it can promote the green transformation of economic development and realize the RAEC by constructing the government's green procurement standard and list system and guiding the public's green consumption behavior [66].

The coordinated implementation of the new urbanization plan and rural revitalization strategy to narrow the urban-rural gaps are a crucial initiative for advancing common prosperity. However, this study indicates that the URC regression coefficients for YRB and YREB are −0.078 and 0.656, respectively. This suggests that URC has become a significant bottleneck hindering RCD in YRB. Additionally, the URC levels between YRB and YREB are exhibiting a widening trend in disparities. For instance, as of 2020, the urbanization rates for YRB and YREB were 57.82% and 64.75%, respectively. Simultaneously, the rural impoverished population in the nine provinces within YRB is relatively concentrated, accounting for approximately 61.0% of the national rural impoverished population. In the future, it is imperative for the basin to place greater emphasis on rural development, continually narrowing the developmental gap with YREB.

EASC, along with MASCC, constitute significant shortcomings in the RCD of YRB and YREB. Remarkably, in provinces with relatively developed economies within the two basins, the EASC level is comparatively lower. This phenomenon may be explained by the fact that economically robust provinces often face challenges in meeting the needs of continuously concentrated populations due to limited supply and allocation of public service resources. Issues such as education, healthcare, and employment services exhibit significant gaps, leading to the occurrence of urban diseases resulting from shortages in public services [2]. On the contrary, some less developed provinces benefit from increasing national policy and material support, and favorable conditions. Additionally, with lower population density, these areas experience less pressure on public services. Thus, a modest enhancement in the supply and allocation of public service resources can notably elevate the EASC level.

Furthermore, there is a pronounced divergence between the MASCC levels and the RCD in YRB. This has become a primary contradiction hindering the RCD. Therefore, in the future, YRB should prioritize the MASCC, addressing the imbalances and inadequacies in the development of spiritual civilization.

7. Conclusions and recommendations

7.1. Conclusions

Based on the orientation of the times of the transformation of the main social contradictions in China, the study takes 19 provinces in YRB and YREB as the study objects, reveals the new connotation of RCD from the perspective of factors coordinated development

within the region, and evaluates the RCD levels with assistant of the Entropy weight-TOPSIS model within the 19 provinces in YRB and YREB in 2010–2019. The main conclusions are as follows:

Firstly, the RCD indices of YRB and YREB ranged from 0.199 to 0.419 and from 0.311 to 0.582, respectively, from 2010 to 2019, and both RCD levels showed an increasing trend; the mean values of the RCD indices from 2010 to 2019 were 0.309 and 0.433 for YRB and YREB, respectively, which indicated that the RCD of both are relatively low.

Secondly, the RCD levels of the provinces in YREB is much higher than that in YRB, where coordinated provinces in YRB and YREB account for 37.50% and 81.82% of the total number of provinces in the basins respectively as of 2019, with uncoordinated and low-coordinated provincial regions all located in YRB.

Thirdly, in 2010–2019, the development level of RAEC and URC in the provinces of YRB and YREB improved gradually, while the development level of REC, EASC, and MASCC is low and the improvement effect is not obvious. Therefore, in the future, the promotion of REC, EASC, and MASCC should be important elements in the promotion of RCD in both basins.

Fourthly, the development of REC and RAEC has an important contribution to the RCD of YRB, while the development of MASCC has an obvious inhibitory effect on its RCD, indicating that insufficient construction of spiritual civilization has become the main contradiction in the RCD of YRB. The development of REC, URC, and RAEC has obvious positive effects on the RCD of YREB, while the development of EASC has significant negative effects on the RCD of YREB, suggesting that there are distortions in the allocation of economic growth and public service resources in YREB, which means that the development of EASC is seriously lagging behind the RCD of YREB as a whole.

7.2. Main recommendations

Firstly, the role of REC should be strengthened. The study found that the overall RCD levels of YRB and YREB is not high and is of an "economy-led" type. Therefore, in the future, we should further strengthen the economic ties and collaboration among cities of different sizes in YRB and YREB, give full play to the advantages of large cities in terms of talents, technology and markets and the advantages of medium and small cities in terms of natural resource and labor, explore the mode of cooperation between the two in terms of industrial transfer and cultivation and industrial division of labor, and encourage the integrated and phased growth of different cities in YRB and YREB, and reduce the economic disparities between them.

Secondly, the role of the RAEC should be enhanced. The study found that the RAEC has an obvious positive influence on the RCD of both YRB and YREB. Therefore, in the future, the provinces in both basins should further implement the concept of "clear water and green mountains are as good as mountains of gold and silver", take ecological protection as the lifeline of HQD in the basins, and actively explore low-carbon and circular green development paths according to their economic conditions and the characteristics of the resource endowments, accelerate the upgrading and adjustment of industrial structures, and encourage green transformation of economic development.

Thirdly, the weak links of MASCC and EASC should be shored up. The study found that MASCC and EASC are important bottlenecks in the RCD of YRB and YREB respectively. Firstly, it is crucial to strengthen investment in the spiritual civilization construction in YRB, especially in the regions in the upper and middle reaches of the Yellow River where poverty is being tackled and where ethnic minorities are concentrated, to dig deeper into the contemporary values of the "Yellow River culture", to better tell the "Yellow River story", to promote the "Yellow River spirit", and to improve the level of spiritual civilization. Secondly, the provinces in YREB should continue to optimise the scale, structure and spatial layout of social service facilities like medical institutions, schools and other infrastructure, achieving a reasonable allocation of public service resources and improve the quality and level of public social services in all provinces in the basin.

Data availability statement

The data that support the findings of this study are available upon request from the authors.

CRediT authorship contribution statement

Xiaolin Yang: Writing – original draft, Supervision, Methodology, Funding acquisition, Formal analysis. **Zengwei Feng:** Writing – review & editing, Software, Data curation. **Yiyan Chen:** Data curation. **Xiangyang Xu:** Investigation.

Declaration of competing interest

We declare that we have no financial and personal relationships with other people or organizations that can inappropriately influence our work, there is no professional or other personal interest of any nature or kind in any product, service and/or company that could be construed as influencing the position presented in, or the review of, the manuscript entitled "A Comparative Analysis of the Levels and Drivers of Regional Coordinated Development in the Yellow River Basin and Yangtze River Economic Belt, China".

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