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Original Research

Regional Difference and Obstacle Factors of China's High-Quality Development from the Perspective of Coupling Coordination

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Abstract

Investigating the regional difference is of enormous practical value in the context of the new normal. Only a few studies, however, explored the regional difference in high-quality development from the perspective of coupling coordination. Based on the panel data set covering China's 30 provinces during 2003-2020, this study explores the spatiotemporal distribution characteristics, regional differences, and obstacle factors of the coupling coordination degree of high-quality development. The results show that: (1) Innovation is the main factor limiting high-quality development. Greenness is the main weak point of the eastern regions; The disadvantages of the central, northeast, and western regions are mainly openness. (2) The coupling coordination degree of high-quality development is low, with a significant spatiotemporal differentiation. The regional difference of coupling coordination degree is reduced, and the main source is the inter-regional difference. (3) The obstacle factors of coupling coordination degree have changed over time. Obstacle factors of the national, eastern, central, and northeast regions are the subsystem of carbon emissions; Obstacle factors of the western regions are distributed in the economy, greenness, coordination, and innovation. Based on the perspective of coupling coordination, this paper proposes policy recommendations for the synergy evolution of China's high-quality development.

Keywords: high-quality development, coupling coordination degree, regional difference, obstacle factors

Introduction

China's economy has experienced phenomenal growth over the past few decades. However, energy dilemmas, environmental pollution, and the greenhouse effect arise over time [1]. Based on the profound changes in China's economic development environment, the 19th National Congress pointed out that China's economy "has shifted from a stage of high-speed growth to a stage of high-quality development". High-quality development is the fundamental embodiment of the new development concept of innovation, coordination, greenness, openness, and sharing [2, 3]. China is a vast country with significant heterogeneity in geographical location, resource endowment, and economic base. Narrowing regional differences and achieving regional balance is a challenge for high-quality development. Therefore, exploring regional differences is a prerequisite for promoting regional collaborative high-quality development.

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Scholars have built multidimensional high-quality development evaluation systems based on the connotation of high-quality development, and evaluation system is changing dynamically. At present, the issue of carbon emissions cannot be ignored [4, 5]. In 2020, China introduced the "dual carbon" goals of "peaking its carbon emissions before 2030 and achieving carbon neutrality by 2060" [6]. The "dual carbon" goal brings pressure and challenges to China's high-quality development and also provides a new impetus.

Coupling is a classical concept in the field of physics. It is concerned with the energy exchange process caused by the interaction of two or more independent units with the matter as the carrier [7]. With the development of system theory, the interaction between multi-subsystem, multi-process, and internal connection mechanisms is emphasized. The concept of coupling coordination is widely utilized in social science, ecological environment, and economics to study the interaction between systems or subsystems [8-10].

The subsystem of high-quality development has a mutually reinforcing and influencing relationship. Developing a low-carbon economy and reducing carbon emissions is the prerequisite for achieving high-quality development [11]. Technological innovation is an indispensable link in achieving high-quality development. Relying on independent innovation, creating new competitiveness with low carbon as the core, and realizing disruptive innovation in energy utilization can further stimulate the potential of innovation [12]. China is still in urbanization, and are significant differences in resource allocation among regions, urban and rural [13]. Green development promotes the transformation of production, lifestyle, and consumption patterns, reduces the emissions of garbage pollutants, and drives high-quality ecological development [14]. Carbon emission reduction and social welfare are inseparable, and the green upgrading of infrastructure, the improvement of public awareness, and the transformation of consumption concepts brought by low-carbon development will all be shared by the whole society [15]. Innovation, coordination, greenness, openness, sharing, and carbon emissions are interdependent and mutually restrictive and it is of great significance for China to achieve higher quality and sustainable development to include carbon emissions in high-quality development. Most studies have analyzed the evolution or influencing factors of high-quality development, however, few have considered the coordinated degree among the subsystem of high-quality development.

The rest of this paper is arranged as follows. Section 2 is the literature review of high-quality development and the coupling coordination degree. Section 3 explains the methodology and data sources. The results and discussions are presented in Section 4. Conclusions and policy suggestions are summarized in Section 5.

Literature Review

The Indicator System of High-Quality Development

The research of high-quality development indicator systems is generally divided into three categories. First, based on the quality of economic growth perspective, some scholars have measured the quality of economic development with total factor productivity (TFP) [16, 17]. As a single index, TFP reflects the economic effects of production factors and resource allocation one-sidedly. Second, based on the perspective of the new development concept, the quality index of economic growth has been constructed, and a multi-dimensional evaluation system has initially been formed. However, the growth quality index focuses on "growth" and was unable to reflect the quality of economic achievements from the perspective of "development" [18]. Third, based on the five development concepts of innovation, coordination, greenness, openness, and sharing, many studies have built the indicator system of high-quality development. Subsequently, the indicator system has been supplemented and expanded [19, 20]. Scholars have not reached a consensus on the indicators system of high-quality development, however, the dynamic and multi-dimensional characteristics of high-quality development have been widely accepted. High-quality development is a multi-dimensional, complex comprehensive system [21], in which the interaction degree and benign interaction ability of the internal subsystems affect the operation of the whole system [22]. However, the existing studies have not explored the characteristics of the collaborative spatiotemporal evolution of subsystems in high-quality development from the perspective of coupling coordination, which is a necessary prerequisite for the benign development of the whole social system.

The Regional Difference in High-Quality Development

The regional difference is the focus on high-quality development which has caught the attention. Scholars have analyzed the regional differences in high-quality development from the perspectives of countries, regions, and urban agglomerations [23, 24]. The main conclusions can be divided into the following three categories. Firstly, there are regional differences in high-quality development [25]. Secondly, the subsystems of high-quality development evolve asynchronously [26]. Third, policies on quality development should take full account of regional differences [27, 28]. Scholars pay more attention to the regional differences in high-quality development, however, there are complex interactions among subsystems of high-quality development, which may be the cause of the differences.

The Study of Coupling Coordinated Degree

The coupled and coordinated development of multiple systems or subsystems has been widely concerned [29]. Coupling refers to the interaction of multiple systems or subsystems, which is denoted by the coupling degree. However, the coupling degree cannot reflect the degree of benign coupling and the quality of coordination. Coupling coordination refers to the benign relationship between multiple systems or subsystems, which is represented by the coupling coordination degree. Coupling coordination is the basic principle of sustainable development, and its core connotation emphasizes sustainable and synergy development [30]. Existing studies showed that carbon emissions have a strong interaction with socio-economic development, eco-environment, technological innovation, opening-up, and regional coordination [31, 32]. Incorporating carbon emissions into high-quality development systems has a realistic basis. [33] indicated that it was significant to control carbon emissions in the context of high-quality economic development. Mitigating carbon emissions is indispensable to sustainable development. Previous studies have discussed the coupling and coordination relationship between the socioeconomic system and the carbon emission system [34]. Some studies believe that the coupling coordination degree of carbon emissions and eco-environmental presented a spatial pattern [35, 36]. Few scholars discussed the evolution of high-quality development including the subsystem of carbon emissions. This paper attempts to remedy this defect.

Methods and Material

Methods

Indicator Systems

This paper constructs a high-quality development indicator system from seven subsystems including economy, innovation, coordination, greenness, openness, sharing, and carbon emissions [37, 38].

(1) The subsystem of the economy. Taking "carbon reduction" as the strategic goal is conducive to promoting the development of new industries and adjusting the industrial structure of high energy consumption. Human capital is transferred from traditional high-carbon industries to low-carbon industries, which creates new opportunities for economic development. In the subsystem of the economy, the indicators are mainly selected from industrial structure, economic stability, and economic stability [39].

(2) The subsystem of innovation. Scientific and technological innovation is the core of achieving net zero emissions. To further stimulate the potential of innovation drive and build new competitiveness with low-carbon, multi-level exploration from basic research to technology application is necessary. Innovation inputs and innovation outputs are the indicators of the subsystem of innovation [40].

(3) The subsystem of coordination. Regional disparity and urban-rural differences are indispensable for urbanization, which is significant to coordinated development. Therefore, the subsystem of coordination focuses on regional coordination and urban-rural coordination [41].

(4) The subsystem of greenness. Green development is concerned with the environmental crisis, focusing on improving the quality of the ecological environment [42]. Reducing the emission of waste pollutants and various harmful gases is vital to ecological conservation and high-quality development. Environmental pollution and environmental protection are utilized to reflect the subsystem of greenness [43].

(5) The subsystem of openness. Under the background of double circulation, forming a new pattern of all-round opening up is a necessity for promoting high-quality development. From the perspective of the international, low-factor cost advantage is not sustainable. From the perspective of the domestic, the construction of the domestic virtuous circle system is of great significance for improving the international competitiveness of the industrial chain and supply chain. This paper mainly evaluates the subsystem of openness from outer circulation and inner circulation [44].

(6) The subsystem of sharing. Sharing development is aimed at solving the unequal distribution and insufficient sharing of social resources in China. Infrastructure, education and health, and social security are used to reflect the subsystem of sharing [45].

(7) The subsystem of carbon emissions. Carbon emissions permeate all aspects of high-quality development and are inseparable from fossil energy consumption. Carbon reduction is aimed at the climate crisis, and the core is the innovation of energy technology and the transformation of energy consumption mode. It is beneficial to promote the development of high-quality energy by ridding the traditional energy structure of high energy consumption and reducing the dependence on fossil energy [46, 47].

The indicator system of high-quality development is shown in Table 1.

Development Index Model

First, this paper standardizes the original data to eliminate different orders of magnitude and dimensions. Secondly, the range standardization method is used to avoid negative values after standardization. Finally, the entropy theory is utilized to calculate the weight, as presented in Eq. (1) to Eq. (2):

$$b_{ijt} = \left\{ \frac{x_{ijt} - \min_{it} x_{ijt}}{\max_{ijt} x_{ijt} - \min_{it} x_{ijt}}, if \quad x_{ijt} \quad is \quad a \quad stimulant \right\} \tag{1}$$

$$b_{ijt}=\left\{\frac{\max_{it} x_{ijt}-x_{ijt}}{\max_{it} x_{ijt}-\min_{it} x_{ijt}}, if \quad x_{ijt} \quad is \quad a \quad destimulant\right\} \tag{2}$$

where $i(i = 1, 2, ..., N)$, $j(j = 1, 2, ..., M)$, and $t(t = 1, 2, ..., T)$ represents provinces, indicators, and years, respectively; $d(d = 1, 2, ..., D)$ is the subsystem; x_{ijt} denote the actual value of the indicator; b_{ijt} stands for the standardized value, and $b_{ijt}\in[0,1]$; $\max_{it} x_{ijt}$ and $\min_{it} x_{ijt}$ is the maximum value and minimum value, respectively.

The calculation of the information entropy is shown in Eq. (3) to Eq. (4):

$$p_{ijt}^{d}=\frac{b_{ijt}^{d}}{\sum_{t=1}^{T}\sum_{i=1}^{N} b_{ijt}^{d}} \tag{3}$$

$$h_{j}^{d}=-\frac{\sum_{t=1}^{T}\sum_{i=1}^{N} p_{ijt}^{d} * \ln p_{ijt}^{d}}{\ln NT} \tag{4}$$

The weight value is calculated through information entropy by Eq. (5) to Eq. (6):

Table 1. Indicator evaluation system of high-quality development.

Subsystem	Area	Indicator	Code	Type
Economy	Economic Structure	Rationalization of industrial structure	X1	-
		Industrial structure upgrading	X2	+
	Resource allocation	GDP/New fixed assets investment	X3	+
		GDP/Number of urban employees	X4	+
	Economic stability	Registered urban unemployment rate	X5	-
		Consumer price index	X6	-
Innovation	Innovation Input	R&D Personnel /Employees	X7	+
		Intramural Expenditure on R&D/GDP	X8	+
	Innovation Output	Authorization of three patent applications /Total population	X9	+
		Technical market turnover/GDP	X10	+
Coordination	Regional coordination	Regional GDP per capita/ GDP per capita	X11	+
		Regional population density	X12	-
	Urban and rural coordination	Per capita disposable income ratio of urban and rural residents	X13	-
		Per capita consumption expenditure ratio of urban and rural residents	X14	-
		Engel coefficient of urban households	X15	+
		Engel coefficient of rural households	X16	
Greenness	Environmental pollution	Industrial waste gas emissions per GDP	X17	-
		Industrial wastewater discharge per GDP	X18	-
		General solid waste discharge per GDP	X19	-
		Industrial sulfur dioxide emissions per GDP	X20	-
	Environmental protection	Urban green space and gardens per capita	X21	+
		Percentage of forest cover	X22	+
		The operation cost of industrial waste gas treatment facilities/GDP	X23	+
		Total sewage treatment/GDP	X24	+
		Disposal volume of general industrial solid waste/GDP	X25	+
Openness	Outer circulation	The total volume of imports and exports/GDP	X26	+
		Foreign direct investment/GDP	X27	+
	Inner circulation	Total retail sales of consumer goods/GDP	X28	+

Table 1. Continued.

Sharing	Infrastructure	Per capita road area	X29	+
		Number of urban bridges per 10,000 people	X30	+
		Urban road lighting per capita	X31	+
		Length of drainage pipe per capita	X32	+
		Mobile telephone exchange capacity per 10,000 households	X33	+
		Postal business outlets per capita	X34	+
	Education and health	Public library collection per capita	X35	+
		Number of institutions of higher learning per 10,000 people	X36	+
		Number of hospital beds per 100 people	X37	+
	Social security	Number of private cars per 10,000 people	X38	+
		Number of employees participating in endowment insurance/ Total population	X39	+
Carbon emissions	Energy utilization	Energy consumption per GDP	X40	-
		Energy consumption per person	X41	-
		The proportion of coal consumption	X42	-
	Carbon reduction	Carbon emissions per energy consumption	X43	-
		Carbon intensity	X44	-
		Carbon emission per capita	X45	-
	Electric power structure	Per capita electricity consumption	X46	-
		Electricity consumption per GDP	X47	-
		The proportion of thermal power generation to total power generation	X48	-

$$e_j^d = 1 - h_j^d \tag{5}$$

$$\alpha_j^d = \frac{e_j^d}{\sum_{j=1}^{M^d} e_j^d} \tag{6}$$

h_j^d is the information entropy; e_j^d represents information entropy redundancy; p_{ijt}^d is the proportion of indicator for *dth* subsystem; α_j^d denotes the weight value.

Calculating the development index by Eq. (7) and Eq. (8):

$$T_{it}^d = \sum_{j=1}^{M^d} b_{ijt}^d * \alpha_j^d \tag{7}$$

$$RD_{it} = \mu T_{it}^1 + \lambda T_{it}^2 + \eta T_{it}^3 + \gamma T_{it}^4 + \varepsilon T_{it}^5 + \beta T_{it}^6 + \omega T_{it}^7 \tag{8}$$

$\mu, \lambda, \eta, \gamma, \varepsilon, \beta, \omega$ is the weight value of the subsystem, and $\mu + \lambda + \eta + \gamma + \varepsilon + \beta + \omega = 1$. Assuming that the impact of each subsystem is equal to the development index, and each weight value is $\frac{1}{7}$ [48].

Coupling Coordination Degree Model

The coupling coordination degree of high-quality development system refers to the systematic coordinated development of economy, innovation, coordination, greenness, openness, sharing, and carbon emissions. The coupling degree is shown in Eq. (9) to Eq. (10):

$$C_{it} = D * \left[\frac{T_{it}^1 * T_{it}^2 \cdots T_{it}^n}{\prod (T_{it}^1 + T_{it}^2 \cdots T_{it}^n)} \right]^{\frac{1}{D}} \tag{9}$$

C_{it} is the coupling degree, and $C_{it} \in [0,1]$. Considering the seven subsystems, the Eq. (9) can be written as Eq. (10):

$$C_{it} = 7 \left[\frac{T_{it}^1 * T_{it}^2 * T_{it}^3 * T_{it}^4 * T_{it}^5 * T_{it}^6 * T_{it}^7}{(T_{it}^1 + T_{it}^2 * T_{it}^3 * T_{it}^4 * T_{it}^5 * T_{it}^6 * T_{it}^7)^7} \right]^{\frac{1}{7}} \tag{10}$$

The coupling coordination degree model is calculated by Eq. (11):

$$CCD_{it} = \sqrt{C_{it} * RD_{it}} \tag{11}$$

CCD_{it} represents the coupling coordination degree, and $CCD_{it} \in [0,1]$. The higher the value is, the more coordinated of the subsystem of the high-quality development is, and vice versa. According to the value, the coupling coordination degree is divided into different types, as shown in Table 2.

The Dagum Gini Coefficient and Its Decomposition

Theil index and its decomposition ignore the overlap of inter-group and intra-group differences. The Herfindahl index is focused on reflecting inter-regional concentration differences. This paper adopts the Dagum Gini coefficient and its decomposition proposed by Dagum, which was originally used to measure the regional income gap [49]. The Dagum Gini coefficient and its decomposition effectively describe the source of regional differences, so it has been widely used to study regional imbalance [50, 51]. The Dagum Gini coefficient avoids the overlapping among samples and can be decomposed into intra-regional contribution (G_a), inter-regional contribution (G_b), and transvariation intensity (G_c). The Dagum Gini coefficient is calculated by Eq. (12) to Eq. (22):

$$G=\frac{\sum_{j=1}^{k}\sum_{h=1}^{k}\sum_{i=1}^{n_j}\sum_{r=1}^{n_h}\left|CCD_{ji}-CCD_{hr}\right|}{2\overline{CCD}n^2} \tag{12}$$

$$G_{jj}=\frac{\sum_{i=1}^{n_i}\sum_{r=1}^{n_j}\left|CCD_{ji}-CCD_{jr}\right|}{2\overline{CCD}_j n_j^2} \tag{13}$$

$$G_{jh}=\frac{\sum_{i=1}^{n_i}\sum_{r=1}^{n_h}\left|CCD_{ji}-CCD_{hr}\right|}{n_j n_h(\overline{CCD}_j+\overline{CCD}_h)} \tag{14}$$

$$P_j=\frac{n_j}{n} \tag{15}$$

$$S_j=\frac{n_j\overline{CCD}_j}{n\overline{CCD}} \tag{16}$$

$$M_{jh}=\int_0^{\infty}dF_j(z)\int_0^{z}(z-x)d_hF(x) \tag{17}$$

$$N_{jh}=\int_0^{\infty}dF_h(z)\int_0^{z}(z-x)d_jF(x) \tag{18}$$

$$D_{jh}=\frac{M_{jh}-N_{jh}}{M_{jh}+N_{jh}} \tag{19}$$

$$G_a=\sum_{j=1}^{k}G_{jj}P_jS_j \tag{20}$$

$$G_b=\sum_{j=2}^{k}\sum_{h=1}^{j-1}G_{jh}D_{jh}(P_jS_h+P_hS_j) \tag{21}$$

$$G_c=\sum_{j=2}^{k}\sum_{h=1}^{j-1}G_{jh}(1-D_{jh})(P_jS_h+P_hS_j) \tag{22}$$

G is the overall Gini coefficient; k and n denote the regions and provinces, respectively. $CCD_{ij}(CCD_{hr})$ is the coupling coordination degree of province $i(r)$ in region $j(h)$; $n_j(n_h)$ is the number of provinces in the region $j(h)$; $\overline{CCD}$ is the average of coupling coordination degree for all provinces. G_{jj} is the Gini coefficient of jth region; G_{jh} is the Gini coefficient between region j and region h; $\overline{CCD}_j(\overline{CCD}_h)$ is the average of coupling coordination degree for region $j(h)$; D_{jh} denotes the relative influence of coupling coordination degree between region j and region h; M_{jh} represents the difference of coupling coordination degree between regions, that is, the mathematical expectation of the sum of all the sample values of $CCD_{ji}-CCD_{hr}>0$ in region j and region h; N_{jh} represents the super variable first moment, which is the mathematical expectation of the sum of all the sample values of $CCD_{hr}-CCD_{ji}>0$; Function $F_j(F_h)$ represents the cumulative density distribution function of region $j(h)$; G, G_a, G_b and G_c satisfy the following equation: $G = G_a + G_b + G_c$.

The Obstacle Factor Diagnosis Model

The obstacle factor diagnosis model is used to analyze the obstacle factors of the coupling coordination degree of high-quality development for facilitating the development of targeted strategies and measures [52]. As is shown in Eq. (23) to Eq. (24):

$$T_{ijt}=1-b_{ijt} \tag{23}$$

Table 2. The type and code of coupling coordination degree.

CCD	Type	Code	CCD	Type	Code
[0.000,0.100)	Extreme disorder recession	I	[0.500, 0.600)	Reluctance coordination	VI
[0.100, 0.200)	Serious disorder recession	II	[0.600, 0.700)	Primary coordination	VI
[0.200, 0.300)	Moderate disorder recession	III	[0.700, 0.800)	Middle coordination	VII
[0.300, 0.400)	Light disorder recession	IV	[0.800, 0.900)	Well coordination	VIII
[0.400, 0.500)	Near disorder recession	V	[0.900, 1.000]	High coordination	IX

$$O_{jt} = \frac{T_{ijt}\alpha_j^d}{\sum_{i=1}^{N}(T_{ijt}\alpha_j^d)} * 100\% \tag{24}$$

T_{ijt} is the deviation degree of the indicator; O_{jt} represents the obstacle degree. The larger the O_{jt} is, the greater the influence on coupling coordination degree is, and the stronger the obstacle is, and vice versa.

Material

To eliminate the influence of unit, order of magnitude, and price change, the intensity indicator and proportion indicator are mainly selected. The positive indicator indicates a positive affection on the coupling coordination degree. The larger the value is, the higher the coupling coordination degree is. The negative indicator represents a negative relationship with the coupling coordination degree. The larger the value is, the lower the coupling coordination degree is. Considering the availability of data, this paper mainly collects panel data of 30 provinces, autonomous regions, and municipalities in China from 2003 to 2020, excluding the Tibet Autonomous Region, Hong Kong, Macao, and Taiwan[1]. The mean value method is used to complete the data. The price indicator is converted into the 2000 constant price. The relevant data is derived from the China Statistical Yearbook, China Statistical Yearbook of Science and Technology, China Environmental Statistical Yearbook, China Urban Statistical Yearbook, and China Energy Statistical Yearbook. Carbon emissions are calculated according to the IPCC method[2].

Results and Discussions

Evaluation of the Development Index of Subsystem

Evolution of Development Index from the National Perspective

Fig. 1 presents that the comprehensive index of high-quality development from 2003 to 2020 shows

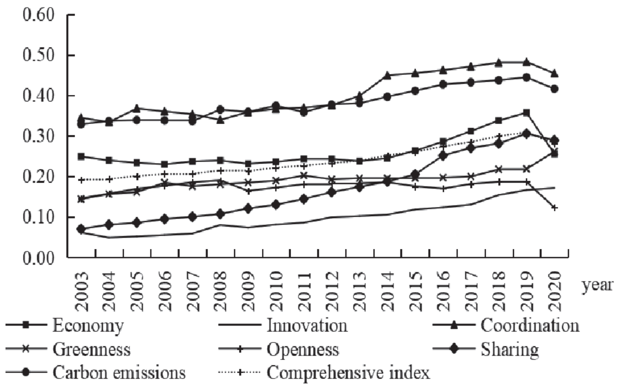

Fig. 1 The evolution characteristics of the development index.

an overall upward trend and ranges from 0.191 to 0.308, indicating a relatively low development level. The coordination index ranges from 0.333 to 0.482, with an annual growth rate of 1.543%. The tendency fluctuates greatly from 2003 to 2013 and increases steadily from 2014 to 2019, however, it decreases slightly in 2020. The carbon emissions index is between 0.328 and 0.444, and the annual growth rate is 1.320%. The growth of the carbon emissions index may be related to the strategies and measures of the government. China's carbon emissions have become increasingly prominent since industrialization. The economy index is between 0.229 and 0.357, with an annual growth rate of 0.141%. From 2003 to 2013, the growth rate of the economy index is small, however, the growth trend is obvious from 2014 to 2019. In 2020, the economy index shows a significant decline. Faced with the unpredictable domestic and international situation and the severe impact of COVID-19, the economy subsystem has been the most affected. [53] showed that COVID-19 has brought negative impacts on the economy, destroyed the original stability of the economic system, and increased the uncertainty of the effect of monetary policy regulation. Industries in most economic regions under COVID-19 lag behind the impact of monetary policy for a longer time.

The sharing index has grown significantly and remained at a low level. China has eliminated absolute poverty and achieved higher levels of shared development, however, it is still a long way to achieve common prosperity. The greenness index from 2003 to 2020 shows an upward trend. Facing the complex natural environment, greenness provides the foundation for adapting to social contradictions and realizing the "double carbon" goal on schedule. The innovation index shows an increasing trend, however, is at a low level, which is a significant factor limiting high-quality development. The evolution trend of the openness index is relatively stable, which is an important factor limiting high-quality development. In 2020, global industrial value chains and supply chains are severely affected by COVID-19, which in turn affects openness. [54] revealed that the novel COVID-19 caused the latest global

[1] The National Bureau of Statistics of the People's Republic of China divides China's economic regions into four regions: the eastern regions, the central regions, the western regions and the northeast regions. The eastern regions include: Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong and Hainan; The central regions include Shanxi, Anhui, Jiangxi, Henan, Hubei and Hunan; The western regions are InnerMongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia and Xinjiang; The northeast regions invole Liaoning, Jilin and Heilongjiang.

[2] The data of carbon emissions and calculation process can be obtained from the author.

economic collapse and seriously affected the operation of the global economy. China is one of the largest energy importers, and fluctuations in energy prices may have a significant impact on China's industrial economy. In addition, COVID-19 has seriously disrupted most industrial and economic activities, which may seriously affect national finance.

The subsystem of economy and openness are considerably affected by COVID-19, and the development index shows a significant decline in 2020. The results illustrate that it is crucial to strengthen the internal driving force for high-quality development. Under the background of double circulation, it is necessary to fully improve the efficiency of domestic large circulation and form more new growth points and poles.

Evolution of Development Index from the Regional Perspective

Fig. 2(a-d) shows the seven subsystem development indexes for the eastern regions, central regions, western regions, and northeast regions. According to the China Five Year Plan for National Economic and Social Development, the average of the development index for 2003-2005, 2006-2010, 2011-2015, and 2016-2020 are presented respectively. As shown in Fig. 2a), the openness and coordination in the eastern regions have obvious advantages, taking the lead among the four regions. Economy, sharing, and carbon emissions are stable. Innovation and greenness are the main "weak points" in the eastern region. Fig. 2b) presents that the central regions have a prominent advantage in coordination and carbon emissions. Economy and greenness are less volatile and relatively stable. Sharing is improving, however, it remains low. The disadvantages of the central regions are openness and innovation. Fig. 2c) indicates that the advantage of the western regions lies in carbon emissions, followed by coordination. Greenness, sharing, and economy are at a low level, and the overall trend is grated and steady. Strengthening innovation and openness is fundamental for promoting the development of the western regions. Fig. 2d) demonstrates that the development of the subsystems in the northeast regions is unbalanced. Following the average value of the development index, the order from largest to smallest is coordination> carbon emissions>economy>sharing>openness>innovation. The evolution of the development index indicates

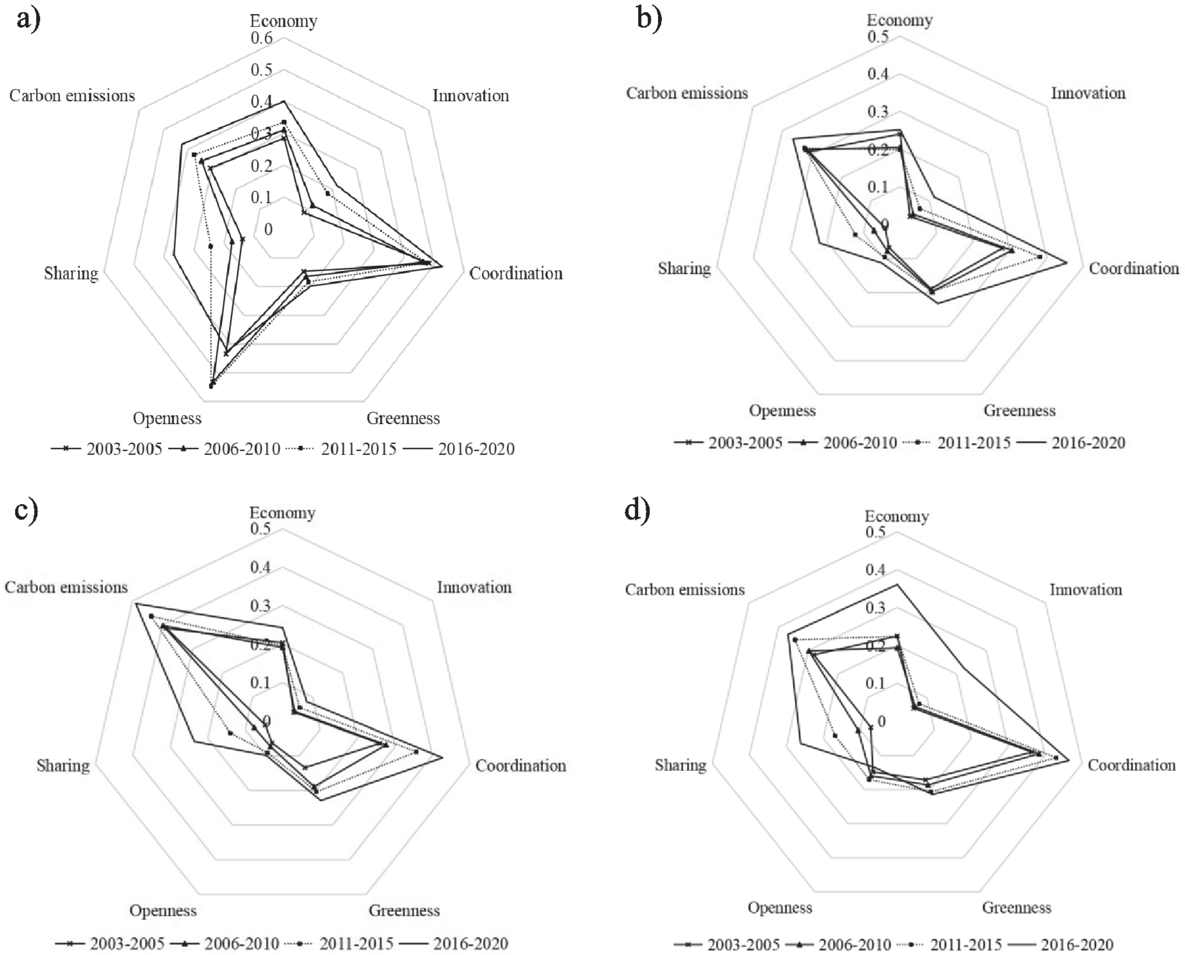

Fig. 2. The development index of subsystems in four regions. a) eastern regions, b) central regions, c) western regions, d) northeast regions.

that northeast regions lack core competitiveness. Openness and innovation are the main problems that limit the development of the northeast regions.

The Coupling Coordination Degree of High-Quality Development

Spatio-Temporal Evolution of the Coupling Coordination Degree

Table 3 shows that the coupling coordination degree increases from 2003 to 2019 and decreases slightly in 2020. The low level of coupling coordination degree may be due to the lack of high-level benign interaction among the subsystem of high-quality development. The evolution trend of the coupling coordination degree is characterized by stages. From 2003 to 2007, the coupling coordination degree is in IV, and the increase is relatively stable. From 2008 to 2017, the coupling coordination degree increased and is in V. VI is introduced from 2018 to 2019, however, there is a decline again in 2020.

At the regional level, the evolution of coupling coordination degree is different. The eastern region has changed from V to VI, and the annual growth rate is 1.269%, and the development of the eastern region is above the national level. In 2014, the central and western regions changed from IV to V, and the annual growth rate is 1.761% and 1.588% respectively. The northeast region has changed from IV to V, with an average annual growth rate of 1.588%. This may be due to the initial state of high-quality development in different regions. The initial level of high-quality economic development in the western, central, and northeastern regions is relatively low, and there is a “catch-up effect” with the regions of high coupling coordination degree.

Regional Difference Analysis of Coupling Coordination Degree

Fig. 3 presents the total Gini coefficient decreased during 2003-2018 and increased during 2019-2020, regional differences show an upward trend. The intra-regional difference of the eastern regions presents an inverted U evolution from 2003 to 2008 and showed a downward tendency from 2009 to 2019. However, the intra-regional difference rebounded in 2020. From the overall evolution trend, the imbalance has alleviated over time. The intra-regional difference of the central regions decreased during 2003-2015 and showed a U-shaped evolution trend during 2016-2020. The intra-regional difference of the western and northeast regions shows a fluctuating evolution characteristic and presents an upward tendency during 2016-2020. The results indicate the development imbalance in the western and northeast regions has been gradually prominent.

Table 3. The evolution of the coupling coordination degree.

	China		Eastern regions		Central regions		Western regions		Northeast regions	
2003	0.373	IV	0.438	V	0.336	IV	0.329	IV	0.396	IV
2004	0.371	IV	0.438	V	0.336	IV	0.326	IV	0.387	IV
2005	0.380	IV	0.449	V	0.342	IV	0.334	IV	0.392	IV
2006	0.388	IV	0.456	V	0.350	IV	0.344	IV	0.396	IV
2007	0.393	IV	0.465	V	0.354	IV	0.345	IV	0.403	V
2008	0.410	V	0.482	V	0.373	IV	0.363	IV	0.415	V
2009	0.408	V	0.484	V	0.367	IV	0.360	IV	0.413	V
2010	0.419	V	0.496	V	0.373	IV	0.372	IV	0.426	V
2011	0.427	V	0.503	VI	0.381	IV	0.380	IV	0.438	V
2012	0.437	V	0.510	VI	0.392	IV	0.393	IV	0.442	V
2013	0.443	V	0.515	VI	0.399	IV	0.399	IV	0.448	V
2014	0.454	V	0.523	VI	0.411	V	0.412	V	0.460	V
2015	0.463	V	0.532	VI	0.425	V	0.424	V	0.453	V
2016	0.475	V	0.546	VI	0.438	V	0.434	V	0.467	V
2017	0.489	V	0.549	VI	0.456	V	0.447	V	0.512	VI
2018	0.505	VI	0.563	VI	0.472	V	0.462	V	0.532	VI
2019	0.514	VI	0.575	VI	0.483	V	0.467	V	0.540	VI
2020	0.484	V	0.549	VI	0.460	V	0.437	V	0.490	V

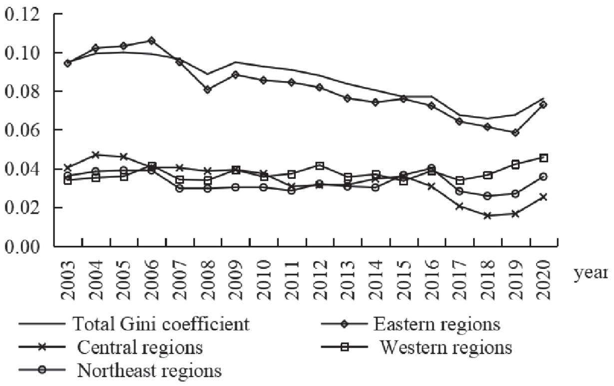

Fig. 3. The total differences and intra-regional differences of coupling coordination degree.

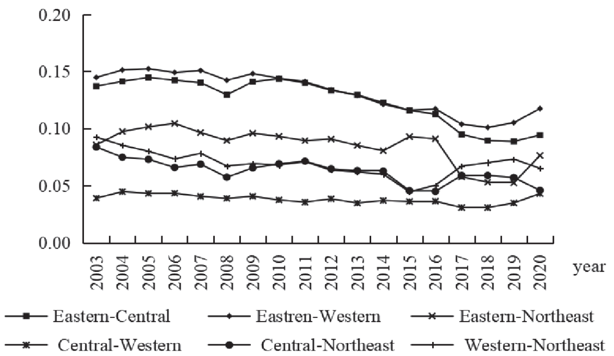

Fig. 4. The inter-regional difference of coupling coordination degree.

Fig. 4 exhibits the inter-regional difference between the eastern-western regions is most prominent, followed by the eastern-central regions. The inter-regional difference of the eastern-western regions and eastern-central regions shows an inverted U-shaped evolution in 2003-2008 and a downward tendency in 2009-2016. From 2017 to 2020, the inverted U-shaped evolution trend appears again. The reason for the evolution trend may be that the external effect of the world financial crisis has narrowed the regional differences. The inter-regional difference between the eastern-northeast regions is the most volatile and the evolution trend is divided into three stages. The first stage is from 2003 to 2008, the inter-regional difference presents a U-shaped evolution; The second stage is from 2009 to 2013, and the tendency declined. The N-shaped trend in 2014-2020 is the third stage. The inter-regional difference of the central-northeast regions and western-northeast regions shows a trend of decline first and then rise, and the interregional differences expand. The evaluation of the inter-regional Gini coefficient in central-western regions is characterized by fluctuation, and the trend is not obvious. The regional difference between the four regions in China gradually narrowed from 2003 to 2018, and the high-quality economic development among regions tended to be coordinated. However, the regional differences rise in 2019-2020, and the unbalanced development among regions has been aggravated.

It can be seen from Fig. 5 that the dynamic contribution rate of the inter-regional difference is between 68.10% and 75.88%, and the average contribution rate is 71.89%; The difference in coupling coordination degree mainly sources from the inter-regional difference. The contribution rate of the intra-regional difference is curves wax and wanes, which ranges from 18.35% to 21.11%, and the average contribution rate is 19.50%. Compared with inter-regional differences, intra-regional differences contribute less to the variation of coupling coordination degree. The contribution rate of the transvariation intensity is between 5.77% and 11.05%, and the average contribution rate is 8.61%. The results indicate that the cross-overlapping phenomenon has little influence on regional differences. To reduce regional differences in high-quality development, the starting point is the narrowing of inter-regional differences.

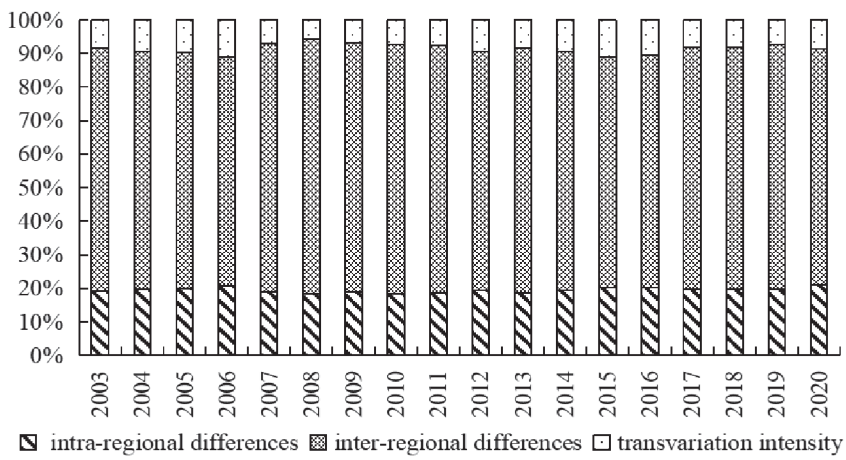

Fig. 5. The source and contribution rate of differences.

Table 4. The obstacle factors of coupling coordination degree from the national perspective.

Year	1	2	3	4	5	6	7	8	9	10
2003	X20	X18	X29	X12	X14	X1	X38	X4	X36	X17
	(12.73)	(10.94)	(9.94)	(9.60)	(8.02)	(7.83)	(7.52)	(7.38)	(7.31)	(7.05)
2004	X20	X18	X12	X14	X17	X38	X1	X36	X4	X13
	(11.85)	(9.91)	(8.98)	(8.44)	(7.54)	(7.45)	(7.31)	(7.22)	(7.16)	(7.10)
2005	X20	X18	X14	X12	X17	X38	X36	X1	X4	X29
	(12.22)	(10.09)	(7.90)	(7.85)	(7.43)	(7.36)	(7.12)	(7.02)	(6.95)	(6.81)
2006	X18	X12	X38	X11	X14	X1	X36	X4	X29	X47
	(8.69)	(7.42)	(7.24)	(7.20)	(7.18)	(6.99)	(6.92)	(6.71)	(6.65)	(6.39)
2007	X20	X17	X18	X12	X11	X14	X38	X36	X13	X47
	(9.82)	(8.66)	(7.88)	(7.44)	(7.19)	(7.19)	(7.11)	(6.60)	(6.58)	(6.49)
2008	X20	X17	(X14	X12	X13	X11	X38	X18	X35	X42
	(8.14)	(8.06)	(7.40)	(7.25)	(7.20)	(7.04)	(6.96)	(6.95)	(6.60)	(6.30)
2009	X17	X12	X11	X20	X38	X13	X14	X37	X18	X29
	(7.89)	(7.19)	(7.14)	(6.80)	(6.70)	(6.69)	(6.52)	(6.10)	(6.09)	(5.99)
2010	X17	X12	X11	X14	X38	X13	X20	X37	X44	X40
	(9.75)	(7.10)	(6.60)	(6.49)	(6.40)	(6.35)	(6.09)	(6.03)	(6.00)	(5.94)
2011	X17	X19	X13	X44	X14	X47	X20	X40	X12	X11
	(9.98)	(7.72)	(6.56)	(6.25)	(6.20)	(6.18)	(6.16)	(6.14)	(6.12)	(6.09)
2012	X17	X19	X13	X45	X41	X46	X44	X11	X6	X3
	(8.74)	(7.05)	(6.50)	(6.42)	(6.31)	(6.04)	(5.96)	(5.96)	(5.95)	(5.92)
2013	X17	X45	X41	X46	X19	X3	X44	X13	X16	X47
	(8.56)	(6.79)	(6.63)	(6.61)	(6.44)	(6.12)	(6.01)	(5.98)	(5.84)	(5.83)
2014	X17	X45	X46	X41	X3	X19	X16	X44	X24	X43
	(8.14)	(7.15)	(6.94)	(6.93)	(6.23)	(5.94)	(5.89)	(5.89)	(5.82)	(5.76)
2015	X45	X41	X17	X46	X3	X16	X24	X19	X33	X43
	(7.45)	(7.17)	(7.10)	(7.00)	(6.30)	(5.92)	(5.83)	(5.78)	(5.72)	(5.72)
2016	X18	X45	X41	X46	X44	X3	X16	X24	X6	X26
	(12.03)	(8.93)	(8.38)	(7.26)	(6.25)	(6.21)	(5.95)	(5.91)	(5.85)	(5.84)
2017	X45	X41	X46	X44	X40	X24	X3	X16	X26	X43
	(10.57)	(9.74)	(7.68)	(6.75)	(6.19)	(6.03)	(6.01)	(5.97)	(5.83)	(5.74)
2018	X45	X41	X46	X16	X24	X6	X3	X26	X19	X44
	(9.52)	(8.92)	(8.52)	(5.99)	(5.98)	(5.97)	(5.80)	(5.80)	(5.76)	(5.75)
2019	X45	X41	X46	X16	X24	X6	X19	X26	X44	X43
	(10.04)	(9.39)	(8.89)	(6.02)	(5.92)	(5.90)	(5.88)	(5.87)	(5.84)	(5.72)
2020	X46	X4	X7	X16	X27	X26	X3	X33	X28	X15
	(9.20)	(6.87)	(6.36)	(6.01)	(5.92)	(5.90)	(5.75)	(5.74)	(5.65)	(5.64)

Table 5. The obstacle factors of coupling coordination degree in the eastern regions.

Year	1	2	3	4	5	6	7	8	9	10
2003	X20	X29	X18	X17	X16	X12	X48	X38	X4	X22
	(1.82)	(1.91)	(1.35)	(2.42)	(2.16)	(1.64)	(2.05)	(1.50)	(1.95)	(1.85)
2004	X20	X17	X16	X48	X12	X22	X18	X38	X29	X36
	(1.71)	(1.92)	(1.47)	(2.32)	(2.14)	(1.97)	(1.98)	(1.86)	(1.95)	(1.83)
2005	X20	X16	X17	X48	X22	X40	X38	X44	X18	X36
	(1.69)	(1.92)	(1.58)	(2.21)	(1.85)	(1.60)	(1.88)	(1.83)	(1.94)	(1.83)
2006	X16	X40	X48	X44	X22	X38	X29	X36	X4	X37
	(1.59)	(1.90)	(1.68)	(2.11)	(2.02)	(1.77)	(1.83)	(1.81)	(1.93)	(1.81)
2007	X17	X16	X20	X48	X22	X29	X40	X44	X38	X41
	(1.60)	(1.88)	(1.71)	(2.00)	(1.93)	(2.10)	(1.78)	(1.82)	(1.92)	(1.81)
2008	X16	X17	X22	X48	X45	X41	X29	X38	X13	X44
	(1.53)	(1.87)	(1.74)	(1.87)	(1.93)	(1.76)	(1.73)	(1.39)	(1.91)	(1.81)
2009	X16	X17	X48	X45	X41	X22	X29	X44	X40	X38
	(1.50)	(1.84)	(1.90)	(1.74)	(1.93)	(1.71)	(1.60)	(1.73)	(1.89)	(1.80)
2010	X16	X17	X45	X41	X48	X22	X44	X40	X29	X46
	(1.46)	(1.85)	(1.92)	(1.60)	(1.89)	(1.60)	(1.55)	(1.72)	(1.85)	(1.79)
2011	X16	X45	X17	X41	X48	X44	X22	X40	X19	X46
	(1.41)	(1.84)	(1.83)	(1.58)	(1.82)	(1.86)	(1.57)	(1.70)	(1.83)	(1.78)
2012	X16	X45	X41	X17	X48	X46	X22	X44	X19	X6
	(1.37)	(1.81)	(1.87)	(1.51)	(1.76)	(2.01)	(1.52)	(1.66)	(1.79)	(1.73)
2013	X16	X45	X41	X17	X46	X48	X22	X44	X24	X40
	(1.33)	(1.78)	(1.92)	(1.61)	(1.79)	(1.58)	(1.62)	(1.63)	(1.79)	(1.73)
2014	X16	X45	X41	X46	X17	X48	X22	X24	X43	X3
	(1.31)	(1.74)	(1.92)	(1.50)	(1.79)	(1.88)	(1.58)	(1.63)	(1.79)	(1.72)
2015	X16	X45	X41	X46	X48	X17	X22	X24	X43	X6
	(1.26)	(1.65)	(1.91)	(1.35)	(1.81)	(1.91)	(1.55)	(1.63)	(1.73)	(1.70)
2016	X16	X45	X41	X18	X46	X48	X22	X6	X24	X43
	(1.23)	(1.59)	(1.78)	(1.20)	(1.82)	(2.06)	(1.51)	(1.63)	(1.73)	(1.68)
2017	X45	X16	X41	X46	X48	X22	X24	X43	X23	X44
	(1.21)	(1.57)	(1.63)	(1.00)	(1.81)	(1.65)	(1.50)	(1.67)	(1.62)	(1.66)
2018	X45	X41	X16	X46	X48	X24	X19	X22	X43	X28
	(1.12)	(1.35)	(1.33)	(0.74)	(1.59)	(1.62)	(1.46)	(1.50)	(1.32)	(1.43)
2019	X45	X41	X16	X46	X6	X48	X24	X22	X43	X28
	(1.15)	(1.50)	(1.47)	(0.71)	(1.69)	(2.17)	(1.45)	(1.63)	(1.48)	(1.56)
2020	X16	X46	X48	X28	X4	X24	X22	X7	X27	X33
	(1.09)	(1.50)	(1.51)	(2.07)	(1.85)	(1.68)	(2.00)	(1.59)	(1.46)	(1.52)

Table 6. The obstacle factors of coupling coordination degree in the central regions.

Year	1	2	3	4	5	6	7	8	9	10
2003	X18	X29	X14	X20	X38	X36	X42	X13	X1	X4
	(1.43)	(1.20)	(0.77)	(1.40)	(1.21)	(0.99)	(1.31)	(1.12)	(1.18)	(1.17)
2004	X18	X14	X20	X38	X13	X36	X42	X28	X4	X29
	(1.26)	(1.21)	(0.86)	(1.36)	(1.21)	(1.09)	(1.30)	(1.25)	(1.18)	(1.17)
2005	X18	X20	X14	X38	X36	X13	X35	X42	X4	X28
	(1.17)	(1.22)	(0.94)	(1.33)	(1.19)	(1.16)	(1.27)	(1.23)	(1.18)	(1.17)
2006	X18	X38	X36	X14	X42	X13	X4	X28	X48	X39
	(1.07)	(1.23)	(1.00)	(1.29)	(1.17)	(1.01)	(1.24)	(1.22)	(1.17)	(1.18)
2007	X18	X38	X14	X42	X13	X28	X36	X48	X37	X4
	(1.03)	(1.23)	(1.03)	(1.23)	(1.13)	(0.90)	(1.20)	(1.21)	(1.16)	(1.18)
2008	X18	X13	X38	X35	X14	X42	X28	X37	X2	X48
	(0.98)	(1.23)	(1.07)	(1.17)	(1.16)	(1.19)	(1.13)	(1.02)	(1.16)	(1.18)
2009	X18	X38	X13	X48	X6	X14	X42	X37	X2	X28
	(0.95)	(1.23)	(1.15)	(1.12)	(1.14)	(1.28)	(1.09)	(1.17)	(1.15)	(1.18)
2010	X38	X18	X48	X13	X14	X2	X37	X28	X33	X10
	(0.90)	(1.23)	(1.17)	(1.07)	(1.10)	(1.07)	(1.06)	(1.16)	(1.13)	(1.18)
2011	X17	X48	X13	X14	X38	X2	X37	X44	X45	X43
	(0.86)	(1.23)	(1.14)	(1.07)	(1.07)	(0.97)	(1.03)	(1.15)	(1.11)	(1.18)
2012	X45	X41	X13	X48	X44	X17	X2	X24	X37	X3
	(0.82)	(1.22)	(1.19)	(1.05)	(1.05)	(1.16)	(1.00)	(1.12)	(1.08)	(1.17)
2013	X45	X41	X44	X48	X40	X24	X3	X43	X2	X6
	(0.78)	(1.22)	(1.23)	(1.06)	(1.03)	(1.20)	(0.99)	(1.11)	(1.07)	(1.17)
2014	X45	X41	X44	X40	X48	X3	X24	X6	X43	X2
	(0.75)	(1.21)	(1.27)	(1.01)	(1.02)	(1.25)	(0.96)	(1.10)	(1.08)	(1.17)
2015	X45	X41	X44	X40	X3	X24	X48	X43	X25	X2
	(0.72)	(1.18)	(1.30)	(0.93)	(1.03)	(1.04)	(0.94)	(1.10)	(1.04)	(1.17)
2016	X45	X41	X44	X18	X40	X3	X24	X46	X43	X25
	(0.68)	(1.16)	(1.30)	(0.85)	(1.05)	(0.96)	(0.92)	(1.08)	(1.04)	(1.16)
2017	X45	X41	X44	X40	X6	X46	X24	X3	X43	X48
	(0.66)	(1.15)	(1.29)	(0.77)	(1.01)	(1.35)	(0.88)	(1.07)	(1.05)	(1.16)
2018	X45	X41	X44	X46	X40	X6	X16	X24	X43	X3
	(0.69)	(1.32)	(1.47)	(0.75)	(1.16)	(1.61	(0.87)	(1.23)	(1.16)	(1.33)
2019	X45	X41	X44	X40	X46	X24)	X3	X43	X16	X25
	(0.57)	(1.11)	(1.27)	(0.54)	(0.96)	(0.89)	(0.69)	(1.06)	(0.97)	(1.13)
2020	X46	X4	X3	X42	X43	X48	X16	X25	X7	X27
	(0.51)	(1.10)	(1.28)	(1.36)	(1.01)	(1.09)	(1.20)	(1.03)	(0.90)	(1.10)

Table 7. The obstacle factors of coupling coordination degree in the western regions.

Year	1	2	3	4	5	6	7	8	9	10
2003	X20	X18	X12	X29	X1	X14	X11	X38	X4	X36
	(3.65)	(2.08)	(1.46)	(2.76)	(2.24)	(2.01)	(2.40)	(1.97)	(2.17)	(2.11)
2004	X18	X20	X17	X14	X11	X1	X13	X12	X42	X38
	(0.34)	(0.19)	(0.12)	(0.25)	(0.22)	(0.18)	(0.23)	(0.22)	(0.20)	(0.20)
2005	X18	X20	X1	X14	X17	X13	X38	X12	X42	X36
	(0.33)	(0.19)	(0.15)	(0.24)	(0.22)	(0.15)	(0.23)	(0.22)	(0.20)	(0.20)
2006	X18	X1	X11	X14	X13	X20	X38	X42	X36	X4
	(0.31)	(0.19)	(0.16)	(0.23)	(0.22)	(0.22)	(0.23)	(0.22)	(0.20)	(0.20)
2007	X18	X20	X17	X11	X14	X13	X1	X42	X38	X12
	(0.26)	(0.19)	(0.17)	(0.22)	(0.20)	(0.13)	(0.22)	(0.22)	(0.20)	(0.20)
2008	X18	X20	X11	X14	X17	X13	X12	X42	X1	X38
	(0.26)	(0.19)	(0.18)	(0.21)	(0.20)	(0.20)	(0.22)	(0.20)	(0.20)	(0.20)
2009	X18	X11	X20	X14	X17	X12	X1	X13	X42	X38
	(0.27)	(0.19)	(0.20)	(0.20)	(0.20)	(0.14)	(0.21)	(0.21)	(0.20)	(0.20)
2010	X18	X11	X12	X20	X14	X17	X6	X1	X42	X13
	(0.26)	(0.19)	(0.21)	(0.19)	(0.19)	(0.28)	(0.21)	(0.21)	(0.20)	(0.20)
2011	X17	X11	X18	X6	X12	X13	X14	X1	X38	X39
	(0.24)	(0.20)	(0.21)	(0.19)	(0.18)	(0.29)	(0.20)	(0.21)	(0.20)	(0.20)
2012	X17	X11	X18	X13	X14	X12	X1	X38	X42	X39
	(0.23)	(0.19)	(0.22)	(0.18)	(0.18)	(0.18)	(0.20)	(0.21)	(0.20)	(0.20)
2013	X17	X13	X3	X18	X11	X1	X39	X15	X38	X34
	(0.22)	(0.19)	(0.22)	(0.18)	(0.18)	(0.17)	(0.21)	(0.21)	(0.20)	(0.20)
2014	X17	X3	X39	X15	X7	X32	X8	X1	X6	X34
	(0.21)	(0.19)	(0.23)	(0.17)	(0.17)	(0.21)	(0.21)	(0.21)	(0.19)	(0.20)
2015	X6	X3	X39	X15	X7	X8	X34	X17	X32	X25
	(0.19)	(0.18)	(0.23)	(0.16)	(0.16)	(0.28)	(0.21)	(0.21)	(0.19)	(0.20)
2016	X6	X3	X15	X8	X7	X39	X25	X32	X26	X10
	(0.17)	(0.18)	(0.23)	(0.15)	(0.16)	(0.31)	(0.21)	(0.21)	(0.19)	(0.20)
2017	X3	X15	X7	X8	X39	X34	X32	X25	X26	X10
	(0.16)	(0.17)	(0.23)	(0.14)	(0.12)	(0.15)	(0.21)	(0.21)	(0.18)	(0.20)
2018	X3	X6	X15	X8	X7	X39	X34	X26	X31	X32
	(0.15)	(0.17)	(0.23)	(0.12)	(0.12)	(0.23)	(0.21)	(0.21)	(0.17)	(0.20)
2019	X3	X15	X8	X34	X7	X39	X26	X25	X10	X31
	(0.13)	(0.17)	(0.23)	(0.12)	(0.14)	(0.11)	(0.20)	(0.21)	(0.17)	(0.19)
2020	X4	X7	X3	X15	X8	X28	X34	X39	X26	X25
	(0.12)	(0.17)	(0.23)	(0.25)	(0.15)	(0.19)	(0.24)	(0.21)	(0.19)	(0.19)

Table 8. The obstacle factors of coupling coordination degree in the northeast regions.

Year	1	2	3	4	5	6	7	8	9	10
2003	X20	X47	X12	X17	X40	X44	X18	X29	X22	X1
	(0.93)	(0.55)	(0.57)	(0.80)	(0.62)	(0.51)	(0.72)	(0.58)	(0.58)	(0.58)
2004	X20	X47	X17	X12	X22	X1	X40	X18	X28	X11
	(0.88)	(0.56)	(0.57)	(0.78)	(0.63)	(0.55)	(0.70)	(0.65)	(0.59)	(0.58)
2005	X20	X47	X18	X17	X22	X12	X40	X1	X44	X4
	(0.86)	(0.58)	(0.57)	(0.77)	(0.65)	(0.55)	(0.70)	(0.65)	(0.59)	(0.59)
2006	X47	X18	X22	X12	X40	X11	X44	X20	X1	X28
	(0.81)	(0.59)	(0.58)	(0.75)	(0.64)	(0.49)	(0.69)	(0.65)	(0.59)	(0.59)
2007	X20	X47	X17	X18	X12	X22	X40	X11	X44	X28
	(0.80)	(0.58)	(0.57)	(0.73)	(0.63)	(0.57)	(0.68)	(0.65)	(0.59)	(0.58)
2008	X20	X17	X47	X18	X22	X40	X11	X44	X12	X28
	(0.79)	(0.59)	(0.57)	(0.71)	(0.63)	(0.69)	(0.69)	(0.57)	(0.59)	(0.58)
2009	X17	X20	X47	X18	X22	X11	X40	X44	X46	X12
	(0.74)	(0.57)	(0.62)	(0.70)	(0.64)	(0.65)	(0.65)	(0.63)	(0.59)	(0.59)
2010	X17	X47	X20	X46	X19	X40	X18	X22	X44	X28
	(0.70)	(0.58)	(0.63)	(0.67)	(0.60)	(0.55)	(0.65)	(0.63)	(0.59)	(0.58)
2011	X19	X17	X47	X20	X46	X40	X44	X22	X28	X18
	(0.69)	(0.59)	(0.64)	(0.66)	(0.60)	(0.43)	(0.65)	(0.63)	(0.59)	(0.58)
2012	X19	X17	X47	X20	X46	X22	X40	X44	X28	X42
	(0.66)	(0.58)	(0.68)	(0.65)	(0.58)	(0.63)	(0.65)	(0.63)	(0.59)	(0.58)
2013	X19	X47	X17	X46	X20	X40	X44	X22	X28	X42
	(0.63)	(0.57)	(0.70)	(0.64)	(0.57)	(0.70)	(0.66)	(0.63)	(0.59)	(0.58)
2014	X19	X17	X47	X46	X20	X40	X22	X44	X28	X42
	(0.61)	(0.56)	(0.71)	(0.61)	(0.55)	(0.45)	(0.65)	(0.63)	(0.59)	(0.58)
2015	X19	X47	X46	X17	X20	X22	X40	X44	X3	X42
	(0.59)	(0.55)	(0.72)	(0.59)	(0.53)	(0.45)	(0.66)	(0.63)	(0.58)	(0.57)
2016	X19	X18	X46	X47	X40	X22	X44	X41	X3	X42
	(0.57)	(0.54)	(0.72)	(0.56)	(0.51)	(0.57)	(0.65)	(0.63)	(0.58)	(0.57)
2017	X19	X46	X47	X40	X44	X22	X41	X6	X45	X42
	(0.57)	(0.55)	(0.71)	(0.54)	(0.50)	(0.77)	(0.64)	(0.62)	(0.58)	(0.56)
2018	X19	X46	X47	X40	X22	X44	X41	X45	X42	X28
	(0.55)	(0.54)	(0.66)	(0.49)	(0.49)	(0.53)	(0.64)	(0.62)	(0.58)	(0.56)
2019	X19	X46	X47	X44	X40	X41	X45	X22	X28	X42
	(0.53)	(0.54)	(0.65)	(0.48)	(0.43)	(0.49)	(0.63)	(0.62)	(0.58)	(0.59)
2020	X19	X46	X22	X47	X28	X4	X7	X41	X40	X42
	(0.49)	(0.53)	(0.65)	(0.75)	(0.45)	(0.47)	(0.72)	(0.62)	(0.55)	(0.59)

Obstacle Factors of Coupling Coordination Degree

Obstacle Factors of Coupling Coordination Degree from the National Perspective

According to the values of the obstacle factor, the top ten are mainly discussed. It can be observed from Table 4 that the frequency and ranking of obstacle factors have changed greatly over time. In terms of frequency, X17 is the main obstacle factor, followed by X44 and X46. X18, X12, X13, X14, X20, X45, and X41. In terms of ranking, the first obstacle factors from 2003 to 20114 are X20, X18, X12, X14, X17, X41, X44, and X45. From 2015 to 2020, the ranking of X45 and X46 continue to rise, which plays an important role in the coupling coordination degree. The evolution of obstacle factors has obvious stage characteristics. The obstacle factors affecting the coupling coordination degree of high-quality development gradually evolved from the subsystem of greenness development to carbon emissions development. The carbon emission subsystem has a prominent function of forcing and leading high-quality development [55]. [56] believed that high-quality development emphasizes the allocation efficiency of green resource elements and the control of carbon emissions, the achievement of the dual carbon goal is closely related to high-quality development. The carbon emission subsystem constructed in this paper includes energy utilization issues. [57] demonstrated that under the dual pressure of short-term difficulty in optimizing energy structure and continuous increase in energy consumption, coordinating the dual goals of greenhouse gas emissions reduction and economic development is significant that the Chinese government and academia solve urgently.

Obstacle Factors of Coupling Coordination Degree from the Regional Perspective

As shown in Table 5, in terms of the frequency of the obstacle factors, X20, X16, X17, X41, X45, and X48 are the main factors hindering high-quality development in the eastern regions. From the rankings of obstacle factors in different years, the top ten obstacle factors mainly experienced the transformation of coordination development, greenness development, and carbon emissions development. Table 6 denotes that the first obstacle factor in the central regions mainly changes from X18 to X45; The ranking of X41 continues to rise. The obstacle factors of central regions mainly experience the evolution of greenness development, sharing development, and carbon emissions development. In Table 7, the evaluation of the first obstacle factor in the western regions mainly experienced X18-X17-X3, and changes from green development to economic development. After 2012, the ranking of X3 keeps rising, which indicates that strengthening the construction of infrastructure is essential to the western regions. The ranking of X7 continues to rise and becomes the second obstacle factor in 2020. The impact of innovative development on the western regions is expanding. The top ten obstacle factors in the western regions are mainly distributed in economic development, greenness development, coordination development, and innovation development. As presented in Table 8, according to the evolution of the obstacle factor in the northeast regions, the first obstacle factor mainly experiences X20-X17-X19; The second obstacle factor is X47-X17-X46. This indicates that the carbon emissions force the northeast region to face severe uncoordinated development. The obstacle factors vary from region to region and the formulation of differentiated development strategies plays a decisive role in the coupling coordinated evolution of high-quality development.

Conclusions and Suggestions

Conclusions

This paper constructs a high-quality development evaluation system that includes carbon emissions indicators. Attention is paid to regional heterogeneity of the coupling coordination degree of high-quality development. The main findings are as follows:

(1) The regional heterogeneity in subsystem development is demonstrable. Innovation and greenness in the eastern regions need to be strengthened; The main weaknesses in the central, western, and northeast regions are openness and innovation. The coupling coordination degree of high-quality development in China is relatively low. In the temporal dimension, the coupling coordination degree shifts from IV to V. In the spatial dimension, the coupling coordination degree presents a decreasing trend of eastern-northeast-central-western regions. The unbalanced development of the regions has existed during the study.

(2) The total difference in the coupling coordination degree is declining. The differences are mainly resourcing from inter-regional differences. The intra-group differences in the four regions also show varying degrees of decline. Intra-regional differences in the eastern regions decreased significantly, followed by the central regions; The intraregional differences in the western regions and the northeast regions decrease slightly.

(3) The main obstacle factors of coupling coordination degree of high-quality development in China and provinces are inconsistent and have changed over time. X17, X18, X20, X44, X45, and X46 are the main factors hindering the coupling coordination degree. The importance of carbon emissions is constantly highlighted.

Suggestions

In the context of the "dual carbon" goals, the harmonious coexistence of nature and humans needs to pay more effort. We reveal the regional differences in the coordinated evolution of high-quality development coupling, identify the main “shortcomings” subsystems and obstacles, and put forward the following policy recommendations from three aspects: improving system coupling coordination scheduling, promoting regional collaborative development, and main influencing factors.

(1) The driving force for the subsystem of innovation is insufficient, regional cooperation and exchanges need to be strengthened to avoid regional technical barriers. Facing the complex external environment, the emphasis should be placed on the subsystem of economy and openness. Remaining the stability of macroeconomic development, and actively preventing and effectively resolving the risks and impacts of opening up.

(2) The inter-regional differences are the main reason for regional imbalance and disharmony. Government should take effective measures for regional coordination and linkage, and give full play to the example of application in the eastern region.

(3) The basic indicators distributed in the subsystem of carbon emissions gradually evolve into the main obstacle factor of coupling coordination degree. The eastern, central, and northeast regions should pay more attention to X45 and X46. In the western regions, the obstacle factors mainly distribute in economic development, and the primary task is to improve the construction of infrastructure.

The contributions mainly include four aspects. First, the indicator system of high-quality development is established from the seven subsystems to improve the research depth and breadth of high-quality development. Second, the development index of subsystems is analyzed from the national and regional levels, and the weakness of regional development are explored. Third, the evolution characteristics and regional differences of the coupling coordination degree of high-quality development are studied. Fourth, identify the obstacle factors from the basic indicators, and explore the resistance of the coupling and coordinated evolution of high-quality development. The study aims to provide a realistic basis for achieving synergistic evolution of high-quality development.

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Conflict of Interest

The authors declare no conflict of interest.

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