

Research Article

Spatiotemporal Coupling Coordination Analysis of Social Economy and Resource Environment of Central Cities in the Yellow River Basin

Huimin Li ¹, Zanmei Jiang ¹, Guanghua Dong ^{1,2}, Lunyan Wang ², Xin Huang ¹,
Xiang Gu ^{1,3} and Yinju Guo ¹

¹Department of Construction Engineering and Management, North China University of Water Resources and Electric Power, Zhengzhou 450046, China

²Henan Key Laboratory of Water Environment Simulation and Treatment, Zhengzhou 450045, China

³Collaborative Innovation Center of Water Resources Efficient Utilization and Protection Engineering, Zhengzhou 450045, China

Correspondence should be addressed to Guanghua Dong; dongguanghua@ncwu.edu.cn

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With the rapid economic and social development and accelerated urbanization, the negative ecological impact of major river basins worldwide has been deepening, which is gradually threatening the sustainable development of cities. This study establishes the model of the coupling coordination relationship between social economy and resources environment of nine central cities in the Yellow River Basin. Based on the evaluation index system of social economy and resource environment, we quantitatively measure the coupling coordination degree and spatiotemporal pattern of the nine central cities from 2010 to 2017. The obstacle factors of coupling coordination were then diagnosed based on the obstacle degree model. The results showed that (1) the social economy and resources environment development indices of the nine central cities in the Yellow River Basin, as well as the coupling coordination of each central city, showed an overall upward trend from 2010 to 2017. (2) Most of the central cities in the Yellow River Basin were in the coordinated coupling stage, among which Xining and Lanzhou have the highest coupling degree. (3) The obstacle factors affecting the harmonious development coupling coordination of the nine central cities were natural growth rate of population, proportion of tertiary industry in GDP and per capita investment in fixed assets in social economy system, and per capita green area of parks, per capita total amount of water resources, and per capita industrial SO₂ emissions in resources environment system. It is necessary to adopt different strategies for different cities to promote the coupling coordination development of urban social economy and resources environment in the Yellow River Basin.

1. Introduction

The Yellow River Basin is the cradle of Chinese culture, with a long history and long mainstream of 5464 km. It flows through Qinghai, Sichuan, Gansu, Ningxia, Inner Mongolia, Shanxi, Shaanxi, Henan, and Shandong and covers 795000 km² [1].

The Yellow River flows through the arid and semiarid regions and undertakes the water supply task of 17.0% for cultivated land and more than 50 large- and medium-sized

cities. It is an important water source for cities in the region. However, the Yellow River Basin is seriously short of water resources. In 2018, the total water resources of the Yellow River basin only accounted for 2.6% of China [2]. The Yellow River Basin plays a vital role in national economic development, and it carried 23.3% of the national population and produced 21.8% of the total economic volume. Driven by the national implementation of the Western development, the economics of cities in the Yellow River Basin have rapidly improved. However, the consequent pollution problems

have seriously affected the self-cleaning capacity of the ecosystem and threatened the resources and environment. In 2017, the water quality of 692.7 km of the Yellow River was class IV and low-grade IV [3]. The extensive scale development of energy and heavy chemical industry led to the pollutants in the Yellow River. The pollution exceeded the water environment carrying capacity of its mainstream and tributaries. Therefore, it is essential to study the relationship between economy and society and resources and the environment in the Yellow River Basin.

The urban economy is composed of industry, commerce, and other nonagricultural economic sectors. Social development refers to the process of the whole human society moving forward, including the overall development of economy, humanities, politics, and other series of social existence. In recent years, the economy of the central cities in the Yellow River Basin has developed rapidly. Simultaneously, as a critical ecological functional area in China, the environmental quality of central cities in the Yellow River Basin is directly related to the national ecological security. The process of rapid economic and social development is often accompanied by problems such as heavy metal pollution of the air, water, and soil and the deterioration of the ecological environment, bringing enormous pressure on the carrying capacity of resources and the environment. In this context, the coupling coordination development of social economy with resources environment has become a strategic issue and scientific problem.

To sum up, the Yellow River Basin is an important ecological barrier and an important economic zone in China, which is of great importance for maintaining social stability and ecological security, promoting national unity, and national economic and social development. However, there is an incongruity between economic development and ecological environment development in the Yellow River Basin. This paper will take nine central cities in the Yellow River Basin as the research object, analyze the spatial and temporal trends of the coupling coordination degree of nine central cities in the Yellow River Basin from 2010 to 2017, identify the main factors affecting the development of these central cities through the barrier degree model, and finally give the corresponding evaluation and opinions on the coordinated development of economic, social, and resource environment in the central cities in the Yellow River Basin concerning the research results.

2. Literature Review

2.1. Environmental Conditions of the Yellow River Basin. The ecological foundation of the Yellow River basin is fragile. The climate of the upper reaches is dry and rainy, and desertification is a serious problem. The problem of soil erosion is serious in the middle reaches [3]. In recent years, the rapid development of various industries in the Yellow River Basin has further aggravated the environmental problems. For example, the middle reaches of the Yellow River Basin are rich in mineral resources. The extensive development of energy and minerals has increased the environmental pressure in the middle reaches, while soil

erosion has increased in Shanxi and desertification has intensified in many areas [4, 5]. Zhu and Wang [6] found that environmental protection facilities of power, coking, and other industries based on coal consumption were operating at a low level. So, the SO₂ emissions seriously exceeded the standard, resulting in serious, atmospheric soot-type pollution in the region.

2.2. Urban Economic and Social Development. Many scholars have studied the high-quality economic development of the Yellow River Basin. Xu et al. [7] constructed the Yellow River Basin high-quality development evaluation index system from the two aspects of economic and social development and ecological security. They measured the level of high-quality development based on nine provinces of the Yellow River Basin from 2008 to 2017. Ma and Xu [8] evaluated the high-quality development of seven city clusters in the Yellow River Basin based on five dimensions: innovation, coordination, green, openness, and sharing. The study found significant spatial differences in the high-quality development of city clusters in the Yellow River Basin. It concluded that the role of core cities in driving the high-quality development of city clusters should be strengthened. Liu et al. [9] compared the relationship between openness and sustainable development in representative river basin economic areas in Asia, Europe, North and South America, and Africa. They found that the openness factors had a complex impact on the functioning state of river basin economic systems and led to diverse river basin economic systems and pathways of development. It was proposed that the experience of forming a positive interaction between openness and sustainable development through the combined effect of independent openness and innovation, coordination, adaptation, and sharing can provide lessons for the high-quality economic development of the Yellow River Basin.

2.3. Relationship between the Resources Environment and Social Economy for City. The coupling coordination of social economy with resources and environment has become a research hotspot in regional development in recent years. Li and Li [10] conducted a coordination analysis of the social economy and resources environmental development of Wuhan from 1988 to 2010 based on the principal component analysis method. The results show that the coupling relationship between social and economic development and the resources environment is gradually changing from severe imbalance to elemental disharmony, indicating that there is still some distance to achieve quality coordination. Sun et al. [11] studied the coupling coordination degree of social economy and resource environment with panel data from 18 cities in Henan Province. The study showed that the east-west and north-south coupling coordination approximated an inverted U curve. Wang and Wu [12] built the coupling process model of regional ecological and economic systems. They quantitatively analyzed the coupling process and trend of the regional eco-economic system in the Yellow River Delta. Li et al. [13] used the coupling coordination model to evaluate the resource environment and social economy in 19

resource-based cities in the northeast of China. This study found that the coordinated development of each city was at a low level, and the social economy development lagged far behind the development of the ecological environment. Song et al. [14] have studied the evolution law of coupling coordination development of agro-ecological environment system and agro-economic system in Ningxia of China. The result showed that the overall coordinated development of the agro-ecological system and agricultural economic system had achieved a shift from transitional development to coordinated development. Based on the data of the economic and ecological environment of Mianyang city of China on 2000–2014, Hu [15] constructed a coordination evaluation model of ecological environment and economic system. The results showed that the ecological environment and economic development are at a low level of coordination. He suggested that the proposed city should return farmland to forests, accelerate the pace of industrial restructuring, and promote clean production and the circular economy to establish a coordinated development system for the economy and the ecological environment. At present, most of the studies on the coupling and coordination of economy, society, and resources environment are based on one province or one region, and there are few studies on the cities in the River Basin.

3. Research Methods

3.1. Study Area and Data Sources. The Yellow River Basin is divided into three parts: upper, middle, and lower reaches. The upper reaches include Xining, Lanzhou, and Yinchuan; the middle reaches include Hohhot, Taiyuan, and Xi'an; and the lower reaches include Zhengzhou, Qingdao, and Jinan (see Figure 1). In terms of ecological environment, most of the cities in the upper reaches of the Yellow River Basin have good vegetation coverage and good air quality. Due to the economic development in the middle reaches, the resources and environment have deteriorated. Due to the severe water loss and soil erosion caused by the dam construction in the lower reaches of the Yellow River, a large amount of sediment was transported to the lower reaches of the Yellow River, and the silt accumulation was severe. In terms of economy and society, the upper reaches have a slower economic development, while those in the middle and lower reaches are at a more advanced level. The GDP and medical education resources in the upper Yellow River Basin cities are relatively backward compared with those in the middle and lower reaches. Xi'an, located in the middle reaches of the Yellow River Basin, is a famous historical and cultural city and a gathering area of colleges and universities. Zhengzhou, located in the Central Plains, has seen rapid growth in the manufacturing and transportation sectors in recent years. Moreover, located in the lower reaches of the Yellow River Basin, Jinan and Qingdao have distinct advantages in three areas: manufacturing, financial services, and tourism.

The quantitative indicator data used in this study are all from the China Statistical Yearbook (2010–2017), China City Statistical Yearbook (2010–2017), Provincial Water Resources Bulletin (2010–2017), National Economy and Resources Development Bulletin (2010–2017), and relevant data website of the National Bureau of Statistics (2010–2017).

3.2. Evaluation Index System. To accurately evaluate the interrelationship between social economy and resources and environment, two indicator systems for social economy and resources environment have been established, as shown in Table 1.

3.3. Model Development

3.3.1. Index Data Process. Consider

$$X_{ij} = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})}, \quad (1)$$

$$X_{ij} = \frac{\max(x_{ij}) - x_{ij}}{\max(x_{ij}) - \min(x_{ij})}, \quad (2)$$

where x_{ij} is the original index value and X_{ij} is the normalization value. The benefit indexes are calculated by formula (1), while cost indexes are calculated by formula (2).

3.3.2. Index Weight. Consider

$$e_j = -k \sum_{i=1}^n (p_{ij} \ln p_{ij}), \quad (3)$$

$$w_j = \frac{1 - e_j}{\sum_{j=1}^m (1 - e_j)}. \quad (4)$$

In formula (3), $k = (1/\ln n)$, $p_{ij} = (y_{ij}/\sum_{i=1}^n y_{ij})$. If $p_{ij} = 0$, then define $\lim_{p_{ij} \rightarrow 0} p_{ij} \ln p_{ij} = 0$. In formula (4), the weight w_j complies with the following conditions: $0 \leq w_j \leq 1$ and $\sum_{j=1}^m w_j = 1$.

3.3.3. Comprehensive Development Index. Consider

$$S = \sum_{i=1}^n X_{ij}^s w_j^s, \quad (5)$$

$$E = \sum_{i=1}^n X_{ij}^e w_j^e.$$

where S, E are social economy level and resources environment level, respectively. w_j^s, w_j^e are the weight and normalization value of index in social economy level, respectively. w_j^e, w_j^s are the weight and normalization value of the index in the resources' environment level, respectively.

3.3.4. *Coupling Coordination Model.* This study adopts the coupling coordination model [21].

$$C = \left\{ \frac{S \cdot E}{[(S + E)/2]^2} \right\}^{1/2},$$

$$T = \alpha U + \beta E, \quad (6)$$

$$D = \sqrt{CT},$$

C is the coupling value, between 0 and 1. α and β are the coefficients to be determined, 0.5 and 0.5, respectively. T is the comprehensive coordination index of social economy and resources environment. D is the degree of coupled coordination. According to the relevant research [22], the coupling degree classification is shown in Table 2. The coupling coordination degree classification is shown in Table 3 [23].

3.3.5. *Obstacle Degree Model.* In order to improve the coupling coordination of the social economy and resource environment of central cities in the Yellow River Basin, it is essential to study the main reasons that hinder the social economy level and resource environment level. Barrier degree model is to filter out the factors that hinder the development of the goal. Therefore, the obstacle degree model is used for further analysis, where W_j denotes the factor contribution, which is the weight of the indicator, $1 - X_{ij}$ represents the deviation of the indicator, which is the gap between a single indicator and the desired target, and the barrier degree (Q_j) is the value of the impact of a single factor on the social and economic level and the level of resources and environment.

$$Q_j = \frac{W_j(1 - X_{ij})}{\sum_{j=1}^m W_j(1 - X_{ij})}. \quad (7)$$

4. Results and Findings

4.1. *Temporal Characteristics Analysis.* In this study, the collected data were used to calculate the development index, coupling degree, and coupling coordination degree of social economy and resource environment in nine central cities of the Yellow River Basin from 2010 to 2017.

The social economy development indexes of the nine central cities in the Yellow River Basin maintained an upward trend, as shown in Figure 2. The rapid social economy development of the cities from 2010 to 2015 was mainly due to the national regional development strategy from 2011, such as promoting a new round of Western development and vigorously promoting the rise of the central region. The Yellow River Basin spans the east, middle, and west of three economic zones of China, which provide a solid foundation for rapid economic development. During this period, Taiyuan rose faster, from 0.037 to 0.477. The rising of Yinchuan was the least, from 0.092 to 0.332. After 2015, the economic growth rate of the nine cities slowed down, but the economic growth momentum was still relatively stable. The

main reason was that after years of rapid development, the Chinese economic development had entered a new trend of slower economic growth, continuous optimizing and upgrading of the economic structure, greening of the energy structure, and moving from rapid economic development to sustainable development. In 2017, Hohhot and Jinan had a downward trend. The social economy development index of Hohhot decreased mainly due to a 20.03% drop in per capita investment in fixed assets and the per capita general budget income of the local fiscal authorities fell by 25.29%. The growth rate in Qingdao did not slow down, with the economic and social development index increasing from 0.2985 to 0.4266.

In terms of the trend of resource and environment index in the central cities of the Yellow River Basin (Figure 3), it showed a fluctuating upward trend. Xining and Lanzhou had the largest increase. Xi'an and Taiyuan followed a steady upward trend. Due to the dry climate in Yinchuan, the total amount of water resources fluctuates wildly, resulting in a more obvious up and down fluctuation of the resource and environment index. In 2010–2014, Hohhot, Jinan, Qingdao, and Zhengzhou increased slowly. After 2015, the resource and environment development index increased significantly due to the reduction of industrial wastewater emissions and industrial sulfur dioxide emissions. In 2016–2017, the resource and environment development index of all the central cities was on an upward trend, which was related to the slow down of Chinese economic development, to construct ecological civilization and green cities.

As shown in Table 4, from 2010 to 2017, most of the cities were at the stage of coordinated coupling, among which Xining and Lanzhou had the highest coupling, indicating that the gap between the economic and social levels of these two cities and the level of resources and environment was not large. In this paper, the coupling coordination values were presented in colors, and the plots in Figure 4 indicated which values are represented by the various colors. In this paper, the coupling coordination levels were classified based on Table 3. From the change of coupling coordination degree, all nine cities were in an increasing trend of coupling coordination, but the increase varied. Yinchuan rose less, and the coordination level rose from mild coordination to primary coordination. Huhehaote rose more, with the coordination level rising from extremely disordered to primary coordination. Specifically, from 2010 to 2012, cities were mostly at the moderate and mildly dysfunctional stage. In 2013, cities were mostly on the verge of a dysfunctional stage. From 2014 to 2017, the coordination level of cities kept increasing, and all cities gradually entered the primary coordination stage. In general, the coupling coordination of cities had been rising, which indicated that the coupling coordination had been moving in a good direction. However, the coupling coordination was in the excessive type and had not yet reached the intermediate coordination stage. Due to the less stable resource and environmental development index, central cities need to reduce environmental pollution and achieve high-quality urban development along with economic development.

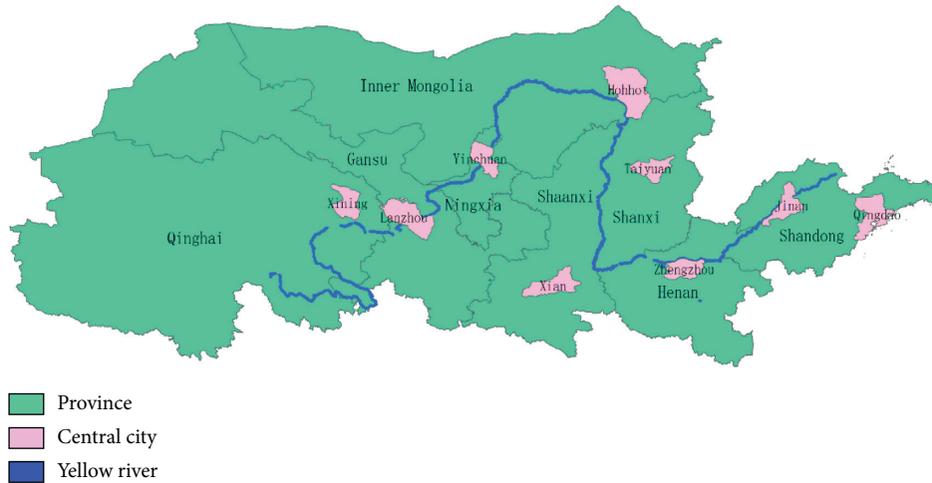


FIGURE 1: The research area of the central cities in the Yellow River Basin.

TABLE 1: Index system of social economy and resources environment.

Index system	Index (code)	Unit	Description	Index type	References
Social economy	Per capita GDP (x1)	10 ⁴ yuan	Economic level of a city	+	Li et al. [13]
	Proportion of the tertiary industry output in GDP (x2)	%	Structure of industry	+	Hu [15]
	General local budget revenue of per capita (x3)	10 ⁴ yuan	Level of government revenue	+	Ta and Ning [16]
	Per capita of fixed assets investment (x4)	10 ⁴ yuan	Economic development capacity of a city	+	Zhang et al. [17]
	Urbanization rate (x5)	%	Level of urbanization	+	Zhang et al. [17]
	Population natural growth rate (x6)	%	Population growth	-	Li et al. [13]
	Per capita retail sales of social consumer goods (x7)	Yuan	Levels of people's material and cultural life	+	Li et al. [13]
	Per ten thousand people of college students (x8)	Unit	Educational attainment of the population	+	Qi et al. [18]
	Number of health facilities per ten thousand people (x9)	Unit	Reflection of medical services	+	Huang et al. [19]
Resources and environment	Per capita of park and green land (x10)	m ²	Greening of the park	+	Li et al. [13]
	Green coverage rate in city (x11)	%	Efforts on afforestation of city	+	Ta and Ning [16]
	Ratio of industrial solid wastes comprehensively utilized (x12)	%	Efforts on pollution abatement	+	Zhang et al. [17]
	Urban sewage treatment rate (x13)	%	Efforts on pollution abatement	+	Li et al. [13]
	Industrial wastewater emissions per unit of GDP (x14)	Ton	Pollutant emission in industrial production process	-	Ma and Xu [8]
	Per capita of water resources (x15)	m ³	Water resources	+	Wang and Liu [20]
	Water consumption per unit of GDP (x16)	Ton	Water use in municipal districts	-	Ta and Ning [16]
	Per capita of industrial sulfur dioxide emission (x17)	Ton	Pollutant emission in industrial production process	-	Hu [15]

4.2. *Spatial Analysis of Coupling Coordination.* To further study the spatial differences in coupling coordination, this study selected four years data of the cities and used ArcGIS software to plot the spatial distribution of coupling coordination levels (see Figures 5–8).

In general, the coupling coordination degrees of cities have all improved. The coupling coordination started with a distribution pattern of high in the central part and low in the west. As the coupling coordination of upstream cities increases, the middle and upper reaches of the Yellow River

TABLE 2: Classification of coupling degree.

Coupling degree	Coupling type	Description
0–0.29	Low coupling	The two subsystems are starting to game, and the coupling is at a low level
0.3–0.49	Antagonism stage	The interaction between the two subsystems intensifies, with the dominant subsystem beginning to occupy space in the other subsystem and the other subsystem declining
0.5–0.79	Running-in stage	The two subsystems check and coordinate with each other and exhibit positive coupling characteristics
0.8–1	Coordinated coupling stage	The benign coupling between the two subsystems becomes stronger and gradually develops in an orderly direction and is at a high level of coupling and coordination

TABLE 3: Coupling coordination degree classification.

Type	D	Degree	Relationship of S and E	Description
Dissonance recession	0–0.09	Profound incoordination	$S > E$	Resources and environment lag
			$S < E$	Social economy lag
			$S = E$	Coordination development
	0.1–0.19	Serious incoordination	$S > E$	Resources and environment lag
			$S < E$	Social economy lag
			$S = E$	Coordination development
0.2–0.29	Moderate incoordination	$S > E$	Resources and environment lag	
		$S < E$	Social economy lag	
		$S = E$	Coordination development	
Transitional category	0.3–0.39	Mild incoordination	$S > E$	Resources and environment lag
			$S < E$	Social economy lag
			$S = E$	Coordination development
	0.4–0.49	On the verge of incoordination	$S > E$	Resources and environment lag
			$S < E$	Social economy lag
			$S = E$	Coordinated development
0.5–0.59	Reluctant coordination	$S > E$	Resources and environment lag	
		$S < E$	Social economy lag	
		$S = E$	Coordinated development	
0.6–0.69	Primary coordination	$S > E$	Resources and environment lag	
		$S < E$	Social economy lag	
		$S = E$	Coordinated development	
Coordinated development	0.7–0.79	Intermediate coordination	$S > E$	Resources and environment lag
			$S < E$	Social economy lag
			$S = E$	Coordinated development
	0.8–0.89	Good coordination	$S > E$	Resources and environment lag
			$S < E$	Social economy lag
			$S = E$	Coordinated development
0.9–1	Quality coordination	$S > E$	Resources and environment lag	
		$S < E$	Social economy lag	
			$S = E$	Coordinated development

had a higher coordination level than the lower reaches. Finally, the pattern of the same coordination level was reached uniformly. In 2010, only the cities of Yinchuan, Zhengzhou, and Xi’an in the middle of the Yellow River Basin were at the stage of mild dissonance, while the rest were at the stage of extreme and moderate dissonance. In 2012, Taiyuan and Hohhot in the middle reaches of the Yellow River Basin and Xining in the upper reaches had a significant increase in coupling coordination. In 2015, only Qingdao, which is in the lower reaches of the Yellow River Basin, was at the near-dissonance stage, while the rest of the cities were at the barely coordinated stage. In 2017, all cities reached primary coordination.

The development types of cities were also different. Most cities changed their development type from economic and

social lagging to resource and environmental lagging, and some cities reached synchronous type. In 2010, the central cities were economic and social lagging type. In 2012, with the development of economic level, the economic and social indexes of Zhengzhou, Xining, and Hohhot cities began to be larger than the resource and environment indexes, and the development type changed to resource and environment lagging type. The development type of Lanzhou and Xi’an basically reached the synchronous type of economic society and resource environment. In 2015, the economic and social indexes of the central cities in the Yellow River Basin further increased, and the development type of the cities was resource-environment lagging type. In 2017, as China began to slow down its economic growth after years of high-speed development, it began to promote the green development of

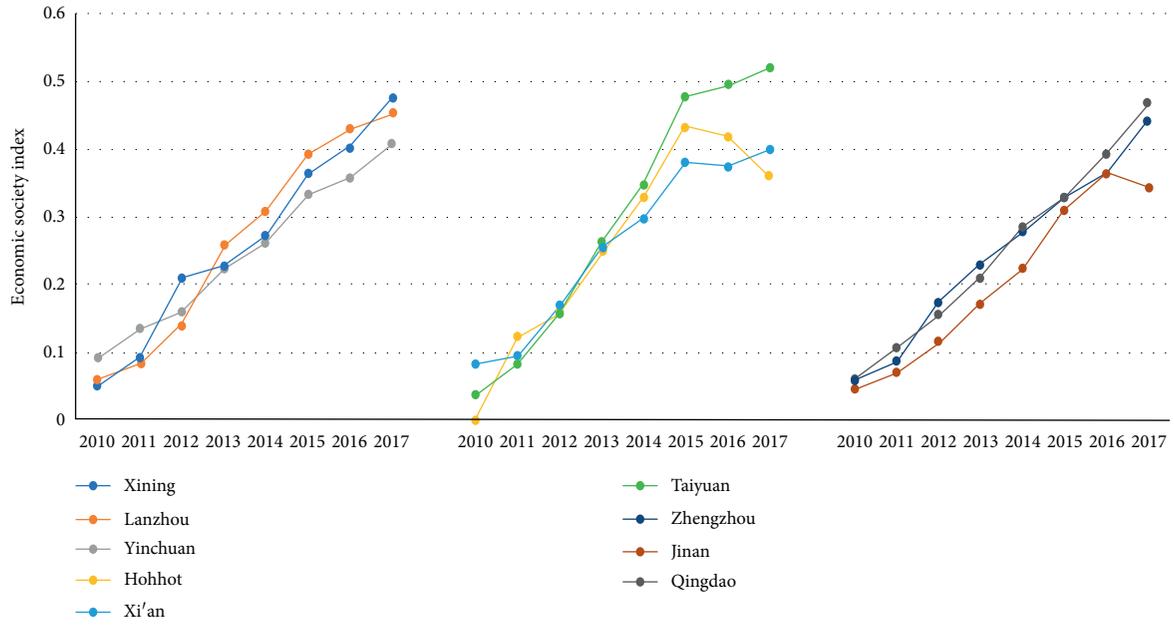


FIGURE 2: Change trend of comprehensive level social economy.

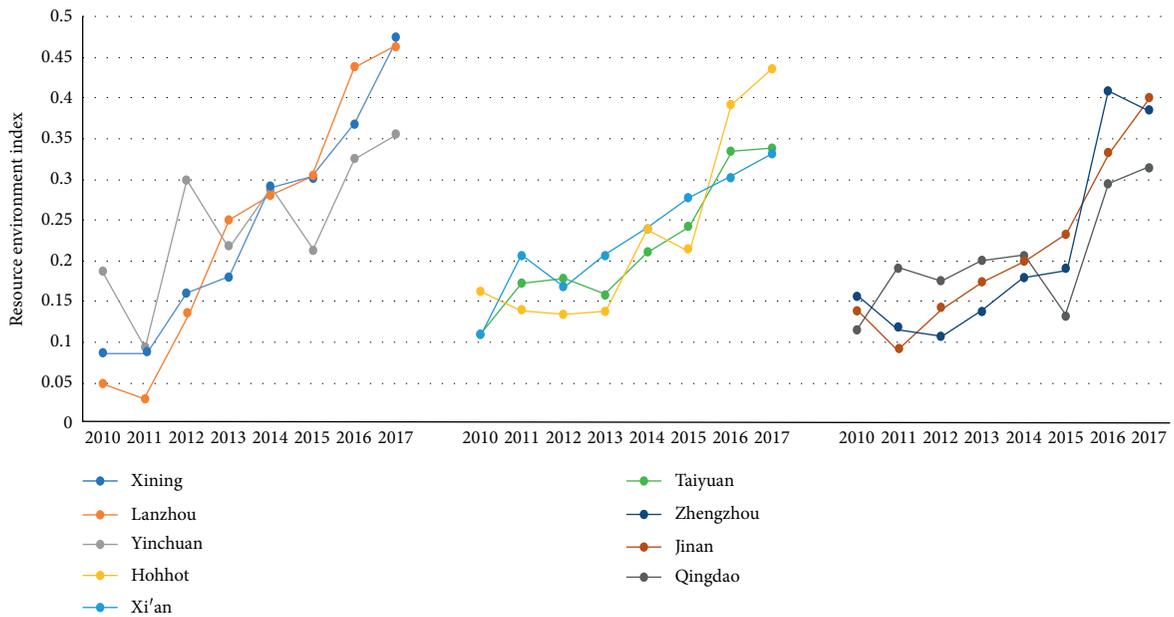


FIGURE 3: Change trend of the comprehensive level of resources environment.

TABLE 4: Coupling degree of social economy and resources environment.

Years	Taiyuan	Jinan	Qingdao	Zhengzhou	Lanzhou	Hohhot	Xi'an	Xining	Yinchuan
2010	0.871	0.867	0.951	0.885	0.993	0.000	0.993	0.965	0.941
2011	0.940	0.992	0.960	0.989	0.865	0.998	0.931	0.999	0.981
2012	0.998	0.995	0.999	0.968	1.000	0.997	1.000	0.990	0.952
2013	0.967	1.000	1.000	0.967	1.000	0.955	0.994	0.993	1.000
2014	0.969	0.998	0.987	0.975	0.999	0.987	0.994	1.000	0.999
2015	0.943	0.989	0.901	0.962	0.992	0.940	0.988	0.995	0.975
2016	0.981	0.999	0.990	0.998	1.000	0.999	0.994	0.999	0.999
2017	0.977	0.997	0.981	0.998	1.000	0.996	0.996	1.000	0.997

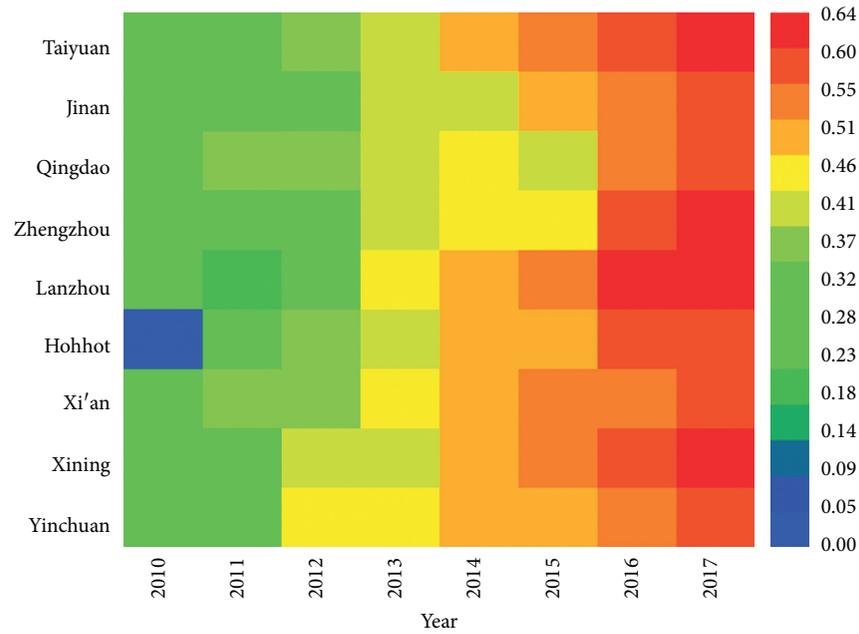


FIGURE 4: Coupling coordination of social economy and resources environment.

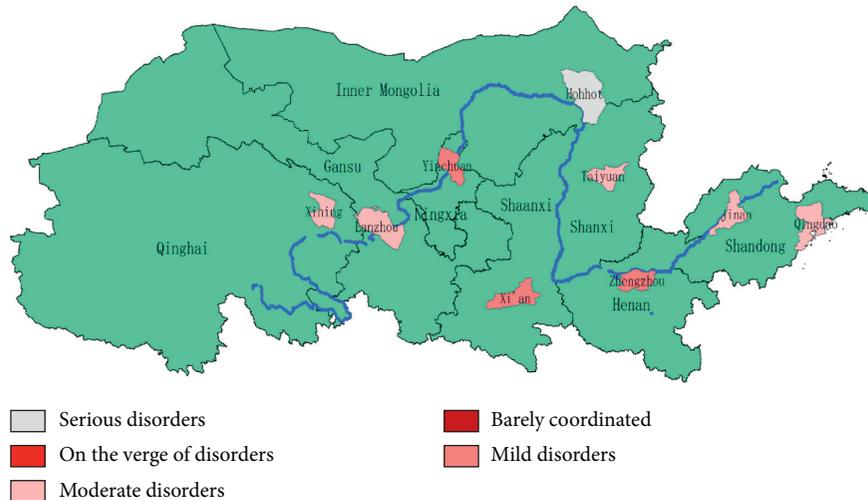


FIGURE 5: Coupling coordination level of central cities in the Yellow River Basin in 2010.

energy structure. The rise of resource and environment indexes in Jinan and Lanzhou increased significantly, and the type of urban development changed to economic and social lagging type. Xining had the highest coupling degree and coupling coordination degree and was in the primary coordination stage, and the city development type basically reached the synchronous type of economic society and resources and environment.

4.3. *Obstacle Factors Analysis.* According to equation (7), the barrier degree value of each central city indicator can be calculated, and finally the average value is obtained to arrive

at the combined barrier degree value of each factor from 2010 to 2017, as shown in Figure 9. From 2010 to 2017, the average obstacle degree of resource environment was 6.19%, slightly higher than the social economy obstacle degree of 5.61%, indicating that the resource environment was an essential obstacle factor that restricts the coupling coordination development of the central cities of the Yellow River Basin. All the cities should improve the local resource and environmental conditions while achieving substantial social economy development in the future. In terms of the annual average obstacle level, among the social economy indicators, the natural population growth rate, the share of tertiary industry in the GDP, and the per capita fixed asset

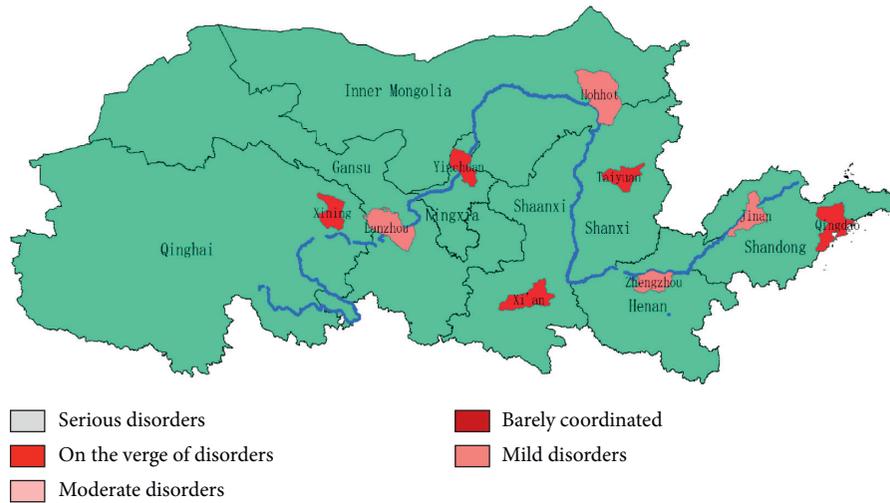


FIGURE 6: Coupling coordination level of central cities in the Yellow River Basin in 2012.

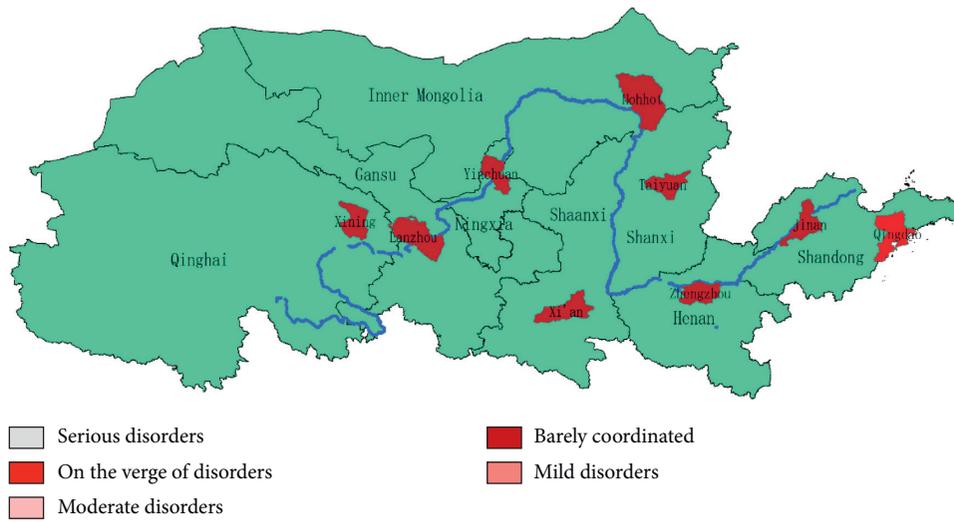


FIGURE 7: Coupling coordination level of central cities in the Yellow River Basin in 2015.

investment are the most crucial obstacle factors, with the multiyear average obstacle degree of 9.86%, 8.73%, and 5.65%, respectively. As to the resource and environment indicators, the per capita green park area, the per capita total water resources, and the per capita industrial SO₂ emissions are the most critical obstacle factors, with the average obstacle degree of with multiyear average barrier factors of 9.19%, 7.95%, and 8.28%, respectively.

In terms of obstacle factors, population natural growth rate, per capita green park area, the proportion of tertiary industry in GDP, per capita industrial SO₂ emissions, and per capita total water resources are the top five obstacle factors, with two factors in the social economy system and three factors in the resources and environment system. It was demonstrated that there is a need to maintain a balanced development while focusing on resources and environmental protection. From 2010 to 2017, the proportion of the tertiary industry in the GDP, per capita green park area, and per capita industrial SO₂

emissions are in the top five obstacle factors for accumulated six times. The indicator of total water resources per capita ranked the top five obstacle degrees five times in the past five years. The obstacle degree of this factor was greater than 10% in the past three years. The obstacle degree of total water resources per capita reached a peak of 16.10% in 2016, indicating that this indicator will be an essential obstacle factor for the coupling coordination development of the region in the future. The indicator of natural population growth rate ranked at the top of five obstacles' degrees in the past three years, with the obstacle degree being more significant than 10%. In 2016 and 2017, it even reached 19.78% and 33.82%. There is no doubt that the high natural population growth rate will become one of the primary factors that hinder the coupling coordination of economic–social and resource environment. From 2010 to 2016, three indicators: per capita local budget revenue, general industrial solid waste utilization rate, and centralized wastewater treatment rate did not appear in the top five obstacles, but

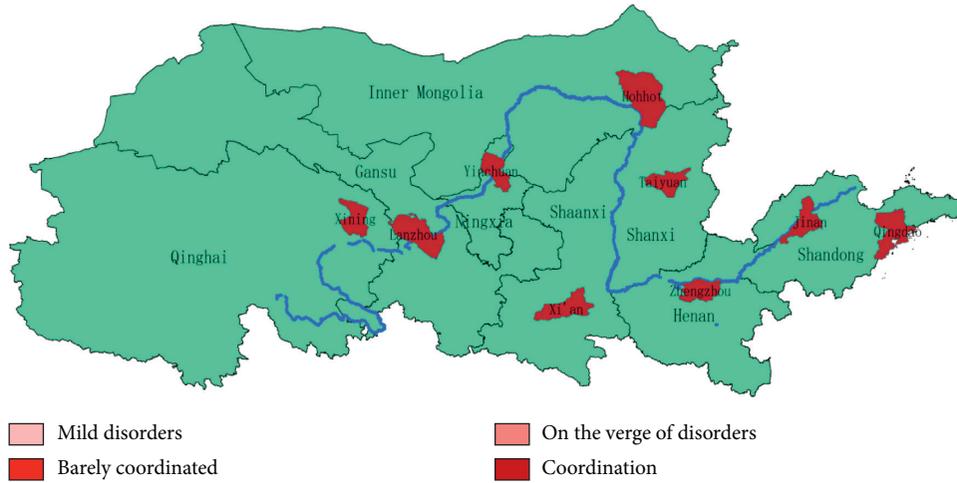


FIGURE 8: Coupling coordination level of central cities in the Yellow River Basin in 2017.

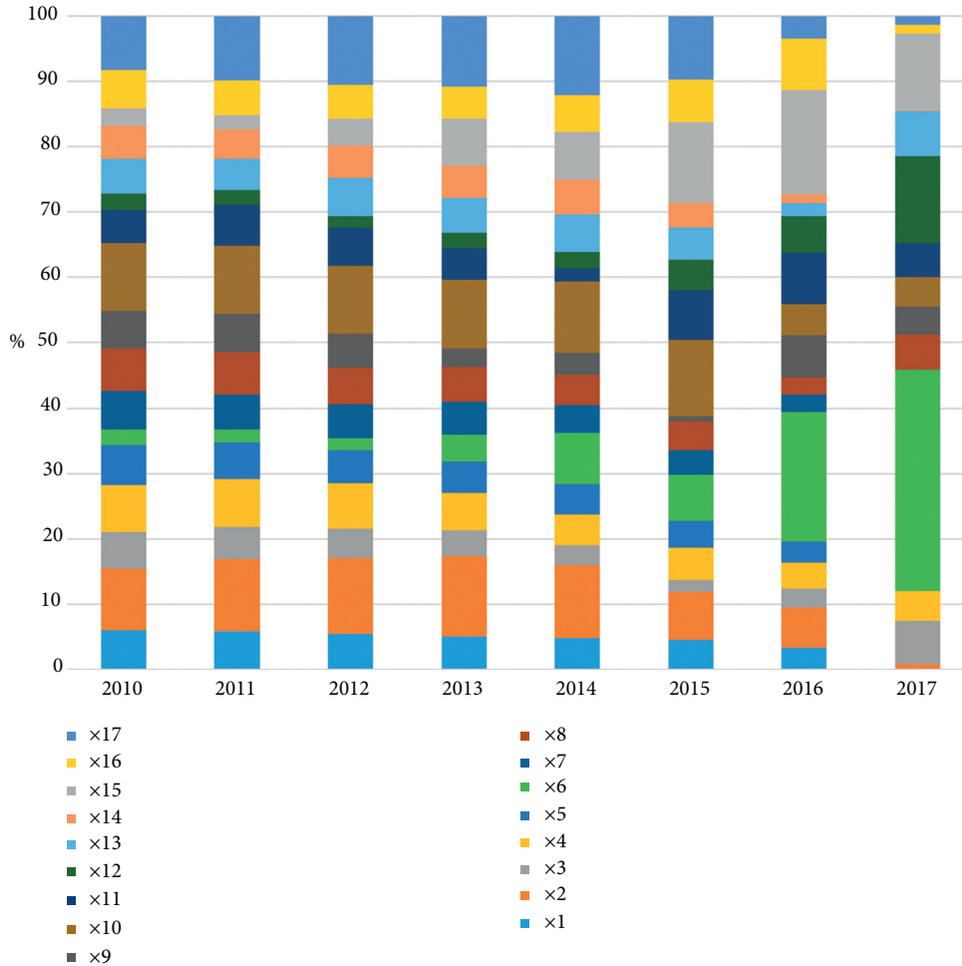


FIGURE 9: The degree of obstacle factors for coupling coordination development of central cities in the Yellow River Basin. X1–X17 presented factors in the index system in Table 1.

the three indicators were in the top five in 2017. The general industrial solid waste utilization rate of the obstacles even reached 13.35%, indicating that the three indicators are likely to become the main obstacle to coupling coordination development of central cities in the Yellow River Basin.

5. Discussion

The economic level of the nine central cities in the Yellow River Basin has developed rapidly because of the improvement of education level, health, and other public services infrastructure. Although Chinese economic strength has been improving and strengthening, there are still problems such as energy consumption and short industrial chains [3]. The Yellow River Basin is rich in energy and mineral resources. The cities in the middle and upper reaches of the river mainly focus on resource-based industries such as energy mining and processing. But the shortage of water resources in the Yellow River Basin and uneven spatial and temporal distribution limited the development of industries. The development of industrialization further increases the pressure on the environment [24]. Therefore, the promotion of new industrialization is of great significance to the sustainable development of cities. With the implementation of the 13th Five-Year Plan policies, the country has begun to focus on adjusting the economic structure, increasing environmental protection, and reducing pollutant emissions [25]. From the above results, since 2016, the economic development in the central cities of the Yellow River Basin has begun to slow down. The economic development model has begun to change. So, the environmental situation has improved significantly. In 2019, China proposed to strengthen ecological and environmental protection and promote high-quality urban development [26]. The importance of the development of the Yellow River Basin in China was emphasized once again. If only the coordinated development of the economy and resources and environment would be adequately handled, can we ensure the healthy development of the Yellow River Basin and improve people's living standards.

The coupling coordination degree of the central cities in the Yellow River Basin was on the rise as a whole, from the social economy lag to the resource and environment lag type. However, due to geographical location differences, the degree of coupling coordination also differs. In order to achieve high-quality urban development, it is necessary to fully consider the natural resources, culture, and other differences between the central cities of the Yellow River Basin and find a suitable development model. Cities in the middle and upper reaches of the Yellow River can improve the construction of new energy industries such as wind energy and solar energy, promote the extension of the nonferrous metal industry chain, speed up the technological transformation of the industry, and improve the market competitiveness of heavy industry. Cities in the lower reaches of the Yellow River can focus on developing electronic information, food, automotive, and other service industries to the high end of the value chain and expand biomedicine, real estate for the elderly, modern logistics, and other

emerging industries. Central cities can also develop cultural tourism and ecotourism according to local characteristics and improve the high-quality development of agricultural storage products.

The obstacle factors should be investigated to improve the coupling coordination development. As to the natural population growth rate, the population cannot be increased significantly due to the fragile resources and environment of the local cities. The proportion of tertiary industry to GDP reflects the level of development of the service industry in the city area. To improve the level of coordinated development of the city, we need to pay attention to the development of the service industry in the city and ensure the rationalization of the industrial layout. The per capita green space area reflects the per capita occupancy of green space in cities and towns, indicating that the central cities in the Yellow River Basin need to improve the environmental carrying capacity of each city. The urban can better carry the economic and social development and the pressure of population and resources. The per capita industrial SO₂ emissions reflect the amount of sulfur dioxide emitted into the air by enterprises in the process of fuel combustion and production process, indicating that the government needs to adjust industrial policy, reduce the number of enterprises with high energy consumption, vigorously promote the development of energy-saving enterprises, and promote the implementation of various environmental protection measures. The per capita water resource reflects the regional water resources level, indicating the need to vigorously promote water conservation in all industries and improve overall water use efficiency. Besides, more investment and construction of urban wastewater treatment plants are needed to increase the centralized wastewater treatment rate. A significant measure is to increase the amount of investment in the solid waste disposal and to improve the promotion, popularization, and implementation of waste utilization to increase the overall utilization rate of general industrial solid waste. The city administration should increase the attractiveness of the city, intensify the introduction of foreign capital, and improve the per capita local budget revenue by increasing taxes.

6. Conclusion

In recent years, the rapid economic and social development of China has led to a series of resource and environmental problems, such as air pollution, water shortage, etc. Coordinating the relationship between social economy development and resources environment has become a hot topic of concern. Therefore, it is of great significance to study the coupling coordination relationship between social economy development and resources environment in order to achieve sustainable development. This study firstly constructed the evaluation system of social economy and resource environment and adopted the coupling coordination degree model to study the changes of coupling coordination degree of social economy and resource environment in nine central cities in the Yellow River Basin from 2010 to 2017. Moreover, based on the changes of the coupling coordination degree of the central cities in the Yellow River Basin in 2010, 2012, 2015, and 2017, the spatial differences of the nine central cities were compared and

analyzed. The study showed that (1) the social economy development index of central cities in the Yellow River Basin maintained an upward trend from 2010 to 2017. The economic development was faster in 2010–2015 and slowed down after 2015, but still in an upward trend. (2) The resource and environment development index of the central cities of the Yellow River Basin showed a fluctuating upward trend. After 2015, the growth rate of the resource and environment index of most cities began to accelerate. (3) The overall coupling coordination of central cities in the Yellow River Basin is on an upward trend, with most cities rising from moderate dissonance to primary coordination stage. (4) In 2010, the coupling coordination of Xining and Lanzhou was generally lower than that of other central cities except for Hohhot. In the following years, the coupling coordination degree of Xining and Lanzhou increased significantly, indicating that the central cities in the upper Yellow River Basin have great potential for development.

This study makes three research contributions as follows:

(1) this study conducts an evaluation index system of social economy and resource and environment to investigate the coupling coordination of them. The social economy subsystem includes social, economic, educational, and medical, involving all aspects of human activities. The resource and environment subsystem index system reflects the development level of the resource and environment from the state of the resource and environment, pressure, and governance aspects. (2) In this study, the coupling coordination degree model was used to calculate the coupling degree and coupling coordination degree of social economy and resource environment for nine central cities in the Yellow River Basin from 2010 to 2017. The changes in the social economy and resource environment of the central cities of the Yellow River Basin were analyzed in spatial and temporal dimensions, respectively. (3) To explore the obstacle degree of the coupled coordination in central cities of the Yellow River Basin, this study introduced the obstacle degree model. The results obtained can provide a targeted reference for policy decision-making in the central cities of the Yellow River Basin, which is conducive to promoting the high-quality development of the relevant cities.

The present study still has research limitations. The first is that the urban social economy and resource environment are two very complex systems. Future studies will focus on the interactive coercive relationship between the two systems. Second, this study only collected several years of data, which is a short time series. In the future, more years of data can be collected and panel data analysis can be conducted to produce more reliable results.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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