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Analysis of Spatial Heterogeneity in Coupling Development of Industrialization and Resource Environmental Bearing Capacity

Ying Huang*, Zhi Zhou and Qin Qin*****

*College of Information Engineering, Wuhan University of Engineering Science, Wuhan, 430200, China
**College of Land and Resources, Agricultural University of Hebei, Baoding, 071001, China
***Department of Tourism, Sport and Society, Lincoln University, Christchurch, 7674, New Zealand
†Corresponding author: Zhi Zhou

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ABSTRACT

The contradiction between supply and demand of resource environment has become increasingly severe because of population expansion and the rapid development of industrial economy. Spatial quantitative evaluation of coupling strength and mutual promotion between industrialization and resource environmental bearing capacity based on panel data can facilitate industrialization and promote sustainable and healthy development of regional economy objectively, scientifically, and rationally. This study proposed a three-level comprehensive evaluation matrix for clustering and comparative analysis of 31 provinces in China to analyse the characteristics of spatial heterogeneity in the coordinated development of industrialization and resource environmental bearing capacity. First, a comprehensive evaluation index system for resource environmental bearing capacity was established based on the differences in resource environmental bearing capacities in various regions of China. Combined with the coordination degree for evaluation model, the coordination between the resource environmental bearing capacity and the industrialization of the 31 provinces in 2018 was evaluated and compared based on their comprehensive evaluation index. Finally, a cluster comparison analysis was performed in the 31 provinces using the three-level comprehensive evaluation matrix of coupling development of regional economy and resource environmental bearing capacity. Moreover, the accuracy of the coordination degree model was verified according to the clustering results. Results show that the regions with good ordination between industrialization and resource environmental bearing capacity include East and North China. Meanwhile, the provinces with poor coordination mainly include Southwest and Northwest China. Resource environment still restricts the coordination between resource environmental bearing capacity and industrialization development. This study provides reference for developing differentiated resource environment management measures and countermeasures in various regions in China.

INTRODUCTION

Industrialization, as an important approach for realizing social and economic development, has certainly brought severe challenges in the current resource environmental bearing capacity. This study aims to realize the coupling and harmonious development between industrialization and population, resources, and environment. Resources not only refer to scarce natural resources but also to rare assets with high significance in social development; scholars have become increasingly concerned with these matters. The contradiction between supply and demand of resource environment has become increasingly severe because of population expansion and the rapid development of industrial economy. The continuous social and economic development has brought challenges to resource environmental bearing capacity, and their relationship has become increasingly complex. The thorough summarization of the coordination relationship between industrial economy and resource environmental bearing capacity is difficult. New-type urbanization and industrialization have continuously developed, and its coordination and coupled development with regional resource environmental bearing capacity should be explored from an innovative perspective. Industrial economy and resource environment are two subsystems of the entire socioeconomic system. These subsystems interact, cooperate, collaborate, and form a virtuous development cycle, which is a strong driving force for the sustainable and healthy development of the regional economy. Therefore, the spatial quantitative evaluation of coupling strength and mutual promotion between industrialization and resource environmental bearing capacity based on panel data is of great significance to facilitate industrialization and promote the sustainable and healthy development of regional economy objectively, scientifically, and rationally.

Scholars have conducted numerous studies regarding the coordination between industrialization and resource environmental bearing capacity. However, some challenges have been encountered in selecting the appropriate coordination degree models for measuring coordination relationship. The accurate evaluation, measurement, and clustering of the coordinated coupling relationship between industrialization and resource environmental bearing capacity in China are urgent problems (Wang et al. 2015). To this end, the present study first evaluated the two subsystems of industrial economy and resource environment comprehensively. Second, the coordinated coupling relationship was analysed according to the comprehensive evaluation index, which is expected to measure the coordinated relationship accurately and comprehensively and provide a reference for evaluating the dissimilarities among different regions in China.

STATE OF THE ART

At present, researchers have conducted numerous studies on the relationship of industrialization and resource environmental bearing capacity. The study on the bearing capacity of individual resources has achieved abundant results. For example, Joardar et al. studied the bearing capacity of urban water resources from the perspective of water supply and integrated it into urban development planning, which was not coupled with economic development (Joardar et al. 1998). Rijsberman et al. also used bearing capacity as a standard for measuring the security of water resources in urban water resource evaluation and management system; however, they did not evaluate the whole resource environment system comprehensively (Rijsberman et al. 2000). Varis et al. focused on the development and utilization of water resources and analysed the pressures on water resource system caused by rapid industrialization, growth of food demand, and deterioration of ecological environment in the Yangtze River region in China. Moreover, the status of the socioeconomic development of the Yangtze River Basin was compared with its water environment bearing capacity according to the economic development process in different regions. Unfortunately, the coordination degree was not analysed (Varis et al. 2001). Scholars have investigated the relationship between economic development and geographical environment. For example, Selden et al. analysed the empirical data and proposed the "inverted U-shaped" curve relationship between economic development and environmental quality, that is, the environmental Kuznets curve. However, they did not perform the cluster analysis combined with the sample area (Selden et al. 1994). Hildebrand investigated the contradictions and conflicts between economic development and resource environment in coastal regions and analysed the vulnerability of the coastal zone and the impact of human activities based on the idea of man–earth relationship (Hildebrand 1992). Moreover, special attention was paid on the influence of the sustainable development of the coastal zone caused by global changes and their corresponding countermeasures. However, the coordination degree was not modelled or verified. The study of the quantitative relationship between industrial economy and resource environment mainly focused on the construction of indicator systems and model calculation. For example, Ayres et al. and Tapio investigated the decoupling relationship between economic development and resource consumption (Ayres et al. 2003). Both factors analysed the time series data and selected the sample area; however, they did not evaluate spatial heterogeneity (Tapio 2005). Dietz et al. and Bartelmus et al. used the System of Integrated Environmental and Economic Accounting (SEEA) to estimate resource consumption, environmental pollution, sustainable development capabilities, and currency (Dietz et al. 2007). They all used the idea of comprehensive evaluation; however, the coordinated development of the two systems of economy and environment was not analysed thoroughly (Bartelmus et al. 2007).

Qualitative study of the threat of industrialization to resource environment has achieved abundant results in China. However, few studies reported on the coordinated development of industrialization and resource environmental bearing capacity. Liao proposed the measures for industrial development in Dehong Autonomous Prefecture under the constraints of resource environment but failed to compare with other regions (Liao 2014). Guo et al. discussed the production efficiency of industrial land under environmental constraints considering the unexpected output of 33 typical cities in China; however, this study did not draw a cluster evaluation of development models in different regions (Guo et al. 2014). Zhu et al. analysed the main reasons and key issues that might cause current resource environment overload through industrialization and urbanization development and proposed to position economic and social development based on resource environment. However, their study lacked the support of quantitative data (Zhu et al. 2015). Liao et al. reviewed the importance, evaluation indicators, and standard of the four types of resource bearing capacity (e.g., land resources, water resources, energy resources, and biological resources) and two types of environmental bearing capacity (e.g., air environment and water environmental bearing capacity) that are closely related to regional sustainable development (Liao et al. 2016). Similarly, the indicator system and evaluation standard were not tested empirically in combination with the sample area data. Some Chinese scholars have explored the coupled development of industry, resources, and environment, but most of them used micro regions as samples. For example, Wang et al. studied and evaluated the coupled development of industry, resources, and environment of Dongping City from the perspective of ecological civilization, which was somewhat one-sided (Wang et al. 2015). Zhen constructed a regression equation and a responsiveness model based on a comprehensive measurement of the industrialization process and ecological environmental quality of Inner Mongolia Zhen. In addition, they conducted a timing analysis of the influence and response characteristics of ecological environment in the industrialization process of Inner Mongolia from 1990 to 2010; however, spatial difference characteristics were neglected (Zhen 2015).

Many qualitative results about the coordinated development of regional and industrial economy and resource environment have been obtained based on the aforementioned study results. The quantitative results are mainly based on the study of micro regions; meanwhile, few results were reported about the comparison of the coordination between resource bearing capacity and industrial development in different regions. Particularly, the analysis and comparison of the spatial heterogeneity of the interactive development of regional industrialization and resource environmental bearing capacity in different regions are still blank. The present study first constructed a comprehensive evaluation index system of regional resource environmental bearing capacity to analyse and evaluate the change characteristics of the spatial heterogeneity of the coordination between industrialization and resource environment in different regions in China. Second, principal component analysis was conducted to evaluate resource environmental bearing capacity comprehensively based on Chinese interprovincial panel data in 2018. Third, the comprehensive scores of resource environmental bearing capacity and industrialization development were used to calculate the regional coordination score based on the coordination degree model. Fourth, the comprehensive evaluation matrix of the three-level cluster was constructed, and the three-level cluster analysis of the sample area was conducted according to the comprehensive evaluation and the regional economic growth rate. Finally, the empirical suggestions for rational and orderly development of industrialization, regional economy, and resource environment were proposed according to the analysis results.

The remainder of this study is organized as follows. Section 3 proposes a coordination model by constructing a comprehensive evaluation index system of resource environmental bearing capacity. Section 4 calculates the resource environmental bearing capacity index of different regions in China and uses the coordination model to analyse the spatial differentiation characteristics of coupled development of resource environmental bearing capacity and industrialization. Finally, Section 5 summarizes the study and draws the conclusions.

METHODOLOGY

Comprehensive Evaluation Indicator System of Resource Environmental Bearing Capacity

Resourced environment is a dynamic ecosystem, and the indicator system for the comprehensive evaluation of the bearing capacity can be classified based on the theoretical composition of the resource environment. Meanwhile, this system also considers the role and evolution that resulted from socioeconomic interaction. "Pressure–State–Response (PSR)" is an evaluation model commonly used in the discipline of environmental quality assessment to achieve sustainable and healthy development between ecosystems and socioeconomics. In this study, the evaluation index system first divides the resource environmental bearing capacity according to the three aspects of pressure, state, and response, and then reflects the resource environment as the support of water, land, and environment for population and economy at each level. The comprehensive evaluation index system for resource environmental bearing capacity is shown in Table 1. The proposed index system is composed of relative and absolute indicators. The original values of the indicators include the performance values in 2018. The data were collected from the official website of the National Bureau of Statistics. The indicators were calculated on the basis of the absolute indicators in combination with the characteristics and representative meaning.

Coordination Model

Industrial economy and resource environmental bearing capacity are two subsystems in the socioeconomic system. The evaluation score of industrialization development speed is measured using the growth rate of the industrial added value in 2018 relative to that in 2017. The resource environmental bearing capacity is a complex system with multivariate measures. Moreover, this system is evaluated comprehensively using the principal component analysis method for the public factor extraction of the multi-index evaluation system, and the public factor score is calculated by SPSS software based on the sample data. The weighted comprehensive model is used to calculate the comprehensive evaluation scores of each sample area. Finally, the spatial differences and comparison

Table 1: Comprehensive evaluation index system of resource environmental bearing capacity.

Category	Dimension	Evaluation index	Index calculation	Unit	Correlation
Pressure	Economy	GDP per capita		yuan	+
	Population	Population density		Ten thousand people/ha	-
Status	Land resource	Grain yield per unit area		Kg/ha	+
	Water resource	Water resources per capita		M^3/person	+
		Water consumption per capita	Total water consumption/ population	M^3/person	-
		Urban water penetration rate		%	-
		Water consumption per 10,000 yuan of industrial output value	Industrial water consumption/industrial added value	T/10,000 yuan	-
	Environment	Wastewater discharge per 10,000 yuan of industrial output value	Wastewater discharge/ industrial added value	T/10,000 yuan	-
		COD emissions per 10,000 yuan GDP	COD emissions/GDP	T/10,000 yuan	-
		Sulfur dioxide emissions per 10,000 yuan GDP	Sulfur dioxide emissions/ GDP	T/10,000 yuan	-
		Nitrogen oxide emissions per 10,000 yuan GDP	Nitrogen oxide emissions/ GDP	T/10,000 yuan	-
		Soot emissions per 10,000 yuan GDP	Soot emissions/GDP	T/10,000 yuan	-
Response	Water resource	Daily sewage treatment capacity		10,000 cubic meters	+
		Cumulative people benefited from rural water improvement		person	+
		Effective irrigation area		Ha	+
	Land resource	Soil erosion control area		Ha	+
		Arable land per capita		Ha/person	+
		Investment in fixed assets per unit area		10,000 yuan/ha	+
	Environment	Daily harmless garbage disposal capacity		10,000 tons	+
		Harmless treatment rate of domestic garbage		%	+
		Completed investment in industrial pollution control		10,000 yuan	+
		Completed investment in ecological construction and protection		10,000 yuan	+

of resource environmental bearing capacity can be realized based on the evaluation scores.

After obtaining comprehensive measurement values for industrialization and resource environmental bearing capacity, the coordination degree is evaluated and calculated using the following model:

$$D_{R_i I_j} = \frac{R_i + I_j}{\sqrt{R_i^2 + I_j^2}},$$

where R_i and I_j represent the comprehensive evaluation indexes of the resource environmental bearing capacity and

Table 2: Meaning of coordination degree between industrialization and resource environmental bearing capacity in different regions.

I_j \ R_i	$R_i \geq 0$	$R_i < 0$
$I_j \geq 0$	$D_{RiIj} \geq 0$, highly coordinated, and both have high development levels	$D_{RiIj} \geq 0$, slight imbalance, and the former has lower development level $D_{RiIj} < 0$, severe imbalance, and the former has lower development level
$I_j < 0$	$D_{RiIj} \geq 0$, the overall coordination is good, and the former has higher development level $D_{RiIj} < 0$, basically coordinated, and the former has higher development level	$D_{RiIj} < 0$, highly uncoordinated, and both have low development levels

industrialization development, respectively; and D_{RiIj} is the coordination degree. According to the research achievements of scholars before (Wang et al. 2016), D_{RiIj} is positively related to the coordination degree between the two systems, and the value range is [–1.414, 1.414]. The relationship between the symbols of the calculation results and the two system indexes and their definitions are listed in Table 2:

Comprehensive Evaluation Matrix

Regional economy, as a dynamic economic subsystem, is not solely determined by industrial development after evaluating the coordination between the industrialization and the resource environmental bearing capacity of the 31 provinces in China. Meanwhile, to combine time and space measures effectively, regional differences are combined with dynamic measures to display the spatial and temporal differentiation characteristics of regions from multiple perspectives intuitively.

This study combines regional resource, environment bearing capacity, and regional economic development speed in constructing a comprehensive evaluation matrix for a systematic and reasonable clustering.

Regional economic development speed can be reflected by dynamic measurement indicators. For example, the growth rate of the regional GDP in 2018 relative to that in 2017. The comprehensive evaluation matrix of resource carrying capacity is listed in Table 3. The evaluation scores of the resource environmental bearing capacity of all regions and the growth rate of regional GDP in 2018 relative to that in 2017 are considered the dividing criteria. Accordingly, the resource environmental bearing capacity and the regional economic growth rate are divided into three evaluation levels. Through pairwise combination of levels, the 31 regions can be divided into 9 categories (Table 3).

RESULT ANALYSIS AND DISCUSSION

Comparative Analysis of The Coordination Degree Between Industrialization and Resource Environmental Bearing Capacity of 31 Provinces, Municipalities and Autonomous Regions in China

The evaluation results of the coordination degree between industrialization and resource environmental bearing capacity in different regions of China in 2018 were calculated according to the comprehensive evaluation index matrix of resource environmental bearing capacity and the coordination model (Table 4 and Fig. 1). The coordination scores show that Zhejiang has obvious advantages and ranks first, followed by

Table 3: Evaluation matrix on resource environmental bearing capacity.

Resource environmental bearing capacity \ Growth rate of regional economy	1st–10th	11th–20th	21st–31st
1st–10th	Strong resource bearing capacity-fast economic growth	Strong resource bearing capacity-general economic growth	Strong resource bearing capacity-poor economic growth
11th–20th	General resource bearing capacity-fast economic growth	General resource bearing capacity-general economic growth	General resource bearing capacity-poor economic growth
21st–31st	Weak resource bearing capacity-fast economic growth	Weak resource bearing capacity-general economic growth	Weak resource bearing capacity-poor economic growth

Henan, Guangdong, Jiangsu, Shandong, and Ningxia ranking second to sixth, respectively. These regions have coordination scores greater than 1 and belong to highly coordinated regions. Inner Mongolia, Xinjiang, Anhui, Hebei, Shanghai, and Heilongjiang ranked 7th to 12th, respectively, and their coordination scores are greater than 0, all of which belong to moderately coordinated regions. From Liaoning at the 13th place and Shanxi at the 14th place, the coordination scores begin to decline sharply and become negative; however, the industrialization and resource environmental bearing capacity are still coordinated. Jilin Province, which also belongs to the basically coordinated area, ranked 17th. Guangxi, Hubei, Hunan, Fujian, Chongqing, Guizhou, Jiangxi, and Tibet belong to severely uncoordinated regions, which rank from 15 to 23 (except 17), and the eight remaining regions belong to highly uncoordinated regions. Combined with the geographical distribution of regions with different coordination types in Fig. 1, the highly and moderately coordinated regions are mainly distributed in East China and North China. Some regions, such as Zhejiang, Guangdong, and Jiangsu, have relative advantages in resource environment and industrial development and have high coordination scores. In the later period, they can maintain such a development momentum and continue to achieve the coordinated development of resource environment and industrial economy; some regions have moderate industrial development that matches with their source environment bearing capacity, and the coordination scores are also high. These regions can accelerate the development of industrial economy moderately on the premise of ensuring a good resource environmental bearing capacity. The majority of the basically coordinated regions is distributed in Northeast China and has general resource environmental bearing capacity and industrial economic development level. However, the coordination and matching advantages are not evident. In the later period, the development pace of industrialization can be adjusted appropriately to achieve the optimal matching with the resource environmental bearing capacity. Severely coordinated regions are mainly in Central China, South China, and Southwest China. Some of these provinces and cities (regions) have rapid industrial development but general or weak source environment bearing capacity and poor coordination degree. Therefore, these regions should slow the pace of industrialization moderately and enhance the self-repair flexibility of resource environment to achieve coupled and coordinated development. The highly uncoordinated regions are mainly in Southwest and Northwest China, and they have weak resource environmental bearing capacity. However, the development of the industrial economy is extremely fast or does not match the local resource bearing

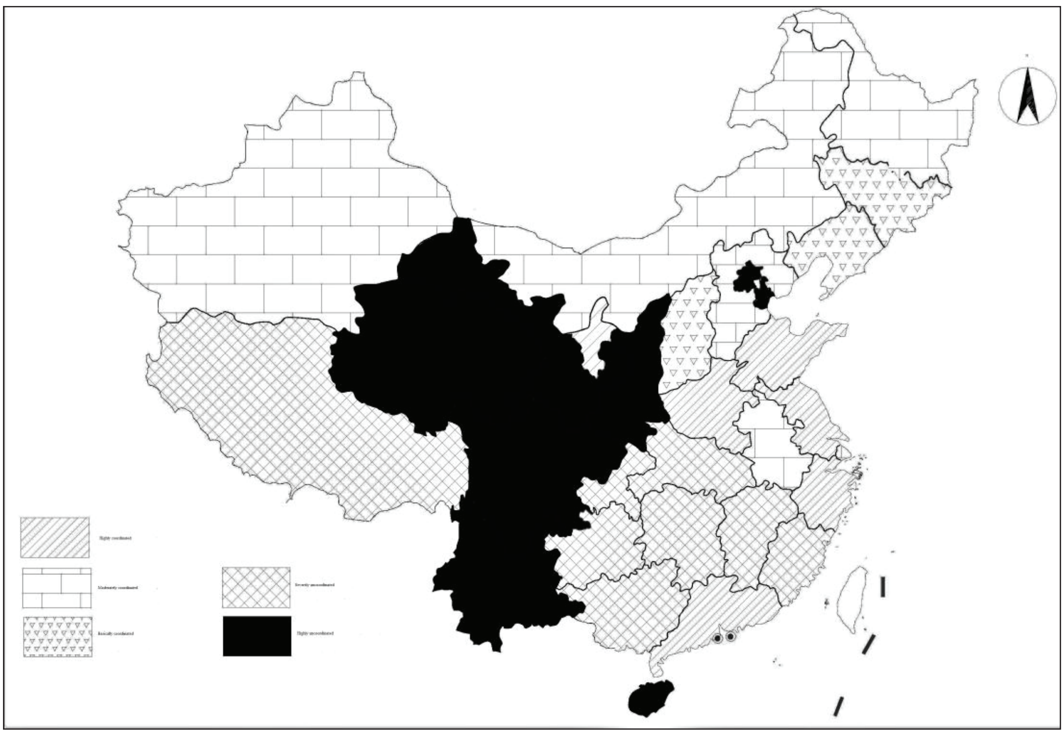

Fig. 1: Classification results based on the comprehensive evaluation matrix on coordination degree.

Table 4: Evaluation on coordination degree between industrialization and resource environmental bearing capacity in different regions in 2018.

Regions	Coordination degree	Rank	Type of coordination degree	Rank of resource and environmental bearing capacity	Rank of regional economic changes	Type of comprehensive evaluation
Zhejiang	1.413	1	Highly coordinated	14	11	General resource environmental bearing capacity-general economic growth
Henan	1.349	2	Highly coordinated	15	16	General resource environmental bearing capacity-general economic growth
Guangdong	1.326	3	Highly coordinated	8	8	Strong resource environmental bearing capacity-fast economic growth
Jiangsu	1.291	4	Highly coordinated	3	7	Strong resource environmental bearing capacity-fast economic growth
Shandong	1.189	5	Highly coordinated	5	15	Strong resource environmental bearing capacity-general economic growth
Ningxia	0.957	6	Highly coordinated	6	17	Strong resource environmental bearing capacity-general economic growth
Inner Mongolia	0.786	7	Moderately coordinated	4	27	Strong resource environmental bearing capacity-slow economic growth
Xinjiang	0.771	8	Moderately coordinated	1	26	Strong resource environmental bearing capacity-slow economic growth
Anhui	0.718	9	Moderately coordinated	11	19	General resource environmental bearing capacity-general economic growth
Hebei	0.595	10	Moderately coordinated	7	25	Strong resource environmental bearing capacity-slow economic growth
Shanghai	0.453	11	Moderately coordinated	9	12	Strong resource environmental bearing capacity-general economic growth
Heilongjiang	0.378	12	Moderately coordinated	2	28	Strong resource environmental bearing capacity-slow economic growth
Liaoning	0.172	13	Basically coordinated	12	29	General resource environmental bearing capacity-slow economic growth
Shanxi	0.149	14	Basically coordinated	10	30	Strong resource environmental bearing capacity-slow economic growth
Guangxi	−0.208	15	Severely uncoordinated	19	9	General resource environmental bearing capacity-fast economic growth
Hubei	−0.414	16	Severely uncoordinated	20	5	General resource environmental bearing capacity-fast economic growth
Jilin	−0.832	17	Basically coordinated	13	23	General resource environmental bearing capacity-slow economic growth
Hunan	−0.947	18	Severely uncoordinated	18	10	General resource environmental bearing capacity-fast economic growth
Fujian	−1.039	19	Severely uncoordinated	23	4	Weak resource environmental bearing capacity-fast economic growth
Chongqing	−1.260	20	Severely uncoordinated	29	3	Weak resource environmental bearing capacity-fast economic growth
Guizhou	−1.307	21	Severely uncoordinated	30	1	Weak resource environmental bearing capacity-fast economic growth
Jiangxi	−1.348	22	Severely uncoordinated	24	13	Weak resource environmental bearing capacity-general economic growth
Tibet	−1.358	23	Severely uncoordinated	31	2	Weak resource environmental bearing capacity-fast economic growth
Beijing	−1.390	24	Highly uncoordinated	27	6	Weak resource environmental bearing capacity-fast economic growth
Yunnan	−1.391	25	Highly uncoordinated	25	14	Weak resource environmental bearing capacity-general economic growth
Hainan	−1.395	26	Highly uncoordinated	28	18	Weak resource environmental bearing capacity-general economic growth
Gansu	−1.398	27	Highly uncoordinated	16	31	General resource environmental bearing capacity-slow economic growth
Tianjin	−1.403	28	Highly uncoordinated	17	21	General resource environmental bearing capacity-slow economic growth
Sichuan	−1.410	29	Highly uncoordinated	26	20	Weak resource environmental bearing capacity-general economic growth
Shaanxi	−1.410	30	Highly uncoordinated	22	24	Weak resource environmental bearing capacity-slow economic growth
Qinghai	−1.414	31	Highly uncoordinated	21	22	Weak resource environmental bearing capacity-slow economic growth

capacity. In the later stage, the investment in improving resource environment should be enhanced while formulating relevant policies.

Clustering Results and Cause Analysis of Spatial Heterogeneity of Coordination between Industrialization and Resource Environmental Bearing Capacity

The regional difference in the coordination between industrialization and resource environmental bearing capacity based on the coordination degree alone is not particularly significant. Therefore, the last column in Table 4 lists the comprehensive clustering results of 31 provinces (cities, districts) in China according to the comprehensive evaluation matrix in Section 2.3. Meanwhile, future improvement direction can be determined accurately by combining coordination and comprehensive evaluation types. Combined with the evaluation level of resource environmental bearing capacity in Table 4, first, the regions with high coordination degree have moderate and good resource environmental bearing capacity, which indicates the importance of resource environmental bearing capacity in coupled development. Guangdong and Jiangsu have perfectly realized the high coordination between resource environmental bearing capacity and regional economic development. As highly coordinated regions, both of regions have advantages in environment pollution control and other indicators and belong to the type of "strong resource environmental bearing capacity-fast economic growth." Other highly coordinated regions, such as Zhejiang and Henan, have general resource environmental bearing capacity, which is benefited from the balanced indicators. However, their advantages in water and land resources and environmental governance are not evident. Therefore, the resource bearing capacity has not exhibited the best performance, but it is relatively matched with the local regional economic development. The GDP growth of Shandong and Ningxia have been slowed down relatively but still matches the resource environmental bearing capacity. Second, many moderately coordinated regions, such as Inner Mongolia, Heilongjiang, and Xinjiang, have strong resource environmental bearing capacity. However, these regions fail to realize the coordinated development of resource environment and regional economy. Third, uncoordinated and even severely uncoordinated regions have weak resource environmental bearing capacity, but most regions still have rapid regional economic growth, which indicates that the regional economic development based on resource consumption and environment pollution is common.

Table 5: Factor loading of indexes regarding resource environmental bearing capacity.

Extraction dimensions	Index	Factor loading	eigenvalues	proportion
Water use	Water resources per capita	0.875	4.196	18.243
	Water consumption per 10,000 yuan of industrial output value	–0.851		
	Daily sewage treatment capacity	0.814		
	Wastewater discharge per 10,000 yuan of industrial output value	–0.753		
	Urban water penetration rate	–0.724		
	Water consumption per capita	–0.781		
Industrial pollutant emissions	nitrogen oxide emissions per 10,000 yuan GDP	–0.761		
	Sulphur dioxide emissions per 10,000 yuan GDP	–0.732		
	Soot emission per 10,000 yuan GDP	–0.661		
Pollution control and improvement of resource environment	Cumulative people benefited from rural water improvement	0.822	3.763	16.360
	Harmless treatment rate of domestic garbage	0.817		
	Harmless daily garbage disposal capacity	0.774		
	Effective irrigation area	0.726		
	Completed investment in industrial pollution control	0.680		
Land bearing	Grain production per unit area	0.927	3.434	14.930
	Arable land per capita	0.848		
	GDP per capita	–0.628		
	Investment in fixed assets per unit area	0.798	2.516	10.937
	Population density	0.784		

These regions should vigorously use green development measures to improve the current state effectively and slow down the economic growth as necessary. Meanwhile, some uncoordinated regions have no resource advantage and slow economic growth. Therefore, they should accelerate the speed of economic development while improving the resource environment in the future.

CONCLUSION

To obtain the current spatial differentiation characteristics of the resource environmental bearing capacity of 31 provinces (municipalities and autonomous regions) in China, this study established a comprehensive evaluation index system for resource bearing capacity from the three levels of PSR of resource environment theoretical system and its population and socioeconomic support and guarantee. A comprehensive evaluation matrix was constructed on the basis of the dynamic evaluation indexes of regional economic development changes, and the 31 provinces in China were divided into 9 categories according to the coordination degree clustering. Finally, the following conclusions were drawn:

1. The evaluation results of the coordination degree between industrialization and resource environmental bearing capacity in the 31 sample regions in 2018 from high to low is ranked as follows: Zhejiang, Henan, Guangdong, Jiangsu, Shandong, Ningxia, Inner Mongolia, Xinjiang, Anhui, Hebei, Shanghai, Heilongjiang, Liaoning, Shanxi, Guangxi, Hubei, Jilin, Hunan, Fujian, Chongqing, Guizhou, Jiangxi, Tibet, Beijing, Yunnan, Hainan, Gansu, Tianjin, Sichuan, Shaanxi, and Qinghai. The majority of the provinces with good coordination between industrialization and resource environmental bearing capacity are in East and North China. Meanwhile, the provinces with poor coordination are mostly in Southwest and Northwest China. Resources and environment are still the main factors that restrict coordination.
2. According to the classification results based on the three-level clustering comprehensive evaluation matrix: Guangdong and Jiangsu belong to the regions with “strong resource environmental bearing capacity-fast economic growth;” Zhejiang, Henan, and Anhui have “general resource environmental bearing capacity-general economic growth;” Shaanxi and Qinghai belong to the regions with “weak resource environmental bearing capacity-slow economic growth.”
3. According to the panel data analysis of 31 provinces and autonomous regions in 2018, the main factors that influence the resource environmental bearing capacity include per capita water resources, water consumption per 10,000 Yuan of industrial output value, daily treatment capacity of urban sewage, wastewater discharge per 10,000 yuan of industrial output value, urban water penetration rate, per capita water consumption, nitrogen oxide emissions per 10,000 Yuan GDP, sulphur dioxide emissions per 10,000 Yuan GDP, soot emissions per 10,000 yuan GDP, cumulative beneficiaries of rural water conversion, harmless treatment rate of domestic waste, average daily harmless garbage disposal capacity, effective irrigated area, completed investment in industrial pollution control, grain yield per unit area, cultivated land per capita, GDP per capita, fixed asset investment per unit area, and population density.

A three-level clustering comprehensive evaluation matrix was established by combining the indicator system construction and model measurement. The evaluation matrix cannot only refine the internal differences in the types of coordination evaluation but also thoroughly present the improvement direction of resource bearing capacity, industrial development, and even regional economic growth combined with the main factor load. In addition, effective empirical suggestions are made to alleviate the contradiction between resource bearing capacity and regional economic development in China, and effective reference in policy formulation is provided to the Chinese government. However, the comprehensive evaluation index system of resource environmental bearing capacity should be continuously updated according to the development trend of resources and environment to measure the coupling relationship accurately and thoroughly because of the limited availability of the latest environmental indicator data.

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REFERENCES

Ayres, R.U., Ayres, L.W. and Warr, B. 2003. Energy, power and work in the US economy, 1900-1998. Energy, 28(3): 219-273.

Bartelmus, P. 2007. SEEA-2003: Accounting for sustainable development? Ecological Economics, 61(4): 613-616.

Dietz, S. and Neumayer, E. 2007. Weak and strong sustainability in the SEEA: Concepts and measurement. Ecological Economics, 61(4): 617-626.

Guo, G.C. and Wen, Q.Y. 2014. Industrial land productivity research under the environmental restriction based on unexpected outputs of 33 typical cities in China. China Population Resources and Environment, 24(6): 121-127.

Hildebrand, L.P. and Norrena, E.J. 1992. Approaches and progress toward effective integrated coastal zone management. Marine Pollution Bulletin, 25(1-4): 94-97.
Joardar, S.D. 1998. Carrying capacities and standards as bases towards urban infrastructure planning in India: A case of urban water supply and sanitation. Habitat International, 22(3): 327-337.
Liao, H.X., Ji, Y.L. and Peng, S.L. 2016. Resource and environmental carrying capacity and sustainable development. Ecology and Environmental Science, 25(7): 1253-1258.
Liao, Y.C. 2014. The Dilemma of industry in Dehongzhou under the restriction of resources and environment. Journal of the Party School of CPC Yunnan Provincial Committee, 15(2): 105-107.
Rijsberman, M.A., Van de Ven, F.H.M. 2000. Different approaches to assessment of design and management of sustainable urban water systems. Environmental Impact Assessment Review, 20(3): 333-345.
Selden, T.M. and Song, D. 1994. Environmental quality and development: Is there a Kuznets Curve for air pollution emissions? Journal of Environmental Economics and Management, 27(2): 147-162.
Tapio, P. 2005. Towards a theory of decoupling: Degrees of decoupling in the EU and the ease of road traffic in Finland between 1970 and 2001. Transport Policy, 12(2): 137-151.
Varis, O. and Vakkilainen, P. 2001. China's 8 challenges to water resources management in the first quarter of the 21st Century. Geomorphology, 41(2-3): 93-104.
Wang, R. and Yuan, Y.R. 2016. Research on the coordinated evolution law of industrialization and resource environment in China's mining economic zone. Ecological Economy, 302(2): 69-73.
Wang, X.Y., Wang, C.X. and Zhao, M.H. 2015. Research on the coupling development of regional industry, resources and environment from the perspective of ecological civilization-taking Dongying city as an example. Coal Economic Research, 35(4): 60-63.
Wang, Z. and Su, X. 2015. Dynamically hierarchical resource-allocation algorithm in cloud computing environment. The Journal of Supercomputing, 71(7): 2748-2766.
Zhen, J., Li, L., He, S. and Luo, S. 2015. Ecological environment impact and its response to the process of industrialization in Inner Mongolia. Journal of Arid Land Resources and Environment, 29(11): 86-92.
Zhu, T., Wang, T.T. and Gao, S. 2015. Orientate the development of economic society based on the environmental carrying capacity by following ecological civilization concept. environmental protection, 43(16): 12-14.