Coupling Coordination of Coordinated Development Level Between Resource and Environment

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Abstract. Environmental problems are drawing more and more attention from all sectors. Considering China's current development background, it is very important to research the coordinated development level of resources and environment. This paper constructs the coupling index system of resource and environment. Then, we analyze the spatio-temporal situation and its influencing factors of the coordinated development in 26 provincial capitals and 4 municipalities in 2005, 2010 and 2015. It is concluded that the spatial distribution of the coupling coordination degree in China is unbalanced. The coupling coordination degree shows the characteristics of decreasing first and then improving. In general, this paper provides theoretical guidance and method support for quantitative analysis of the horizontal coupling coordination degree between resource and environmental development.

1. Introduction
Urbanization is a crucial symbol to estimate the development degree of a country. While promoting the rapid development of China's economy, it reduces resources and worsens the environment. From 2013 to 2017, extreme weather phenomena, such as haze, appeared in the whole range in north China, which greatly affected people's travel and even caused great harm to human health. Coordinate the relationship among urbanization, resources and environment is conducive to realizing the development goal of attaching equal importance to China's economic, social and ecological civilization.

The relationship between urbanization and ecological environment has long been a hot topic for scholars. Rodewald A D proposed the theory of comodulation [1]. He emphasizes the mutual adaptability and feedback mechanism between economic and ecological environment. Isaac B emphasized the importance of understanding the relationship between them [2]. Later, researches on the relationship between urbanization and resources and environment mainly focus on the evolutionary trend.

Few qualitative examinations have been done on the coupling coordination of resources and environment. In addition, less from the perspective of space to explore its influencing factors. This paper firstly constructs the coupling coordination degree model of resources and environment. We utilize a sample of 26 provincial capitals and 4 municipalities. ESDA-GIS is used to analyze the spatiotemporal pattern evolution of the coupling coordinated development of the them. Then, combing with the spatial econometric model to explore the influencing factors.
2. Research design

2.1. Data source and indicator system
We utilize a sample of 26 provincial capitals and 4 municipalities. Based on the existing research results (zhang Rongtian et al)[3], and combined with the characteristics of the research area, the coordination evaluation index system was shown in table 1. We selected three time cross-section data of 2005, 2010 and 2015. Evaluation index data are from China urban statistics yearbook (2005-2015) and National Bureau of Statistics[4].

| Decision-making layer | Restraint layer | Index level |
|-----------------------|----------------|-------------|
| Resource level B1     | C1 Water supply per capita (t) | |
| Resources A1          | C2 Per capita consumption of liquefied petroleum gas (kg) | |
|                       | C3 Per capita arable land area (hm² / 10,000 people) | |
|                       | C4 Per capita annual water consumption (L / person) | |
| Resource pressure B2  | C5 Energy consumption per capita (t/person) | |
|                       | C6 per capita woodland area (hm² / person) | |
| Resource protection B3| C7 Raw coal consumption of secondary industry (10,000t) | |
| Environmental level B4| C8 Urban domestic coal energy consumption (10,000t) | |
| Environmental pressure B5 | C9 Green coverage rate of built-up area (%) | |
| Environment A2        | C10 Per capita industrial wastewater discharge (t/ person) | |
|                       | C11 Industrial solid waste production per capita (t/ person) | |
|                       | C12 Industrial wastewater discharge per unit area (10,000t/km²) | |
|                       | C13 per capita industrial soot production (t/ person) | |
|                       | C14 Production of industrial solid waste per unit area (10,000t/km²) | |
|                       | C15 Wastewater discharge compliance rate (%) | |
|                       | C16 Comprehensive utilization rate of solid waste (%) | |
|                       | C17 Output value of per capita comprehensive utilization of three wastes (yuan/person) | |
|                       | C18 urban per capita investment in wastewater treatment (yuan/person) | |
|                       | C19 urban per capita waste gas treatment investment (yuan person) | |

2.2. Coupling coordination degree model
In this paper, the coupling degree model mainly discusses the degree of resource and environment interaction. The higher of the coupling degree, the more orderly the development direction of each subsystem element is, and vice versa. The calculation is as follows:

$$C_z = \sqrt{\frac{gz \times h_z}{(gz + h_z)}}$$ (1)
Gz and hz respectively represent the comprehensive level of resources, environment and other systems. Cz is the coupling degree of two systems in the study region z. Cz is evaluated at [0,1]. Cz=0 stands for that the system elements are in disorder. Cz=1 represents the most orderly development among the system elements.

In order to avoid the situation that the evaluation scores of the subsystems are all low, but the coupling degree is high, we introduce the coupling coordination degree mode. The specific calculation formula is as follows:

\[ T_z = \beta g_z + \gamma h_z \]  \hspace{1cm} (2)

\[ D_z = \sqrt[3]{C_z} \times \sqrt{T_z} \]  \hspace{1cm} (3)

Dz is the coupling coordination degree. Tz is the comprehensive coordination index. This paper measures the coupling model of resource and environment composed of two subsystems, so β = γ = 1/2. Generally speaking, the greater of Dz, the better the coupling coordination degree between subsystems. According to the classification standard of research results of Wang Chunping, the coupling coordination degree is divided into the following three levels in this paper. [0-0.4]: disequilibrium recession interval; [0.4-0.6]: low-degree coordination interval; [0.6-1]: coordinated development range.

2.3. Spatial autocorrelation analysis
Spatial autocorrelation analysis incorporates global spatial autocorrelation and local spatial autocorrelation.

2.4. Spatial econometric model
Since this paper is cross-sectional data, we select the spatial error model and the spatial lag model. The spatial error model is mainly used to inspect the spatial autocorrelation between the error terms. Spatial hysteresis model describes the hysteresis effect of things in the process of spatial diffusion.

3. Results

3.1. Spatial and temporal distribution
Through coupling coordination degree model, the results of coupling coordination degree of resources and environment in 26 provincial capitals and 4 municipalities in 2005, 2010 and 2015 were calculated.

In 2005, the spatial distribution of the coupling coordination degree of resources and environmental development was lopsided. The development of Beijing, Shanghai, Tianjin and Hohhot is comparatively harmonized. This is principally because the three municipalities are the centers of China's economic development. The economic development of Hohhot in Inner Mongolia autonomous region is at a low level, which gives full play to the advantages of clean energy resources, so the two develop harmoniously. The dissonance recession area prevailingly distributes in the Yellow River south, the Yangtze river north central provincial capital city. The primary cause why the coupling coordination degree of these cities is in disequilibrium recession is that the economic development process consumes a lot of resources and the comprehensive score of resources and environment is low.

In 2010, the spatial distribution of coupling coordination degree changed. The overall coupling and coordination degree decreased, and the maladjusted recession area increased, which was concentrated in the south of the Yellow River. This is chiefly due to the establishment of coal mining and coal processing bases in these areas. They ignore the efficiency of resource utilization and blindly destroy the environment, resulting in a low level of coupling and coordination among the three. Hohhot, Beijing and Shanghai are still in the zone of coordinated development. But the coordination level has declined. Urbanization puts more pressure on resources and environment.

In 2015, the coupling coordination degree was significantly improved compared with the previous years. The number of maladjusted coupling area decreased and the number of comodulated development
area aggrandized. The prime reason of this situation is that government attaches great importance to ecological environment problems. But Changchun, Shenyang, Taiyuan, Wuhan, and Guiyang are still in the area of imbalance and recession. These cities still have an economic structure dominated by heavy industry.

Generally speaking, the coupling coordination degree between resource and environment of provincial cities and municipalities in China from 2005 to 2015 showed a first decline and then improvement.

3.2. Global spatial autocorrelation analysis
We used GeoDa software to measure the global value of Moran’s I for the coupling coordination degree of 26 provincial capitals and 4 municipalities in 3 periods. Subsequently, significance tests were performed.

| Year | Moran’s I value | Z value  | P value |
|------|----------------|----------|---------|
| 2005 | -0.0838        | -19.1446 | 0.001   |
| 2010 | -0.0829        | -26.1673 | 0.001   |
| 2015 | -0.0761        | -16.7063 | 0.001   |

In 2005, 2010 and 2015, the Moran’s I value of coordination degree was negative, and passed the significance test of 0.05. In these three periods, the agglomeration trend of coupling coordination degree is not strong and the correlation is comparatively weak. On the whole, there is a tendency of high - high, high - low and low - low concentration.

3.3. Local spatial autocorrelation analysis
We select Moran scatter plot and local Moran’s I index to further analyze regional spatial heterogeneity. On the basis of z-value test (P<0.05), we drew LISA agglomeration graphs of coupling coordination degree in 2005, 2010 and 2015. After drawing with GeoDa software, the results are displayed in the overall region of the province.

From the perspective of spatial distribution, the coupling coordination degree between the pearl river delta urban agglomeration and Yunnan-Guizhou plateau region is a high-type coordination agglomeration in these three years. Pearl river delta urban agglomeration is the most economically dynamic and innovative region in China. In the development of urbanization, attention is paid to the use of resources and environmental protection, so the three coordination degree is high. The economic development of Yunnan-Guizhou plateau concentrates on tourism and service industry. They are bent on ecological environment protection and consume less resources. The high-low coupling coordination cluster is nearly located in the south of Yangtze river. This is closely related to the development route of China's one-sided pursuit of economic growth and neglect of ecological construction in the past period of time. The low-low coordination cluster is mainly concentrated in central China and northeast China. The industrial structure of these regions is dominated by the secondary industry, with low utilization rate of resources and serious environmental destruction.

From the perspective of time distribution, the concentration intensity of high-high coupling coordination degree in China presents an increasing trend. The low-low agglomeration area in the central region is getting smaller and smaller. However, the low-low agglomeration area in northeast China expanded. Restricted by natural conditions, the northeastern marginal areas failed to seize opportunities in the process of deepening reform. The development of northeast area is relative lag, and industrial structure adjustment is slow. Finally, the clusters of high-low remain basically unchanged. The above analysis shows that China is constantly improving its economic growth mode in the process of urbanization and achieve certain results.
3.4. Coupling coordination degree driving mechanism analysis

The Moran’s I index obtained above indicates that there is a certain spatial heterogeneity of the coupling coordination degree between resource and environmental development level in various provinces and cities in China. We employ the spatial econometric model to analyze the causes for the heterogeneity in coupling coordination degree.

We choose Geoda software for quantitative analysis. The simulation parameters of SEM model and SLM model were compared and selected. The simulation parameters are as shown in table 3.

Table 3. Simulating Test Parameters.

| Model  | R2    | LogL   | AIC    | SC     |
|--------|-------|--------|--------|--------|
| SEL    | 0.8280| 35.1122| -56.2245| -45.5399|
| SLM    | 0.8216| 35.4791| -54.9583| -42.7474|

The model with the largest index above has the best effect. We finally select SLM model.

Table 4. SLM Model Results.

| Variables                                      | Regression coefficient | Z value | P value |
|------------------------------------------------|------------------------|---------|---------|
| C                                              | 0.0669772              | 1.49198 | 0.13570 |
| Investment in environmental protection as a share of GDP(x1) | 0.00929668              | -0.323496 | 0.70476 |
| GDP per capita(x2)                              | 4.92074e-007           | 0.266094 | 0.09017 |
| Industrial output ratio(x3)                     | 0.00847322             | 6.63127  | 0.00000 |
| Per capita fixed assets investment(x4)          | 1.00088e-005           | 2.02851  | 0.00463 |
| Energy production(x5)                           | 7.62871e-007           | 0.372586 | 0.00406 |
| Number of college students per 10,000 people(x6)| 0.000436422             | 2.00447  | 0.24153 |

In accordance with table 3, x3, x4 and x5 are all significant at the level of 5%. X2 is significant at the level of 10%. X1 and x6 fail the test.

4. Conclusion

In this paper, we calculate the coupling coordination degree of 26 provincial cities and 4 municipalities directly under the central government in China in 2005, 2010 and 2015 by building a coupling coordination degree model. We also apply GeoDa to conduct spatial autocorrelation analysis and select the spatial econometric model to analyze the driving force mechanism.

The spatial distribution of the coupling coordination degree between the development level of resources and environment in China is unbalanced. From 2005 to 2015, the degree of coupling and coordination in provincial capitals of China showed a V-shape. The global Moran’s I index indicates the spatial agglomeration of the coordination degree. The results of the spatial econometric model show which factors promote coordinated development.

How to find a balance among the healthy development of urbanization, the maximization of resource utilization and the optimization of environmental protection is momentous. It is requisite to further research the mechanism of coupling relationship.

Acknowledgments

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