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# Economic development and eco-environment coordination degree evaluation and optimization of coal cities in China

*Based on panel data of economic development and eco-environment system from 2003 to 2013 of 30 China coal cities, with reference to the physics field coupling coordination degree model, the diachronic and synchronic evolution pattern of the coupling coordination degree is analyzed with GIS. Research indicates: (1) Coal city's economic development is relatively stable, eco-environment index showed a downward trend, and stage development level standard deviation of economic development is slighter higher than that of eco-environment. (2) Coordination degree and economic competitiveness of coal cities have obvious relevance. High coordination degree cities Tangshan and Ordos belong to eco-environment lag type city, Xuzhou is economic development lag type city, Zibo belongs to economic development and eco-environment synchronous type city. The principal of moderate coordination degree cities belong to economic development lag type while benefit loss type of economic development is the main coordination form of low coordination degree cities. (3) The coupling coordination level has obvious regional imbalance. Among them, East China region plate has higher coupled coordination level. North and Central China region plate is the second. Coupling coordination level of Northeast and Southwest region plate is low. Northwest region plate is the one having lowest coupling coordination level.*

**Keywords:** *Coal city, coordination degree, economic development, eco-environment, system coupling model.*

## 1. Introduction

As we all know, the economic development of the society cannot be separated from the coal mine resources and the stock of coal resources in China is rich. But because of constrains in technology and management system, resource advantage has not been fully utilized. Meanwhile, because of the mining property market is not standardized, results in the phenomenon of insufficient exploitation and disorderly competition which is a serious waste of resources. Coupled with the ecological damage caused by the development of mining industry, there are many inharmonious factors in resource allocation, economic sustainability and environmental protection during the development of coal mining cities in recent years. The central government's new draft plan (13th Five Year Plan) clearly pointed out that " to improve the quality of the environment as the core, to solve the outstanding problems in the field of eco-environment as the focus, strengthen the protection of eco-environment, improve the efficiency of resource use, adhere to the coordinated development and green development". This is the main line of the coordinated development of urban economy, resources and environment in the future. The ideal process should be a dynamic equilibrium factor exchange relation of the city, the resources and the eco-environment, which is prominent in the process of the development of the coal city. So in this situation, the degree of coordinated development of coal resource type cities in China needs to be evaluated scientifically. Therefore, the economic development of China's coal resource type cities, coordination of eco-environment and sustainable development needs to be investigated and the relevant countermeasures and suggestions are of great practical significance.

Recent years, local and foreign research of urban economic development and coordination degree of eco-environment mainly adopt coordination degree model, including static coordination model and dynamic evolution coordination model. The static coordination model mainly includes coupling coordination degree model, membership function coordination degree model, distance coordination degree model, data envelopment analysis coordination model and so on. The dynamic evolution coordination degree model includes elastic coefficient method, system evolution method and so on. Norgaard (1990) puts forward the theory of coordinated development, regarding the economic

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development process as a process of constantly adapt to the environment changes and it achieving coordinated development through the feedback loop in the social and eco-environment systems [1]. Du (2006) evaluates urban environment and economic coordination degree of Hebei province with coordination degree model. The results show that Hebei coordinated development degree of urban environment and economy is not high [2]. Qi and Tong (2008) by using the fuzzy membership degree function quantitatively analyze the coordinated development of population, economy and environment resources of five provinces in Northwest China. Results show that Shaanxi province belongs to intermediate coordination, Ningxia, Gansu and Qinghai belong to mild imbalance state, and Xinjiang is the primary coordination type [3]. Zhang (2013), by a system theory angle, builds the evaluation model of the coordinated development of Xining's eco-environment and social economy system, and make a quantitative evaluation of the coordinated development of Xining's eco-environment and economy from 2000 to 2010. In general, a relatively stable upward trend is found from the coordinated development of the city's eco-environment system and social economy system [4]. To study the interactive relationship between economic growth and environmental indicators, the mainstream methods are Ecological Footprint Model, EKC Model, Input-Output Model, CGE Model, Structural Equation Model, System Dynamics Model, Causality Test Econometric Method etc... For example, Grossman (1995) by means of ecological footprint model and energy value analysis method discovers a process from mutual competition and mutual exclusion to mutual adaptation and mutual complement between economic development and resources environment changes. Eco-environment and economic development present an inverted U-shaped relationship; this is the famous Environmental Kuznets Curve (EKC) [5]. Yang and Ye (2003) verify the existence of Environmental Kuznets Curve by using Shanghai's economic development and environment data [6]. Wang, Chen and Zou (2005) apply a Recursive Dynamic CGE Model to comprehensively describe the economy, energy and environment system of China. The results show that when the reduction rate is between 0 % and 40 %, the GDP loss rate will be between the 0 % and 3.9 %, and the marginal social cost of emission reduction is about 2 times of the marginal cost of technology. Implementation of CO2 emission reduction policies in China will contribute to the improvement of energy efficiency, but also will bring a negative impact on China's economic growth and employment [7]. Gong and Shi (2014) study the coupling relationship between Inner Mongolia mineral resource exploitation and ecological environment by adopting system dynamics model, and find that the coupling relationship between mineral resource exploitation and eco-environment is influence factor coupling relationship [8]. In the existing research, the study object often focus on China's economically developed cities, relatively little literature targets coal resource cities which in the economic structure with strong dependence on energy resources and increasingly serious environmental degradation. Moreover, subjective or objective individual weight method is existing chief approaches, thus lack of subjective and objective combined comprehensive weight determination model. It is difficult to guarantee the accuracy and scientificalness of computing the coupling coordination level of the follow-up economic development and eco-environment. In order to overcome the above shortcomings. In this paper, the coupling theory of physics is adopted and by using Attribute Hierarchical Model (AHM) and Entropy Weighting Method (EWM), economic development and eco-environment coupling coordination system evaluation index weight is determined from the subjective and objective aspects, and a coupling evaluation model between them is constructed as well. Then panel data of China's 30 coal resources cities from 2000 to 2013 is taken as research object and it is empirically analyzed from two aspects, namely time trend and spatial difference.

## 2. Measurement method and evaluation index system

### 2.1 Measurement method

*(1) Attribute Hierarchical Model (AHM) and Entropy Weighting Method (EWM)*

Before computing coal city's coupling coordination degree of urban economic development and ecological environment, it is necessary to measure the comprehensive development level of them.

This article established coal city economic development system and the eco-environment system comprehensive evaluation index is as follows:

$$f(x,t)=\sum_{i=1}^{m}\alpha_i x_i'; \ g(y,t)=\sum_{j=1}^{n}\beta_j y_j' \quad ... \quad (1)$$

$x$, $y$ is the eigenvector, $t$ is time period. In order to eliminate the impact from indicator unit inconsistencies and huge difference of the same indicator to evaluation results, it needs dimensionless and non-negative treatment to the indicators. The indicators are divided into positive and negative indicators index categories, let $x_i$ be the $i$th indicator of the economic development system, $x_i'$ represents the index after normalization, the standardized formula is as follows:

Positive indicator:

$$x_i' = [x_i - \min(x_i)]/[\max(x_i) - \min(x_i)] \quad ... \quad (2)$$

Negative indicator:

$$x_i' = [\max(x_i) - x_i]/[\max(x_i) - \min(x_i)] \quad ... \quad (3)$$

$\alpha_i$ and $\beta_j$ are comprehensive assessment weight of the selected indicators. Using AHM and EMW method to determine the subjective weights and objective weights of indicators separately.

The principle of AHM is: set C as a criterion, $b_1, b_2, ..., b_n$ as $n$ elements. For criterion C, comparing two different elements $b_i$ and $b_j$ $(i \neq j)$, $b_i$ and $b_j$ have their own relative importance to C, namely $\mu_{ij}$ and $\mu_{ji}$. By the requirements of attribute measures, $\mu_{ij}$ and $\mu_{ji}$ are fulfilled:

$$\mu_{ij} \geq 0, \mu_{ji} \geq 0, \mu_{ij} + \mu_{ji} = 1, i = j \quad ... \quad (4)$$

$$\mu_{ij} = 0, i = j, 1 \leq i \leq n, 1 \leq j \leq n \quad ... \quad (5)$$

$\mu_{ij}$ is called relative attribute measure if it satisfy above constraints and the $n$ order matrix $(\mu_{ij})$ $1 \leq i, j \leq n$ is called attribute judgment matrix. $(\mu_{ij})$ $1 \leq i, j \leq n$ can be obtained by converting analytic hierarchy process judgment matrix $(a_{ij})$ $1 \leq i, j \leq n$ and the converting formula could following equation (6). Here $k$ is a positive integer above 1, value of $a_{ij}$ is scaled from 1 to 9 following proportion criteria (by constructing analytic hierarchy process judgment matrix proposed by American operational research experts Saaty).

$$\mu_{ij} = \begin{cases} \frac{k}{k+1}, & a_{ij} = k, i \neq j \\ \frac{1}{k+1}, & a_{ij} = \frac{1}{k}, i \neq j \\ 0, & a_{ij} = 1, i = j \end{cases} \quad ... \quad (6)$$

Attribute judgment matrix is consistent, so it does not need to calculate the eigenvalues and eigenvectors of the matrix, and also does not need to carry out the consistency test.

Formula Wc for computing attribute weight is as below:

$$Wc = (Wc(1), Wc(2), ..., Wc(n))^T = \frac{2}{n(n-1)} \sum_{i=1}^{n} \mu_{ij}, 1 \leq i \leq n \quad ... \quad (7)$$

The entropy weighting method is computed by following steps:

(1) Taking average of the original data gives standard value of evaluation indicator.

The weight of indicator value is transformed as below:

$$P_{ij} = \frac{X_{ij}}{\sum_{i=1}^{n} X_{ij}}, (i = 1,2,...,n, j = 1,2,...,m) \quad ... \quad (8)$$

(2) Computing entropy value of $j$th indicator:

$$e_j = -\frac{1}{\ln(n)} \sum_{i=1}^{n} p_{ij} \ln(p_{ij}) \quad ... \quad (9)$$

(3) Computing differential degree of $j$th indicator:

$$g_j = 1 - e_j \quad ... \quad (10)$$

(4) $w_j$ is the weight of $j$th indicator:

$$w_j = \frac{g_j}{\sum_{j=1}^{m} g_j}, (1 \leq j \leq m) \quad ... \quad (11)$$

*(2) System coupling model*

By referring to the concept of capacity coupling and capacity system coupling model from physics, the coordination degree between economic development and eco-environment system of coal city is:

$$C = \left\{ f(x,t) \cdot g(x,t) \Big/ \left| \frac{f(x,t) + g(x,t)}{2} \right|^2 \right\}^k \quad ... \quad (12)$$

Among them, C is the coordination degree (or known as the coordination coefficient), K is adjust coefficient, let K = 2. Smaller the C is, the greater the disharmony between the two subsystems is. The greater the number is, the better the system coordination state is. However, in the case of two subsystems with equal scores at low values, there may be a higher degree of coordination of the evaluation results, which is obviously inconsistent with the facts. Further optimization leads to the system coupling coordination degree:

$$U = (C \times T)^\theta$$
$$T = \alpha f(x,t) + \beta g(x,t) \quad ... \quad (13)$$

Here U is coupling coordination degree, C is coordination degree, T getting through AHM and EWM method, is the comprehensive development level evaluation index of the coal city economic development and eco-environment, reflecting overall developing level of them *a*, *b*, *q* are undetermined coefficient. Because the two in coordination process have different degrees of mutual influence and interactions, by consulting 17 industry experts, their values are determined as 0.6, 0.4 and 0.5. Based on the above analysis, with the help of the uniform distribution functions, coal city economic development and eco-environment coupling coordinated development type is divided into 5 categories, namely good coordination development, moderate coordinated development, basic coordinated development, moderate imbalance recession and severe imbalance recession. According to the size of their own comprehensive evaluation index of coal city economic development and eco-environment, three subtypes of each category is divided as lag type $f(x,t)<g(x,t)$, synchronous type $f(x,t) = g(x,t)$, and $f(x,t)>g(x,t)$profits and losses type. A total of 15 kinds of evaluation types.

### 2.2 Evaluation index system and weight setting

In order to scientifically define specific indicators of coal city economic development and eco-environment, in October 2015, the author use CNKI literature retrieval tools, using "economy", "environment", "coal mining" and "coordination" as retrieval conditions, and find 86 Chinese literature between year 2000 and 2015. The involved system index is taken high frequency classification and an index set is selected in the preliminary selection to represent coal city economic development and eco-environment. After many adjustments and modifications, 4 factors as scale of the economy, resource endowment, environmental pollution and environmental governance, 14 indicators and economic development and eco-environment two subsystems, jointly construct coal city economic development and eco-environment coupling coordination degree evaluation system and their corresponding weights, see Table 1.

### 3. Measurement results and evaluation

#### 3.1 Comprehensive development level analysis

In general, each coal city's comprehensive economic development in stage 2003-2005, 2006-2010 and 2011-2013 kept at steady state (Fig.1), but the level of comprehensive development of the eco-environment had a small decline trend (Fig.2). To the level of comprehensive economic developments, the mean of coal cities at these 3 stages are ?0.22?0.20?0.19?, the stage standard deviations are respectively (0.17, 0.16, 0.16), both mean and standard deviation have a decreased trend. Out of them, Tangshan, Ordos, Xuzhou and Zibo's comprehensive economic development level is greater than the average (0.22, 0.20, 0.19), indicating that these coal cities' economic development is relatively good. Comprehensive economic development level of Xingtai, Yangquan and Fushun have a wave fall; the rest of the coal cities' comprehensive economic development level mean is less than each stage mean, indicating that these coal cities' comprehensive economic development level is relatively poor. For the comprehensive development of eco-environment, mean of coal city comprehensive development level of eco-environment in the three stages are respectively (0.47, 0.43, 0.40), and standard deviations are respectively (0.08, 0.06, 0.05). The mean values and standard deviations also showed a decline trend. Tangshan, Fushun, Fuxin, Jixi, Hegang, Shuangyashan, Huaibei, Pingxiang, Zibo, Zaozhuang, Hebi and Tongchuan have ecological environment

Table 1: The coordinated development evaluation index system and the weight of coal economy and eco-environment

| Target layer | System layer | Factor layer | Index layer | Unit | AHM weight | EWM weight | Synthetic weight | Type |
|---|---|---|---|---|---|---|---|---|
| Coal city economic development and eco-environment coupling coordination system | Economic development | Scale of the economy | Per capita gross regional product | Yuan | 0.18 | 0.09 | 0.14 | + |
| | | | Total investment in fixed assets | $10^4$ yuan | 0.14 | 0.12 | 0.13 | + |
| | | | General budgetary revenue of local finance | $10^4$ yuan | 0.10 | 0.13 | 0.12 | + |
| | | | Gross industrial output value | $10^4$ yuan | 0.15 | 0.18 | 0.16 | + |
| | | Resource endowment | Number of workers in the mining industry | $10^4$ person | 0.12 | 0.09 | 0.11 | + |
| | | | Industrial power consumption | $10^4$ KW/H | 0.15 | 0.22 | 0.18 | + |
| | | | Raw coal production | $10^4$ t | 0.16 | 0.17 | 0.16 | + |
| | Eco-environment | Environmental pollution | The discharge amount of industrial waste water | $10^4$ t | 0.18 | 0.04 | 0.11 | - |
| | | | Industrial sulfur dioxide emissions amount | t | 0.17 | 0.05 | 0.11 | - |
| | | | Industrial smoke and dust emissions amount | t | 0.18 | 0.03 | 0.11 | - |
| | | Environmental governance | Comprehensive utilization rate of industrial solid waste | % | 0.11 | 0.07 | 0.09 | + |
| | | | Built-up area green coverage rate | % | 0.12 | 0.04 | 0.08 | + |
| | | | The output value of comprehensive utilization of 3 waste products | $10^4$ puan | 0.12 | 0.50 | 0.31 | + |
| | | | Per capita green space | $M^2$/person | 0.12 | 0.27 | 0.19 | + |

Note: 1. compound weight = (AHM weight + EWM weight)/2; 2. "+" indicates positive indicators, "-" indicates negative indicators. 3. Data from "China City Statistical Yearbook", "China Coal statistics yearbook", "China regional economic statistical yearbook" and statistical year book of provinces and cities from 2004 to 2014.

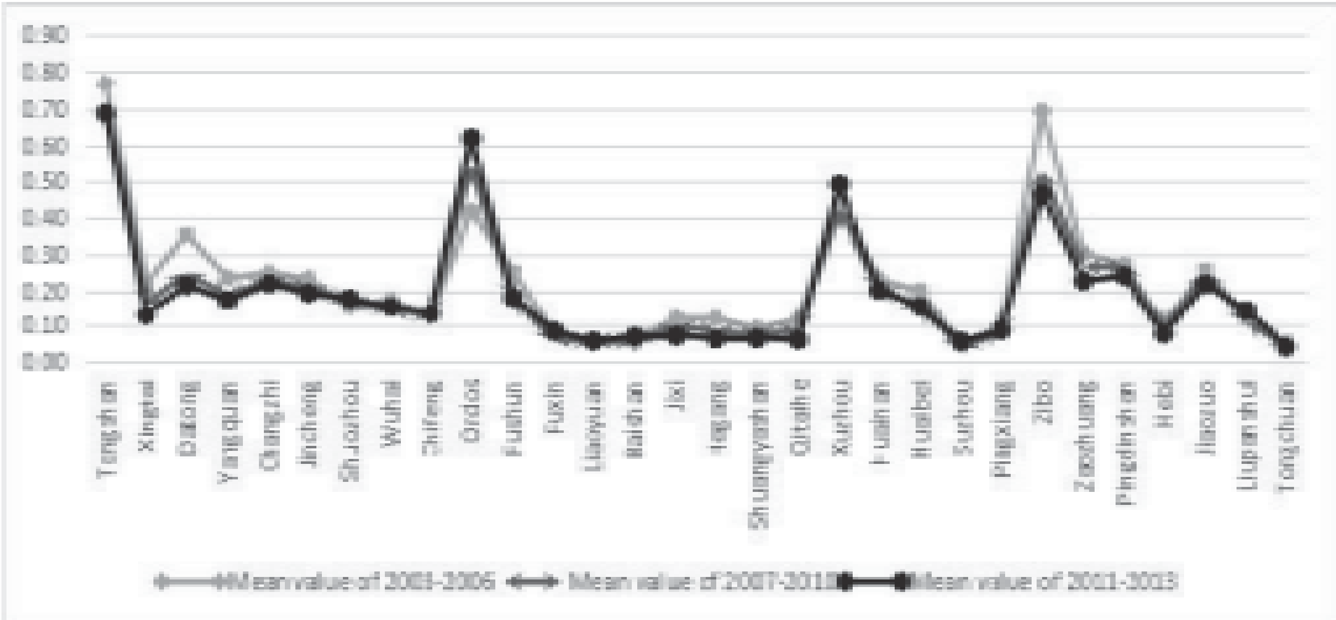

Fig.1 The comprehensive economic development level of 30 coal cities in China

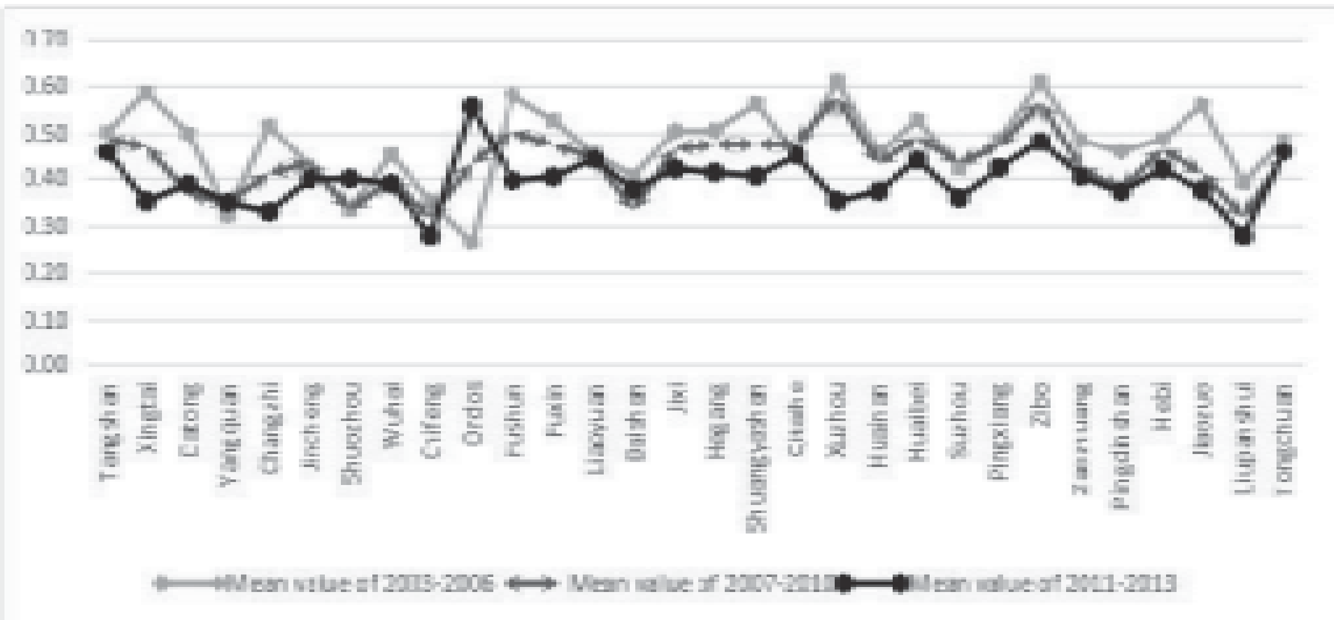

Fig.2 The comprehensive eco-environment development level of 30 coal cities in China

comprehensive development level mean greater than the stage mean values (0.47, 0.43, 0.40), indicating that the coal cities' eco-environment is good. Datong, Changzhi, Jiaozuo, Xingtai, Xuzhou and Suzhou have a wave down comprehensive eco-environment level, which shows that the eco-environment is getting worse. Although the comprehensive eco-environment level in Liaoyuan, Qitaihe and Jincheng has increased, but the eco-environment of the three cities is still poor relative to the average level. Comprehensive eco-environment level of Ordos is less than first stage mean, but greater than the mean of the second and third stage, reflecting a gradual improvement in eco-environment. The rest coal cities' comprehensive eco-environment level are less than the average of each stage, indicating that the eco-environment of these coal cities is the worst.

### 3.2 Sequential coupling analysis

The evaluation values of the coupling coordination degree of economic development and eco-environment in coal cities are shown in Figure 3. According to the classification criteria

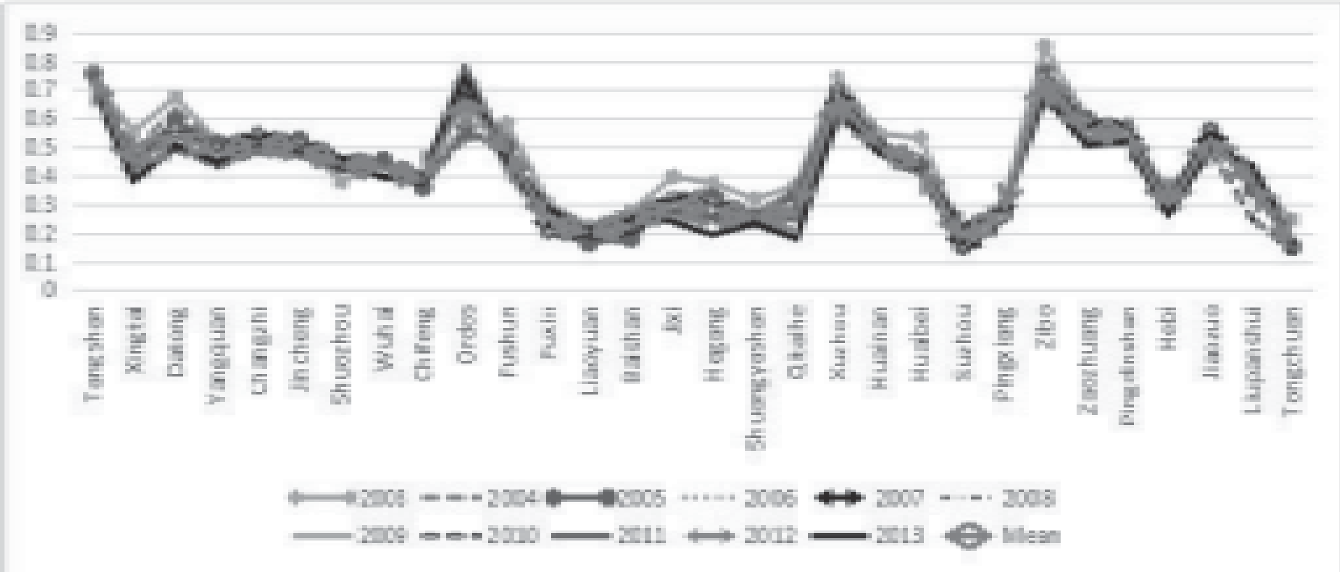


Fig.3 The coupling coordination degree of economic development and eco-environment of 30 coal cities in China from 2003-2013

of the coupling coordination relation and the evaluation results obtained in this paper, 4 kinds of main coupling coordination types are concluded. The essential reasons for the differences in the coupling coordination level are analyzed as follows:

(1) Tangshan, Ordos, Xuzhou and Zibo have coupling coordination degree between 0.6-0.8, belonging to moderate type of coordination development. Meanwhile, the coal city's economic development and eco-environmental levels are higher and basically realized mutually promoting type optimum coupling coordinated developing situation. Tangshan has peak coupling coordination degree value in 2004 and 2006 (0.78), with the lowest value in 2012 (0.70). Ordos has its highest coupling coordination degree value in 2011 (0.78), the lowest year is 2004 (0.53). Xuzhou has peak coupling coordination degree value appeared in 2003 (0.75), the lowest value appeared in 2012 and 2013 (0.62). Zibo has highest coupling coordination degree value in 2003 (0.85), the lowest year is 2013 (0.67). Tangshan and Ordos have the comprehensive evaluation index of eco-environment lower than the comprehensive evaluation index of economic development, thus belongs to eco-environment lag type cities. Xuzhou has comprehensive evaluation index of economic development lower than the comprehensive evaluation index of eco-environment, and is an economic development lag type city. Zibo has comparable comprehensive evaluation index of eco-environment and the comprehensive evaluation index of economic development, and belongs to the synchronous type city.

(2) Xingtai, Datong, Yangquan, Changzhi, Jincheng, Shuozhou, Wuhai, Fushun, Huainan, Huaibei, Zaozhuang, Pingdingshan and Jiaozuo have coupling coordination degree between 0.4 and 0.6, which belongs to the basic type of coordination development. At this time economic development and eco-environment system is still in the Run-in phase. Both should strengthen the structure, size and other matching aspects. Except Shuozhou, coupling coordination degree of other cities has been generally reduced during the study period. Xingtai made the largest decline (-0.17), Changzhi and Jincheng made the smallest decline (-0.03). It can be known by the comprehensive evaluation index, 13 coal cities are economic development lag type cities.

(3) Chifeng, Fuxin, Liaoyuan, Baishan, Jixi, Hegang, Shuangyashan, Qitaihe, Pingxiang, Hebi and Liupanshui have coupling coordination degree between 0.2 and 0.4, belonging to moderate imbalance recession type. Except Chifeng and Liupanshui, other cities of this type have their coupling coordination degree reduced during the research period. Qitaihe has the largest decline (-0.19), Fuxin and Pingxiang have the smallest decline (-0.01), Chifeng basically remained stable, Liupanshui has an increase (0.04). All these 11 cities belong to the economic development profit and loss type.

(4) Suzhou and Tongchuan have coupling coordination degree value below 0.2, which belongs to the type of severe imbalance recession. During the study period, the coupling coordination degree of Tongchuan decreased by 0.08, while Suzhou increased (0.03). According to the comprehensive evaluation index, these cities belong to the economic development profit and loss type. And the comprehensive evaluation index of the two cities' economic development and eco-environment are ranked on the bottom of all the researched cities.

### 3.3 Spatial coupling analysis

According to the object of study's coupling coordination classification results in periods of 10th, 11th, and 12th “Five

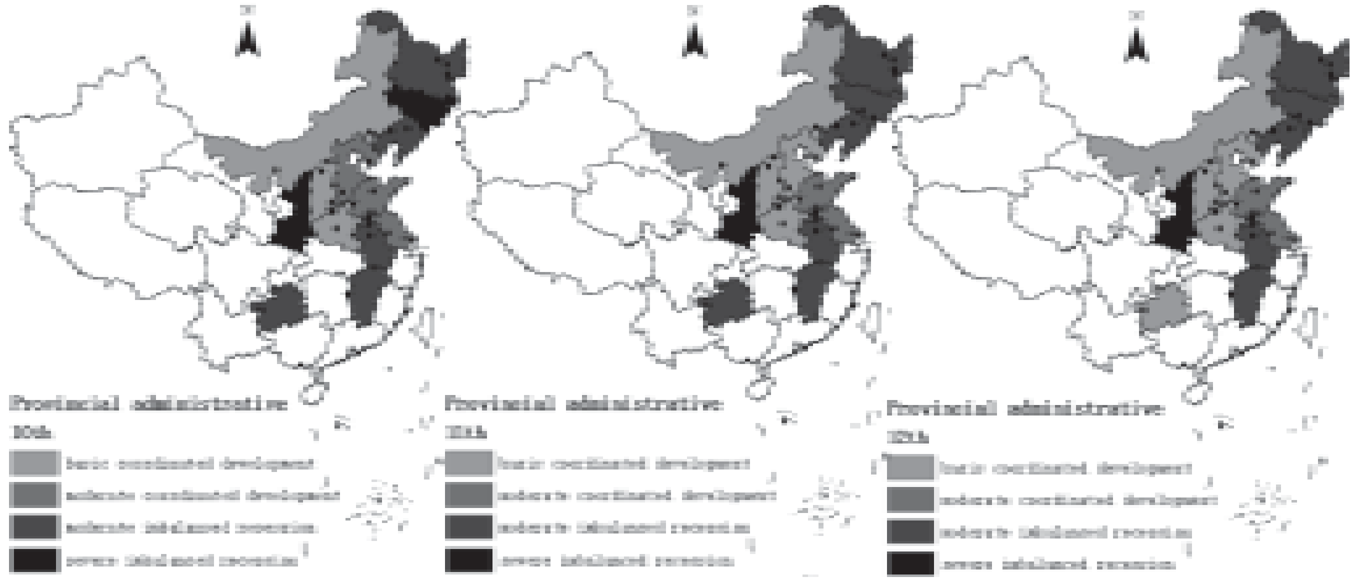

Fig.4 The spatial difference of coupling coordination degree between economic development and eco-environment of 30 coal cities in China

Year Plan", combined with ArcGIS10.2 re-classification tools, economic development and ecological environment coupling coordination degree distribution map of the provinces in which 30 coal cities belongs to are drawn(see Figure 4), and they are divided into six plates according to the common geographical partition to analyze, and they are North, Northeast, East, Central, Northwest and Southwest plates. Specific features are as follows:

(1) For North China regional plate, during the study period, Datong city of Shanxi province downgraded from moderate coordinated development stage to basic coordinated development stage. Yangquan, Changzhi, Jincheng and Shuozhou are in basic coordinated development stage for all the three periods. Wuhai of Inner Mongolia rose from basic coordinated development type to moderate coordinated development and then fell back to basic coordinated development type again. Chifeng was always in moderate imbalance recession. Ordos rose from basic coordinated development stage to moderate coordinated development stage. In Hebei province, Tangshan kept in moderate coordinated development stage and Xingtai dropped from basic coordinated development stage to moderate imbalance recession stage.

(2) For Northeast regional plate, except for Fushun of Liaoning province which was in basic coordinated development stage throughout the time, other cities such as the Fuxin of Liaoning province, Jixi, Hegang, Shuangyashan, Qitaihe of Heilongjiang province, and Baishan of Jilin province are in moderate imbalance recession stage. Liaoyuan of Jilin province also transferred from severe imbalance recession stage into moderate imbalance recession stage.

(3) For East China regional plate, Xuzhou in Jiangsu province stayed in moderate coordinated development stage during the research period. Zaozhuang in Shandong province and Huainan and Huaibei in Anhui province stayed in basic coordinated development stage. Moreover, Shandong Zibo downgraded from good coordination development stage to moderate coordinated development stage. Anhui Suzhou experienced a change from severe imbalance recession stage to moderate imbalance recession stage.

(4) For Central China regional plate, Jiangxi Pingxiang and Henan Hebi were in moderate imbalance recession stage and Henan Pingdingshan and Jiaozuo belonged to basic coordinated development type.

(5) For Northwest and Southwest regional plate, Guizhou in the Southwest of China has risen to the basic coordinated development stage from moderate imbalance recession stage, and Shaanxi in the Northwest has been in severe imbalance recession stage. Among them, Guizhou Liupanshui rose from moderate imbalance recession stage to basic coordinated development stage, but Shaanxi Tongchuan remained in severe imbalance recession stage all the time.

## 4. Conclusion

In this paper, by using the system coupling model, an empirical study on the spatial and temporal characteristics of the coupling coordinated development of economic development and eco-environment of 30 coal cities in China during year 2003 and 2013 is carried out. The results of analysis are as follows:

(1) From the perspective of comprehensive evaluation index, comprehensive economic development level of Tangshan, Ordos, Xuzhou and Zibo is relatively good, Xingtai,

Yangquan and Fushun have a wave fall, and the comprehensive economic development level of other cities is relatively poor. Comprehensive eco-environment level of Tangshan, Fushun, Fuxin, Jixi, Hegang, Shuangyashan, Huaibei, Pingxiang, Zibo, Zaozhuang, Hebi and Tongchuan is better. Datong, Changzhi, Jiaozuo, Xingtai, Xuzhou and Suzhou has a wave fall and comprehensive eco-environment level of other cities is very poor.

(2) From the point of view of sequential coupling, the coordination level difference of economic development and eco-environment of the coal cities is relatively large. In higher coordination degree group, Tangshan and Ordos belong to the eco-environment lag type cities, Xuzhou belongs to the economic development lag type the city, while Zibo is an economic development and eco-environment synchronous type city. In the secondary high coordination degree group, Xingtai, Datong, Yangquan, Changzhi, Jincheng, Shuozhou, Wuhai, Fushun, Huainan, Huaibei, Zaozhuang, Pingdingshan and Jiaozuo belong to economic development lag type cities. Low coordination degree cities Chifeng, Fuxin, Liaoyuan, Jixi, Hegang, Baishan, Shuangyashan, Qitaihe, Pingxiang, Hebi and Liupanshui and the lowest coordination degree cities Suzhou and Tongchuan belong to the economic development benefit loss type city.

(3) From the perspective of space, the coupling coordination level has obvious regional imbalance. East regional plate has higher coupling coordination level and belongs to the moderate coordinated development state of the 3 stages, such as Xuzhou in Jiangsu province and Zibo in Shandong province. The coupling coordination level of North and Central regional plate follows that of the East regional plate during the study period and belongs to basic coordinated development mode, such as Yangquan, Changzhi, Jincheng and Shuozhou in Shanxi province, Wuhai in Inner Mongolia province and Pingdingshan and Jiaozuo in Henan province. The coupling coordination level of Northeast and Southwest regional plate is low and moderate imbalance recession state is the typical type, such as the Fuxin in Liaoning province, Baishan in Jilin province and Jixi, Hegang, Shuangyashan and Qitaihe in Heilongjiang province. Northwest regional plate has the lowest development speed and coupling coordination level. Severe imbalance recession type is the major type in this area, such as Shaanxi Tongchuan.

## 5. Optimization measures

(1) Constructing a harmonious eco-economic system dominated by circular economy. The coal cities should fully develop its advantages in resources, adjust and optimize the economic structure, foster development of circular economy, actively develop ecological industry, advocate green consumption, eliminate backward production mode and process, promote the transformation of the mode of economic development and the mode of growth, implement green GDP, enhance the green guide and green control ability of government, form coal cities' own characteristics of the eco-economic pattern as soon as possible. Coal cities should also pay equal attention to environmental protection and ecological construction, focus on pollution control of key mining areas, key areas and key regions, Focus on solving the problem of urban air pollution, water pollution, vegetation system damage, geological environment deterioration caused by the coal industry, strengthen the construction of urban ecological function areas, protect biodiversity, enhance anti disaster ability, improve coordination, circulation, autopoietic function of the cities, enhance the environmental support capacity of economic society, to establish a harmonious landscaping, purification, beautification and activating sustainable ecosystems between human and nature.

(2) Guiding various mining economic zone to explore the development model with different characteristics. First, it is of importance to regulate the orderly development of the eco-environment of the mining economic zone, to determine the intensity of regional mineral resources development within the bearing capacity threshold and to promote the coordinated development of new industrialization and new urbanization. Second, it is valuable to promote the spanning development of development lag mining zone, to accelerate the development of deep processing of resources leading enterprises and industrial cluster, while forming following alternative industries for loss type development mining economic region. Finally, the support for industrial system construction of eco-environment lag type mining economic zone sets the direction of intensification and environmental protection, strictly limit the new project of high consumption, high emission, and carry out technical renovation for typical high pollution industry and install desulphurization, dust removal and water purification equipment.

(3) Optimizing the organizational structure of mining economic zones in different regions. In the East region, which is dominated by the moderate coordinated development type, they should fully stimulate the advantages of coal resources mining, but it is not limited to the coal mining industry itself. East coal cities should expand industry chain and value chain to the upstream and downstream, increase coal mining machinery and equipment manufacturing industry, the exploration of coal industry, coal deep processing and even the transportation of coal and coal industry consulting area or even more. So that the coal industry chain is not limited to the city’s coal mining, and is the type of full realization of the cross regional, cross-border mining, manufacturing and services. North and Central region plates, the basic

state of coordinated development type, could increase R & D investment, increase more support for knowledge intensive enterprises, construct harmonious and ecological cities. Northeast and Southwest regional plates, dominated by the moderate disorders of recession state, should put importance to the industrial structure adjustment and new industry cultivation, with particular emphasis on support and development of the high technology industry and the third industry, change the over dependence status of the coal mining industry, transfer coal city into a comprehensive modern city with multiple leading industries and pillar industries, including mining industry itself. In the Northwest region, which is dominated by the severe recession, they should optimize and adjust the industrial structure, and develop the new industry with high technology content, low resource consumption and high added value.

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