

# Clustering analysis of the effectiveness of China's Environmental Governance

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**Abstract.** This study constructs an index system to evaluate the effectiveness of environmental governance and executes the evaluation by using a China's provincial-level panel data from 2001 to 2012 and employing the generalized principle component analysis method. The results showed that over the sample period, the effectiveness of China's environmental governance has been improved greatly. But the effectiveness was unevenly improved across China with a geographic distribution of "east high west low", which hasn't been ameliorated much over the period. The clustering analysis also suggests that there is gradient phenomenon on the environmental governance performance.

**Key Words.** Effectiveness; Environmental governance; Principle Component Analysis

## 1. Introduction

With fast economic development over the past four decades, China became the world's second largest economy in terms of GDP in 2010 and was the world's biggest energy consumer in 2009. China is facing many serious environmental problems in spite of great economic achievement, including pollution in the air, groundwater and soil (Wu et al., 1999). Take air pollution as an example, cities such as Beijing, Tianjin, and Shanghai witnessed record-breaking smog in recent years. Concentrations of fine particulate matter (PM 2.5) reached far more than recommended safety levels (Zhang et al., 2007). The severe air pollution causes great harm to health. A report studied by the World Bank, WHO, and the Chinese Academy for Environmental Planning on the effect of air pollution on health claimed that between 350,000 and 500,000 people die prematurely each year as a result of outdoor air pollution in China (World Bank, 2007).

The prevailing explanations to the severer environmental problems in China include the deficiency and weak enforcement of green laws, which can be ascribed to the administrative nonfeasance. However, a fact what can hardly be denied is that Chinese government has been making great endeavors to protect the natural environment. From the aspect of environmental legislation, in the past 30 years, China enacted nine laws on environmental protection as well as seventeen laws on resource efficiency (Zhang et al., 2008).

Nevertheless, the efforts made by the government don't seem to be very effective and are unable to prevent the environment from deteriorating. Levels of wastewater and solid-waste produced in China



have continued to increase over the period 2000 to 2012. Chemical Oxygen Demand (COD), a water pollution measurement, grew rapidly in 2010.

The contradiction between worse environment and greater efforts on environment protection raises a question. How effective are the efforts of environment protection made by China government? In order to address this question, we need to know the effectiveness of environmental governance should be evaluated from a comprehensive perspective, rather than a unidirectional view, for example, taking an increase of pollution as the unique evidence to testify the ineffectiveness of environmental governance. To this end, we construct an evaluation index system to evaluate the effectiveness of China's environmental governance from different aspects including economic development, resource-bearing and environment protection. We then calculate the score of the environmental governance by applying a provincial panel data from 2001 to 2012 and the generalized principle component analysis method.

The results show that over the sample period, the effectiveness of China's environmental governance has been improved greatly. But the effectiveness was unevenly improved across China with a geographic distribution of "east high west low", which hasn't been ameliorated much over the period. The clustering analysis also suggests that there is gradient phenomenon on the environmental governance performance.

The rest of our paper is organized as follows: section 2 introduces the evaluation index system of environmental governance and describes the data we calculate or use. Section 3 introduces the GPCA model. Section 4 analyses the measurement results of China's environmental governance. The last section concludes the paper

## 2. The index system

### 2.1. Index system construction

In order to evaluate the effectiveness of China's environmental governance, we construct an index system, which constitutes three dimensions including economic development, resource-bearing and environmental protection. The dimension of economic development includes economic growth and structure, the resource-bearing dimension includes natural resource (renewable resources) and mineral resource (non-renewable resources). The quantization of resource load follows the method of the sum of net present value of resource economic profit flow in various periods (World Bank, 2011). The dimension of environmental protection includes the efforts of environmental restoration and pollution reduction in CO<sub>2</sub>, SO<sub>2</sub>, dust, waste water, solid waste pollution. Table 1 describes the index system in detail.

### 2.2. Measurements and data

Following Zhang (2008), the capital stock is measured by the Perpetual Inventory Method and updated to 2012 with 9.6% discount rate and 10% of the fixed asset investment in 1978 is used as the base capital stock. The Thiel index of Urban-rural income gap is calculated in following form:

$$T_{i,t} = \sum_{j=1}^2 \left( \frac{p_{ij,t}}{p_{i,t}} \right) \ln \left( \frac{p_{ij,t}}{p_{i,t}} / \frac{z_{ij,t}}{z_{i,t}} \right) \quad (1)$$

Where  $j=1,2$  denotes urban region and rural region respectively.  $z_{ij}$  is the urban or rural population in province  $i$ .  $z_i$  Is the total population in region  $i$ ?  $p_{ij}$  Is the gross income in urban or rural region.  $p_i$  Is the gross income in province  $i$ . The industrial structure rationalization index is given by:

$$ISR = \frac{1}{\sum_{i=1}^n (Y_i / Y) \left| \frac{Y_i / L_i}{Y / L} - 1 \right|} \quad (2)$$

Where  $Y_i$  the output in industry is  $i$ ,  $L$  is the labor input. The bigger value of this index means higher rationalization of industrial structure.

**Table 1.** The index system of environmental governance

Dimension	Sub-dimension	Index	Unit	Direction	
				+	-
Economic development	Growth	Industrial added value	100million	●	
		Capital stock	100million	●	
		Employment	10 thousand	●	
		R&D expenditure	100million	●	
	Structure	Theil index of Urban-rural income gap	-		●
		Industrial structure rationalization index	-	●	
		Industrial structure height index	-	●	
		Energy consumption per GDP	Ton standard coal/100million	●	
Resource-bearing	Natural resources	Cultivated area	Ha./person	●	
		Grassland area	Thousand ha.	●	
		Forest coverage rate	%	●	
		National reserve area	Ha.	●	
	Mineral resources	Nonferrous metal bearing capacity	100million	●	
		Oil and natural gas bearing capacity	100million	●	
		Coal bearing capacity	100million	●	
		Black metal bearing capacity	100million	●	
Environmental protection	Environmental restoration	Number of completion of pollution remediation projects	-	●	
		Treatment rate of living garbage	%	●	
		Investment in industrial pollution control	10 thousand	●	
		Public green land area	m <sup>2</sup> /person	●	
	Pollution reduction	CO <sub>2</sub> emissions	100million ton		●
		SO <sub>2</sub> emissions	Ton		●
		Dust emissions	Ton		●
		Waste water emissions	10 thousand ton		●
		Solid waste production	10 thousand ton		●

Note: The minus sign suggests a negative contribution to the index.

The industrial structure supererogation index is given by:

$$ISS = \sum_{i=1}^n \left( \frac{Y_{it}}{Y_t} \right) \left( \frac{LP_{it}}{LP_{if}} \right) \quad (3)$$

Where  $Y_{it}$  is the output in industry  $i$  in year  $t$ .  $LP_{it}$  Is the labor productivity in industry  $i$  in year  $t$ .  $LP_{if}$  Is the labor productivity in industry  $i$  after the industrialization? The end period is chosen as Chenery et al. (1986). The bigger value of this index means higher supererogation of industrial structure.

The data concerning other indices is collected or calculated from datasets or yearbooks including China statistical yearbook, China industrial economic statistical yearbook, China agricultural yearbook, China forestry yearbook, China environmental yearbook, China environmental statistical yearbook, China energy statistical yearbook, China economic census yearbook, Compilation of statistics of 60 years new China, other provincial or prefectural statistical yearbooks and statistical bulletins, as well as CEINET and WIND database. Due to the data availability, the indicators for Taiwan, Hong Kong and Macau are not calculated.

### 3. Methodology

Based on the evaluation system and evaluation methodology, we proceed to execute the evaluation by following steps:

Step1: Homodyne and standardize the original data due to the inconsistency between the dimension of the basic index and the magnitude of the attribute. The homing method is to take the inverse of the inverse indicators. The standardized processing formula is given by:

$$\tilde{x}_{ij}^t = (x_{ij}^t - \mu_j) / \sigma_j \quad (15)$$

The KMO test of partial correlation is conducted for the processed data. The value of KMO statistics is 0.7672, which suggests that there is a strong correlation between variables and the processed data is appropriate for the principle component analysis.

Step 2: Calculate the variance covariance matrix  $V$  of the data system  $\tilde{x}_{ij}^t$ .

Step 3: Calculate the characteristic roots in and eigenvectors air of covariance matrix  $V$ .

Step 4: Calculate the variance contribution rate and the cumulative variance contribution rate of the characteristic roots in. . The variance contribution rate  $\beta_i$  of the  $i$  the principle component  $Cu$  ( $1 \leq i \leq m$ ) is:

$$\beta_i = \lambda_i / \sum_{i=1}^m \lambda_i \quad (16)$$

And, the cumulative variance contribution rate  $\theta_k$  ( $1 \leq k \leq l$ ) is calculated as:

$$\theta_k = \sum_{i=1}^k \lambda_i / \sum_{i=1}^m \lambda_i \quad (17)$$

Table 2 shows the results of principal component variance decomposition. As shown in this table, the eigenvalues of the first 6 principle components are all greater than 1, and the cumulative variance contribution rate is up to 75.63%. The first 6 principle components are selected according to the law of PCA ( $l=6$ ).

**Table 2.** The results of principal component variance decomposition

component	Eigenvalue	difference	variance contribution rate	cumulative variance contribution rate
Comp1	7.3574	3.1213	0.2943	0.2943
Comp2	4.2362	1.3933	0.1694	0.4637
Comp3	2.8428	0.7831	0.1137	0.5775
Comp4	2.0597	0.8396	0.0824	0.6598
Comp5	1.2201	0.0292	0.0488	0.7086
Comp6	1.1909	0.2572	0.0476	0.7563

Step 5: Calculate the generalized principal components. The score of the h the ( $1 \leq h \leq 6$ ) component is:

$$C_h = a_i \tilde{X}_i = a_1 \tilde{x}_1 + a_2 \tilde{x}_2 + \cdots + a_m \tilde{x}_m \quad (18)$$

Where  $\tilde{x}_i$  is the standardized data?  $m=25$ . Air is the corresponding eigenvectors.

Step 6: Calculate the overall score. The overall score of a certain province in year t is:

$$C_t = \beta_1 C_1 + \beta_2 C_2 + \cdots + \beta_l C_l \quad (19)$$

Where  $C_u$  is the score of each component.  $\beta_l$  is the variance contribution rate.

Step 7: Apply the K-means clustering gradient method to analyze the overall score for each region, and draw a quartile spatial evolution diagram.

#### 4. Empirical results

Table 3 presents the evaluation results of china's environmental governance over the period of 2001-2012 using generalized principle component analysis. We can explore some findings from this table.

First, the overall score of environmental governance reach a sustainable growth during the period and increases by 0.3288 from -0.1103 in 2001 to 0.2185 in 2012, which indicates a remarkable promotion in the effectiveness of environmental governance in China. Moreover, the overall score achieves a transition from negative to positive in 2007 and increases faster after that year.

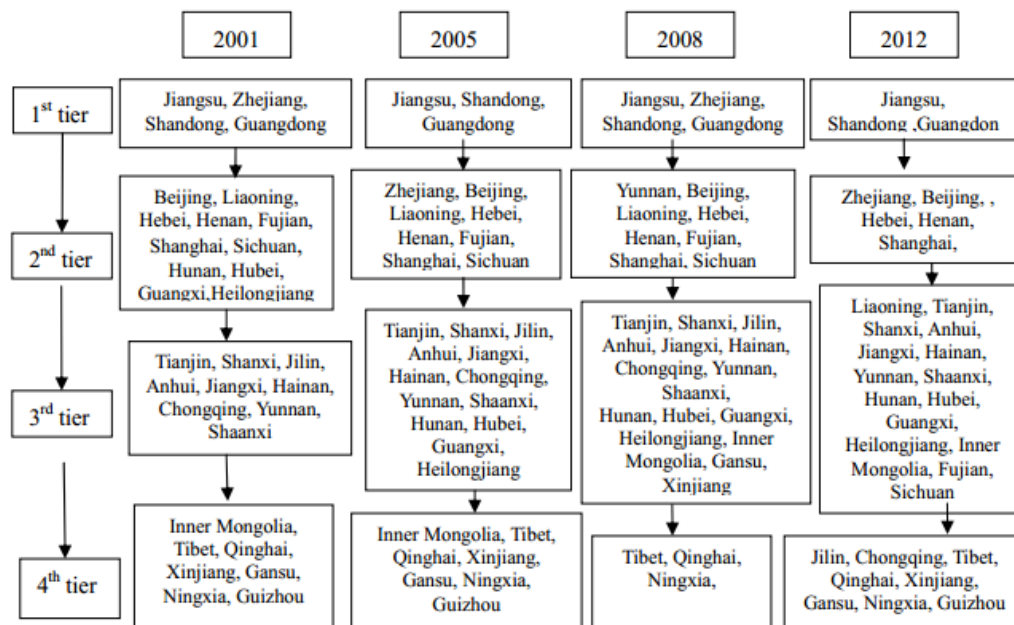
**Table 3.** The evaluation results

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Beijing	-0.0588	-0.0175	0.0222	0.0416	0.0584	0.1218	0.1453	0.1794	0.1910	0.2548	0.3384	0.3955
Tianjin	-0.1346	-0.1275	-0.0999	-0.0884	-0.0839	0.0149	0.0336	0.0294	0.0916	0.1265	0.2042	0.2897
Hebei	-0.0609	-0.0871	-0.0756	-0.0598	-0.0143	0.0468	0.0766	0.0677	0.1883	0.1624	0.2522	0.3943
Shanxi	-0.1767	-0.2298	-0.2139	-0.1918	-0.1207	-0.0958	-0.0205	0.0136	0.1671	0.1127	0.1509	0.2018
Inner Mongolia	-0.2446	-0.2716	-0.2662	-0.2593	-0.2401	-0.2033	-0.0865	-0.0567	0.0332	0.0660	0.1466	0.2795
Liaoning	-0.0784	-0.0891	-0.0848	-0.0584	-0.0239	0.0557	0.1152	0.1511	0.1014	0.1223	0.1800	0.2497
Jilin	-0.1489	-0.1798	-0.1752	-0.1750	-0.1491	-0.1368	-0.1371	-0.1241	-0.0904	-0.0713	-0.0458	-0.0029
Heilongjiang	-0.0731	-0.1042	-0.0964	-0.0994	-0.0709	-0.0251	-0.0031	-0.0285	0.0616	-0.0050	0.0221	0.0795
Shanghai	-0.0548	-0.0896	-0.0690	-0.0602	-0.0273	0.0396	0.0613	0.1021	0.1551	0.2299	0.3076	0.3719
Jiangsu	0.1233	0.0786	0.0815	0.1390	0.2053	0.2945	0.2979	0.3600	0.4898	0.5143	0.5848	0.7658
Zhejiang	0.1466	0.0413	0.0360	0.0548	0.0872	0.1504	0.2070	0.2512	0.2769	0.3145	0.3618	0.4601
Anhui	-0.1172	-0.1298	-0.1279	-0.1031	-0.0915	-0.0892	-0.0524	-0.0163	0.0310	0.0549	0.0847	0.1595
Fujian	-0.0389	-0.0730	-0.0630	-0.0329	0.0264	0.0817	0.0385	0.0831	0.1072	0.1164	0.1930	0.2186
Jiangxi	-0.1435	-0.1497	-0.1462	-0.1394	-0.1040	-0.0869	-0.0643	-0.0557	-0.0332	-0.0120	0.0396	0.0980
Shandong	0.1631	0.1511	0.1891	0.2310	0.3177	0.4351	0.4845	0.4688	0.6958	0.6473	0.7625	0.9852
Henan	-0.0099	-0.0213	-0.0014	0.0379	0.0800	0.1454	0.2198	0.1431	0.3116	0.3470	0.4340	0.5836
Hubei	-0.0561	-0.0872	-0.0802	-0.0660	-0.0637	-0.0141	-0.0093	0.0099	0.0583	0.1268	0.1689	0.1655
Hunan	-0.0691	-0.0974	-0.0987	-0.0925	-0.0540	-0.0046	0.0169	0.0290	0.0787	0.0966	0.1590	0.2192
Guangdong	0.1391	0.1471	0.1302	0.2191	0.2676	0.3639	0.3876	0.4452	0.5876	0.5699	0.6987	0.7822
Guangxi	-0.0614	-0.1157	-0.1125	-0.1181	-0.1066	-0.0733	-0.0531	-0.0421	0.0163	0.0131	0.0480	0.0950
Hainan	-0.1726	-0.1838	-0.1814	-0.1674	-0.1588	-0.1471	-0.1338	-0.0396	-0.0160	0.0035	0.0386	0.1023
Chongqing	-0.1713	-0.1920	-0.1845	-0.1828	-0.1549	-0.1427	-0.1261	-0.0995	-0.0692	-0.0556	-0.0320	-0.0065
Guizhou	-0.2567	-0.2588	-0.2381	-0.2333	-0.2060	-0.1799	-0.1224	-0.0978	-0.0993	-0.0913	-0.0774	-0.0323
Yunnan	-0.1086	-0.1372	-0.1331	-0.1161	-0.0980	-0.0663	-0.0086	0.0472	0.0450	0.0438	0.0961	0.1442
Sichuan	-0.0225	-0.0773	-0.0498	-0.0187	0.0683	0.0759	0.0955	0.1127	0.1513	0.1545	0.2128	0.3167
Tibet	-0.5189	-0.5061	-0.5339	-0.5716	-0.5018	-0.5199	-0.5279	-0.5148	-0.4736	-0.4348	-0.4635	-0.4785
Shaanxi	-0.1470	-0.1616	-0.1429	-0.1234	-0.0881	0.0061	0.0050	-0.0583	-0.0084	0.1064	0.2162	0.2779
Gansu	-0.2336	-0.2467	-0.2332	-0.2247	-0.2104	-0.2042	-0.1591	-0.1543	-0.1437	-0.1343	-0.1039	-0.0900
Qinghai	-0.2926	-0.2920	-0.2858	-0.2755	-0.2677	-0.2476	-0.2230	-0.2395	-0.2189	-0.2085	-0.1857	-0.1590
Ningxia	-0.3023	-0.2886	-0.2822	-0.2996	-0.2742	-0.2618	-0.2407	-0.2117	-0.1640	-0.1715	-0.1194	-0.1124
Xinjiang	-0.2381	-0.2396	-0.2413	-0.2219	-0.1983	-0.1626	-0.1318	-0.0958	-0.1024	-0.0707	-0.0448	0.0208
Overall	-0.1103	-0.1302	-0.1212	-0.1050	-0.0709	-0.0267	0.0027	0.0213	0.0781	0.0945	0.1493	0.2185

Second, looking at the scores of each region, we find that most regions make a progress in level of environmental governance, nevertheless, there is a certain geographical imbalance across regions. As a whole, the scores of eastern regions grow faster than the rest regions, for instance, over the period of 2001-2012, the score of Shandong increases by 0.8221, Guangdong by 0.6431 and Jiangsu by 0.6425. While in western regions, the increases in the scores are much slower, for example, Tibet increases by 0.0405, Qinghai by 0.1336 and Gansu by .01436. The unbalanced development of environmental governance performance indicates that there is no obvious “club effect”.

Finally, although the overall progress in environmental governance performance, there are several undesirable outcomes, for example, the scores of some regions retrogress in some years, the scores of some regions stay negative over the period. These facts suggest that more efforts should be paid to the environmental governance in China.

In order to explore the geographic characteristics of the regional environmental governance, we further investigate the evaluation results using k-means cluster analysis. The Euclidean distance (L2) is used as the similarity index. Figure 1 shows the results of cluster analysis.



**Figure 1.** The results of K-means cluster analysis

From figure 1, we find that 4 tiers are classified and there is no big change in the list of each tier in different years. The first tier includes Jiangsu, Zhejiang, Shandong and Guangdong in most years. It must be pointed out that these four provinces are located along the east coast an excellent performance in economic development, technological strength, labor quality and industrial structure. Moreover, the energy utilization efficiency, ecological conservation and environmental management input and environmental regulation standards of the four provinces have also increased rapidly in recent years.

The most frequent appearances in the second tier are Beijing, Shanghai, Hebei, Henan, Fujian and Sichuan. The possible explanation why Beijing and Shanghai are not listed in the first tier is their poor environmental quality, despite of their outstanding economic performance. Sichuan is the only western province which can be listed in the second tier because it achieves the fast economic growth and good ecological environment simultaneously. Some west regions including Tibet, Qinghai, Xinjiang, Gansu, Ningxia and Guizhou are listed in the fourth tier in most years because of their less developed economy and low resource utilization efficiency. Eventually, Jilin and Chongqing was degraded to the 4th tier in 2012. The relatively slow economic growth is the main reason for the degradation of Jilin.



The contradiction between low resource bearing capacity and fast economic growth can explain the demotion of Chongqing.

## 5. Conclusions

This study addresses the question whether the effectiveness of China's environmental governance is improved. For that purpose, we construct an index system to evaluate the effectiveness of China's environmental governance. Using a provincial-level panel data over the period of 2001-2012, we calculate the provincial scores of the environmental governance adopting the Generalized Principle Component Analysis method. On the basis of the scores, we investigate the evolution of the environmental governance during the sample period from some aspects including score changes, rankings and ranking changes. The geographic evolution of environmental governance performance is also explored in this study using K-means cluster analysis.

The findings we draw from the research can be summarized as follows: First, from 2001 to 2012, the overall effectiveness of China's environmental governance has been greatly improved. Compared with the western regions, the improvement of environmental governance performance in the east and central regions is even greater. Second, over the sample period, the unbalanced development of the environmental governance performance remains unchanged, which suggests that there is no "club effect". Finally, there is a gradient phenomenon that the level of environmental governance is decreasing from the east to the west, which presents a geographic characteristic of "west low east high".

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## References

- [1] Chenery, H., et al. 1986. *Industrialization and Growth: A Comparative Study*. Oxford Press, Oxford.
- [2] Daniel C. Bonzo, Augusto Y. Hermosilla. 2002. Clustering Panel Data via Perturbed Adaptive Simulated Annealing and Genetic Algorithms. *Advances in Complex Systems*, 5(4):339-360.
- [3] The World Bank. 2007. *Cost of pollution in China: economic estimates of physical damages*. The World Bank, Washington.
- [4] Wu C, Maurer C, Wang Y, Xue S, Davis DL. 1999. Water pollution and human health in China. *Environment Health Perspective* 107:251-256.
- [5] Zhang Jun. 2008. Estimation of China's provincial capital stock (1952-2004) with applications, *Journal of Chinese Economic and Business Studies*, 6(2): 177-196.
- [6] Zhu Chen, et. al. 2013. China Tackles the Health Effects of Air Pollution. *Lancet*, 382 (9909):1959-60.
- [7] Zhang JJ, Smith KR. 2007. Household air pollution from coal and biomass fuels in china: measurements, health impacts, and interventions. *Environment Health Perspectives* 115:848-855.
- [8] Zhang M, Song Y, Cai X, Zhou J. 2008. Economic assessment of the health effects related to par Economic assessment of the health effects related to particulate matter pollution in 111 Chinese cities by using economic burden of disease analysis. *Journal of Environmental Management* 88(4):947-954.