“The application of the vertical and horizontal method – China’s regional environmental quality evaluation”

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The application of the vertical and horizontal method – China's regional environmental quality evaluation

Abstract

China's reform and opening up achieves remarkable economic results but paid heavy environmental cost in the last three decades. Under the background of China's active transformation of the pattern of economic development, this paper built the environmental quality comprehensive evaluation system contains 11 indicators including air, water, wastes, soil, etc. through vertical and horizontal method. The result of environmental quality comprehensive evaluation of China's 30 provinces from different angles from 2003 to 2012 shows: the western region has the lowest environmental pollution emissions. The environmental comprehensive quality of the eastern region is the best. China should prevent pollution transfer from the developed areas to the underdeveloped areas. Transformation of economic development patterns in the central region is the focus of China's future development.

Keywords: environmental quality, comprehensive evaluation, vertical and horizontal method.
JEL Classification: O33, Q56.

Introduction

2014 central economic work conference held in Beijing on December 9 to 11 points out that the energy resources and ecological environment space was opposite bigger, but now environmental carrying capacity is at or close to the limit. The government must conform to the people looking forward to living in a good ecological environment and promote new ways of green low carbon cycle development. It is the first time in history to combine economic development with environmental carrying capacity in the central economic work conference. Taking Chinese provincial and regional economic units as research objectives, we establish an environmental quality comprehensive evaluation system of multi-dimension and multi-index introducing the evaluation method based on the overall differences driving and characterize environmental quality status and dynamic changes from environmental pollution index, environmental pollution intensity index and per capita environmental pollution index.

There is no practical environmental indicator that can fully characterize the overall level of the environmental damage and resource depletion. Common environmental evaluation index can be divided into single dimension environmental quality evaluation index and multi dimension environmental quality evaluation index. Numerous studies have demonstrated that single dimension index is mainly used to study the local problems and targeted evaluation of environmental quality which can reflect the present situation of environment through carbon dioxide (Lindmark, 2002; Huang et al., 2008; Lin Bo-Qiang, Jiang Zhu-Jun, 2009), sulfur dioxide (Stern, 2004; Merlevede et al., 2006; Tu Zheng-Ge, 2008; Chen Hong-Lei, Chen Qiu-Feng, 2009), suspended particle (Dasgupta et al., 2005; Akbostanei et al., 2009), carbonic oxide (Bartz et al., 2008), water pollutant (Roca et al., 2007), forest coverage rate (Culas, 2007; Wang et al., 2007), utilization of natural resources (Luzzati et al., 2009; Esmaeili et al., 2007), but to study the overall environmental quality evaluation will be quite narrow. Human environment is an organic whole based on multiple factors, it will not be able to judge the environment overall quality if water environment is improving, meanwhile air condition is deteriorating, or indicators reflect soil quality improving meanwhile other indicators are facing the risk of deterioration. Multidimension index considering various environmental factors is beneficial to make a comprehensive analysis on environmental quality, Rolf Fare, Shawna Grosskopf (2010) use toxic release inventory (TRI) to build a comprehensive environmental performance evaluation index containing a variety of pollutants to estimate the power plant performance. Shen Feng (2008), Yang Wan-Ping, Yuan Xiao-Ling (2008), Yuan Xiao-Ling, Zhang Bao-Shan (2009), Yang Long, Hu Xiao-Zhen (2010), Shen Neng (2010) construct the China's comprehensive pollution index through Barometer of Sustainability (1995), the United Nations Sustainable Development Index (2001), Environmental Sustainability Index (2002), Environmental Performance Index (2006) et al. However, the existing research scope of index of China is a lack of authoritative and practicability due to the data availability and continuity. It is necessary to build an environmental quality comprehensive evaluation system which accords with the situation of China.

Common environmental quality evaluation methods include index method, main component method, factor analysis and analytic hierarchy process (AHP), fuzzy evaluation method, grey measuring method, entropy method. The several kinds of evaluation methods above have their own advantages, but all of them neglect the degree of difference between each index evaluation object and only focus on the important indicators in the evaluation, but ignore the variation degree of different evaluation object index information and the degree of impact on the rest of the indicators.

1. Comprehensive environmental quality evaluation system

1.1. Evaluation system. In order to fully reflect the environmental quality as much as possible, combining with research data availability, continuity and consistency of statistical data, this article selects 11 indicators, including selection of carbon dioxide emissions, industrial waste gas emissions, sulfur dioxide emissions, dust and soot emissions, industrial emissions, industrial wastewater emissions, sewage, industrial solid waste emissions and noise equivalent sound level, living garbage, to estimate the provincial environmental quality. This article also constructs environmental pollution index ($EN_{index\text{-}1}$), environmental pollution intensity index ($EN_{index\text{-}2}$), per capita environmental pollution index ($EN_{index\text{-}3}$) to characterize environmental status from different perspectives.

For carbon emissions, China has not formally published data from official statistics and authorities, the calculation methods are also different (Lin Bo-Qiang, Jiang Zhu-Jun, 2009; Lei Li, Zhong Yun-Yun, Yuan Xiao-Ling, 2011). The estimation method of this paper is based on the IPCC (2006). Energy consumption is from terminal energy consumption data of all the provinces. Calculation method is shown in formula (2-1):

$$C_{it} = \sum E_{ijt} \times \eta_j \; i = 1,2...30 \; j = 1,2...9. \quad (1)$$

C_{it} represents carbon dioxide emission of the province i in year t. E_{ijt} represents the terminal energy consumption j of the province i in year t. η_j represents the energy emission coefficient j. According to the China Energy Statistical Yearbook, we divide the types of terminal energy consumption into raw coal, coke, crude oil, gasoline, kerosene, diesel oil, fuel oil, natural gas, electricity. Energy conversion coefficient and discharge coefficient are shown in Table 1.

Table 1. Coefficient of standard coal and CO_2 emission in energy

	Raw coal	Coke	Crude oil	Gasoline	Kerosene	Diesel oil	Fuel oil	Natural gas	Electricity
Conversion coefficient	0.714	0.971	1.429	1.471	1.471	1.457	1.429	13.3	1.229
Discharge coefficient	0.755	0.855	0.585	0.591	0.574	0.591	0.618	0.448	reformulate

Electric discharge coefficient is evaluated according to the provincial generated energy every year (mainly coal-fired power) and power generation fuel emissions of carbon dioxide. Data are from national bureau of statistics (NBS) environment statistical materials except the data on carbon dioxide.

1.2. Evaluation methodology. This article uses vertical and horizontal method proposed by Guo Ya-Jun (2007). This method makes empowerment of the original information directly from the objective environment, calculates the corresponding weight according to the size of the information provided by the index thus utmost ground reflects the overall difference between the evaluated object. Moreover, it's completely objective evaluation which avoids the influence of man's subjective preferences on the result of evaluation. Each evaluation objects are comparable in between meets objectivity, diversity, complexity and dynamic requirements of environmental quality evaluation, particularly suitable for panel data. Set up the comprehensive evaluation function as formula (2):

$$y_i(t_k) = \sum_{j=1}^{m} \omega_j x_{ij}(t_k), \; (k = 1,2,...,N, N = 8; i = 1,2,...,n, n = 30; j = 1,2,...,m, m = 11), \quad (2)$$

$y_i(t_k)$ is integrated evaluation value of evaluated regional in year t_k, ω_j is factor weight, $x_{ij}(t_k)$ is the pollutant index j of province i in year t_k. ω_j is based on the maximum of the difference between evaluated regionals as:

$$\sigma^2 = \sum_{k=1}^{N}\sum_{i=1}^{n}(y_i(t_k) - \bar{y})^2 \quad (3)$$

$\{x_{ij}(t_k)\}$ needs a dimensionless processing as $\bar{y} = \frac{1}{N}\sum_{k=1}^{N}\left(\frac{1}{n}\sum_{i=1}^{n}\sum_{j=1}^{m}\omega_j x_{ij}(t_k)\right) = 0$. Formula (3) can be expressed as Formula (4):

$$\sigma^2 = \sum_{k=1}^{N}\sum_{i=1}^{n}\left(y_i(t_k)\right)^2 = \sum_{k=1}^{N}\left[\omega^T H_k \omega\right] = \omega^T \sum_{k=1}^{N} H_k \omega$$

$$\omega = \omega_1, \omega_2, ..., \omega_m)^T$$

$$H_k = A_k^T A_k (k = 1,2,...,N) \quad (4)$$

$$A_k = \begin{bmatrix} x_{11}(t_k) & ... & x_{1m}t_k) \\ ... & & ... \\ x_{n1}(t_k) & ... & x_{nm}(t_k) \end{bmatrix}$$

$$H = \sum_{k=1}^{N} H_k$$

It can be proved that:

1. If $\omega^T\omega = 1$, σ^2 reaches maximum and $\max_{\|\omega\|=1} \omega^T H\omega = \lambda_{\max}(H)$ when ω is the eigenvector of maximum eigenvalue $\lambda_{\max}(H)$ of matrix H.
2. When $H_k > 0 (k = 1,2,...,N)$, the order of evaluated objects is the same by means of horizontal method and vertical and horizontal method in year t_k.

1.3. Evaluation procedure

1. Data pre-processing. Raw data needs a dimensionless processing for each index cannot be directly weighted rally with different dimension, magnitude and lack of comparability between each other. Dimensionless processing methods include standardized treatment method, the extreme value method, the linear ratio method, the normalization processing method, vector norm method and efficacy coefficient method, etc. Due to the dimensionless processing method has a great influence on the result of vertical and horizontal method, we choose the dimensionless method which makes the overall difference larger between evaluation objects. $\forall_j$, if $M_j > 2m_j > 0$, $x_{ij}^* = x_{ij}/m_j$ is ideal, if $0 < M_j < 2m_j$, $x_{ij}^* = (x_{ij} - m_j)/(M_j - m_j)$ is ideal. If $\exists j'$ and $\exists j''$, $M_{j'} > 2m_{j'}$ and $0 < M_{j''} < 2m_{j''}$, $j' \neq j''$, the larger the $\sum s_j^{*2}$, the better.
2. Calculates the real symmetric matrix $H_k = A_k^T A_k (k = 1,2,...,N)$ according to formula (5).
3. Solves the eigenvalue of maximum and the standard feature vector λ' of the real symmetric matrix H, $H = \sum_{k=1}^{N} H_k$.
4. Normalization processes the standard feature vector λ' to determine the combination weight vector w_j.
5. Formula (2) is used to calculate different environment index.

2. China regional environmental quality comprehensive evaluation

2.1. Environmental pollution index ($EN_{index-1}$).

Make use of pollutant total amount for comprehensive evaluation and analyze through different areas[1]. The higher the index $EN_{index-1}$, the more comprehensive pollutant emissions and the worse environmental quality.

Table 2. Environmental pollution index $EN_{index-1}$ from 2003 to 2012

Province	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Mean value
Beijing	6.4	6.1	5.5	5.4	5	4.5	4.5	4.4	4.3	3.9	5
Tianjin	5.8	5.1	6.4	6.2	5.2	5	5	5	4.8	4.7	5.32
Hebei	45.2	54.1	50.5	47.8	49.4	45.1	44.8	47.7	48.9	49.5	48.3
Shanxi	43.3	43	45.4	44.5	42	38.3	35.3	36.3	36.1	36.7	40.09
Inner Mongolia	24.1	27.2	32.9	32.3	31.1	29.8	29.5	33.4	31.2	32.1	30.36
Liaoning	33.6	32.1	38.3	39	38.9	36.3	34.3	33	32	33	35.05
Jilin	12.8	13.9	17	17.6	15.2	14.6	15	14	13.8	14	14.79
Heilongjiang	18.8	18.5	22.8	23.1	19.2	18.6	18.4	17.5	17.1	17.2	19.12
Shanghai	11.7	10.9	10.8	10.6	9.6	9.1	8.6	8.4	7.9	7.5	9.51
Jiangsu	37.2	37.3	37.9	37.6	34.2	31.8	30.7	30.8	31.2	31.5	34.02
Zhejiang	22	22.1	19.7	19.6	20	19.2	18.8	18.4	17.7	17.2	19.47
Anhui	22.4	22.4	20.9	21.5	23.2	23.7	23.3	22.9	23.1	23.3	22.67
Fujian	14.6	15.1	14.6	14.4	15.8	15.3	15.4	16	15.7	15.5	15.24
Jiangxi	20.3	20.7	19.4	18.9	20.4	19.1	18.5	18.1	18	17.9	19.13
Shandong	48.2	45	48	46.5	43.5	41.3	40.5	39.7	38.6	38.9	43.02
Henan	40.1	42.9	48.3	46.2	43	40	39.7	37.7	38.2	38.5	41.46
Hubei	24.3	24.8	23.4	23.2	22.8	21.8	21.2	20.6	20.2	20.6	22.29
Hunan	28.4	30.2	26.5	25.3	29.7	27.9	27.1	24.7	24.5	25.1	26.94
Guangdong	30.5	30.2	29.3	28.8	29.8	29.9	27.1	26.8	25.9	25.5	28.38
Guangxi	27.3	28.4	27.7	26	26.1	25.9	25.6	23.9	24.2	24.1	25.92
Hainan	1.7	1.8	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.58	1.628
Chongqing	14.7	14.9	13.8	13.8	14.2	14.2	13.6	12.5	12.8	12.6	13.71
Sichuan	35.7	36.5	36	33.4	30.5	26	24.8	26.3	25.8	26.2	30.12
Guizhou	21.7	21	20.3	19.6	19.7	18.9	20.8	17.3	18.9	19.2	19.74

[1] China can be divided into three regions: Eastern region includes Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Hainan, Shandong, Guangdong; central region includes Shanxi Province, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan; western region includes Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang.

Table 2 (cont.). Environmental pollution index $EN_{index\text{-}1}$ from 2003 to 2012

Province	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Mean value
Yunnan	14.5	14.8	15.6	16.4	17.2	16.3	16.3	15.4	15.7	15.5	15.77
Shaanxi	19.2	20.9	20.5	20.3	21	19.8	17.4	17.6	18	18.2	19.29
Gansu	11.8	11	10.9	10.5	10.3	10.1	10.4	10.7	10.5	10.9	10.71
Qinghai	2.6	3.2	3	3.2	4.2	4.4	4.3	5.1	5	5.2	4.02
Ningxia	6.8	5.7	6.4	6.4	6.5	6.1	5.8	8.4	7.8	6.9	6.68
Xinjiang	10.2	11.8	11.6	12.3	14	15.2	15.7	16.6	15.8	16.2	13.94

From a regional perspective, $EN_{index\text{-}1}$ has a downward trend in the central region, the eastern region and the western region which conforms to the fact of the highest proportion of secondary industry in central region. Judging from the provinces, the comprehensive environmental quality of Hainan, Qinghai, Beijing are the best, Hebei, Henan, Shandong are the worst. Chronologically speaking, China's comprehensive environmental quality increases year by year as a whole, while the comprehensive environmental quality of Hebei, Inner Mongolia, Anhui, Fujian, Gansu, Qinghai, Xinjiang shows a downward trend which is noteworthy. From a policy plan period perspective, during the tenth 5-years project (2001-2005), most of provinces were not systematically to carry out the environmental protection plan, comprehensive environmental quality changes mainly depends on economic growth and industrial structure adjustment. During the eleventh 5-years project (2006-2010), more environmental protection pressure was borne by the less developed areas for many polluting enterprises such as chemical plants, power plants, etc. moved from more developed areas as administrative measure required and pollution control requirements got higher. It can be clearly seen that comprehensive environmental quality improved in the developed region while deteriorated in less developed areas though all regions were introduced with the environmental protection policy. This trend has still not fundamentally changed until 2012.

2.2. Environmental pollution intensity index ($EN_{index\text{-}2}$). Evaluating the regional environmental quality from the perspective of economic development cost has great significance to China's economic development, which side reflects the quality and sustainability of economic development among regions. Environmental pollution intensity refers to the pollutants produced per unit of GDP. The higher $EN_{index\text{-}2}$, the greater the environmental cost of economic development.

Table 3. Environmental pollution intensity index $EN_{index\text{-}2}$

Province	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Mean value
Beijing	1.6	1.7	1.4	1.3	1.6	1.5	1.6	1.5	1.5	1.4	1.51
Tianjin	3.1	3	4.3	4.3	3.4	3.2	3.4	3.4	3.3	3.2	3.46
Hebei	11.5	12.6	9.6	10.6	16.5	15.5	14.7	12.2	12.3	12.2	12.77
Shanxi	25.7	25.7	22.1	25.3	38.2	29.3	29	22.6	26.3	25.7	26.99
Inner Mongolia	18	20.1	19.5	20.2	23.2	22.4	21.2	21.1	21.5	21.9	20.91
Liaoning	8	8.5	8.9	9.6	15.3	11.8	10.8	8.7	9.5	9.3	10.04
Jilin	8	9	11	12.8	12.4	10.7	11.3	10.3	11.1	10.8	10.74
Heilongjiang	6.3	6.6	9.8	11.2	10.3	10	10.6	8.8	9.2	9.2	9.2
Shanghai	1.7	1.7	1.9	2	1.8	1.9	1.8	1.8	1.7	1.8	1.81
Jiangsu	5.8	5.5	5.3	5.7	6.8	6.1	5.8	5.5	6.1	6	5.86
Zhejiang	4.7	4.6	3.4	3.8	5.8	5.5	5.6	4.8	4.6	4.5	4.73
Anhui	13.3	13.5	9.6	10.9	18.5	18.1	17.3	14.9	16.8	17	14.99
Fujian	5.3	5.8	4.9	5.4	9.5	9.2	9	7.8	8.3	8.1	7.33
Jiangxi	13.8	14.2	9.6	10.4	21.1	19.4	18.5	14.7	18.1	17.6	15.74
Shandong	8.2	6.3	6	6.3	8	7.4	7.3	7	7.2	7.5	7.12
Henan	12.9	12.9	11.5	12.2	14.8	12.4	12.8	12.1	12.8	12.6	12.7
Hubei	10	10.3	8.2	8.9	13.3	11.9	11.4	9.9	10.7	10.2	10.48
Hunan	14.5	14.9	9.2	9.6	22.7	19.1	19.9	13.5	18.4	18.1	15.99
Guangdong	3.8	3.8	2.9	3.3	4.7	4.5	3.7	3.6	3.9	4.1	3.83
Guangxi	19.9	20.1	16.4	17.4	27.5	26	30.7	21.7	28.6	27.5	23.58
Hainan	6.6	7.3	6.8	7.1	8.8	8.4	8.9	8.2	8.3	8.5	7.89
Chongqing	12.2	12.4	8.9	9.1	16.3	14.4	12.7	10.4	11.8	12.3	12.05
Sichuan	11.4	11.3	10.2	10.5	11.2	9.3	9	9.2	10.8	11.2	10.41

Table 3 (cont.). Environmental pollution intensity index $EN_{index\text{-}2}$

Province	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Mean value
Guizhou	22.1	21.6	14.4	14.5	23.4	20.8	20.3	17	19.5	18.7	19.23
Yunnan	8.5	8.7	8	9.3	13.4	12.5	12.3	11.5	12.7	11.8	10.87
Shaanxi	15	15.8	11.1	11.9	21	16.6	14.4	14.4	15.8	15.8	15.18
Gansu	14.9	14.2	10.9	11.1	16.7	15.5	16.3	15.2	16.8	17.1	14.87
Qinghai	17.7	22.2	11.5	12.5	34.8	32.7	31.7	33.8	34.2	33.7	26.48
Ningxia	39.3	25	23.3	24.5	32.7	23	23	28.4	25.7	26.1	27.1
Xinjiang	10.8	11.9	9	10.5	20.2	20.3	22.5	19	21.2	20.1	16.55

The ranks of $EN_{index\text{-}3}$ between the east, the central and the west are identical to $EN_{index\text{-}2}$, showing that the western region needs to take seriously the economic development pattern transformation and improve the efficiency of comprehensive pollution environment. The trend shows that, $EN_{index\text{-}3}$ of the eastern region declines year by year, especially accelerates significantly after 2008. There is also a downward trend in more developed provinces in the central region, but smaller compared with the eastern region. $EN_{index\text{-}3}$ of the central region and the relatively backward areas of the western region change little or even appear rising trend. On the one hand, economic development pattern transformation and industrial structure adjustment are faster in the eastern part than the other areas, on the other hand, it results in the population flowing from the middle-western region to the eastern region.

Conclusion

This paper constructs an environmental quality comprehensive evaluation system consisted of 6 dimensions containing 11 factors, dynamically evaluates China's regional comprehensive environmental quality in 2003-2012 through the vertical and horizontal method. Results indicate that:

1. From the perspective of environment pollution total amount, environmental quality is best in the western region, and the eastern region takes second place, the central region is the worst. For all that, environmental quality presents downtrend in the western region in recent years which needs to draw high attention. Hebei, Henan, Shandong are the key areas of environmental protection due to $EN_{index\text{-}1}$.
2. From the perspective of environmental costs, the environmental cost of economic development in the western region is the largest, with the conclusion (1), we believe that the rich environmental resources in the western region and low degree of economic development can explain this difference of ranking. For the past few years, there are heavily polluting enterprises transferring from developed regions to the underdeveloped areas in order to be out of pollution emissions limits. However, the lagging development regions are always plagued with fragile ecological environment, these transfers tend to cause more serious pollution, even make the local people get severe disease, such as cancer, asthma and leukemia. The unified national emission standard and monitoring system are badly in need.
3. From the perspective of the per capita emissions, the western region is the largest, just like the conclusion (2), also proves our point of view in conclusion (2). We find $EN_{index\text{-}3}$ of the central region and the relatively backward areas of the western region change little or even appear rising trend because of the larger labor demand of the highly developed third industry such as catering industry, housemaid service, pension services, etc. in the eastern region, meanwhile. Population transition is always faster than the economic development mode transformation.

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