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Evolution of Environmental Quality of Jiangsu Prefecture Cities

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Abstract: Being one of the most developed provinces in China, Jiangsu pays heavy ecological and environmental costs. This paper establishes a comprehensive evaluation system of environmental status in prefecture cities of Jiangsu Province. Waste in water, gas and solid waste are used as indicators. The method of "Vertical and Horizontal scatter" is applied to obtain the comprehensive index. Industrial waste water discharge is the main factor influencing environmental quality. Environmental quality is reflected by total amount of pollution emissions and environmental costs of economic development. Results show that the two indexes both increase in the research period. Environmental quality in the total pollution emissions is negative related to the level of economic development. Cities in lease developed noth area perform best in total pollution emissions while those in the most developed south part does the worst. Environmental quality in economic cost does not show a clear spacial distribution.

Keywords: environment quality; comprehensive evaluation; Vertical and Horizontal scatter;pollution emission; Jiangsu

1 Introduction

Jiangsu province is the largest administrative unit in Chinese government, after the nation itself. Jiangsu is a microcosm of contemporary China: it is the third-wealthiest province, but there exists a stark divide between its prosperous south, centered on the former national capital of Nanjing, and its poor, rural north. Urban air quality is so poor that Jiangsu provincial authorities shuttered factories and power plants throughout the Nanjing area in the weeks leading up to the 2014 Youth Olympics, in order to ensure clean air for athletic events. Other cities in this province suffers a lot in certain kinds of pollution. It is practically significant to make comprehensive evaluation of the environmental situation at prefecture level of Jiangsu Province.

A number of approaches to assessing environment quality are currently in use. The most common urban environmental assessment tools can be divided into two major types. The first is a set of indicators that can be used to assess a single environmental property; for example, the concentrations of a set of air pollutants is used to assess overall air quality. The second is an index in which the indicators for environmental components of interest are synthesized into single metrics or index values. Environmental quality are assessed by those metrics or index values[1–3]. Li and Zhang [4] built a comprehensive environment quality assessment index by the AHP method. They analyzed the tendency of environment quality of China Wen et al. [5] applied the matter-element extension theory and the entropy weight method to build environment quality evaluation model.In [6], the environmental pollution and disposal effect of each province was evaluated by entropy-TOPSIS method and dynamic evaluation method. Liu and Li [7] used a BP neural network model for urban environment quality evaluation. In the model the neural network method without the artificial weights can objectively reflect the relationship among the evaluation indices through the self-learning process of the neural network, but it needs a large number of the samples for training, and is easy to fall into the local optimum[8].

In this paper, we build a comprehensive index to measure the environment quality from four indicator: industrial water discharge, industrial waste gas, industrial solid wastes generation and industrial smoke dust emissions. We use the "Vertical and Horizontal scatter" method [9]. Each indicator is integrated in the index by its weight. The greater the weight, the more important the indicator. It has been proved that the weight obtained in this way can grantee a maximum

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variance in values of the index [9]. Compared to the AHP method in which there is a calculation of the consistency test besides a weight matrix, the method in this study is better. The method in this study also outperforms entropy method [9]. The principle of the entropy method [9] is that the greater the difference among the measured values of the indictor, the lager the weight, vice versa. But the most important index may not make the attribute of all the evaluated objects with the largest difference, and the unimportant one may make the attribute of all the evaluated ones with the largest difference. Therefore important indictors might have small weight coefficient but the unimportant one big. The method used in this paper overcomes the shortcoming of the entropy method.

The rest of the paper is organized as follows. Section 2 presents the methodology. Section 3 gives the empirical results as well as analysis. The last section devotes to conclusion.

2 Methodology

2.1 Indicators

The purpose of the index is to enable a comprehensive and thorough assessment of prefecture environment quality. We construct a comprehensive evaluation system for environment quality. In this system, we consider the environment quality from the topic of water, gas, solid waste and smoke dust. Then there are four indicators in the system: industrial water discharge, industrial waste gas, industrial solid wastes generation and industrial smoke dust emissions. They are selected to be the indictors due to two reasons. The first is that industrial waste emissions are the most important indicators of environmental pollution in Jiangsu [10]. The second is that data for those indicators is available in the study cities.

2.2 Data

There are 13 prefecture cities in our study: Changzhou (CZ), Huaian (HA), Lianyungang (LYG), Nanjing (NJ), Nantong (NT), Suqian (SQ), Suzhou (SZ), Taizhou (TZ), Wuxi (WX), Xuzhou (XZ), Yancheng (YC), Yangzhou (YZ) and Zhenjiang (ZJ). We select the study period to be 2007-2014.Data for the four indicators are obtained from statistical yearbooks. Unites for the indictors are: ten thousand of tons for water and solid waste, ton for smoke dust, hundred of million standard m^3 for waste gas. The unit for gross domestic product (GDP) is measured in hundred of million Chinese Yuan. The value GDP is converted in 2005 constant price.

Data are standardized at the first stage to eliminate the impact of differences in the units. Methods of data standardization in the literature includes: extreme method, linear proportion method, normalization processing method, vector norm method and efficacy coefficient method and so on. Different dimensionless methods has a great impact on the values of the comprehensive index, we select the one which "reflects the overall differences of the evaluation object as much as possible"[11].

Let x_{ij} be the original data for the $i-$th cityand the $j-$th indicator. Let x^*_{ij} be the standardized value of x_{ij}. Let M_j and m_j be the maximum and minimum of the $j-$th indicator respectively. Then the original data are transformed into the dimensionless once as the following:

- If $M_j > 2m_j > 0$ for any j, we use the linear proportion method: $x^*_{ij} = x_{ij}/m_j$.
- If $m_j > M_j > 0$ for any j, we use the extreme method: $x^*_{ij} = x_{ij} - m_j)/(M_j - m_j)$.
- If there exist j' and j'' such thar $M_j > 2m_j > 0$ and $2m_j > M_j > 0$, we select the one from the linear proportional method and the extreme method with the larger variance.

2.3 Evaluation Model

We calculate the comprehensive environment quality index from the above four indicators by the "Vertical and Horizontal scatter" method [9].

The comprehensive environmental quality is given in the following

$$y_i(t_k) = \sum_{j=1}^{4} \omega_j x^*_{ij}(t_k), (k = 1, 2, \cdots, 8; i = 1, 2, \cdots, 13), \tag{1}$$

where $y_i(t_k)$ is the value of environment quality, x_j^* is the standardized indicator, the subscripts i and j refer to the order of cities and indicators, t_k stands for the year from 2007-2014 consecutively, ω_j stands for the weight of x_{ij}^*.

The weight is the key to evaluate the environment quality. It is calculated as the following steps:

1. Make the standardized indicator matrix for each year: $A_k = \begin{bmatrix} x_{11}^*(t_k) & \cdots & x_{1m}^*(t_k) \\ \vdots & \vdots & \vdots \\ x_{n1}^*(t_k) & \cdots & x_{mm}^*(t_k) \end{bmatrix}$, where n is the number of cities and m is the number of indicators.
2. Make the m-order symmetric matrix $H = \sum_{k=1}^{N} H_k$, where $H_k = A_k^T A_k (k = 1, 2, \cdots, N)$.
3. The weight $\omega = (\omega_1, \omega_2, \cdots, \omega_m)^T$ is taken as the normalized eigenvector corresponding to the largest eigenvalue of the matrix H.

3 Evaluation results and analysis

We used two indexes to measure environment quality. One is called $EN_{index} - 1$ which is an absolute measure. Another is called $EN_{index} - 2$ which is an intensity measure. Both indexes were calculated by using (1). The difference lies in that $EN_{index} - 2$ uses the relative data, i.e., pollution value divided by the GDP, while $EN_{index} - 1$ used the absolute data, i.e., the pollution value.

Firstly, we calculated Environmental pollution index $EN_{index} - 1$. Linear proportion method was applied to standardize the original pollution data. Following the steps in section 2.3, after a normalization, we obtained the weight vector $\omega = (0.6180, 0.1090, 0.2184, 0.0547)$. This means that waste water discharge is the most important component influencing environment quality. Then we had the comprehensive environmental evaluation index of each city by (1).

$EN\_index-1$ is a comprehensive evaluation value of the total pollution emissions, and is a comprehensive evaluation of the environmental conditions from the absolute perspective[12]. Fig. 1 shows the evolution of $EN\_index-1$ for some cities. Greater value in $EN\_index-1$ indicates worse quality in environment. It can be seen from the figure that environmental situation deteriorated for every city. Fig. 2 shows the ranking of cities according to $EN\_index-1$. The greater the $EN\_index-1$, the lower rank and the worse environmental situation. It is shown that there are spacial variation in environmental situation. The south part (Suzhou, Nanjing, Wuxi) maintained the worst environmental quality, the center the intermediate and the north the best. The ranking for the center and most cities of the north varied in the research period. As we mentioned in the introduction, the developing level decreases from the south to the north. Thus economic development does do harm to the environment.

Secondly, we calculate the environmental pollution intensity index $EN_{index} - 2$. This index is generated by (1) using the unit GDP (per million). It evaluates environmental pollution situation from the perspective of economic development costs in these cities.

Fig. 3 shows the evolution of $EN\_index-2$ for some cities. We can see that the $EN\_index-2$ of the six cities continuously rise from 2007 to 2011, indicating that the environmental costs of economic development are increasing year by year. From 20012 to 2014, the $EN\_index-2$ of Suzhou and Xuzhou decreased, reflecting that economic development efficiency was improved. But Lianyungang and Suqian have rapid growth indicating that the environmental costs of economic development were seriously declined. Thus,in order to avoid exacerbating environmental pollution, local governments should pay attention to and make efforts in improving economic efficiency. We also note that there is not a unique trend for the evolution except for that of Suqian, which is increasing. Intensity indexes of most cities fluctuate with a minimum at 2009. This can be thought as the result of 2008 Asian Financial Crisis. Compared to Fig. 2, the north part still has the best relative environment quality but some south cities, such as Suzhou, improve their relative quality value. This is because they have a great amount of GDP.

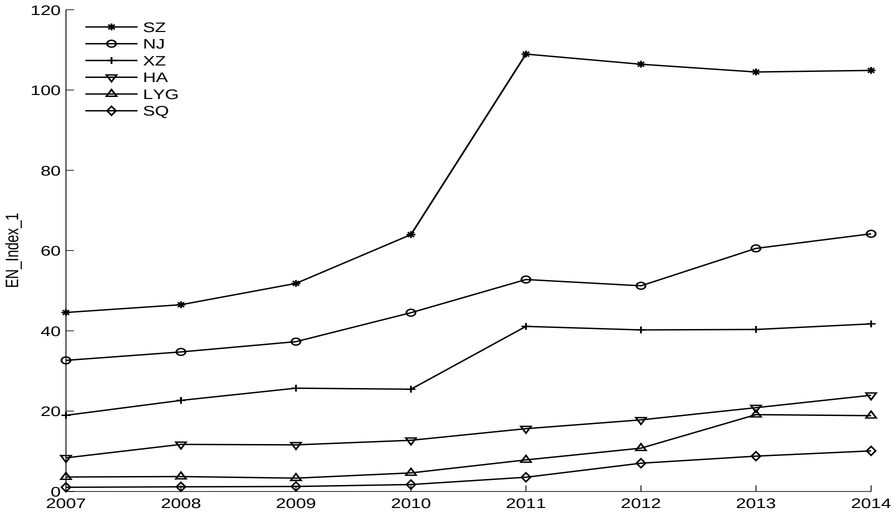

Figure 1: Evolution of $EN\_index\!-\!1$ of some cities

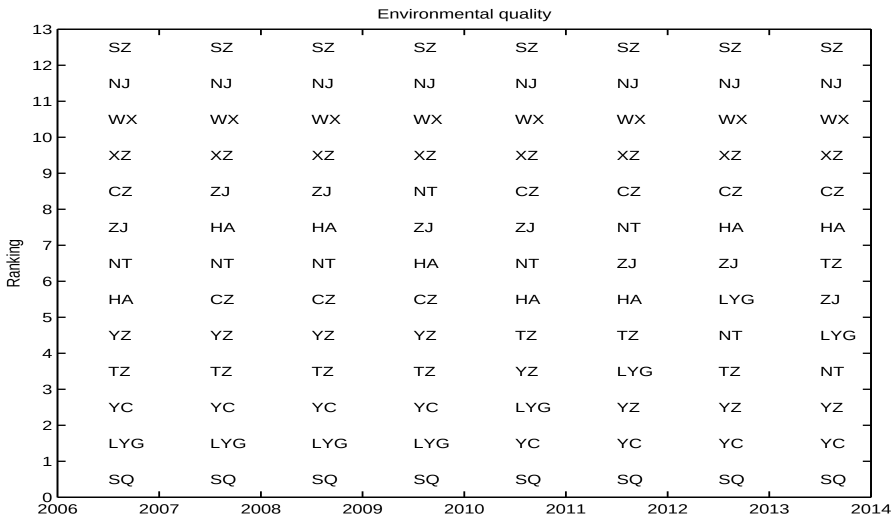

Figure 2: Rangking of environment quality

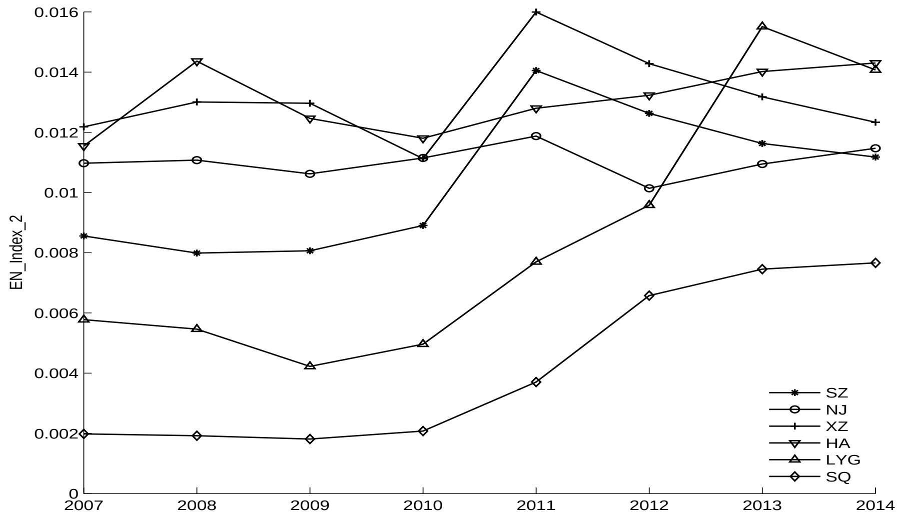

Figure 3: Evolution of $EN\_index{-}2$ of some cities

Fig. 4 shows the ranking of relative environment quality. As it can be seen in the figure, Yancheng and Suqian have smaller ranking value, indicting smaller environment costs for economic development. And the pollution intensity index ranking of Xuzhou, Huaian, Nanjing and Zhenjiang are higher which reflects that environmental costs of economic development in these cities are greater. Therefore, for those four cities, to improve the efficiency of economic development is the key of energy conservation and emissions reduction.

4 Conclusion

Based on the index set of industrial waste water discharge, industrial waste gas, industrial solid wastes generation and industrial smoke dust emissions, this paper constructed an evaluation system of environment quality. We applied the "Vertical and Horizontal scatter" method to give a quantitative index of the environment quality in prefecture cities in Jiangsu province. We provided policy makers and the public with valuable information:

(1) During the whole research period, the environment quality has been deteriorating, the environmental costs of economic development have been keeping increasing. How to maintain a sustainable development is a hard task for the provincial government.

(2)In terms of the perspective of environmental total pollution emissions, the $EN\_index{-}1$ of Suqian, Lianyungang and Yancheng are lower,which indicates less pollution emissions. The $EN\_index{-}1$ are the highest in Suzhou, Nanjing, Wuxi and Xuzhou , indicating that pollution emissions are the largest and integrated environmental situation is worse. Therefore,the environmental protection departments should make efforts to control pollution emissions and prevent environmental degradation.

(3)In terms of the perspective of environmental costs of economic development,with the lower environmental pollution intensity index $EN\_index{-}2$, environmental costs of economic development in Yancheng and Suqian are lower. With higher ranking of $EN\_index{-}2$, the cities of Xuzhou,Huaian, Nanjing and Zhenjiang have higher environmental costs of economic development and are weak insustainable development. It is urgently needed to improve economic efficiency to avoid deterioration of the environment.The value of $EN\_index{-}2$ Lianyungang and Suqian economic efficiency. Local authorities need to pay attention to environmental protection.

However, assessment tool in this study has some shortcomings: there are only four indictor while some important components in social field have not been included; it is a relative assessment in which environmental performance is evaluated relative to other cities, not against established environmental benchmarks. Further studies could improve the assessment tool.

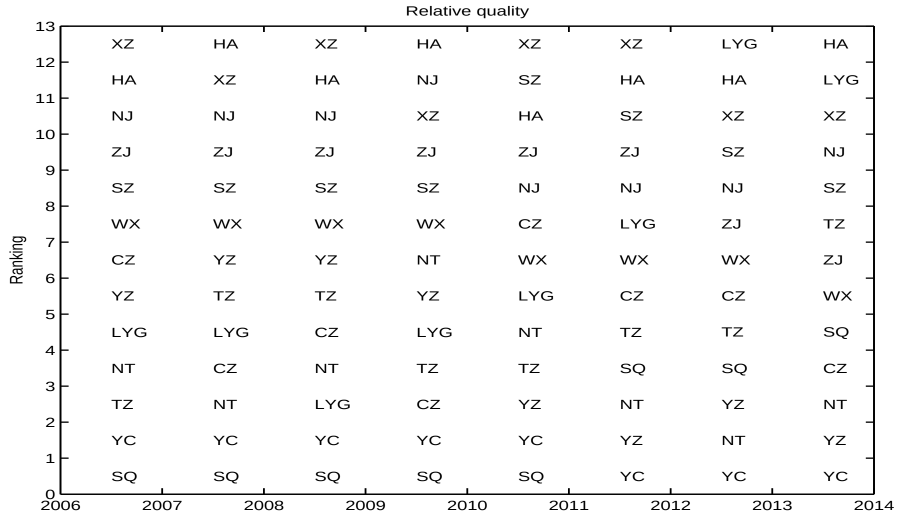

Figure 4: Rangking of relative quality

Acknowledgement

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