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Study on Environment Performance Evaluation and Regional Differences of Strictly-Environmental-Monitored Cities in China

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Abstract: With the rapid economic growth and development, the problem of environmental pollution in China's cities is becoming increasingly serious, and environmental pollution takes on a regional difference. There is, however, little comprehensive evaluation on the environmental performance and the regional difference of strictly-environmental-monitored cities in China. In this paper, the environmental performance of 109 strictly-environmental-monitored cities in China is evaluated in terms of natural performance, management performance, and scale performance by Data Envelopment Analysis (DEA), incorporating $PM_{2.5}$ and PM_{10} as undesirable outputs. The empirical results show that: (1) At present, the natural performance is quite high, while the management performance is noticeably low for most cities. (2) The gap between the level of economic development and environmental protection among cities in China is large, and the scale efficiency of big cities is better than that of smaller cities. The efficiency value of large-scale cities such as Beijing, Shanghai, Guangzhou, Shenzhen, etc. is high, equaling 1; the value of smaller cities such as Sanmenxia, Baoding, Mudanjiang, and Pingdingshan is low, close to 0, indicating that big cities are characterized by high environmental efficiency. (3) From the perspective of region, the level of environmental performance in China is very uneven. For example, the environmental efficiency level of the Pan-Pearl River Delta region is superior to that of the Pan-Yangtze River region and the Bahia Rim region, whose values of environmental efficiency are 0.858, 0.658, and 0.622 respectively. The average efficiency of the Southern Coastal Economic Zone, Eastern Coastal Comprehensive Economic Zone, and the Comprehensive Economic Zone in the middle reaches of the Yangtze River is higher than that of other regions. Finally, corresponding countermeasures and suggestions are put forward. The method used in this paper is applicable to the performance evaluation of cities, and the results of the evaluation reflect the differences of the environmental performance level between strictly-environmental-monitored cities and different regions in China, providing reference for the balanced environmental development of cities and regions.

Keywords: DEA; environment performance; strictly-environmental-monitored cities; $PM_{2.5}$; PM_{10}

1. Introduction

With rapid economic growth, the problem of air pollution is increasingly serious. $PM_{2.5}$ and PM_{10}, the embodiment of air pollution, have instigated widespread public attention from the community. The Environmental Performance Index: 2016 report [1] released by Yale University has ranked the air quality in more than 180 countries in the world, with China ranking last but one. Among the index, China's exposure to nitrogen dioxide averaged at 15.29 (falling into the bottom five in the world), the average exposure to $PM_{2.5}$ was 2.256 (last-placed worldwide) and the $PM_{2.5}$ exceedance was 0 (the second worst out of 180). In addition, according to data from WHO, nearly 2.4 million people die of air pollution every year in China, of which about 300,000 are dead because of outdoor air pollutants [2]. $PM_{2.5}$ consists mainly of black carbon, sulfates, nitrates(NO^{3-}), ammonium, K(K^+), Mg, Ca, Na, Cr, etc., of which black carbon and K^+ may increase the risk of contracting asthma [3]. Moreover, Cr poses the highest risk for developing carcinogenic illness [4]. Thus, it can be seen that the problem of air pollution in China is extremely serious, and therefore studies on the environment performance evaluation are considerably significant and urgent.

At present, there are 113 strictly-environmental-monitored cities in China, only 23.9% [5] of whose air qualities meet the standards. The national development depends largely on cities that lead the future development of the country. The sustainable development of cities is an important basis for the country's future development competitiveness. The evaluation of the environmental performance of strictly-environmental-monitored cities in China and the regional comparative analysis can provide empirical support for the sustainable development of cities. However, there is no research on the methods and indicators that can be adopted to evaluate the environmental performance of strictly-environmental-monitored cities in China, and on the differences of the environmental performance of Chinese cities in different regions, etc. In light of the above circumstances, the advanced Data Envelopment Analysis (DEA) method is employed in the paper and $PM_{2.5}$, PM_{10} and other pollutants are used as the indicators in the evaluation. The environmental performance of 109 strictly-environmental-monitored cities in China is evaluated in terms of natural performance and management performance. The *t*-test is conducted to compare the regional differences of environmental performance of different Chinese cities. Finally, relative suggestions concerning the management of Chinese environmental pollution are put forward.

The remaining parts are as follows: the second part is a related literature review; the third part concerns model, indicators and data description; the third part deals with empirical results; and the final part proposes conclusions and suggestions.

2. Related Work and Literature Review

In recent years, the application of the DEA model to environmental performance evaluation has been the mainstream approach. A great many scholars have taken the DEA model to evaluate environmental performance. Based on the pollutants involved in studies, the existing literature can be divided into the following two parts.

The first kind of researches, regarding CO_2, SO_2, NO_2, waste gas, waste water, and waste as undesirable outputs, focus on the analysis of the influence of air pollutants on energy efficiency and environmental performance [6–8]. Wu et al. [9], Hua [10], Sun [11], Wang [12], Zha [13], Bian [14], and others, with the help of the DEA method, studied issues relevant to energy efficiency given that CO_2, SO_2, NO_2, and waste gas were all undesirable outputs. Using pollutants as undesirable outputs, Zhang [15] carried out research on the environment performance of 30 provincial capitals in China with the application of the REES (regional environmental efficiency SBM (Slacks Based Measure)) model; Zaim et al. [16] studied the environmental performance and regulatory standards of OECD (Organization for Economic Co-operation and Development) countries regarding CO_2 emission as undesirable outputs; Lee et al. [17] evaluated the environment performance of port cities from OECD countries after selecting the emission of NO_X, SO_2, and CO_2 as undesirable output indexes. Li et al. [18] improved the ISBM-DEA (Improved slacks based measure-Data Envelopment Analysis) model and based on this, they conducted empirical research on the environment performance from 30 regions in China in the year 2009. Yang [19] used the DEA-SBM method to evaluate the environmental performance of city agglomerations in the northeastern region with pollutant emission as undesirable output index; Li et al. [20] used the SEDEA (super-efficiency Data Envelopment Analysis) model and data from 30 provinces between 2000 and 2010 to analyze the efficiency of China's environment policies. The results showed that there were remarked differences of environment performance in different regions: the environment performance in eastern regions was apparently better than that in the middle and western regions.

The second kind of researches also set $PM_{2.5}$ and PM_{10} as research indexes on the basis of traditional pollutants. Reyes et al. [21] used the RAMP (Regionalized Air quality Performance) Model to explore novel ways of visualizing and evaluating CMAQ (Community Multiscale Air Quality) model performance and errors for daily $PM_{2.5}$ concentrations across the continental United States. Gokhale et al. [22] used several models to evaluate roadside air quality and analyzed the prevailing meteorology and the temporal distribution of the measured daily average PM_{10} and $PM_{2.5}$ concentrations in wintertime. Zhou et al. [23] simulated the dynamic trends of gross domestic production (GDP), $PM_{2.5}$, and six air pollutant emissions between 2015 and 2030 in four different scenarios and calculated the results of AEC (Atmospheric environmental capacity) and AECC (Atmospheric environmental carrying capacity) constrained by GDP and $PM_{2.5}$. Kang D et al. [24] estimated real-time bias-adjusted O_3 and $PM_{2.5}$ air quality index forecasts and their performance evaluations over the continental United States. Sueyoshi et al. [25] applied the DEA method to evaluate the environment performance of 28 provincial capitals in China after setting indexes like $PM_{2.5}$ and PM_{10} as undesirable outputs; Feng et al. [26] used the SBM model on the basis of non-radial perspective to incorporate haze precursors as undesirable outputs into the energy efficiency framework of total factors in order to estimate the total-factor energy efficiency of the Beijing-Tianjin-Hebei region between 2003–2012 and analyzed the influencing factors of energy efficiency using the Tobit model. He et al. [27] estimated the provincial environment technology efficiency of China from 2001 to 2012 after incorporating haze into the research framework of environment technology efficiency and constructing the SBM regional model of undesirable outputs. Guo et al. [28] discussed the provincial distribution efficiency of $PM_{2.5}$ emission permits under the premise of fixed total targets using the ZSG-DEA (Zero-sum Gains Data Envelopment Analysis) model.

Besides, scholars like Wu [29], Li [30], Bai [31], Wang [32], and Cheng [33] also made many analyses on environmental performance evaluation and the differences between various regions on the condition that CO_2, SO_2, NO_2, waste gas, waste water, and waste were regarded as undesirable outputs. Limited by space, this paper will not enumerate those researches at length.

It can be seen from the above research that the most existing studies selected provinces as research units, which to a certain degree limited the environmental performance evaluation of China's cities, regions or even the whole. Moreover, most researches regarded single air pollutants like CO_2, SO_2, NO_2, and waste gas as undesirable outputs, while studies using undesirable outputs like $PM_{2.5}$ and PM_{10} are rarely seen, let alone literature analysis on the regional differences of environmental pollution. In light of the above insufficiencies of previous studies, this paper has constructed a comprehensive environmental performance evaluation of 109 strictly-environmental-monitored cities in China (The 109 cities are strictly-environmental-monitored, noted by China Statistical Yearbook (except for Lasa, Haikou, Nanchong and Tongchuan while there is lack of data for Nanchong and Tongchuan) from the perspective of natural performance, management performance, as well as scale performance by Data Envelopment Analysis (DEA), incorporating $PM_{2.5}$ and PM_{10} as undesirable outputs. What is more, the environmental performance differences of different regions were further analyzed. It can be seen that this paper is a beneficial supplement to the existing research and is of great significance in terms of both the choice of objects and practical guides.

3. Model, Indexes, and Data

3.1. DEA Model

The method of data envelopment analysis (DEA) was proposed by Charnes, Coopor, and Rhodes in 1978. The main principle of this method is to keep the input or output of the decision-making units (DMU) unchanged. The relatively efficient production frontier is determined by mathematical programming and statistics. Each decision-making unit is projected onto the production frontier of DEA and its relative effectiveness is evaluated by the degree of the deviation of the decision making unit from the DEA frontier. This paper employed the DEA model put forward by Toshiyuki Sueyoshi (The main differences between this paper and Toshiyuki Sueyoshi (2015) are as follows: The first is a research object and data. Toshiyuki Sueyoshi selected provincial cities as the research object, while this paper chose 109 strictly-environmental-monitored cities as the research unit which to a certain degree overcomes the limitation in evaluating the environmental performance of China's cities, regions or even the whole country. The second is the empirical analysis and conclusion. Rather than emphasizing the analysis of regional differences like Toshiyuki Suyoshi, this paper discussed the environmental performance of Chinese cities both regionally and on the whole. In addition, it also illustrated the environmental performance distribution of each city which can reflect the environmental performance of cities in each region in a more direct way. In general, the current environmental performance in China is quite low while the research result of Toshiyuki Sueyoshi tended to be rather positive. What is more, the empirical result of this paper differs from that of Toshiyuki Sueyoshi in that it is based on more scientific regional division with regional differential analysis. For instance, according to Toshiyuki Sueyoshi, the environmental performance of the eastern costal region (0.930) is better than that of the southern coastal region (0.629), while this research finds that the environmental performance of the costal economic regions is evidently higher than that of other regions and the environmental performance of the eastern coastal economic region is among the bottom ones. The environmental performance of the northern coastal economic region is rather lower, far from that given by Toshiyuki Sueyoshi, which is more in line with the reality) to comprehensively evaluate the environment performance from the perspective of natural performance, management performance as well as scale performance. This is in line with the current situation that Chinese cities differ in economic growth, scale and geographical distribution and the environment performance of 109 strictly-environmental-monitored cities as well as other areas can thus be better evaluated.

A brief introduction of the DEA environment performance evaluation model was put forward by Toshiyuki Sueyoshi [20]. Due to space limitations, we will not introduce it in detail here.

3.2. *t*-Test

The *t*-test, also known as student's *t* test proposed by British statistician Gossett, is to use the *t* distribution theory to infer the probability of the occurrence of difference so as to compare two averages and to see whether the difference is significant. In this paper, the test of the averages of two independent samples is used to test the difference of the data obtained from two non-related samples. Firstly, it is assumed that the two regions are independent, that is, there is no correlation between the two experimental groups. Then the difference between the environmental performances of the two regions is analyzed.

$$t = \frac{\overline{X_1} - \overline{X_2}}{\sqrt{\frac{(n_1-1)S_1^2+(n_2-1)S_2^2}{n_1+n_2-2}\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}} \tag{1}$$

In the equation, $\overline{X_1}$, $\overline{X_2}$ are the averages of the two samples, S_1^2, S_2^2 are the variances, n_1, n_2 are the sample sizes. According to the calculation results, it can be determined whether the difference is significant by referring to the t distribution table. This statistical method is used in Section 4.4.

3.3. Indexes

The outputs can be divided into the desirable one and the undesirable one in the DEA environment performance evaluation model. GDP, an ultimate fruit of regional production in a certain period, can suitably embody the regional economic growth and therefore, it can be regarded as a desirable output. On the basis of air pollutants, $PM_{2.5}$ and PM_{10} are also taken into consideration. Given the data availability, the National Bureau of Statistics has categorized strictly-monitored indexes such as NO_2,

SO_2, $PM_{2.5,}$ and PM_{10} in 109 strictly-environmental-monitored cities into undesirable outputs, the total population at the end of every year, investment in pollution control, total electricity consumption, and the total expense of per capita consumption into input indexes, among which, the total population at the end of every year has something to do with the city scale and will influence its scale efficiency; While the total electricity consumption as well as total expense of per capital consumption is relevant to economic development, many researches regard these three indexes as input indexes. In addition, investment in pollution control can directly influence environment protection efficiency, and therefore, this paper also regards it as an input index. The introduction of specific indexes is detailed as follows:

Input index: (1) total population at the end of the year: the number of population at 24.00 h on 31 December every year, measured by ten thousand; (2) investment in pollution control: the investment in pollution in a certain time and area, measured by ten thousand yuan; (3) total electricity consumption: the total consumption of the whole city in a year, measured by ten thousand kwh; (4) per capita consumption expenditure: total spending on daily household activities, measured by yuan.

Desirable output index: GDP: the ultimate fruit of production activities made by all permanent residents united in some areas during a certain period, measured by hundred million yuan.

Undesirable output index: (1) mean annual concentration of PM_{10}, measured by μ/m^3. PM_{10} refers to particles whose diameter are less than or equal to 10 μm. (2) The mean annual concentration of $PM_{2.5}$, measured by μ/m^3. $PM_{2.5}$ refers to particles whose diameters are less than or equal to 2.5 μm in aerodynamics. (3) NO_2: mean annual concentration, measured by μ/m^3. (4) SO_2: mean annual concentration, measured by μ/m^3.

3.4. Data

This paper used the panel data collected from 109 strictly-environmental-monitored cities in 2014, among which, the data about PM_{10}, $PM_{2.5}$, $NO_{2,}$ and SO_2 came from the *China Statistical Yearbook* 2015, data about investment in pollution control from the *Almanac of China's Cities 2015*, and data about total population at the end of every year, total electricity consumption, as well as GDP from the *China City Statistical Yearbook 2015*. Data about per capital consumption expenditure came from the statistical yearbooks of each province. Since specific per capital consumption expenditures of some cities were not given by the statistical yearbooks; they were obtained through weighted average of data in the statistical bulletin. It can be seen from the data that, among all the cities, Shanghai has the largest GDP, total electricity consumption, and per capita consumption expenditure; Chongqing has the largest population of 19.439 million; Wuhan spent 6334.429 billion yuan on pollution control, ranking first among all the cities. In addition, the concentrations of $PM_{2.5}$ and PM_{10} in Baoding are the highest, 129 μ/m^3 and 224 μ/m^3, respectively. The concentrations of NO_2 and SO_2 in Zibo are the highest, 123 μ/m^3 and 67 μ/m^3, respectively. The specific data are shown in Table 1:

Table 1. Data description of 109 strictly-environmental-monitored cities in 2014.

	Index	Unite	Minimum	Upper Quartile	Median	Lower Quartile	Maximum	Arithmetic Average	Standard Deviation
Input	Total population at the end of every year	Ten thousand people	23.2	96.3	149.9	276.8	1943.9	240.85	272.6
	Investment in pollution control	Ten thousand yuan	15	13,997.6	33,157.6	74,270	633,442.9	57,916.22	80,358.01
	Total electricity consumption	The thousand kwh	93,942	597,249	1,108,120	1,877,765	13,465,607	1,725,849.2	2,089,113.6
	Per capita consumption	Yuan	4195.22	12,274	14,569.128	19,000.927	33,064.8	15,984.25	5444.74
Desirable output	GDP	Hundred thousand yuan	166,001	6,690,569	12,597,088	31,004,800	232,920,300	27,512,453	40,445,118
Undesirable output	$PM_{2.5}$	$\mu g/m^3$	29	52	65	74	129	64.53	19.12
	PM_{10}	$\mu g/m^3$	47	86	108	128	224	109.22	33.25
	SO_2	$\mu g/m^3$	8	24	31	50	123	37.37	20.31
	NO_2	$\mu g/m^3$	14	32	39	47	67	39.62	10.43

4. Empirical Result and Discussion

4.1. Empirical Results

First of all, from the perspective of natural performance under variable return to scale, the performance values are all bigger than 0.2, most are concentrated between 0.600 and 1.000. The natural performances in southern coastal cities are much higher compared with those in cities of Hebei, Shandong, and Henan provinces. Cities with the highest natural performance are Beijing, Dalian, Shanghai, Fuzhou, Shenzhen, and Zhuhai. Their performance values are all 1. While Baoding, whose performance value is 0.318, is at the bottom in terms of natural performance.

Second, from the perspective of the natural performance under constant return to scale, Dalian, Shanghai, Guangzhou, Shenzhen, Changsha, and Chengdu have the highest natural performance, the performance value being 1. While Sanmenxia has the lowest performance value of 0.018, followed by Jinzhou, Maanshan, Shizuishan, and Jinchang. In general, the performance values of most cities are lower than 0.2, dominant by Shandong, Henan, Shanxi, Hebei, and Liaoning provinces. The performance values of cities in the Yangtze River Delta are concentrated between 0.2 and 0.6, with lower efficiency on the whole.

Third, the scale performance of most cities in Hebei, Henan, Shanxi, Liaoning, Gansu, Qinghai, and Ningxia provinces is lower than 0.2, cities in the Yangtze River Delta have lower performance values and the scale performance in southern coastal cities is comparatively higher. Cities with the highest scale performance under natural performance are Dalian, Shanghai, Guangzhou, Shenzhen, Changsha, and Chengdu, with the performance values being 1. Cities with the lowest scale performance are Sanmenxia, Mudanjiang, Shaoguan, Yangquan, and Jiaozuo, with the performance values being lower than 0.1.

Fourth, under variable massive loss, the management performance of each city is overall higher with the highest being Shanghai, Fuzhou, Shenzhen, Quanzhou, Shantou, Wuhan, and Chongqing. Their performance values are 1. The management performance of Baoding is the lowest, being merely 0.272. The management performance of cities in Guangdong and Fujian provinces is evidently higher than those in other provinces and the management performance in some cities of Shandong, Henan, and Hebei provinces is lower.

Fifth, under constant massive loss, the management performance of Shanghai, Quanzhou, Shenzhen, Wuhan, and Chongqing is the best with the performance values being 1. Mudanjiang has the lowest performance value of only 0.161. The management performance in Qinhuangdao, Yanan, Yangquan, and Anyang is also comparatively lower. As shown in the Appendix A Table A1, the management performances of some cities in Hebei, Shandong, Henan, and Shanxi provinces are clearly lower than cities in other provinces.

Sixth, from the perspective of scale performance under management performance, bigger cities such as Tianjin, Shanghai, Quanzhou, Shenzhen, Wuhan and Chongqing have higher performance values, being 1. Mudanjiang has the lowest scale performance and small cities like Yanan and Qujing also have lower scale performance. In general, the scale performance of cities in the southern and eastern coastal cities is much higher than that in the middle and western cities.

As can be seen above, the environment performance of big cities represented by provincial capitals is higher than other middle-or-small sized cities under whatever type of performance. What is more, cities with higher environment performance are clustered in provinces like Guangdong, Fujian, Shanghai, Jiangsu, and Zhejiang, while cities with lower environment performance are gathered in such provinces as Hebei, Henan, Shandong, Shanxi, Gansu, and Ningxia. In order to further expound the differences between various cities and regions, the following section analyzes the environmental performance differences between big and small cities as well as different regions.

4.2. Overall Analysis on Environmental Performance

As we can see from the environmental performance of 109 strictly-environmental-monitored cities (see in Table 2), the management performance of most cities is lower than natural performance, which reveals that at present, most cities in China still put economic development first while environmental protection is second. In addition, as Table 2 shows, the highest efficiency value is 1, while the lowest is only 0.018, which shows that the environmental performance between various cities is quite different and economic development does not become balanced in hand with environmental protection. Natural performance, management performance, and scale performance are comparatively lower on the whole, which shows the overall environment performance of cities in China is rather low.

Table 2. Environment performance value description of 109 strictly-environmental-monitored cities in 2014.

	Natural Performance under Variable Return to Scale	Natural Performance under Constant Return to Scale	Scale Performance under Natural Performance	Management Performance under Variable Massive Loss	Management Performance under Constant Massive Loss	Scale Performance under Management Performance
Average	0.714	0.373	0.485	0.618	0.526	0.845
Standard deviation	0.226	0.316	0.329	0.187	0.197	0.135
Minimum	0.318	0.018	0.018	0.272	0.161	0.310
Upper quartiles	0.524	0.113	0.178	0.491	0.391	0.773
Medians	0.706	0.256	0.425	0.577	0.503	0.881
Lower quartiles	1	0.596	0.776	0.704	0.588	0.939
Maximum	1.000	1.000	1.000	1.000	1.000	1.000

4.3. Regional Environment Performance Analysis

4.3.1. Regional Division

In order to analyze the environment performance difference between different cities, the 109 strictly-environmental-monitored cities are sorted from three perspectives: provincial capitals or non-provincial capitals. The three regions division method is based on economic distribution put forward by Sun [34] (The Pan-Yangtze river region: an economic region which connects the lower reaches of the Yangtze river economic center with the middle and upper yellow river delta economic region to form an economic center covering 15 cities in the Yangtze river delta and economically radioactive to more than 10 provinces like Hu, Su, Zhe, Wan, Yu, Shan, Gan, Ning, Qing, and Jiang. The Pan-Pearl river delta region: an economic region that connects the Pearl river and Min river coastal economic regions with the upper and middle reach of the Yangtze river economic center to form a new economic center including 14 cities such as Guangzhou and Shenzhen, sub-centered at coastal cities in Fujian province like Xia, Zhang, and Quan, which have a radial influence on Yue, Min, Qiong, Gui, Xiang, E, Gan, Yu, Gui, Dian, Chuan, and Zang provinces. The great Bo sea surrounding area: an economic region that connects the city group in the Bo sea bay with the economic region located in the downstream area of the Yellow river as well as the north China plain and the northeastern plain, including nine provinces like Jing, Jin, Liao, Lu, Ji, Jin, Ji, Hei, and Meng). Eight economic regions including 30 provincial capitals divided by the development center of the State Council (The southern coastal economic region includes Fujian, Guangdong, and Hainan; the northern coastal comprehensive economic region includes Beijing, Tianjin, Hebei, and Shandong; the eastern coastal comprehensive economic region includes Shanghai, Jiangsu, and Zhejing; the middle Yellow river comprehensive economic region includes Neimenggu, Henan, Shanxi and Shanxi; the middle Yangtze river comprehensive economic region includes Hubei, Hunan, Anhui, and Jiangxi; the northeastern comprehensive economic region consists of Liaoning, Jilin, and Heilongjiang; the southwestern comprehensive economic region includes Guangxi, Sichuan, Chongqing, Yunnan, and Guizhou; the northwestern comprehensive economic region consists of Gansu, Qinghai, Ningxia, and Xinjiang).

Supposing there is no significant difference between provincial cities and non-provincial cities, there is also no significant difference between regions according to the division of "three regions" and "eight economic regions".

4.3.2. Natural Performance, Management Performance, and Scale Performance

Natural performance and management performance in various regions are evidently different which signifies that there are differences of economic development and environmental protection among regions.

First, the average natural performance of provincial cities is 0.774, higher than 0.693 of non-provincial cities and the management performance of provincial cities is 0.670 higher than 0.600 of non-provincial provinces, which shows that provincial cities pay more attention to environmental protection. In addition, the efficiency value variance of provincial cities is less than non-provincial cities, which reveals that the environmental performance of provincial cities is less fluctuant than that of non-provincial cities, namely, the development gap between non-provincial cities is wider.

Second, among the three regional divisions, the efficiency value of the Pan-Pearl River Delta is the highest, followed by the Pan-Yangtze River Delta and the greater Bo Sea surrounding area. The latter two are similar in terms of efficiency value while the management performance average of the greater Bo Sea surrounding area is the lowest, reflecting that this region attaches more importance to economic development and lacks efforts on environmental protection. This conclusion accords with the current situation that air pollution occurs more frequently and becomes increasingly serious in this region where heavy industry dominates while this deviates from the environmental evaluation made by Chen [35] according to the traditional regional division method of Beijing-Tianjin-Hebei, the Yangtze River delta, and the Pearl River Delta.

Third, in the eight regions division, the averages of natural performance and management performance in the southern costal economic region are the highest, being 0.948 and 0.943 respectively, which reflects that the southern coastal economic region attaches equal importance to both economic growth and environmental protection. The environmental performance of the southern coastal economic region is higher than that of other regions. However, the management performance average of the same developed eastern coastal comprehensive economic region is 0.629, much lower than that of the southern coastal economic region, revealing that the environmental protection in the eastern costal comprehensive economic region is not as good as that in the southern coastal region. Besides, the management performance of the northern coastal comprehensive region is the lowest, being only 0.492, which reflects that the environmental protection situation in this region is worse. Please refer to Table 3 for more specific results.

The result also demonstrates that the natural performance under constant return to scale and the management performance under constant massive loss are much higher than those of non-provincial cities, which signifies that the economic development and environmental protection level of bigger cities are much higher than those of middle-and-small sized cities. Of the three regions, the efficiency of the Pan-pearl River Delta is the highest, followed by similar values of the Pan-Yangtze River Delta and great Bo Sea surrounding area. Among the eight regions, the efficiency of the southern costal economic region still tops, while the natural performance value of the northwestern comprehensive economic region is only 0.194, indicating that its economic development is much lower than other regions. The management performance average value of the middle Yellow river comprehensive economic region is 0.415 which shows that its environmental protection level is lower than other regions. Specific results are shown in Table 4.

Table 3. Environmental performance value of each region under variable return to scale and variable massive loss.

Regional Division		Natural Performance		Management Performance	
		Arithmetic Average	Standard Deviation	Arithmetic Average	Standard Deviation
Provincial cities and non-provincial cities	Provincial cities	0.774	0.211	0.670	0.184
	Non-provincial cities	0.693	0.229	0.600	0.185
Three regions	Pan-Pearl River Delta	0.858	0.171	0.740	0.198
	Pan-Yangtze River Delta	0.658	0.214	0.573	0.156
	Greater Bo sea surrounding area	0.622	0.219	0.538	0.137
Eight economic regions	Northern coastal comprehensive economic region	0.538	0.229	0.492	0.160
	Northeastern comprehensive economic region	0.743	0.180	0.566	0.100
	Eastern coastal comprehensive economic region	0.643	0.135	0.629	0.133
	Southern coastal economic region	0.948	0.085	0.943	0.094
	The middle Yellow river comprehensive economic region	0.642	0.253	0.508	0.116
	The middle Yangtze river comprehensive region	0.735	0.209	0.623	0.154
	Greater southern comprehensive economic region	0.888	0.129	0.700	0.181
	Greater northern comprehensive economic region	0.668	0.233	0.657	0.216

Table 4. Environmental performance value of each region under constant return to scale and constant massive loss.

Regional Division		Natural Performance		Management Performance	
		Arithmetic Average	Standard Deviation	Arithmetic Average	Standard Deviation
Provincial/non-provincial cities	Provincial cities	0.654	0.294	0.586	0.202
	Non-provincial cities	0.271	0.257	0.505	0.1920
Three regions	Pan-Pearl River Delta	0.471	0.325	0.614	0.216
	Pan-Yangtze River Delta	0.326	0.279	0.508	0.181
	Greater Bo sea surrounding area	0.318	0.327	0.453	0.158
Eight regions	Northern coastal comprehensive economic region	0.344	0.325	0.428	0.172
	Northeastern comprehensive economic region	0.345	0.357	0.471	0.159
	Eastern coastal comprehensive economic region	0.406	0.237	0.588	0.147
	Southern coastal economic region	0.498	0.341	0.849	0.162
	The middle yellow river comprehensive economic region	0.261	0.316	0.415	0.128
	The middle Yangtze river comprehensive economic region	0.457	0.334	0.562	0.162
	Southwestern comprehensive economic region	0.459	0.328	0.518	0.172
	Northwestern comprehensive economic region	0.194	0.201	0.559	0.261

In addition, the scale performance average of provincial cities under natural performance and management performance are 0.802 and 0.866 respectively, much higher than the responding 0.370 and 0.837 of non-provincial cities. The scale performance averages of the southern coastal economic region, the eastern coastal comprehensive economic region, the middle Yangtze river comprehensive region, and the northern costal comprehensive region where lots of cities gather are clearly higher than those of other regions, which shows that bigger cities are able to make use of their city scale to promote economic development and environmental protection and eventually to enhance their environmental performance while small cities are unable to get higher scale performance, which results in their low environmental performance. Specific results can be referred to in Table 5.

Table 5. Scale performance value of each region.

Regional Division		Scale Performance under Natural Performance		Scale Performance under Management Performance	
		Arithmetic Average	Standard Deviation	Arithmetic Average	Standard Deviation
Provincial/non-provincial cities	Provincial cities	0.802	0.244	0.866	0.119
	Non-provincial cities	0.370	0.276	0.837	0.140
Three regions	Pan-Pearl River Delta region	0.526	0.320	0.825	0.134
	Pan-Yangtze River Delta Region	0.470	0.327	0.875	0.121
	Great Bo sea region	0.458	0.345	0.833	0.146
Eight economic regions	Northern coastal comprehensive region	0.540	0.313	0.856	0.112
	Northern comprehensive economic region	0.438	0.398	0.821	0.195
	Eastern coastal comprehensive region	0.618	0.282	0.930	0.054
	Southern coastal economic region	0.511	0.334	0.894	0.119
	The middle Yellow river comprehensive economic region	0.357	0.338	0.817	0.157
	The middle Yangtze river comprehensive economic region	0.566	0.323	0.898	0.060
	The southwestern comprehensive economic region	0.499	0.323	0.744	0.133
	The northwestern comprehensive economic region	0.290	0.248	0.824	0.107

4.4. Differences between Regional Environment Performances

In order to examine the differences between regional environment performances, *t*-test analysis was made on the natural performance under variable return to scale as well as on the management performance under variable massive loss. Tables 6–9 show the values of *t*-test and *p* under different regional divisions.

Table 6. Environment performance *t*-test value and *p* value of provincial cities and non-provincial cities.

Grouping	Natural Performance	Management Performance
Provincial cities and non-provincial cities	1.672 (0.098)	1.765 (0.080)

Note: (1) Insignificant below the confidence level of 5%. (2) Within the bracket is the value of *p*.

Table 7. Environmental performance *t*-test value and *p* value in three regions.

Grouping	Natural Performance		Management Performance	
	Great Bo Sea Surrounding Area	Pan-Pearl River Delta Region	Great Bo Sea Surrounding Region	Pan-Pearl River Delta Region
Pan-Pearl river delta region	0.698 (0.487)	−4.454 * (0.000)	1.006 (0.318)	−4.021 * (0.000)
Great Bo sea surrounding region		−5.129 * (0.000)		−5.000 * (0.000)

Note: (1) * Significant below the confidence level of 5%. (2) The value of *p* is within the bracket.

Table 6 shows the *t*-test value and *p* value of natural performance and management performance under variable return to scale and variable massive loss of provincial cities and non-provincial cities respectively. As we can see, the *p* values of natural performance and management performance are both greater than 0.05, the result is not significant and the test also fails, which means that there are no significant differences between provincial cities and non-provincial cities. This is due to the fact that air pollutants represented by $PM_{2.5}$ and PM_{10} are likely to be influenced by air flow, wind direction, and water vapor. All in all, they are more fluid compared with other kinds of environmental pollution [36]. This leads to the result that the air condition in a city will be influenced by surrounding cities and vice versa. And therefore, differences between cities are narrowed and the difference test fails.

Table 8. Natural performance t-test value and p value of eight regions.

	The Northeastern	The Eastern	The Southern	The Yellow River	The Yangtze River	The Southwestern	The Northwestern
The northern	−2.489 * (0.020)	−1.542 (0.134)	−5.146 * (0.000)	−1.283 (0.208)	−2.392 * (0.023)	−5.458 * (0.000)	−1.250 (0.225)
The northeastern		1.631 (0.116)	−3.129 * (0.006)	1.169 (0.252)	0.103 (0.919)	−2.480 * (0.020)	0.772 (0.451)
The eastern			−6.089 * (0.000)	0.007 (0.994)	−1.427 (0.165)	−5.254 * (0.000)	−0.325 (0.749)
The southern				3.513 * (0.002)	2.895 * (0.009)	1.253 (0.222)	3.364 * (0.005)
The Yellow river					−1.131 (0.267)	−3.624 * (0.001)	−0.237 (0.814)
The Yangtze river						−2.501 * (0.018)	0.669 (0.512)
The southwestern							2.987 * (0.007)

Note: (1) * Significant below the confidence level of 5%. (2) The value of p is within the bracket. (3) The northern coastal comprehensive economic region (the northern), the northeastern comprehensive economic region (the northeastern), the eastern coastal comprehensive economic region (the eastern), the southern coastal economic region (the southern), the middle Yellow river comprehensive economic region (the Yellow river), the middle Yangtze comprehensive economic region (the Yangtze river), the southwestern comprehensive economic region (the southern region) and the northwestern comprehensive economic region (the northwestern).

Table 9. Management performance t-test value and p value of eight regions.

	The Northeastern	The Eastern	The Southern	The Yellow River	The Yangtze River	The Southwestern	The Northwestern
The northern	−1.355 (0.187)	−2.581 * (0.015)	−7.702 * (0.000)	−0.341 (0.735)	−2.264 * (0.031)	−3.493 * (0.001)	−2.050 (0.053)
The northeastern		−1.317 (0.200)	−8.600 * (0.000)	1.394 (0.174)	−1.051 (0.304)	−2.240 * (0.034)	−1.224 (0.239)
The eastern			−6.185 * (0.000)	2.865 * (0.007)	0.120 (0.905)	−1.254 (0.219)	−0.381 (0.708)
The southern				9.830 * (0.000)	5.569 * (0.000)	3.741 * (0.001)	3.576 * (0.003)
The Yellow river					−2.471 * (0.019)	−3.904 * (0.000)	−2.319 * (0.029)
The Yangtze river						−1.270 (0.214)	−0.426 (0.675)
The southeastern							0.500 (0.622)

Note: (1) * Significant below the confidence level of 5%. (2) The value of p is within the bracket. (3) The northern comprehensive economic region (the northern), the northeastern comprehensive economic region(the northeastern), the eastern coastal comprehensive economic region (the eastern), the southern coastal economic region (the southern), the middle Yellow comprehensive economic region (the Yellow river), the middle Yangtze river comprehensive economic region (the Yangtze river), the southwestern comprehensive economic region (the southwestern) and the northwestern comprehensive economic region (the northwestern).

In Table 7, the p values of natural performance and management performance in the Pan-Yangtze River Delta, and Great Bo Sea surrounding area are 0.487 and 0.318 respectively. Both are higher than 0.05 and the value of t also fails the test, which reveals that there are no evident differences between the Pan-Yangtze river delta and the great Bo sea surrounding area. However, the p values of natural performance and management performance in the Pan-Pearl river delta, Pan-Yangtze river delta and the great Bo sea surrounding area are both 0, which means it passes the *t*-test, namely, there exist significant differences between the above regions: the economic growth and environmental protection in the Pan-Pearl river delta region is conspicuously better than that in the Pan-Yangtze river delta and the great Bo sea surrounding area.

Tables 8 and 9 are *t*-test values and *p* values of the natural performance under variable return to scale and management performance under variable massive loss. As the table shows, the *p* values of most regions (like the northeastern economic regions and the northern coastal comprehensive economic regions, southern coastal economic regions, and northern coastal comprehensive economic regions) are less than 0.05, which signifies that the environmental performance between these regions is significant, with that between the middle-and-southern coastal economic regions and other regions being the most evident. The *p* values of several regions (such as the middle Yellow river comprehensive region and eastern coastal comprehensive region, the middle Yellow river comprehensive economic region and the northwestern comprehensive economic region) are greater than 0.05, and fail the significance test. In a word, there are significant differences between the eight regions, namely, there exist significant environmental performance differences between the regions and economic development as well as environmental protection differences between regions which are noted.

5. Conclusions and Suggestion

Regarding $PM_{2.5}$ and PM_{10} as undesirable outputs, this paper employed the DEA model method to evaluate the environment performance of 109 strictly-environmental-monitored cities from the perspective of natural performance, management performance, and scale performance. The result shows that first, the natural performance of most cities is relatively higher while the management performance is significantly lower. This reveals that most cities in China still give priority to economic development while putting environmental protection in second place. Second, generally, the environmental performance of the 109 cities differs greatly: the environmental performance of provincial cities is higher than that of non-provincial cities which signifies that the overall performance of bigger cities is better than that of smaller cities, as bigger cities can make use of their city scale to promote economic development and environmental protection. Third, from the perspective of regional analysis, the environmental performance between regions is quite different which reveals that the economic development and environmental protection between regions is imbalanced. The environmental performance of the Pan-Pearl river delta region is higher than those of the Pan-Yangtze river delta and great Bo Sea surrounding area. The efficiency averages of the southern coastal economic region, the eastern coastal comprehensive economic region, the middle Yangtze river comprehensive economic region, and the northern coastal comprehensive economic region are all higher than those of other regions, showing that the economic development and environmental protection of these regions are better than those of such less developed regions as the middle Yellow river comprehensive economic region, the southwestern comprehensive economic region, as well as the northwestern comprehensive economic region.

The main differences between this paper and Toshiyuki Sueyoshi's research (2015) are as follows:

First, this paper focuses on the environmental performance of 109 Chinese cities and discusses the general imbalance between economic development and environmental protection in Chinese cities.

Second, the previous research employed fitting data, which is quite different from real data. Compared with previous research, the results of this paper are more reliable.

Third, this paper selects three kinds of classification methods, the provincial capitals and non-provincial capitals, three regions, and eight economic regions. The influence of the sizes of the cities on the balance of the city's economic development and environmental protection is discussed, and the regional differences are analyzed. Previous studies focused on demonstrating regional differences and analyzing the differences, but the results were too optimistic. Therefore, this study is different from previous studies and the results obtained are themselves different from those of previous studies.

Based on the above conclusion, we can derive the following policy enlightenment:

First, pay more attention to enhancing management level and environmental performance. First of all, a fully-fledged environmental performance evaluation system should be established and the difference between the environmental pollution consequence and the intended environmental target should also be realized. The environmental regulatory content, the inspectors' responsibility as well as the corresponding punishment should be clearly defined in order to provide a scientific decision-making foundation for governments and enterprises. In addition, in light of the current serious pollution, cities should select a proper development model based on their own comparative advantages to enhance their environmental performance and government should restructure industry, optimize the city's expanding route, transform economic growth mode, introduce market regulation [37], pay more attention to the transformation of old industrial cities, and ensure the leading role of technical innovation in improving environmental performance in order to promote the cities' sustainable development [38].

Second, place emphasis on the environmental protection of smaller cities. With the rapid urbanization, there exist lots of problems relevant to ecology, the environment, and the economy [39]. The government should take positive measures for smaller cities (such as Sanmenxia, Baoding, Mudanjiang, and Pingdingshan) with backward economy and low environment performance and encourage them to learn the necessary experience about economic development and environmental protection from bigger cities (like Beijing, Guangzhou, Shenzhen and Shanghai). At the same time, the government should also respond to the mission of building national central cities (National central city is the highest level of urban system put forward by Ministry of Housing and Urban-Rural Development in the National Urban System Planning in 2010. National central cities play a leading and distributive role nationwide in terms of politics, economy, culture as well as foreign exchanges), promote the construction of bigger cities, facilitate the development of small cities with the scale of radiation function of bigger cities and channel talents, capital as well as pollution treatment equipment to middle and small sized cities. In addition, the government should give more policy support to middle and small sized cities, promote their economic development, and improve their environment performance [40] to reach ecological balance and sustainable development.

Third, attach more importance to sustainable development. Different environmental protection strategies should be tailored to the features of less developed regions such as the middle Yellow river comprehensive economic region, the southwestern comprehensive economic region, and the northwestern comprehensive economic region [41]. Meanwhile, experience can be learned from the Pan-Pearl river delta to enhance more investments in technology and innovation, promote the development of high-end service industry, and integrate advanced manufacturing industry with the high-end service industry in order to realize industrial structural optimization and upgrading [42]. According to the emission reduction target, the government can make use of the emission rights transaction and subsidies to reduce the pollutant emission allowance distributed to relevant industrial enterprises and allow enterprises to fulfill their emission targets by transacting emission rights. The government should also strengthen regional cooperation and set up special regional coordinative organizations to directly implement the management right or give advice towards surrounding regional coordination behavior [43] in order to realize coordinated and sustainable development between regions.

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Appendix A

Table A1. Environmental performance 109 strictly-environmental-monitored cities.

Cities	Natural Performance under Variable Return to Scale	Natural Performance under Constant Return to Scale	Scale Performance under Natural Performance	Management Performance under Variable Massive Loss	Management Performance under Constant Massive Loss	Scale Performance under Management Performance
Beijing	1.000	0.996	0.996	0.892	0.838	0.939
Tianjin	0.795	0.793	0.997	0.746	0.746	1.000
Shijiazhuang	0.397	0.225	0.566	0.429	0.339	0.790
Qinhuangdao	0.485	0.068	0.140	0.476	0.270	0.567
Tangshan	0.343	0.186	0.543	0.542	0.540	0.997
Baoding	0.318	0.038	0.120	0.272	0.196	0.721
Handan	0.340	0.058	0.172	0.407	0.317	0.779
Jinan	0.709	0.686	0.968	0.415	0.392	0.945
Qindao	0.957	0.931	0.973	0.587	0.540	0.921
Zibo	0.333	0.216	0.649	0.350	0.305	0.872
Zaozhuang	0.385	0.182	0.472	0.356	0.325	0.914
Yantai	0.678	0.438	0.647	0.643	0.529	0.823
Weifang	0.386	0.134	0.346	0.491	0.436	0.888
Jining	0.362	0.106	0.293	0.397	0.347	0.874
Taian	0.637	0.327	0.513	0.396	0.357	0.902
Rizhao	0.477	0.121	0.254	0.480	0.370	0.770
Shenyang	0.782	0.761	0.973	0.548	0.537	0.979
Dalian	1.000	1.000	1.000	0.758	0.748	0.987
Anshan	0.702	0.121	0.172	0.539	0.511	0.948
Fushun	0.503	0.092	0.183	0.569	0.536	0.941
Benxi	0.528	0.077	0.146	0.599	0.567	0.947
Jinzhou	0.752	0.103	0.137	0.477	0.408	0.856
Changchun	0.883	0.791	0.896	0.491	0.351	0.716
Jilin	0.532	0.145	0.273	0.494	0.375	0.758
Haeibin	0.642	0.553	0.862	0.485	0.369	0.761
Qiqihaer	0.850	0.113	0.133	0.749	0.621	0.829
Mudanjiang	1.000	0.038	0.038	0.518	0.161	0.310
Shanghai	1.000	1.000	1.000	1.000	1.000	1.000
Nanjing	0.705	0.686	0.973	0.567	0.554	0.977
Xuzhou	0.543	0.343	0.631	0.518	0.428	0.827

Table A1. *Cont.*

Cities	Natural Performance under Variable Return to Scale	Natural Performance under Constant Return to Scale	Scale Performance under Natural Performance	Management Performance under Variable Massive Loss	Management Performance under Constant Massive Loss	Scale Performance under Management Performance
Lianyungang	0.490	0.131	0.268	0.494	0.435	0.881
Yangzhou	0.706	0.596	0.844	0.534	0.500	0.936
Nantong	0.596	0.332	0.556	0.557	0.520	0.934
Zhenjiang	0.800	0.245	0.306	0.494	0.459	0.928
Changzhou	0.524	0.372	0.710	0.616	0.597	0.969
Wuxi	0.556	0.466	0.838	0.632	0.625	0.988
Suzhou	0.588	0.449	0.763	0.646	0.602	0.932
Hangzhou	0.577	0.539	0.934	0.697	0.696	0.999
Ningbo	0.698	0.448	0.641	0.799	0.760	0.951
Wenzhou	0.721	0.193	0.268	0.704	0.602	0.855
Huzhou	0.634	0.105	0.165	0.593	0.509	0.858
Shaoxing	0.501	0.185	0.370	0.584	0.538	0.921
Fuzhou	1.000	0.759	0.759	1.000	0.767	0.767
Xiamen	0.897	0.472	0.526	0.896	0.845	0.943
Quanzhou	1.000	0.347	0.347	1.000	1.000	1.000
Guangzhou	1.000	1.000	1.000	0.887	0.864	0.975
Shenzhen	1.000	1.000	1.000	1.000	1.000	1.000
Zhuhai	1.000	0.330	0.330	0.976	0.916	0.939
Shantou	0.865	0.270	0.312	1.000	0.881	0.881
Shaoguan	0.771	0.064	0.083	0.724	0.464	0.641
Zhanjiang	1.000	0.244	0.244	1.000	0.900	0.900
Xian	0.661	0.610	0.923	0.519	0.485	0.933
Baoji	0.879	0.664	0.755	0.497	0.459	0.924
Xianyang	1.000	1.000	1.000	0.412	0.318	0.772
Weinan	1.000	0.496	0.496	0.441	0.273	0.619
Yanan	1.000	0.055	0.055	0.547	0.211	0.385
Taiyuan	0.497	0.245	0.493	0.694	0.676	0.974
Datong	0.702	0.098	0.139	0.682	0.388	0.570
Yangquan	0.408	0.032	0.078	0.409	0.294	0.719
Changzhi	0.499	0.039	0.078	0.467	0.420	0.899
Linfen	0.706	0.030	0.042	0.511	0.344	0.673
Zhengzhou	0.414	0.256	0.618	0.596	0.588	0.987
Kaifeng	0.434	0.056	0.128	0.451	0.411	0.912

Table A1. *Cont.*

Cities	Natural Performance under Variable Return to Scale	Natural Performance under Constant Return to Scale	Scale Performance under Natural Performance	Management Performance under Variable Massive Loss	Management Performance under Constant Massive Loss	Scale Performance under Management Performance
Luoyang	0.397	0.113	0.285	0.459	0.411	0.895
Pingdingshan	0.362	0.038	0.106	0.352	0.316	0.898
Jiaozuo	0.382	0.034	0.089	0.465	0.442	0.951
Anyang	0.322	0.034	0.106	0.308	0.263	0.855
Sanmenxia	1.000	0.018	0.018	0.384	0.306	0.796
Huhehaote	1.000	0.970	0.970	0.700	0.585	0.837
Baotou	0.550	0.274	0.499	0.604	0.583	0.965
Chifeng	0.628	0.161	0.255	0.665	0.522	0.784
Wuhan	0.807	0.787	0.976	1.000	1.000	1.000
Jingzhou	0.393	0.064	0.164	0.372	0.316	0.852
Yichang	0.578	0.386	0.668	0.738	0.731	0.990
Changsha	1.000	1.000	1.000	0.603	0.529	0.878
Zhuzhou	0.560	0.162	0.289	0.509	0.466	0.916
Xiangtan	0.517	0.116	0.224	0.448	0.391	0.873
Yueyang	0.604	0.332	0.550	0.587	0.535	0.912
Changde	1.000	1.000	1.000	0.700	0.647	0.923
Zhangjiajie	1.000	0.271	0.271	0.778	0.586	0.753
Nanchang	0.777	0.629	0.810	0.587	0.517	0.881
Jiujiang	0.888	0.389	0.438	0.659	0.563	0.855
Hefei	0.933	0.848	0.909	0.632	0.584	0.924
Wuhu	0.719	0.321	0.446	0.586	0.530	0.905
Maanshan	0.514	0.089	0.173	0.518	0.475	0.916
Kunming	1.000	0.888	0.888	0.902	0.588	0.652
Qujing	1.000	0.177	0.177	0.877	0.395	0.451
Yuxi	1.000	0.297	0.297	0.967	0.564	0.584
Guiyang	1.000	0.776	0.776	0.655	0.506	0.773
Zunyi	0.870	0.148	0.170	0.518	0.320	0.618
Chengdu	1.000	1.000	1.000	0.599	0.439	0.733
Zigong	1.000	1.000	1.000	0.585	0.466	0.797
Panzhihua	0.757	0.077	0.102	0.745	0.511	0.686
Luzhou	0.647	0.177	0.273	0.510	0.366	0.718
Deyang	1.000	0.208	0.208	0.564	0.408	0.723
Mianyang	0.751	0.204	0.272	0.655	0.533	0.814

Table A1. *Cont*.

Cities	Natural Performance under Variable Return to Scale	Natural Performance under Constant Return to Scale	Scale Performance under Natural Performance	Management Performance under Variable Massive Loss	Management Performance under Constant Massive Loss	Scale Performance under Management Performance
Yibin	0.685	0.207	0.302	0.485	0.425	0.876
Chongqing	0.945	0.862	0.912	1.000	1.000	1.000
Nanning	0.866	0.598	0.691	0.707	0.459	0.649
Liuzhou	0.727	0.513	0.706	0.562	0.503	0.895
Guilin	0.848	0.240	0.283	0.572	0.461	0.806
Beihai	1.000	0.425	0.425	1.000	0.867	0.867
Lanzhou	0.485	0.156	0.323	0.501	0.341	0.680
Jinchang	1.000	0.036	0.036	0.935	0.864	0.924
Xining	0.463	0.083	0.178	0.472	0.389	0.824
Yinchuan	0.550	0.101	0.183	0.576	0.435	0.755
Shizuishan	0.625	0.041	0.065	0.577	0.459	0.796
Wulumuqi	0.552	0.375	0.679	0.541	0.425	0.787
Kelamayi	1.000	0.568	0.568	1.000	1.000	1.000

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