Correlation study on environmental performance of Chengdu and economic development

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Abstract. This paper evaluated the environmental performance from 2013 to 2018 based on establishing environmental performance assessment system of Chengdu and the correlation of environmental performance increasing rate and GDP increasing rate was analyzed. In addition, Pearson's correlation analysis on environmental performance index and GDP was carried out by using SPSS and we can see from the results that environmental performance shows an increasing tendency with the growth of GDP, environmental performance increasing rate is lower than GDP increasing rate. And there was no obvious correlation between environmental performance index and GDP (some high economical areas have low environmental performance levels). In another word, the rapid development of the economy does little help to rapidly improve environmental performance level. So Chengdu should pay more attention to protect environment, and be a coordinated development relationship between economy and environment.

1. Introduction
Under the new normal of China’s economic environment, ecological progress and environmental protection have also entered the new normal stage. Environmental performance evaluation is a form of expression and technical means to quantify the effectiveness of environmental management under the new normal [1], and the research and practice of environmental performance evaluation at home and abroad have gained some achievements [2-4]. Environmental protection and economic development have been the key issues in the field of strategic management research [5]. At present, some scholars in China have studied the relationship between environmental performance and economic performance, but the conclusions are relatively scattered, and are mainly concentrated at the micro level of enterprises [6-10]. Therefore, in order to carry out correlation study on Chengdu's environmental performance and economy, it is necessary to provide a reference for environmental performance assessment at the municipal level, at the same time, clarifying the degree of synergy between the environmental performance of Chengdu and economic development is also of great importance.

2. Methods
2.1. Environmental Performance Calculation Method
Based on the existing research results, we used the "driver-pressure-state-impacts-response (DPSIR)" model and thematic framework model. Combining indicators such as "Chengdu Green Development Index System" and "Chengdu Ecological Civilization Construction Assessment Target System" and “Indicative County and City Indicator System for Ecological Civilization Construction” as well as
major issues are related to the ecological environment characteristics and environmental performance of Chengdu; in accordance with the six selection principles which are policy relevance, simplicity, representativeness, comparability, scientificity, data availability, and timeliness, we have determined four 2nd-level indicators, ten 3rd-level indicators, and thirty-two 4th-level indicators, and finally constructed the Chengdu Environmental Performance Evaluation Index System.

The goal progressive method is used to quantify the value of each indicator, and we converted the original statistical (or processed) data of the indicator into a comparable index score between 0 and 100. The indicator is divided into positive and negative parts, and here is the calculation method:

Standardization of positive indicators: the larger is the observed value, the better is the performance.

$$t_{ij} = \begin{cases} \frac{100}{a_{ij} - a_{\min}} \times 100, & a_{ij} \geq a_{\text{target value}} \\ \frac{a_{\text{target value}} - a_{\min}}{a_{ij} - a_{\min}} \times 100, & a_{ij} < a_{\text{target value}} \end{cases}$$

Standardization of negative indicators: the smaller the observed value, the better is the performance.

$$t_{ij} = \begin{cases} \frac{100}{a_{\text{target value}} - a_{\max}} \times 100, & a_{ij} \geq a_{\text{target value}} \\ \frac{a_{ij} - a_{\max}}{a_{\text{target value}} - a_{\max}} \times 100, & a_{ij} < a_{\text{target value}} \end{cases}$$

In this formula, $a_{ij}$, $a_{\max}$ and $a_{\min}$ represent indicator value, maximum and minimum values, respectively. The basis for setting the indicator is mainly from the World Health Organization (WHO), "National Ecological Civilization Demonstration County and City Indicators (Trial)" "National Ecological Civilization Demonstration Village and Town Indicators (Trial)" "Chengdu Environmental Protection" The 13th Five-Year Plan "", "Chengdu Forestry and Garden Development "Thirteenth Five-Year Plan", etc. Also, they are determined by the ideal state target value, the city's optimal target value, and empirical target value.

After standardizing the index data, subjective and objective weighting methods can be used to weight each indicator. The subjective weighting method is a method for researchers to specify the weight of each index according to their subjective value judgment. In order to avoid the instability of the subjective judgment standard, we choose the objective weighting method to determine the weight of each index. The common objective weighting methods includes principal component analysis method, standard deviation method, entropy value method, and equal weight method, etc. According to the conditions of each method, the characteristics of the index system and the calculation results of the index weight distribution, the standard deviation method is finally used to determine the weight of the indicator.

The Environmental Performance Index (EPI) is used to assess the level of comprehensive environmental performance in Chengdu. The higher the index, the better the overall environmental performance. The calculation formula is as follows:

$$EPI = \sum_{i=1}^{n} \left( w_i x_i / 100 \right)$$

In this formula: i represents the index number; n represents the total number of indexes; $w_i$ represents the weight of the i-th index; $x_i$ is the standardized value of the i-th index. Starting from the 4th-level indicators, the weighted summation is gradually obtained to obtain the scores of each indicator and the final EPI score. The performance of the 2nd, 3rd, and 4th-level indicators is expressed by the proportion of the indicators that complete the target level.

| 2nd Class Indicators | 3rd Class Indicators | 4th Class Indicators | Weights | Target value (basis) |
|----------------------|----------------------|----------------------|---------|----------------------|

Table 1 Environmental Performance Evaluation Index System and Weight of Chengdu
| 2nd Class Indicators       | 3rd Class Indicators | 4th Class Indicators                                                              | Weights | Target value (basis)                                                                 |
|---------------------------|---------------------|-----------------------------------------------------------------------------------|---------|-----------------------------------------------------------------------------------|
| Air quality               |                     | Ratio of days with good air quality (S)                                            | 4.744   | 70 （The 13th five-year plan of environmental protection in Chengdu）                |
|                           |                     | Annual concentration of PM$_{2.5}$ (S)                                            | 2.373   | 10 （WHO）                                                                         |
|                           |                     | Annual concentration of NO$_{2}$ (S)                                              | 3.076   | 40 （WHO）                                                                          |
|                           |                     | Daily maximum 8-hour average ozone concentration (S)                                | 3.502   | 100 （WHO）                                                                         |
| Environmental health      |                     | Proportion of excellent water quality (attained or better than Class III) in sections above the city control (S) | 6.986   | 100 （Ideal value）                                                                 |
| Water quality             |                     | Water quality compliance rate of urban and rural centralized drinking water source protection areas (S) | 0.778   | 100 （Ideal value）                                                                 |
|                           |                     | Road traffic noise (S)                                                              | 3.424   | 58.3 （Best in the city）                                                            |
|                           |                     | Regional environmental noise (S)                                                   | 3.294   | 48.3 （Best in the city）                                                            |
|                           |                     | Public green area per capita (I)                                                   | 4.891   | 15 （"The 13th Five-Year Plan" of forestry garden development in Chengdu）            |
|                           |                     | Green coverage rate in built-up area (I)                                           | 1.991   | 45 （"The 13th Five-Year Plan" of forestry garden development in Chengdu）            |
| Eco-environment           |                     | Eco-environment status index (I)                                                   | 3.438   | 55 （Ecological demonstrative county）                                               |
| Agricultural and land     |                     | Use intensity of pesticides（D）                                                     | 4.669   | 2.5 （Eco-civilized villages and towns）                                             |
| management                |                     | Use intensity of fertilizers（D）                                                    | 4.420   | 200 （Eco-civilized villages and towns）                                             |
| Resources and energy      |                     | Total energy consumption per unit of GDP（D）                                        | 2.992   | 0.7 （Eco City）                                                                    |
| utilization               |                     | Coal consumption per unit of industrial value added（D）                              | 2.082   | 0.597 （Average value）                                                             |
| Resources utilization     |                     | Comprehensive utilization rate of industrial solid wastes                           | 2.390   | 100 （Ideal value）                                                                 |
| 2nd Class Indicators | 3rd Class Indicators | 4th Class Indicators | Weights | Target value (basis) |
|----------------------|----------------------|----------------------|---------|---------------------|
|                      |                      | (D) Water consumption per unit of GDP (D) | 3.970   | 80 (Eco County)     |
|                      |                      | (D) Water penetration rate (D) | 3.293   | 100 (Ideal value)   |
|                      |                      | (D) Gas penetration rate (D) | 4.031   | 100 (Ideal value)   |
|                      |                      | (D) Emission intensity of Chemical Oxygen Demand (P) | 3.734   | 3.5 (Eco County)    |
|                      | Pollution control    | (P) Emission intensity of NH3-N (P) | 3.767   | 0.459 (Average value) |
|                      |                      | (P) Emission intensity of NOx (P) | 2.207   | 1.814 (Average value) |
|                      |                      | (P) Emission intensity of industrial SO2 (P) | 1.795   | 4.5 (Eco County)    |
|                      |                      | (P) Emission intensity of industrial solid wastes (P) | 2.375   | 298.628 (Average value) |
|                      | Environmental governance | (P) Emission intensity of industrial dust (P) | 3.562   | 1.192 (Average value) |
|                      | Pollution treatment  | (P) Treatment rate of domestic sewage (R) | 3.132   | 100 (Ideal value)   |
|                      |                      | (P) Hazardous waste safe disposal rate (R) | 1.348   | 100 (Ideal value)   |
|                      |                      | (P) Harmless treatment rate of domestic garbage (R) | 2.212   | 100 (Ideal value)   |
|                      |                      | (P) Proportion of investment in environmental governance to GDP (R) | 5.114   | 0.142 (Average value) |
|                      | Environmental management | (R) The proportion of handling environmental petition (R) | 0.875   | 100 (Ideal value)   |
|                      |                      | (R) Handling rate of illegal cases (R) | 0.836   | 100 (Ideal value)   |
|                      |                      | (R) Environmental accident rate (R) | 2.698   | 0 (Ideal value)     |

2.2. Correlation Analysis Method
We conducted a normal distribution test and conversion on the environmental performance scores and GDP of a total 90 samples in various regions in Chengdu from 2013 to 2018 by using SPSS method. And then the Pearson correlation was used to perform bivariate correlations. This analysis method is used to measure whether two data sets are on a line and the linear relationship between fixed-distance variables: negative correlation coefficient shows that the two indicators are negative correlation (high
economic but low environmental performance); positive correlation coefficient shows that the two indicators are positively correlated (high economic and high environmental performance); the closer the correlation coefficient is close to 0, the weaker the correlation is (the economic level is high but the level of environmental performance is not necessarily high).

2.3. Data Sources
Based on the 2013-2018 statistical data of various districts (cities) and counties in Chengdu, the data used were mainly from "Chengdu Statistical Yearbook", "Chengdu Statistical Manual", "Chengdu Environmental Quality Report", "Chengdu Environmental Statistics Annual Report", "Statistical Yearbook of Chengdu City (County) and Village and Town Construction", "Chengdu Water Resources Bulletin" and related planning reports.

3. Results and Discussion
3.1. Correlation Analysis of Comprehensive Environmental Performance and Economy
From 2013 to 2018, the GDP showed a slightly increase. In 2018, Chengdu's comprehensive environmental performance score reached 75.64 points, which increases by 5.6 points comparing with 2013. In 2015, the comprehensive environmental performance decreased slightly comparing with 2014. Therefore, although the overall environmental performance level of Chengdu has fluctuated, it still shows an increase with economic development, as shown in Figure 1.

Judging from the average annual growth rate of six years: Chengdu’s GDP annual average growth rate reached 9.17%, indicating the rapid economy growth; the average annual growth rate of comprehensive environmental performance was only 1.55%, which was significantly lower than the GDP average annual growth rate. It shows that the rapid development of Chengdu's economy has not promoted a significant increase in the level of comprehensive environmental performance, as shown in Figure 2.

![Figure 1. Changes in Chengdu ’s EPI and GDP from 2013 to 2018.](image)
Figure 2. Comparison of Chengdu’s annual average growth rate of EPI and GDP.

In order to further understand the correlation between comprehensive environmental performance and economic development level, the Pearson correlation analysis of comprehensive environmental performance and GDP was conducted, and the results are shown in Table 2. There is no obvious correlation between comprehensive environmental performance and GDP, these results indicate that some districts, cities and counties with high levels of economic development have lower levels of comprehensive environmental performance.

Table 2 Pearson Correlation Analysis of Comprehensive Environmental Performance and GDP

| Index                     | N(GDP)  |
|---------------------------|---------|
| Comprehensive environmental performance | Pearson correlation |
|                           | Sig. (Two-tailed) |
|                           | Cases    |
|                           | -0.007   |
|                           | 0.948    |
|                           | 90       |

**. At the level of 0.01 (Two-tailed), significant correlation.

*. At the level of 0.05 (Two-tailed), significant correlation.

N (GDP) means that the GDP index has been normalized, and the following is the same.

3.2. Analysis of the Correlation Between the Performance of Secondary Indicators and Economy

The performance level of each secondary indicator in Chengdu from 2013 to 2018 is quite different, as shown in Figure 3: environmental governance (82.98%) > energy and resource utilization (78.86%) > ecological protection (71.63%) > environmental quality (52.24%). From the perspective of the average annual growth rate: the performance of the environmental quality indicators showed a negative growth while the environmental performance of the other three indicators increased, and the annual average growth rate of environmental performance of all secondary indicators is lower than GDP, as shown in Figure 4.
Figure 3. Performance of Chengdu’s secondary indicators from 2013 to 2018.

Figure 4. Comparison of the performance of secondary indicators with the average annual growth rate of GDP in Chengdu.

From the Pearson correlation analysis results of the performance of secondary indicators and GDP, the performance of ecological protection, energy and resource utilization, and environmental governance has a significant positive correlation with GDP, while the environmental quality performance and GDP have a negative correlation, as shown in Table 3.

Table 3 Pearson Correlation Analysis of the Performance of the 2nd-Level Index and GDP

| Index                               | N (GDP)       |
|-------------------------------------|---------------|
| N (Environmental Quality)           | Pearson correlation -.762** |
|                                     | Sig. (Two-tailed) 0.000    |
|                                     | Cases 90       |
| Ecological Protection               | Pearson correlation .285**  |
|                                     | Sig. (Two-tailed) 0.006    |
|                                     | Cases 90       |
| N (Energy and resource utilization) | Pearson correlation .575**  |
|                                     | Sig. (Two-tailed) 0.000    |
|                                     | Cases 90       |
3.3. Analysis of the Correlation Between the Performance of 3rd-level Indicators and Economy

There are significant differences in the performance of the 3rd-level indicators. The best one in 2018 is pollution control indicator (99.73%), and the second one is energy utilization indicator, with a performance of 94.27%. In addition, pollution control (87.35%), resource utilization (81.50%), and ecological environment (80.02%) also performed well. However, the performance of other five indicators including atmospheric environmental quality, water environmental quality, acoustic environmental quality, agriculture and land management, and environmental management did not reach 80% of the target. Comparing the average annual growth rate of these five indicators with the average annual growth rate of GDP, the performance of the three indicators of atmospheric environmental quality, water environmental quality and acoustic environment quality all show negative growth, and only the performance levels of agriculture and land management indicators and environmental management indicator have improved, but the growth rate is slower than GDP, as shown in Fig. 5 and Fig. 6.

**. At the level of 0.01 (Two-tailed), significant correlation.
*. At the level of 0.05 (Two-tailed), significant correlation.

| Environmental governance | Pearson correlation | Sig. (Two-tailed) | Cases |
|--------------------------|---------------------|-------------------|-------|
|                          | .514**              | 0.000             | 90    |

**. At the level of 0.01 (Two-tailed), significant correlation.
*. At the level of 0.05 (Two-tailed), significant correlation.

Figure 5. Performance of Chengdu's 3rd-level indicators from 2013 to 2018.
Figure 6. Comparison of the performance of 3rd-level indicators with the average annual growth rate of GDP in Chengdu.

From the Pearson correlation analysis results of the 3rd-level indicator performance and GDP, the performance of agriculture and land management indicators has a significant positive correlation with GDP, while the atmospheric environmental quality, water environmental quality, acoustic environmental quality, and environmental management showed a negative correlation with GDP, as shown in Table 4.

Table 4 Pearson Correlation Analysis of the Performance of 3rd-Level Indicators Less than 80% of Target Level and GDP

| Index                                | Pearson correlation | Sig. (Two-tailed) | Cases | N (GDP)  |
|--------------------------------------|---------------------|-------------------|-------|----------|
| Atmospheric environmental quality    | -0.582**            | 0.000             | 90    | -0.515** |
| N (Water quality)                    | -0.695**            | 0.000             | 90    | -0.353** |
| Noise                                | 0.250*              | 0.017             | 90    | 0.001    |
| Agricultural and land management     | -0.353**            | 0.001             | 90    |          |

**. At the level of 0.01 (Two-tailed), significant correlation.
*. At the level of 0.05 (Two-tailed), significant correlation.

3.4. Analysis of the Correlation Between the Performance of the 4th-level Indicators and the Economy

Fourteen 4th-level indicators, which did not meet the 3rd-level indicators of 80% of the target, were further analyzed, as shown in Fig. 7. The four indicators of the water quality compliance rate of urban
and rural centralized drinking water source protection areas, the proportion of environmental petition, the handling rate of illegal cases and the environmental accident rate performed very well, and they all reached or approached the target level in 2018. The annual average concentration of NO\textsubscript{2} also performed well, and it reached 85.07\% of the target, while the remaining 9 indicators were all below the 80\% of the target, especially the performance of the five indicators including good air quality days, annual average PM\textsubscript{2.5} concentration, daily maximum 8-hour average ozone concentration, road traffic noise, and regional environmental noise is less than 60\% of the target level.

Comparing the average annual growth rate of 9 indicators that are less than 80\% of the target with the average annual growth rate of GDP, the growth rate of these 9 indicators is lower than GDP. In addition, the ratio of days with good air quality, daily maximum 8-hour average of ozone concentration, the ratio of the water quality above the city control section (at or above category III), road traffic noise, and regional environmental noise showed negative growth, as shown in Fig. 8.

![Figure 7. Performance of 4th-level indicators from 2013 to 2018.](image)

![Figure 8. Comparison of the performance of 4th-level indicators with the average annual growth rate of GDP.](image)
From the Pearson correlation analysis results of the performance of the 4th-level indicators and GDP, the performance of pesticide use intensity indicators has a significant positive correlation with GDP; There is no significant correlation with the daily maximum 8-hour average of ozone concentration, the intensity of fertilizer use, and environmental protection capacity building funds. The indicator performance of the proportion of days with good air quality, the annual average concentration of PM$_{2.5}$, the proportion of water quality above the city control section (attained or better than category III), road traffic noise, regional environmental noise, has a significant negative correlation with GDP, these results were shown in Table 5.

Table 5 The Pearson Correlation Analysis of the Performance of 4th-Level Indicators Less than 80% of the Target Level and GDP

| Index                                                                 | Pearson correlation | Cases |
|-----------------------------------------------------------------------|---------------------|-------|
| N (Ratio of days with good air environment quality)                   | -.631**             | 90    |
| N (Annual concentration of PM$_{2.5}$)                               | -.468**             | 90    |
| Daily maximum 8-hour average ozone concentration                      | 0.152               | 90    |
| N (Excellent rate of section water quality above municipal control)   | -.526**             | 90    |
| Road traffic noise                                                    | -.624**             | 90    |
| Regional environmental noise                                          | -.506**             | 90    |
| N (Use intensity of pesticides)                                       | .478**              | 90    |
| N (Use intensity of fertilizers)                                      | 0.090               | 90    |
| N (Total use of environmental protection capacity building funds at this level as a percentage of GDP) | -0.180             | 90    |

**. At the level of 0.01 (Two-tailed), significant correlation.
*. At the level of 0.05 (Two-tailed), significant correlation.

4. Conclusion
The environmental performance levels of various indicators are quite different, and have different degrees of correlation with economic indicators. Although Chengdu's comprehensive environmental performance level shows an increase with economic development, the growth rate of Chengdu's
comprehensive environmental performance and the performance of the 2nd-level, 3rd- and 4th-level indicators lags behind the economic growth rate. There is no obvious correlation between comprehensive environmental performance and GDP, and there is a significant negative correlation between the performance of environmental quality indicators and GDP in the 2nd-level indicators; Among the 3rd-level indicators, the performance of atmospheric environment quality, water environment quality, acoustic environment quality, and environmental management has a significant negative correlation with GDP; Among the 4th-level indicators, only one indicator that has a significant positive correlation with GDP, and three indicators has no significant correlation with GDP, and other five indicators have a significant negative correlation.

5. Recommendations
While accelerating economic development, we must pay more attention to protecting the ecological environment to achieve coordinated development of economy and environment. Districts, cities and counties with a high level of economic development should pay more attention to improving the quality of the atmosphere, water and reducing noise as well as increasing investment in environmental protection, so as to greatly improve the overall environmental performance level. Districts, cities and counties with low levels of economic development should accelerate economic green development and improve management support in order to strengthen ecological protection and sustainable use of resources and energy and improve the level of environmental governance significantly. It also improves the overall environmental performance level.

The article is an index system and evaluation method of Chengdu's environmental performance evaluation based on the existing research results. Although it has certain reference significance, environmental performance evaluation requires a unified and specific environmental performance evaluation system, this will give full play to the role of environmental performance assessment in environmental management. In order to make the environmental performance evaluation results more scientific and oriented, it is necessary to strengthen the construction of the environmental performance evaluation system, strengthen the research on performance evaluation theory and key technical methods, and establish a unified long-term mechanism for environmental performance evaluation across the country and localities.

Acknowledgments
We gratefully appreciate the Ministry of Ecology and Environment's financial budget project "National Environmental Performance Evaluation and Management Research Project" (Grant No. 1441401800019).

References
[1] Zuo, X., Hua, H., Dong, Z.F., Hao, C.X. (2016) Environmental performance index at the provincial level for china 2006-2011. Ecological Indicators, 75:48-56.
[2] Pham, H., Sutton, B.G., Brown, P.J., Brown, D.A. (2020) Moving towards sustainability: A theoretical design of environmental performance measurement systems. Journal of Cleaner Production, 122273:0959-6526.
[3] Xie, S.Y., Hayase, K. (2010) Corporate environmental performance evaluation: a measurement model and a new concept. Business strategy and environment, 16: 148-168.
[4] Chen, J. D., Song, M.L., Xu, L. (2015) Evaluation of environmental efficiency in China using data envelopment analysis. Ecol. Indic, 52: 577-583.
[5] Liu, J., Wang, H.Z., (2014) Environmental performance evaluation research of Tianjin. Future Dev, 3:81-86.
[6] Wu, J.N., Xu, M.M., Zhang, P. (2018) The impacts of governmental performance assessment policy and citizen participation on improving environmental performance across. Journal of Cleaner Production, 184: 227-238.
[7] Bulkeley, H., Mol, A.P.J. (2003) Participation and environmental governance: consensus,
ambivalence and debate. Environ. Val, 12:143-154.

[8] Sun, J.H., Hu, J., Yan, J.M., Liu, Z., Shi, Y.R. (2012) Regional environmental performance evaluation: a case of western regions in China. Energy Procedia, 16: 377-382.

[9] Niemeijer, D., de Groot, R.S. (2008) A conceptual framework for selecting environmental indicator sets. Ecological Indicators, 8:14-25.

[10] Zheng, S.N., He, C.H., Hsu, S.C., Sarkis, J., Chen, J.H. (2020) Corporate environmental performance prediction in China: An empirical study of energy service companies, Journal of Cleaner Production, 121395: 0959-6526.