Coupling Spatial Distribution and Industrial Structure Optimization Analysis of Economic and Environmental Pollution in Chongqing

Xiaomeng Gou 1, Yao Li 2, * 
1 School of General, Chongqing Water Resources and Electric Engineering College, Chongqing, China  
2 School of Economics and Trade, Chongqing College of Finance and Economics, Chongqing, China  
*Corresponding author e-mail: Muhong2007@cqut.edu.cn

Abstract. In recent years, as one of the old industrial bases in China, although it has been promoting the construction of new industrialization, Chongqing is still facing a more severe situation of industrial pollution. In order to further upgrade the optimization of industrial structure in Chongqing, the paper combined with 2773 cases of Chongqing pollution administrative penalties. Select industrial pollution enterprises administrative penalty amount of the 38 districts and counties in Chongqing as cross-sectional data, the spatial correlation of industrial pollution in Chongqing was analyzed by exploratory spatial analysis. Then, using the coupled coordination degree model, the evaluation index system of economic development and industrial pollution coupling degree in Chongqing area is established, and the spatial pattern of the economic environment coupling degree in Chongqing is analyzed. It is found that the spatial agglomeration characteristics of industrial pollution in Chongqing are not obvious, and the regional pollution is different, the economic environment system is in the state of low coupling, the spatial types of the coupling degree of regional economic environment are the most antagonistic economic environment, and the minority is the low coupling region. Based on the results of spatial layout, this paper analyzes the industrial structure of Chongqing City and put forward the optimization strategy of industrial structure.

1. Introduction
During the Eleventh Five-Year Plan and the Twelfth Five-Year Plan period, Chongqing's industrial production showed a rapid expansion trend. From 2005 to 2018, the industrial added value of Chongqing increased from 156.683 billion yuan to 599.770 billion yuan, an increase of nearly four times. However, the industrial pollution caused by the rapid growth of industrial economy can not be ignored. According to the report data of "green economy and green GDP index of 300 provinces and cities in China" (CCGEI 2012), with the development of the western region, industrial pollution has shifted from coastal areas to Chongqing and other western inland areas. Chongqing ranks first in the list of industrial waste water and industrial smoke emissions of all cities in China, and has become a worst-hit areas in the discharge of industrial waste water and industrial dust in China. To this end, Chongqing has taken a series of powerful measures to promote the industrial economic restructuring, such as making pillar industries
bigger and stronger, cultivating strategic emerging industries, speeding up the elimination of backward production capacity, and optimizing the industrial investment structure. In this case, promoting the optimization of industrial structure has important practical significance for reducing environmental pollution, promoting the sustainable development of Chongqing industry and enhancing the comprehensive economic strength of Chongqing.

2. Quality analysis of survey data

2.1. Respondents
There are many types of industrial pollution, and the existing research literature mostly takes the total discharge amount of industrial waste water, industrial waste gas, industrial dust and industrial solid waste as the evaluation standard of regional pollution level [1, 2], and pays less attention to the pollution intensity. From the perspective of administrative punishment of industrial polluting enterprises, this paper investigates the industrial pollution in Chongqing. The pollution intensity is measured by the total amount of administrative penalty for industrial polluting enterprises in Chongqing.

2.2. Survey data sources
In this paper, 2773 administrative penalty data of polluting enterprises in Chongqing were collected from the official website of Chongqing municipal government. The collected information includes 13 aspects: law enforcement type, report number, law enforcement unit, violation type, illegal behavior, violation of law, decision basis, law enforcement measures, fine amount, decision making time, law enforcement unit, whether it has been overdue and illegal information sources.

2.3. Basic results of the survey
The investigation time is about one month. A total of 2773 administrative penalty data of polluting enterprises from Chongqing municipal government and 38 districts and counties under its jurisdiction were obtained. According to the national standard classification of industrial enterprises in national economic industry classification (GB / t4754-2011), 2773 administrative punishment data of polluting enterprises in Chongqing were screened out. The total amount of administrative penalty of industrial pollution enterprises in each district and county was counted by Chongqing administrative division.

3. Analysis on coupling degree pattern of economy and environmental pollution in Chongqing
Chongqing is located in the Midwest of China. In 2019, Chongqing's GDP will reach 2.36 trillion yuan, the economic growth rate was 6.8%, and the resident population are 31.2432 million. It is one of the economic centers and important cities in central and Western China. At present, Chongqing Municipality has 26 districts, 8 counties and 4 autonomous counties. The main reason for Chongqing's strong economic performance is to seize the opportunity of opening to the west, accelerate the export of high-end products, focus on the domestic demand market, and accelerate the development of industry and service industry.

3.1. Coupling relationship between economy and environment
The coupling relationship between economic and environmental system mainly describes the input and output of factors between economic growth and other sectors and environmental sustainability. The research methods of the relationship between economy and environment are mainly include green national accounting method, Kuznets curve and hypothesis. It is not enough to use a single indicator to analyze the relationship between economy and environment, and it should to use composite indicators to research [3]. Scholars use the concept of coupling and coordinated development degree in physics to study the coordinated relationship between economic and environmental systems. Wu Yueming (1996) established a quantitative calculation model of coupling degree and used gray system to predict coupling degree [4]. Liu Yaobin (2005) established the correlation degree model and coupling degree model of regional urbanization and ecological environment in China by using the grey correlation degree method,
and analyzed the spatial law of coupling between provincial urbanization and ecological environment system in China [5]. Coupling refers to the phenomenon that two (or more) systems or motion forms influence each other through various interactions. There is an interactive coupling relationship between regional economy and environmental subsystems. Therefore, the degree of mutual influence between the two factors, regional economic development and ecological environment state, which affect the environmental carrying capacity through their respective coupling elements, can be defined as the coupling degree of regional economy environment system.

3.2. Evaluation index system of Chongqing regional economy and environment subsystem

Combined with the overall coordination relationship between the regional economic development and the environment in Chongqing, the following index system is constructed, in which the environmental subsystem is more complex and the measurement standard is difficult to unify due to the comprehensive consideration of the elements affecting the environment subsystem. Therefore, this paper mainly measures the functional state of the system by qualitative index pollution degree, and uses the result variable (administrative penalty amount) to reflect the degree of pollution. As shown in table 1.

| Table 1. Comprehensive evaluation index system of Chongqing Economic and environmental administrative punishment subsystem |
|---------------------------------------------------------------|
| Subsystem | Function | Index |
| Economy subsystem | Economic strength | GDP |
| | | Total industrial output value |
| | Economic support | Fiscal expenditure |
| | | Investment in fixed assets |
| | Economic development | GDP growth rate |
| Environment subsystem | Pollution level | Punishment intensity |

3.3. Calculation of efficacy function

Chongqing economic environment coupling system is composed of two subsystems: economy and environment. The economic subsystem is composed of several indicators, and the environmental subsystem uses the environmental administrative penalty amount index of each district and county in Chongqing. Suppose subsystem have n indexes, which are $x_1$, $x_2$, $x_n$. The calculation formula of efficiency coefficient of different indexes in Chongqing economic environment coupling system is as follows:

$$d_{ij} = \frac{(x_{ij} - x_{ij_{\text{min}}})}{(x_{ij_{\text{max}}} - x_{ij_{\text{min}}})}$$  \hspace{1cm} (1)

$$d_{iy} = \frac{(x_{ij_{\text{max}}} - x_1)}{(x_{ij_{\text{max}}} - x_{ij_{\text{min}}})}$$  \hspace{1cm} (2)

3.4. Comprehensive evaluation of subsystem efficacy

The comprehensive effect of Chongqing Economic and environmental subsystem is the synthesis of the contribution of all indicators in each system to the subsystem, which is realized by the integration method. The calculation formula is as follows:

$$U_i = \sum W_y \times d_{ij}, W_y \text{ greater than or equal to } 0, \sum W_y = 1, j = 1, 2, \ldots, n$$

3.4.1. Economic subsystem weight. Using the method of principal component analysis to determine the weight is mainly to take the variance contribution rate of the principal component as the weight to normalize the weighted average of the coefficients of the index in the linear combination of the principal components. The coefficient of the index in the linear combination of different components is calculated by the load number and characteristic follow-up value, and the linear combination of two principal components can be obtained as follows:
\[ F_1 = 0.482X_1 + 0.489X_2 + 0.432X_3 + 0.484X_4 + 0.327X_5 \]
\[ F_2 = -0.203X_1 + 0.181X_2 - 0.503X_3 - 0.082X_4 + 0.816X_5 \]

3.4.2. Fuzzification of evaluation index system of environment subsystem weight and deconstruction. In Consider of the environmental subsystem is divided by administrative penalty index, the specific value is obtained by using five level index evaluation method and fuzzy number transformation. Linguistic variables are phrases in natural language, rather than numbers expressed by specific numerical values. The linguistic evaluation of indicator values can be expressed by trapezoidal fuzzy numbers (Table 3-3).

Table 2. Transformation relationship between language variable evaluation and trapezoidal fuzzy number

| Language variable evaluation | Trapezoidal Fuzzy Number |
|-----------------------------|--------------------------|
| very large                  | (0.8,0.9,0,9,1)          |
| large                       | (0.6,0.7,0.7,0.8)        |
| moderate                    | (0.4,0.5,0.5,0.6)        |
| not large                   | (0.2,0.3,0.3,0.4)        |
| Very small                  | (0.0,1.0,1.0,2)          |

It can be concluded that after the fuzzification of language variable evaluation, the specific values of pollution degree are very large, pollution degree is large, pollution degree is general, pollution degree is not large, and pollution degree is very small, the specific values are: 0.881, 0.696, 0.5, 0.304, 0.119.

3.5. Analysis of coupling coordination degree between economic development and environmental pollution in Chongqing

\[ C = \left\{ \frac{U_1 \times U_2 \times \ldots \times U_n}{\prod (U_i + U_j)} \right\}^{1/n} \]  

(3)

C is the coupling degree, \( U_j \) is the comprehensive efficacy of each subsystem. The coupling degree is determined by the size of each subsystem \( U_j \). Because the coupling degree system measured in this paper is composed of Chongqing Economic and environmental subsystems, \( n = 2 \). When \( C = 0 \), the coupling degree is very small, and there is no relationship between the systems or the internal elements of the system, and the system will develop disorderly. When \( C = 1 \), the coupling degree is very large, and the relationship between systems or internal elements is close, and the system operates effectively.

The degree of coordination refers to the attribute that each element in the process of system evolution is in harmony with each other. The coupling degree of environmental pollution model can coordinate the development of environmental pollution better. The calculation formula is as follows:

\[ T = \sqrt{aU_1 \times \beta U_2} \]  

(4)

\[ D = \sqrt{C \times T} \]  

(5)

4. Analysis on calculation results of coupling coordination degree of regional economic environment of prefecture level units

4.1. Spatial pattern of coupling degree of economic environment

From the above analysis, it can get the spatial distribution value of coupling degree between economic development and environmental pollution of 38 districts under the jurisdiction of Chongqing. The spatial distribution is relatively balanced, and the coupling degree value basically maintains between 0.3 and 0.5. It means most areas are in medium strong coupling areas, among which Nanan District and Jiangjin...
district have the highest coupling degree. Low intensity coupling area (coupling degree value below 0.3) is Changshou District.

4.2. Spatial pattern of coordination degree of economic environment
Coordination degree is a quantitative index to measure the coordination between systems or between systems [6]. The coordination degree of economic and environmental system of 38 districts and counties under the jurisdiction of Chongqing is basically distributed between 0.14 and 0.3, which is in the low-level coordination stage. The highest coordination degree is in Yubei District, and the lowest is Changshou District. The results show that although Chongqing has made some progress in promoting industrial restructuring, the overall environmental pollution level exceeds the self-purification capacity of the environment, and the industrial pollution problem is still prominent.

4.3. Spatial type division of coupling coordination degree of economic environment
Generally speaking, the comprehensive coordination degree and coupling degree can be divided into four categories: economic environment harmonious area (high coupling and high coordination area), economic environment running in area (high coupling and low Harmony area), economic environment antagonistic area (medium coupling low Harmony area), economic environment low coupling area (low coupling and low coordination area). To sum up, the results show that the coupling degree of economic environment in Chongqing is basically in the antagonistic area of economic environment. The coupling degree of most districts and counties is between 0.2 and 0.5, and the coordination degree is below 0.3, which is consistent with the analysis results of domestic scholars Ma Li and Jin Fengjun (2012) on the coupling degree of China's industrial economy and environmental pollution. Among them, Changshou
District is located in the low coupling area of economic environment (coupling degree and coordination degree are below 0.3), which is the area with the least interaction between economic environment.

Figure 3. Spatial pattern of coupling degree of economy and environment in Chongqing

Through the overall evaluation of the coupling coordination degree of economic environment, the following conclusions can be drawn: firstly, the environment and economic development of Chongqing do not present a good health state, and the economic development and environmental sustainability show the phenomenon of inhibition. This is because Chongqing's industrial structure still has the problems of unreasonable industrial space layout and low industrial technology level in the current economic transformation period. Secondly, the spatial difference of coupling coordination degree between economic and environmental pollution in Chongqing is small, and there is no obvious cluster pollution belt, which indicates that the overall industrial structure adjustment of Chongqing is in a good development trend. Only by accelerating the optimization of Chongqing's industrial structure can we provide impetus and conditions for the overall social environment and economic system of Chongqing.

5. Conclusion
Although the industrial structure of Chongqing is not well coordinated with the industrial structure, the overall industrial structure of Chongqing is still not balanced. The problem of high industrial pollution also means that Chongqing needs to strengthen the development of new industrialization. As the pillar industries of Chongqing, electronic information, automobile industry and other industries have certain scale and agglomeration effect. However, the production capacity consumption and industrial pollution of these traditional industries are large, and the efficiency ratio is not high. Therefore, it is necessary to strengthen energy conservation and emission reduction and technology research and development to reduce energy consumption and industrial pollution. As the key development of chemical raw materials and chemical products industry, non-metallic materials and pharmaceutical manufacturing in the future, its industrial output value gradually increases. However, due to the serious pollution, pollution monitoring should be strengthened in the construction of new industrialization to prevent environmental pollution risks. Reducing industrial energy consumption and reducing environmental pollution are not only the basic requirements of the new industrialization strategy, but also the premise of industrial sustainable development [7].

This paper discusses the coupling relationship between industrial pollution and industrial economy from the perspective of industrial pollution administrative penalty data, which is form comprehensive perspective. In the future study of industrial pollution, we can use the industrial pollution index value (for example, industrial output value waste water discharge, industrial output value sulfur dioxide emission, etc.) to explore the relationship between different types of industrial pollution and economic development in Chongqing, and provide quantitative decision-making basis and targeted treatment suggestions for the realization of industrial structure upgrading and industrial economic development in Chongqing.
References

[1] Li Lin, Zhu Jinshan, Gao Runxia. The Study on Relationship Between Economic Growth and Environmental Pollution in Chongqing Base on VAR Model [J]. Journal of Southwest University (Natural Science Edition), 2009, 31(11): 92-96.

[2] Zhang Ling. Study on influencing factors and trend prediction of industrial pollution in Chongqing -- Based on Grey System Theory [J]. Economic Affairs, 2012, (3): 56-61.

[3] Xue Bing, Zhang Zilong, Guo Xiaojia. Analysis of coupling effect between regional ecological environment evolution and economic growth -- a case study of Ningxia Hui Autonomous Region [J]. Ecology and Environmental Sciences, 2010, 19(5): 1125-1131.

[4] Wu Yueming, Zhang Ziheng, Lang Dongfeng. A new prediction model of environmental economic coordination degree and its application [J]. JOURNAL OF NAIJING UNIVERSITY (NATURAL SCIENCES), 1996, (3): 466-473.

[5] Liu Yaobin, Li Rendong, Song Xuefeng. Correlation analysis of coupling between regional urbanization and ecological environment in China [J]. Acta Geographica Sinica, 2005, 60(2): 237-247.

[6] Zhang Xiaodong, Chi Tianhe. Analysis on the coordination degree of regional economy and environment at provincial level in China in 1990s [J]. Geographical Research, 2001, 20(4): 506-515.

[7] Hou Pei, Yang Qingyuan, He Jian. Evaluation of coupling coordination degree between urbanization and ecological environment development -- a case study of 38 districts and counties in Chongqing [J]. Journal of Southwest China Normal University (Natural Science Edition), 2014(2): 81-87.