Coordinated Development of Energy, Environment and Economic Systems (3E) - Based On a Comparison of Regional Differences

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Coordinated Development of Energy, Environment and Economic Systems (3E) - Based On a Comparison of Regional Differences

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Abstract. By constructing the 3E symbiosis system model and the 3E system coordination degree evaluation model, this paper measures the coordination degree of 3E system in the three regions of Beijing-Tianjin-Hebei Urban Agglomerations (BTH), Yangtze River Delta Urban Agglomerations (YRD) and Pearl River Delta (PRD). The study found that the 3E system coordination degree in the three regions is in an intermediate coordination state, and the energy system and the environmental system are lagging behind. This paper provides assistance for understanding the coordinated development of China's 3E system, and provides empirical support for China's promotion of ecological civilization.

1. Introduction

Energy is the power basis for the development of human society and economy and an important guarantee for the sustainable development of society and economy. The environment is the carrier on which human beings and resources depend and provides resource support for economic development. Energy, environment and economic development are indivisible as a whole. The dynamic balance of energy system, environmental system and economic system has been widely concerned by domestic and foreign scholars (Galinis, 2000, Lazzaretto et al., 2004).

In the coordinated development of energy system, environmental system and economic system, a fact that cannot be ignored is that the regional characteristics of economic development always exist. The BTH, YRD and PRD are the three most rapidly developing urban economic circles in China. After analyzing the symbiotic relationship model of energy system, environmental system and economic system, this paper constructs the evaluation index system and system coordination degree model of 3E system, and then makes a comprehensive comparison of the coordination degree of 3E system in the BTH, YRD and PRD city clusters through data analysis. Through the analysis, we hope to understand the frontier issues of the coordinated development of China's energy, environment and economy, so as to provide a scientific basis for formulating the coordinated development strategy among regional energy, environment and economy.

2. Energy - environment - economy symbiosis model

Early studies on energy, environment and economy focused on the "2E" relationship between energy system and economic system, and between environmental system and economic system. (Hawdon and Pearson, 1995). However, more and more scholars have found that the energy system, environmental system and economic system are an interactive whole, and proposed the “3E”
relationship, namely the symbiotic relationship between energy, environment and economy (Oliveira, 2004, Soytas, 2009, Oliveira, 2011). According to previous research, the symbiotic model of energy, environment and economy is shown in figure 1. Economic system is the core part of the whole model. Both energy system and environment system depend on and act on economic system. The healthy development of the economic system provides the material basis for the benign operation of the ecosystem and energy system, while the production of energy in the energy system provides the power support for the society, and all kinds of emissions generated in the production and life of the society return to the ecosystem, thus forming a dynamic cycle process.

Figure 1. Symbiotic models of energy, environment and economy

3. Evaluation model of coordination degree of 3E system

3.1. Index system
This paper adheres to the principles of hierarchy, comparability, dynamics and operability to collect and screen the relevant indicators in the BTH, the YRD and the PRD respectively, and confirm the rationality of the index to the scholars in related fields. At the same time, by referring to relevant literatures, this paper constructed the comprehensive index system as shown in table 1 below, and finally established 9 second-level indicators and 24 third-level indicators, so as to measure the coordination degree of the three 3E systems.

Table 1. Evaluation index system of coordination degree of 3E system

| Level indicators            | Secondary indicators | Weight | Weight | Third-level indicators                                      | Weight |
|-----------------------------|----------------------|--------|--------|-------------------------------------------------------------|--------|
| Energy system level index(X)| Growth index         | 0.3    |        | Total energy production(10 kilo-tons/standard coal)         | 0.4    |
|                             |                      |        |        | Total energy consumption(10 kilo-tons/standard coal)       | 0.4    |
|                             |                      |        |        | Total oil import (10 kilo-tons)                            | 0.2    |
|                             | Structure index      | 0.3    |        | Proportion of coal consumption (%)                         | 0.4    |
|                             |                      |        |        | Proportion of oil and natural gas production (%)           | 0.4    |
|                             | Quality index        | 0.4    |        | Per capita electricity consumption (KWH)                   | 0.5    |
|                             |                      |        |        | Per capita energy consumption (kg standard coal)           | 0.5    |
| Environmental system level index(Y) | Total indicator     | 0.4    |        | Total wastewater discharge (100 million tons)*             | 0.5    |
|                             |                      |        |        | Total carbon emission (ten thousand tons)*                 | 0.5    |
|                             |                      |        |        | Per capita water resources (m3 / person)                   | 0.2    |
|                             |                      |        |        | PM2.5 concentration (mg/m3)                                | 0.2    |
|                             |                      |        |        | Green coverage rate of built-up area (%)                   | 0.3    |
|                             |                      |        |        | Landscape green area (%)                                   | 0.3    |
| Economic system level index(Z)| Growth index         | 0.25   |        | GDP(100 million)                                           | 0.5    |
|                             | Structure index      | 0.25   |        | Per capita GDP (yuan)                                      | 0.5    |
|                             |                      |        |        | The added value of service industry of GDP (%)             | 0.3    |
|                             | Quality index        | 0.25   |        | Residents' consumption share of GDP (%)                    | 0.3    |
|                             |                      |        |        | The proportion of secondary industry (%)                   | 0.3    |
|                             |                      |        |        | The tertiary industry proportion (%)                       | 0.4    |
|                             |                      |        |        | Fiscal revenue share of GDP (%)                            | 0.4    |
|                             |                      |        |        | GDP growth rate (%)                                        | 0.6    |
3.2. 3E system coordination degree evaluation model

Considering the difference of secondary indexes in the evaluation index system, the dimensionless treatment was carried out to eliminate the influence of different measurement units. Data processing is realized through the following standardized formula:

Positive index standardization: \( x' = \frac{x - \bar{x}}{\alpha} \quad y' = \frac{y - \bar{y}}{\beta} \quad z' = \frac{z - \bar{z}}{\gamma} \)

Negative index standardization: \( x' = \frac{x - \bar{x}}{\alpha} \quad y' = -\frac{y - \bar{y}}{\beta} \quad z' = -\frac{z - \bar{z}}{\gamma} \)

The \( x', y' \) and \( z' \) refer to the standardized secondary index, and \( x, y \) and \( z \) are the original values. The \( \alpha, \beta \) and \( \gamma \) is the standard deviation of our original value.

According to the standardized index, the comprehensive index of coordination degree of energy system, environmental system and economic system can be calculated as follows:

\[
X_i = a_1x'_i + a_2x'_2 + \ldots + a_mx'_m, \quad X = \sum \omega_i X_i
\]

\[
Y_i = b_1y'_i + b_2y'_2 + \ldots + b_my'_m, \quad Y = \sum \nu_i Y_i
\]

\[
Z_i = c_1z'_i + c_2z'_2 + \ldots + c_mz'_m, \quad Z = \sum \theta_i Z_i
\]

Where, \( X, Y \) and \( Z \) represent the first-level indicators, \( \omega_i, \nu_i \) and \( \theta_i \) represent the weight of the first-level indicators, \( a_i, b_i \) and \( c_i \) represent the weight of the second-level indicators.

According to the above formula, the coordination degree of 3E system in the BTH, the YRD and the PRD is measured. In addition, due to regional differences, this paper divides the degree of coordination into sections for more intuitive comparative analysis. Referring to previous studies, we define the degree of coordination as:

\[
C_{xyz} = \frac{X + Y + Z}{\sqrt{(X^2 + Y^2 + Z^2)}}
\]

Where, \( X \) represents the comprehensive level index of energy system, \( Y \) represents the comprehensive level index of environmental system, and \( Z \) represents the comprehensive level index of economic system. Calculated its scope is: \(-1.94 \leq C_{xyz} \leq 1.94\), according to the scope will coordinate degree is divided into six types, shown in the table below:

Table 2. Classification of degree of coordination of 3E system

| Compatibility type | Cxy≤ | 0.4 | 0.8 | 1.2 | 1.6 | 1.94 |
|-------------------|------|-----|-----|-----|-----|------|
| Severe disorder    | -1.94 | 0-0.4 | 0.4-0.8 | 0.8-1.2 | 1.2-1.6 | 1.6-1.94 |
| Moderate disorder  |      |      |      |      |      |      |
| Mild disorder      |      |      |      |      |      |      |
| Primary coordination |      |      |      |      |      |      |
| Intermediate coordinate |      |      |      |      |      |      |
| Advanced coordination |    |      |      |      |      |      |

4. Spatial and temporal analysis of coordination degree of 3E system

Based on the above data and analysis methods, this paper selects the urban development data of the BTH, the YRD and the PRD from 2012 to 2017, and calculates the development status of the coordination degree of the 3E system in the three regions, as shown in table 3.

Table 3. BTH, YRD and PRD of degree of coordination of 3E system

| Year | X  | Y  | Z  | Cxyz  | Type            |
|------|----|----|----|-------|-----------------|
| BTH  |    |    |    |       |                 |
| 2012 | 0.93 | -1.34 | 1.63 | 0.53  | Mild disorder   |
| 2013 | 0.84 | -0.67 | 1.95 | 0.95  | Primary coordination |
| 2014 | 0.84 | 0.34 | 2.98 | 1.34  | Intermediate coordinate |
| 2015 | 0.71 | 0.52 | 3.45 | 1.31  | Intermediate coordinate |
| 2016 | 0.81 | 0.86 | 3.85 | 1.37  | Intermediate coordinate |
| 2017 | 0.92 | 0.93 | 4.36 | 1.36  | Intermediate coordinate |
| YRD  | 2012 | 0.76 | -0.72 | 1.97 | 0.90 | Primary coordination |
As can be seen from table 3, the overall coordination degree of the 3E system in the BTH, the YRD and the PRD reaches the intermediate level. Among them, the coordination degree of the 3E system in the PRD is the highest, while that in the BTH is the lowest. In 2012 and 2013, the environmental system indexes of the three regions all showed negative values, indicating that the environmental development and economic development were unbalanced at this stage, and the environmental system lagged behind the energy and economic development. Specifically, the coordination degree of the BTH 3E system presents an obvious fluctuating state. In 2012, the system is slightly out of balance and the comprehensive index of environmental system is low. The possible reasons are that the development of heavy industry in Hebei and the air quality in Beijing lead to the decline of environmental quality. As a whole, the 3E system in the YRD presents a balanced development. The energy system, environmental system and economic system go hand in hand, strengthening the protection of the ecological environment while developing the economy. The coordination degree of the 3E system reached the intermediate level in 2014, and the coordination degree of the 3E system is relatively stable. Driven by the central cities of Guangzhou, Shenzhen and Zhuhai, the PRD has witnessed rapid development in energy systems, environmental systems and economic systems. In 2012, there was a slight imbalance, mainly due to the development of heavy industry, which produced a lot of pollution and increased the content of sulfur dioxide and carbon dioxide, which increased the frequency of acid rain and unbalanced the environmental system. The development level of the BTH, the YRD and the PRD represents the frontier of China's development at present. According to the development status of the coordination degree of the 3E system in the three regions, the coordination degree of China's energy, environment and economy is still in the preliminary coordination stage, and the more developed areas in the east are gradually moving towards a highly coordinated stage.

5. Conclusion
It can be seen from the above analysis that in China's development in recent years, energy, environment and economy have reached a preliminary coordination state to a certain extent, which is mainly due to the promotion of China's "ecological civilization construction" policy, and also shows that China has made certain achievements in ecological civilization construction. By measuring the three regions of the BTH, the YRD and the PRD, this paper finds that the coordination of the three regions' 3E systems is generally in the intermediate coordination state, among which the energy system and the environmental system lag behind the development of the economic system. In addition, due to the fact that China's unbalanced regional development, energy, environment and economy coordinated development in the central and western regions in our country is still grim, but thankfully, like the BTH, the YRD and the PRD has made a certain development experience, to our country to promote energy, environment and economy coordinated development has the important guiding significance. In the future development process, we should pay special attention to the energy system and the environmental system. The current state of development has initially shown the lag of the...
energy system and the environmental system. Therefore, while maintaining economic development, we should make full use of the results of economic development to promote and maintain the ecological environment and energy resources, so as to achieve more long-term coordinated development.

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