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Analysis of relationship between economic growth and environment in Benxi Shiqiaozi Development Zone

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Abstract——How to express and assess the coordination between environmental system and economic system is one crucial problem for the studies on regional sustainable development. The present study applies environmental supporting capacity (ESC) to evaluate the comparative coordination of economic development plans in a case study in Shiqiaozi Development Zone. The analysis conclusion showed the method is practicable. A new method for judging the efficiency of utilization of environmental system is also discussed in this paper.

Keywords: sustainable development; coordination; environmental supporting capacity (ESC); Benxi Shiqiaozi Development Zone (BSDZ).

1 Introduction

Sustainable development strategy is addressed as the first of "Ten Countermeasures for China's Environment and Development" (SPC, 1994). To achieve this goal, it is important to coordinate environmental protection and economic development. Therefore we can avoid the vicious way of "pollution then control" from the very beginning of planning process.

During the comprehensive planning which involves economic and environmental issues, the key problem is to judge whether the environment construction and the economic development is coordinated. Environmental suporting capacity (ESC), which has been discussed in some literatures (Ye, 1992; 1994), works as the linkage of environment and economy and interface of macroscopic and microscopic levels in environmental planning process.

2 Environmental supporting capacity (ESC)

2.1 Definition

Environment, which supplies food, energy and other indispensable things for human being, is the basis for human living and social development. Environmental system, including natural resources such as minerals, biological resources, water resources and so on, and the self-purification capacity of pollutants, provides essential conditions for human development. ESC is "the supporting capacity of environment for human economic activities at a given period and region, which reflects comprehensively the material composition and structure, and the relevant function" (Ye, 1992).

As we know, the environmental system of a particular area also has some limits to human activities. Correspondingly the ESC has a threshold for economic growth in a particular development stage. It is demanded that the magnitude and intensity of human activities be limited within the bearable capacity of ESC. Otherwise, the environment system will be overloaded. Heavy pollution, as well as irreversible ecological damages, will be caused, which at last undermines the basis for human survival and development.

ESC, as the objective property of environment system, can be expressed in quality and quantity. The quality mainly connected with the contents of economic activities, such as industrial sectors and its structure; the quantity mainly corresponded to the intensity of human economic behaviors, such as industrial scale and the distribution.

2.2 The laws for ESC

2.2.1 ESC changes on temporal scale

The components and structure of environmental system are variable with time. Some varieties are caused by natural transition, such as atmospheric cycles, earthquakes and so on. Others are derived from human activities, such as pollution, urbanization and so on. The later factor, that is, human behavior affects the environmental components and structure. These changes in composition and structure of environmental system more and more significantly in changing the environmental system always lead to unfavorable changes in environment function and in ESC.

2.2.2 ESC distribution with spatial scale

Different areas have different components and structure of environmental system, which causes the varieties of ESC with areas. Environmental capacity, which expresses the maximum capability to accept pollutants, can be used to address the changes of ESC with areas. For example, the significant difference of the self-purification capacity exists between the southern rivers and the northern ones in China.

Human activities can apply such laws and are required to comply to such laws, so as not to be punished by the nature. For example, we are to modify the industrial structure according to the ESC changes with time and to allocate the industries based on the spatial distribution of ESC.

2.3 Methods for expression of ESC

2.3.1 Indicator system

We select three kinds of indicator express the ESC, they are: (1) Natural resources indicators: including water resources, land resources, mineral resources, forest and so on; (2) Social indicators: including population, traffic conditions, energies, economic status and so on; (3) Pollution indicators: including transformation and immigration capability of pollutants in air, waters and soils.

2.3.2 Analysis method

Ye Wenhu and his colleagues (Ye, 1992) put forward development variables and limitation variables. Development variables are used to address the magnitude of human impacts on environment system, such as the demands and consumption of natural resources, the discharges of pollutants, and the changes in environmental quality as well. All the development variables (d_1) consist of an array of n-dimensional vectors: $D=(d_1, d_2, d_3, \ldots\ldots d_n)$. Limitation variables are used to express the limits or restriction of environmental system to social behavior and economic activities, which include the environmental quality of atmosphere, land, and waters as well as the supplies of natural resources. All limitation variables (C_1) consist of an array of n-dimensional vector: $C=(C_1, C_2, C_3, \ldots\ldots C_n)$.

As spatial vectors, the direction of development variables and limitation variables indicates the property of social-economic activities; the module explains the magnitude or intensity of these activities.

Therefore, ESC is to be calculated as follows:

If there are m development plans for an area, and plan j consists of n factors $E_j=(E_{1j}, E_{2j}, \ldots\ldots E_{nj})$, the ESC for plan j is expressed as:

$$|\tilde{E}_j| = \sqrt{\sum_{i=1}^{n} \tilde{E}_{ij}^2}, \tag{1}$$

where,

$$\tilde{E}_{ij} = \frac{E_{ij}}{\sum_{j=1}^{m} E_{ij}}.$$

In the social production model, the production process is accomplished with the input of environmental resources, labor and technologies. To assess the efficiency of taking advantage of environment resources, we develop a criteria embodying economic output, the environmental impact (development variables) and the environmental restriction (limitation variables).

$$X = P/(L - D), \tag{2}$$

where X is judgment factor; P is economic output factor, in output value or output value per capita; D is development variables factor, in discharge of pollutants or consumption of natural resources; L is limitation variables factor, in environmental capacity or available natural resources.

From the formula, we can find out that if the magnitude of human activities exceeds the environmental restriction ($D>L$), we get a minus X, which means heavy pollution or unreasonable consumption of resources may occur and the environment is overloaded. A bigger X indicates the plan is more efficient and profitable.

3 Case study—— coordination development planning for Benxi Shiqiaozi Development Zone (BSDZ)

3.1 Introduction of BSDZ

To alleviate the urban environmental problems such as urban pollution, traffic congestion and land deficiency, as well as to improve the industrial structure and adjust its distribution, the Benxi Government of Liaoning Province, decided to construct BSDZ. BSDZ will be constructed as a new urban industrial district with an area of 27.8 square kilometers and a population of 200 thousand. A higher economic, environmental and social benefits are to be achieved during the construction process.

3.2 Prediction of economic development in BSDZ

On the basis of comparative analysis on the advantages of natural resources and economic-territorial location of Shiqiaozi, we choose mechanical industry and medical industry as the leading industries. The engineering and electrical industries, medical industry, food and beverage making industries, and commerce and service trade are elected as four main industries in economic structure, totally occupying 80% for the gross industry output value. According to three supposed investment projects, we can get the economic development of the three projects through DYNAMO (Forrester, 1969; Pugh-Roberts Associate, 1986) model-BSCDM (Benxi Shiqiaozi Coordination Development Model; Table 1).

Table 1 The prediction results of output value of the three economic development plans in BSDZ

Unit: million RMB Yuan

Industry	Base Year	Plan I			Plan II			Plan III		
	1992	2000	2010	2024	2000	2010	2024	2000	2010	2024
M & E	2.6	80.6	223.0	401.0	381.5	554.4	594.2	440.5	722.7	856.0
L & F	61.6	70.8	80.0	122.0	70.8	80.1	121.8	81.3	126.6	204.7
Medicine	27.7	263.0	425.0	571.0	262.5	425.3	570.7	317.3	616.6	862.6
C & S	4.9	156.0	287.0	383.0	142.6	242.3	357.4	206.7	377.4	497.3
Total	96.8	570.2	1016.0	1481.7	857.4	1302.0	1644.1	1046.4	1838.3	2440.6

Note: M & E: mechanical and electrical industries; L & F: light industry, food and beverage industries;
C & S: commerce and service trade.

3.3 The prediction of population

Correspondingly, we can get the population growth through BSCDM (Table 2).

Table 2 Prediction results of population growth in BSDZ **Unit: 1000**

Year	2000	2010	2024
Plan I	53.0	86.0	119.0
Plan II	77.0	98.8	142.0
Plan III	119.5	188.0	212.0

3.4 The impacts on the environmental system

It is no doubt that the economic development can cause great influence on environmental system, including natural resources and environmental quality. This study predicts respectively the demands for water resource and pollutants discharges along with the development of three plans.

3.4.1 Demands for water resources

To predict demands for water resource, we use the following formula:

$$W = W_1 + W_2 + W_3, \quad W_1 = \sum P_i \cdot A_i \cdot (1 - B_i), \quad W_2 = N \cdot C, W_3 = R \cdot D, \quad (3)$$

where W is whole demand for water resource; W_1 is industrial demands for water resource; W_2 is agricultural demands for water resource; W_3 is household demands for water resource; P_i is the output value of i industry; A_i is demand coefficient of water resource; B_i is recycling rate of water; N is the area of agricultural lands; C is agricultural demand of water resource per unit area; R is population; D is household demand of water per capita.

3.4.2 Prediction of pollutants discharges

For atmospheric pollutants, including SO_2 and TSP, we use the following formula:

$$Q = Q_1 + Q_2, \quad Q_1 = \sum P_i \cdot \alpha_i, \quad Q_2 = R \cdot A \cdot L, \quad (4)$$

where Q is the total quantity of atmospheric pollutants (SO_2 or TSP); Q_1 is the industrial discharges of SO_2 or TSP; Q_2 is the household and infrastructure discharges of SO_2 or TSP; α is discharge coefficient of SO_2 or TSP for i industry; A is residential area per capita or infrastructure facilities per capita; L is discharge of SO_2 or TSP per unit area.

For water pollutants, we choose two indicators, the production of waste water and the discharge of BOD.

$$S = W_1 \cdot \beta; \quad B = S \cdot t \cdot \gamma, \quad (5)$$

where S is waste water produced from industries; β is coefficient of waste water from the consumption of water resources; B is BOD produced from industries; t is modification coefficient indicating technical development; γ is conversion coefficient.

For solid waste, we predict two sectors of industries and household the relevant formulas are:

$$G_1 = \sum P_i \cdot \varepsilon_i, \quad G_2 = R \cdot g \cdot (1 + r)^n, \quad (6)$$

where G_1 is solid waste produced from industries; G_2 is household solid waste; ε_i is the coefficient of solid waste from industries; g is solid waste produced per capita; r is growth rate per year of solid waste; n is years from base year to the predicted year.

3.4.3 Results

The predicted data of these impacts on environmental system are listed in Table 3.

Table 3 Prediction data of impacts for three plans

	Plan I			Plan II			Plan III		
	2000	2010	2024	2000	2010	2024	2000	2010	2024
Water demand, 10^6T	12.0	19.1	25.7	18.0	23.6	30.1	23.2	40.8	44.9
Waste water, 10^6T	8.2	11.5	20.6	13.0	18.1	24.1	17.2	31.8	40.5
BOD, 10^3T/a	2.3	3.0	4.1	2.7	3.2	4.6	3.6	5.9	7.2
SO_2, 10^5T	3.2	5.4	7.8	4.7	6.7	9.4	5.9	10.8	13.1
TSP, 10^3T	11.0	18.1	26.4	16.0	22.7	31.8	19.9	36.4	44.1
Solid waste, 10^3T	68.0	115.7	201.0	97.0	157.2	230.1	132.4	249.4	345.6

3.4.4 Analysis

As the industrial components of three economic plans are similar and the difference lies in the industrial scales and magnitudes. The three plans root in the same environmental conditions, including the natural resources, environmental quality, so it is deluded that the limitation variables have the same value (0.333).

Using Formula (1) and (2), we can get the development variable array D, output variable array P and output variable per capita P', and also the criteria X (from P) and X' (from P') for judgment. These results are listed in Table 4.

Table 4 Results of comprehensive analysis about environment-economy system

Variable	Plan I	Plan II	Plan III
C	0.333	0.333	0.333
D	0.240	0.302	0.457
P	0.251	0.312	0.437
P'	0.347	0.356	0.297
X	2.31	10.1	-3.52
X'	3.73	11.5	-2.40

From Table 4, we can find out that plan III has minus judgment factor, which means that the economic development excessively overloads the ESC; plan II has highest judgment values, which means this plan has more efficient and reasonable utilization of ESC. The plan I has a lower efficient utilization of environmental system where ESC is not fully taken advantage of by human.

4 Conclusion

The analysis is based on the consideration of economic growth, the environmental impacts (including demands for resources) of economy and the environmental restriction as well. The conclusion that plan II is more favorable is consistent with the conclusion derived from the possible industrial programs at Shiqiaozi, which proves this method for analysis is practicable.

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