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Analysis of coordinated development between urban economic and environmental system

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ABSTRACT

There exists a complex coupling mechanism between urban economic and environmental system. The two systems promote and restrict each other. In this paper, we analyze the development of Nantong City based on the "pressure state response (PSR)" model. Eight indicators such as the natural population growth rate are selected to build the urban economic system. And similarly, we build the urban environmental system with another eight indicators such as industrial electricity consumption, daily water supply capacity etc. This two systems constitute the economic and environmental coordinated development evaluation system. Then we use weighted method to calculate comprehensive index of urban economic system, comprehensive index of urban environment system and the coordination degree between them. Conclusions are as follows: From the year 2005 to 2012, Nantong City's economic and environmental system has experienced three stages: uncoordinated stage, basic coordinated stage and high quality coordinated stage. And comprehensive index of urban economic system showed a significant linear growth trend, while the comprehensive index of urban environmental system presents a fluctuating rise. However, the growth rate of urban environmental pressure index is far greater than the rate of urban environment response index and state index. Therefore, the coordinated development of urban economy and environment is still under huge pressure.

KEYWORDS

Urban economic and environmental system; Measurement; Coordinated development; Nantong city.

INTRODUCTION

City is a compound system composed of economic and environmental factors. On the one hand, economic development requires necessary support of environmental system while it also leads to pollution. On the other hand, protecting and improving the environmental system requires appropriate manpower, funding and material support of economic systems. Therefore, there is a complex coupling mechanism between urban economic and environmental system, which constitute a relationship of "pressure-state-response" (referred to as PSR)[1]. Research on coordinated development of urban economic and environmental system can provide policy and technical guidance for the sustainable development of the city.

GENERAL SITUATION OF THE STUDY AREA

Jiangsu province is one of China's most economically developed provinces in the eastern coastal areas. It is located in the intersection of the three productivity lines including the Yellow Sea, the Yangtze river and "Longhai-Lanxin" railway. Jiangsu coastal areas have three cities Lianyungang, Yancheng and Nantong, with a total area of 32588km^2, coastline of 954km and total population of about 20.9 million[2]. Nantong is among the most representative city due to its unique regional advantage (as shown in Figure 1). In 2012, the city has a total population of 7.297 million, GDP of 455.87 billion yuan (62506 yuan per capita) and urbanization rate of 58.7%. However, with the rapid development of economic, urban population growth and the discharge of industrial wastes have posed a significant threat to the environment. Conflict between urban economic and environmental systems also become increasingly apparent.

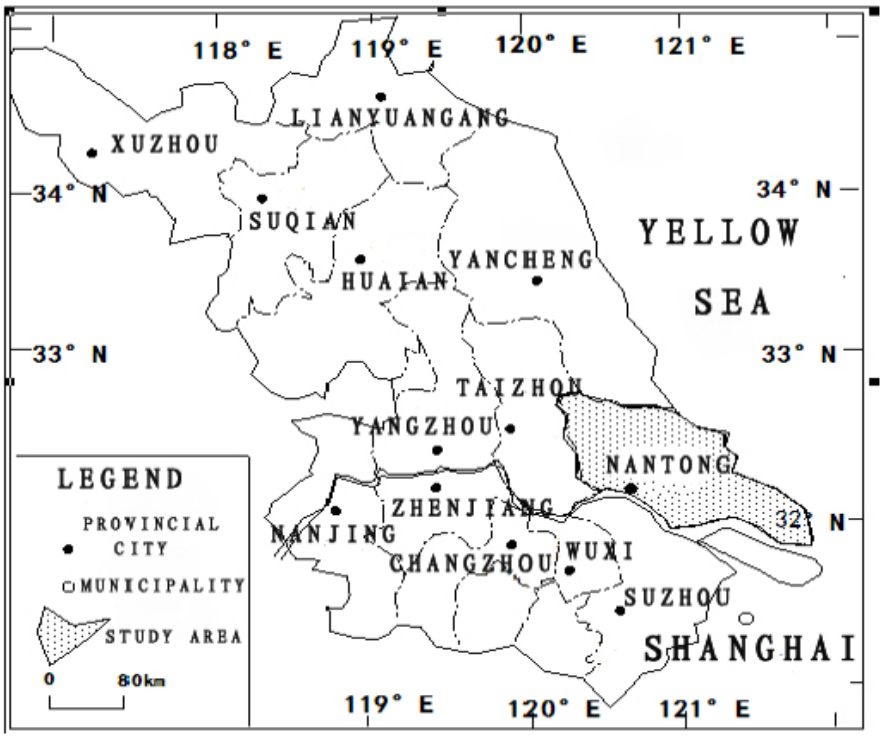

Figure 1: Location map of Nantong city

RESEARCH METHODS

Construction of index system

Based on the three principles of scientific, representative and feasible, eight indicators were selected according to the "Pressure-State-Response (PSR)" framework to construct two sub-index

system of urban economic systems and urban environmental systems, which together constitute the coordinated development of urban economy and environment evaluation system. Among them, pressure indicators reflect a range of factors caused by human activity to the system, status indicators show the current status of the system, and the response indicators reflect human's positive efforts to further improve the system. Three types of indicators have differences and relations, jointly push forward the development of the system (see TABLE 1, Figure 2)[3-7].

TABLE 1: Economic and environmental coordinated development evaluation system of Jiangsu coastal cities

Index of urban economic system X	Unit	Index of urban environmental system Y	Unit
Natural population growth rate X_1	‰	Above-scale industrial added value Y_1	￥100M
Ten thousand yuan GDP energy consumption X_2	tce	Industrial electricity consumption Y_2	billion kw· h
GDP X_3	￥100M	The number of respirable particulate in the air Y_3	mg/m^3
Added value of the tertiary industry X_4	￥100M	SO_2 content Y_4	mg/m^3
Per capita disposable income of urban residents X_5	yuan	Days of air pollution index reached well above Y_5	days
Fixed assets investment X_6	￥100M	Daily water supply capacity Y_6	thousand m^3 / d
Infrastructure investment X_7	￥100M	Sewage treatment capacity Y_7	thousand tons / d
Provide jobs X_8	thousand	City new green area Y_8	hectare

Note: ￥100M means 100 million yuan

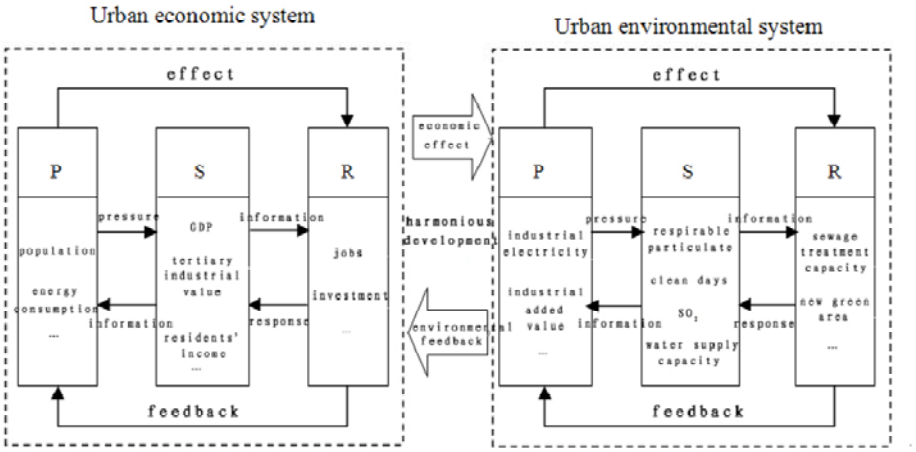

Figure 2: PSR running mechanism and coupling relationship diagram

Data sources

This paper intends to take Nantong city as an example, based on the evaluation index system above, obtain the necessary initial data from the "Nantong Statistical Yearbook 2006-2012" and the government work report. Through the analysis on the coupling condition of Nantong city's social economy and natural environment, the intention is to explore the universal law of the coordinated development of economy and environment in Jiangsu coastal areas.

Data processing

(a) Data preprocessing

Since units of the index in evaluation system are different, we must first carry out data preprocessing in order to compare between different indicators and determine the weights, i.e. for each data dimensionless normalized. This paper uses the maximum difference normalization method for

further data processing. There are two types of evaluation, efficiency index and cost -based index. Efficiency index refers that the attribute values show a positive correlation with coordination degree of economy and environment, the greater its value, the better. While the cost-based indicators, by contrast, refers to the negative correlation between its attribute values and coordination degree of economy and environment.

efficiency index $X'_{ij} = \frac{X_{ij} - \min(X_j)}{\max(X_j) - \min(X_j)}$ **(1)**

cost -based index $X'_{ij} = \frac{\max(X_j) - X_{ij}}{\max(X_j) - \min(X_j)}$ **(2)**

In this formula, X_{ij} means the original value of index j in year i, X'_{ij} is the normalized value, $\max(X_j)$ and $\min(X_j)$ refer to the maximum and minimum value of index j.

(b) Mean square difference method to determine the index weight

In this paper, an objective mean square difference method is used to determine the index weights. And in order to eliminate the impact of different indicators means, the concept of variation coefficient is introduced.

$$CV_j = \frac{\sigma_j}{\overline{X}_j} \quad \textbf{(3)}$$

$$W_j = \frac{CV_j}{\sum_{j=1}^{n} CV_j} \quad \textbf{(4)}$$

In this formula, CV_j represents a variation coefficient of index j, σ_j says the average variance of index j (i.e., standard deviation), and $\overline{X}_j$, W_j respectively refer to their mean value and weight value.

(c) Urban economy and urban environment comprehensive index calculation

Multiply the standardized values of each index by the corresponding weights and come to the comprehensive index of city economy f(x) and the comprehensive index of city environment g (y). They respectively refer to the city's comprehensive development of economic systems and environmental systems.

$$f(x) = \sum_{i=1}^{m} X'_{ij} W_x \quad \textbf{(5)}$$

$$g(y) = \sum_{i=1}^{n} Y'_{ij} W_y \quad \textbf{(6)}$$

(d) Coordination degree analysis

Coordinate degree is a quantitative indicator used to reflect the degree of harmony between systems in the process of development. Comprehensive evaluation index is a measure of the overall function and benefits of the parent system. But in some cases there will be two parent system, such as A and B, whose coordinate degrees are the same while comprehensive evaluation indexes are different from each other. In this case, even if they have the same coordination degree, it is also difficult to show that their coordinated development situations are consistent.

$$C = \left\{ \frac{f(x) \times g(y)}{\left[\frac{f(x)+g(y)}{2} \right]^2} \right\}^k \quad (7)$$

$$T = \alpha f(x) + \beta g(y) \quad (8)$$

$$D = \sqrt{C \times T} \quad (9)$$

In this formula, C is coordination degree, K means the adjustment coefficient (the k=2), T is the comprehensive evaluation index of urban economy and the environment system, α and β coefficients to be determined. In this paper the development of urban economy and urban environmental protection are equally important, so take α = β = 0.5. D refers to the coordinated development coefficient[8-10].

RESULTS AND ANALYSIS

According to the above steps, the data processing results can be obtained in TABLE 2.

TABLE 2: Urban economy and environment coordinated development index in Nantong

Year	Comprehensive index of city economy f(x)	Comprehensive index of city environment g(y)	Coordination degree C	Comprehensive evaluation index T	Coordinated development coefficient D
2005	0.1102	0.1136	0.8927	0.1484	0.3640
2006	0.1971	0.2312	0.9978	0.2390	0.4884
2007	0.2565	0.2864	0.9992	0.2810	0.5299
2008	0.3651	0.3397	0.9999	0.3418	0.5846
2009	0.4579	0.4427	0.9971	0.4266	0.6522
2010	0.5785	0.4391	0.9859	0.4794	0.6875
2011	0.6617	0.6703	0.9882	0.6225	0.7843
2012	0.7551	0.7485	0.9916	0.7029	0.8349

Comprehensive Index Analysis of Urban economic system

The results show that the PSR index of the internal economic system in Nantong city showed a trend of diversification (as shown in Figure 3). The economic pressure index decreased significantly in 2006, especially after "eleventh five-year" when government request to reduce energy consumption by 20% per unit of GDP. Since 2007 the economic pressure index fell sharply, energy-saving economic construction see early results. And status and response index significantly increased due to the city's economic development and local government's effort to actively construct people's livelihood.

And at the macro level, the comprehensive index of Nantong economic system grew rapidly from 0.1102 in 2005 to 0.7551 in 2012. Due to the rapid development of regional economy, especially after a new round of coastal development strategy in 2007, urban economic system comprehensive index showed a trend of obvious linear growth.

Comprehensive index analysis of urban environment system

Process the relevant data of Nantong environmental system, so that we can find a simple upward trend of the environmental pressure and response index. Due to the construction of the urban greening and gradually improving ability to deal with pollution, environmental response index increased from 0.8972 in 2012 to 0.1170 in 2005. While along with the further industrialization, the ecological environment is facing serious challenges, environmental pressure index surged from 0.0333 in 2005 to

0.8540 in 2012. At the same time, since environmental awareness have been increasing, environmental state index shows a fluctuant upward trend as a whole (see in Figure 4).

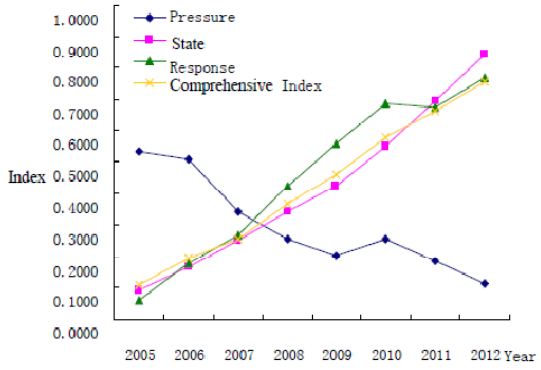

Figure 3: PSR and the comprehensive index trend chart of economic system in Nantong city

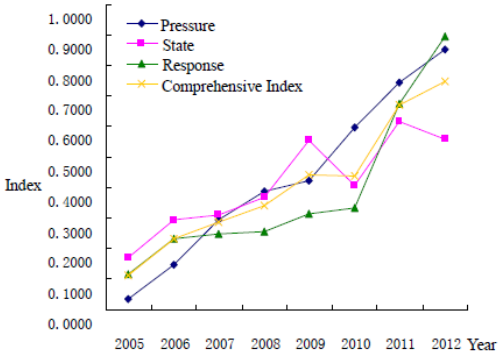

Figure 4: PSR and the comprehensive index trend chart of environmental system in Nantong city

The comprehensive index of Nantong environmental system still presents a fluctuant upward trend on the whole, although the recovery of industrial economy after the financial crisis in 2010 caused a slight downward trend in the comprehensive index of Nantong environmental system, which rose from 0.7485 in 2012 to 0.1136 in 2005[11].

Coordination degree analysis between economic system and environmental system

According to the data processing results in TABLE 2, we draw the coordinated development degree chart between urban economic system and environment system in Nantong City (as shown in Figure 5). As can be seen from the chart, we find the coordination degree between economic development and environmental protection of Nantong city optimized continuously during 8 years from 2005 to 2012. The coordinated development coefficient increase from 0.3640 in 2005 to 0.8349 in 2012. In accordance with the low to high regularity, we divide the coordinated development coefficient into five stages from serious lack of coordination to high quality coordination (as shown in TABLE 3).

TABLE 3: The classification standard of coordinated development coefficient

Coordinated development coefficient（D）	0≤D≤0.2	0.2<D≤0.4	0.4<D≤0.6	0.6<D≤0.8	0.9<D≤1
Standard	Serious lack of coordinated stage	Uncoordinated stage	Basic coordinated stage	Good coordinated stage	High quality coordinated stage
Nantong City	-	before 2005	2006-2008	2009-2012	-

CONCLUSIONS AND RECOMMENDATIONS

There exists a complex coupling mechanism between urban economic and environmental systems. Economic development funds for environmental protection while it also brings pollution. Environment provides resources for economic development such as land, energy, etc. While it also can be counterproductive in economic construction. This paper builds the economic and environmental coordinated development evaluation system of Jiangsu coastal cities, taking Nantong city as an example, analyzes the coordinated development mechanism between the urban economic environment. The main conclusions and recommendations are as follows:

The relationship between economic and environmental systems continue to improve in Jiangsu coastal cities

The results show that the coordination degree of urban economic and environmental systems changes from uncoordinated to basic coordinated and well-coordinated. Urban economic system comprehensive index shows a trend of obvious linear growth, economic pressure indexes such as energy consumption decreased, and regional GDP and revenue increased significantly. At the same time the government paid significant attention to environmental protection, and actively carried out the construction of people's livelihood. What's more, due to the increase of urban greening and the processing ability to deal with pollution, the regional ecological environment improved significantly, Urban Environmental Systems Comprehensive Index shows a overall fluctuated upward trend.

The coordinated development of urban economy and environment in Jiangsu coastal areas is still faced with challenges

Urban environmental pressure index increased far greater than the urban response index and urban state index. Urban development of Jiangsu coastal areas should adhere to the path of ecological development. For example, to adjust the industrial structure and improve industry scale and benefit; to give priority to the development of Marine industry ;to optimize urban production, life and ecology spatial layout and expand urban green space; to enhance environmental pollution prevention and control and improve the environmental quality of water, air, etc. Through these ways, we can achieve a more coordinated development between urban construction and environmental protection.

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