

Early-Warning for Environment-Economy Development Based on Boom Analysis in Dalian, China

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Keywords: environment-economy, early-warning system, boom analysis, Dalian.

Abstract: Environment-Economy development is a priority in China and it is supported by national policy. However, the study about measuring and warning regional development status of environment-economy is limited. In order to identify the impact of socio-economic development on the environment, we build an early-warning system to assess the current status of environment-economy development and predicate the future trend of this composite system. Our results show that the development status of environment-economy changed from boom decline to stable between 2005 and 2014, the overall status are in good condition, and the predicted results in next decade are in a stable state, but still need to guard against some indicators overheating.

1. Introduction

The early-warning research on the development of the environment-economy is developed from single field. Based on the synthetically consideration of the relationship between social economic activities and environment, the early-warning theory of environment-economy system is gradually formed. Some efforts have been taken to make early-warning analysis for the development of environment-economy previously. The most common is to set up the indicator system, and draw the comprehensive early-warning index for analysis [1, 2]. The common early-warning models such as multicriteria decision analysis [3], system dynamics [4] and so on. Wang [5] uses a single early-warning indicator of the elastic coefficient to make research of early-warning on regional environment-economy. In addition, as far as the current researches, most of them rely on specific categories, such as energy-environment-economy, forest-environment-economy and other complex systems [6, 7]. However, the above researches usually lacked of regional characteristics and neglected the interaction between environmental and economic system. Wang has built an early warning system based on booming analysis, which divided the indicators into three categories, to analyze the development of environment-economy by the diffusion index and composite index [8], which make up some shortcomings of the above methods. But this kind of research is only limited to the current time, and there is neither early-warning about the future development, nor the running state of development of environment-economy intuitively.

The objective of this paper is to develop an early-warning system of environmental and economic development based on the boom theory, and build a more comprehensive early-warning indicator system combined with regional characteristics. Moreover, the time series method based on BP neural network was used to predict the value of warning indicators in the next 10 years, and to address decision makers in the allocation of their resources, to maintain and improve the level of environment-economy development. The case study refers to Dalian, a region in northeast of China.

2. Materials and methods

2.1 Early-warning system

The early-warning system is to incorporate the multiple environmental economic warning indicators as a comprehensive indicator through the method of data processing. Comparing the environmental economic warning line, we issued a different signal to the current environmental economic development status of indicators and the comprehensive indicator. Finally, by observing and analyzing the changes of the signal, to judge the current and future status of the environment-economy system. The early-warning system was divided into five intervals, which could reflect the status of environmental and economic development and with different signal lights respectively. Among them, the "red light" represents the boom of environmental and economic system is overheating and may be in a state of overload, and an internal tightening is required in this case; "yellow light" represents the boom of system is still steady, but heat transfer or ultra-stable is possible in short-term; "green light" represents the boom of environmental and economic system is stable and running well; "light blue light" represents the boom is decreased, but stable transfer or turn cold is possible in short-term; "blue light" represents the boom is shrinking and may be in a state of stagnation, which need to take strong measures to stimulate environmental and economic growth.

2.2 Grey correlation analysis

Grey theory is to study phenomenon with uncertainties whose inner information is not clear [9]. It quantitatively describes the relative change of the factors in the process of the system development, that is, the relativity of indicators such as the change of the size, direction, speed and others. In our case, the grey correlation analysis is used to determine the weight of indicators. The calculation steps of grey correlation analysis are as follows:

(1) Determination of the reference sequence. The reference sequence which represents system characteristics is expressed as $\{X_0(t)\}=\{X_{01}, X_{02}, \dots, X_{0n}\}$. In our case, the gross industrial output value (X_0) was used as the reference.

(2) Standardization of X_0 and X_i . Data processing which makes dates dimensionless should be carried out before grey correlation analysis. That is,

$$Y_i = \frac{X_i - \bar{X}}{S} \quad (1)$$

Among them, Y_i is the value of each indicator after the standardized transformation, X_i is the initial value of each indicator, \bar{X} is the sample mean, and S is the sample standard deviation.

(3) Calculation of correlation coefficient. The correlation coefficient $L_{0i}(t)$ between the reference sequence $\{X_0(t)\}$ and the comparison sequence $\{X_i(t)\}$ can be calculated by the following formula:

$$L_{0i} = \frac{\Delta_{\min} + \Delta_{\max}}{\Delta_{0i}(t) + \rho \Delta_{\max}} \quad (2)$$

In the formula, $\Delta_{0i}(t)$ represents the absolute difference of two comparison sequence at t moments, Δ_{\max} and Δ_{\min} represents the maximum value and minimum value of the absolute difference of all comparison sequence each time respectively. ρ is the resolution factor, used to increase the significant difference between correlation coefficient, usually take 0.1~0.5.

(4) Calculation of correlation degree. The correlation degree between the comparison sequence and reference sequence is calculated by the average value of its correlation coefficient each moment:

$$r_{0i} = \frac{1}{N} \sum_{t=1}^N L_{0i}(t) \quad (3)$$

In the formula, r_{0i} represents the correlation degree of comparison sequence X_i and reference sequence X_0 , N is the length of the comparison sequence (i.e. number of data). The software of data processing, DPS, was used to calculate the correlation degree of the data, and the correlation degree between each indicator and X_0 is regarded as the weight of it.

2.3 Time series method based on BP neural network

In this paper, the time series method based on BP neural network is used to predict the values of early warning indicators. BP neural network is a kind of multi-layer feed forward networks [10]. It includes input layer, hidden layer and output layer. The main features of the network are the

transmission signals forward and errors backward [11]. The software of Matlab 2014a was used to program and design BP neural network. For each indicator, the data of each adjacent 3 years was selected as a set of input, and the fourth year as the output. Three layers of BP neural network are used in our case, the input layer neuron number is 3, the output layer neuron number is 1, and the hidden layer neuron satisfies both the formula (4) and (5).

$$2^m > n \quad (4)$$

$$m = \sqrt{w+n} + R(10) \quad (5)$$

In the formula, m indicates the number of hidden neurons; n and w indicate the number of neurons in the input layer and the output layer; $R(10)$ takes any number between 0~10.

3. Calculation

3.1 Indicators

The early-warning indicator system of environment-economy development is comprehensive, systematic, which not only include the internal indicators of environment and economy, but also affected by the external factors such as social environment, environment-economy and other aspects. The social development, environment, economy, environment-economy and other aspects should be considered. According to the principle of indicator selection (Science, feasibility, hierarchy, completeness, dynamic) [12], expert opinion, and regional characteristics of Dalian city and other factors, 4 categories and 29 indicators were selected ultimately. (Table 1)

Table 1 Early-warning indicator system

Category	Sub category	Indicator	Category	Sub category	Indicator
Economy	Economic development	Per capita GDP (X1) Per capita fiscal revenue (X2) Consumer price index (X3) Total social fixed investment (X4)	Environment	Pollution emission	Discharge of industrial waste water (X11) Industrial SO ₂ emissions (X12) Industrial solid waste production(X13)Industrial smoke (dust) emissions (X14) Severely polluted sea area near the coast (X15)
	Economic structure	Second industry accounted for GDP (X5) Third industry accounted for GDP (X6)		Environmental control	Discharge attainment rate of industrial waste water (X16) Removal rate of Industrial SO ₂ (X17)Disposal rate of Industrial solid waste (X18) Removal rate of Industrial smoke (dust) (X19)
	Economic benefit	Industrial added value (X7) Total social labor productivity (X8) Average annual balance of current assets (X9) Tax rate of output value (X10)			
Environment economy	Environment economy	Waste water discharge of ten thousand yuan output value (X20) SO ₂ emission of ten thousand yuan output value (X21) Industrial solid waste production of ten thousand yuan output value (X22) Smoke (dust) emissions of ten thousand Yuan output value (X23) Urban environmental investment accounted for GDP (X24)	Society	Social security	Natural population growth rate (X25) Per capita housing area (X26) Per capita living electricity consumption (X27) Unemployment rate (X28) Hospital beds of one thousand people (X29)

3.2 Determine the limits of early-warning indicators

In this paper, mathematical statistics method is used to determine the boundaries of early-warning indicators, which will be divided into five sections based on the boom theory. According to the principle of statistics, the value of random variable follows the normal distribution. Referring to the previous research experience [13] and the characteristics of the environment-economy development in Dalian City, chose $(\mu \pm \sigma)$ as the boom normal interval, $(\mu \pm \sigma, \mu \pm 2\sigma)$ as the boom steady and boom decreasing interval respectively, deviate $\pm 2\sigma$ from the expected μ outside were the boom overheating and the boom shrinking interval respectively. Limits of some indicators were adjusted

refer to previous research, expert consultation and current situation of Dalian's environmental economic development. The limits of early-warning indicators see Table 2.

Table 2 The limits of early-warning indicators

	Red←	Yellow←	Green←	Light Blue		Red←	Yellow←	Green←	Light Blue
X1	125538	100486	50383	25331	X16	98.52	97.60	95.76	94.84
X2	14734.0	11527.9	5115.7	1909.6	X17	81.80	70.28	47.25	35.73
X3	106.6	104.8	101.3	99.5	X18	99.87	97.85	95.31	93.29
X4	7705.0	5745.8	2806.7	847.3	X19	99.35	98.24	96.58	95.47
X5	52.5	50.9	47.5	45.8	X20	17.82	12.96	5.68	0.83
X6	46.6	44.9	41.7	40.0	X21	0.0041	0.0032	0.0015	0.0006
X7	4078.2	3123.6	1214.4	259.8	X22	0.1267	0.1098	0.0760	0.0591
X8	30.68	24.91	13.36	7.58	X23	0.0021	0.0016	0.0006	0.0001
X9	6185.7	4840.7	2150.8	805.8	X24	3.06	2.64	1.81	1.39
X10	21.68	16.34	8.33	4.32	X25	4.20	2.43	-1.10	-2.86
X11	42921.51	37568.55	26862.61	21509.64	X26	40.34	35.49	25.79	20.94
X12	13.64	11.92	8.47	6.75	X27	703.7	639.6	511.6	447.5
X13	700.87	567.24	299.99	166.37	X28	3.28	3.01	2.47	2.21
X14	8.44	6.69	3.21	1.46	X29	6.92	6.09	4.42	3.58
X15	1804	1138	339	52					

3.3 Determine the limits of comprehensive early-warning index

Due to the different impact of the indicators on the system, so the comprehensive early-warning index should calculate according to the weight of each indicator (Table 3). According to the limits division of indicators, score for five lights respectively, "red light" means five scores, "yellow light" means four scores, "green light" means three scores, "light blue light" means two scores, "blue light" means one score. The score of indicator is determined by the interval of the actual value belong to.

$$E = \sum_{i=1}^n E_i \cdot X_i \quad (6)$$

In the formula, *E* represents the comprehensive early-warning index, *n* represents the number of indicators, *E_i* represents the point of indicator *i*, *X_i* represents the weight of indicator *i*.

Table 3 The weight of indicators

Indicator	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10
Weight	0.9687	0.9205	0.7099	0.9307	0.8019	0.6429	0.9243	0.8751	0.9285	0.7658
Indicator	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20
Weight	0.6255	0.7188	0.8994	0.8000	0.7230	0.7089	0.6218	0.8499	0.6424	0.6280
Indicator	X21	X22	X23	X24	X25	X26	X27	X28	X29	
Weight	0.7196	0.6230	0.7457	0.7941	0.6909	0.9615	0.8521	0.7096	0.8569	

If the number of indicators you choose is *M*, when all the indicators for the red light, the overall score for the highest is *5M*, the lowest score is *M* when all the indicators for the blue light. Determine the limits of comprehensive early-warning index: take out 85% of *5M* for the boundary of "red light" and "yellow light", take out 74% and 50% of *5M* for the upper and lower boundaries of "green light", and take out 36% of *5M* for the boundary of "light blue light" and "blue light". In our case, *M*=29, the limits of comprehensive early-warning index are shown in Table 4.

Table 4 The limits of comprehensive early-warning index

Early- warning state	overheating	steady	stable	decrease	shrinking
Signal light	●	●	●	●	●
Interval limits	>123.85	[107.3,123.85]	[72.5,107.3]	[52.2, 72.5]	<52.2

4. Results and Discussion

4.1 The result and analysis of early-warning signal

Through calculating according to the above value and limits of early-warning indicators, obtain the warning degree which showed by boom warning signal lights (Fig. 1) of environment-economy development of Dalian City. As shown in Figure 1, the whole status of environment-economy development transformed from the "light blue light" interval to the "green light" interval between 2005 and 2014, with the comprehensive early-warning index increasing gradually. From 2005 to

2011, the overall stability is in the “light blue light” interval. It indicates that the environmental economic situation is getting cold during this period, the speed of development slow down, but the overall development is showing a rising state. Since 2012, the state of environment-economy development began to enter the "green light" interval, and has been on the rise until 2014. It indicates that the environmental economic system is stable, but there is still a trend of getting heater. Therefore, closely attention should be paid to the boom change of environmental economic development system, so as to take measures to prevent overheating of the system in time.

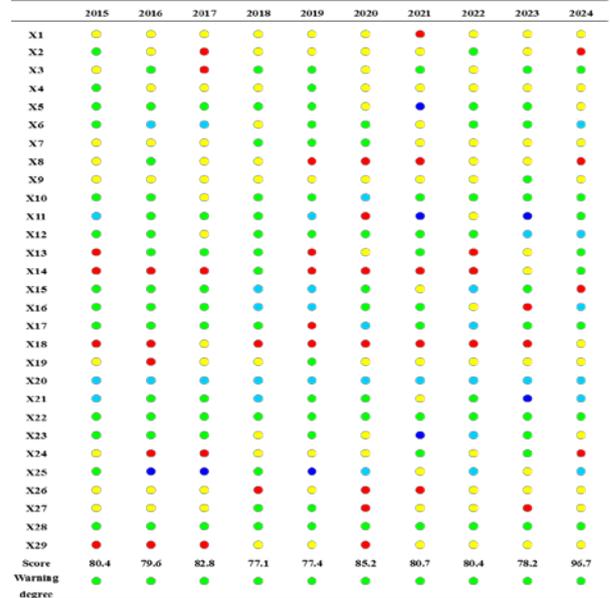
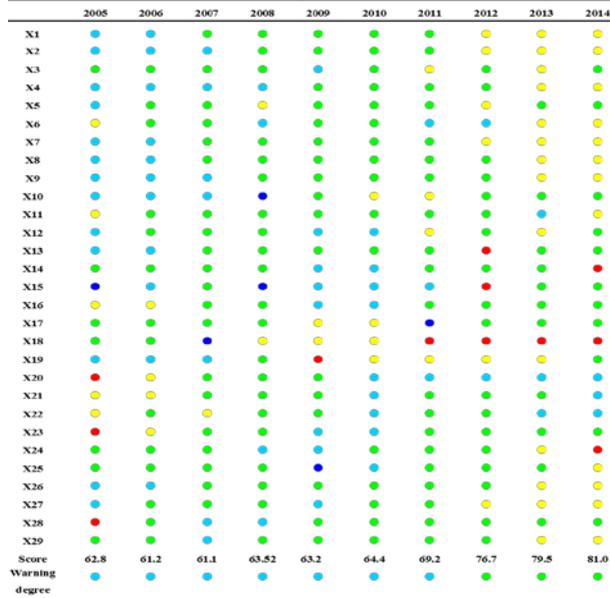


Fig. 1 The boom warning signal lights prediction

Fig. 2 The boom warning signal lights of prediction

4.2 The result of early-warning system prediction

Predicting the value of indicators in ten years based on the value’s development trend between 2005 and 2014. It was divided into 8 groups from 2005 to 2014, and the data of six groups was selected as training data, with the data of 2014 as a test. In this study, R (10) is 4, it can be calculated that the hidden layer is 6. The structure of the 3-6-1 BP neural network has been constructed, which satisfy the formula (4) and (5). Taking the index X1 (per capita GDP) as an example, the test results in 2014 were 111070, the difference with true value of 109939 is 1.03%, which was satisfactory. The comprehensive scores and warning degree has been calculated in the next ten years according to the predicted value of the indicators (limited to length, not a list), which showed by boom warning single lights (Fig. 2). In Fig. 2, the whole status of environment-economy development of Dalian City is stable and running in good condition in next ten years. But some indicators such as total social labor productivity, industrial smoke (dust) emissions, and industrial solid waste disposal rate and so on still need to be vigilant against to avoid overheating.

5. Conclusion

An early-warning system from the perspective of boom analysis was applied to evaluate the status of environment-economy development. We showed that the early-warning system has several good properties within this context: transparency, the use of qualitative evaluations, easy to understand, and traceability. In this paper, the indicator system was adjusted refer to the actual situation of Dalian city in the process of establishment which is enriched and optimized on the basis of predecessors. The early-warning system was introduced into the system of environment-economy development, pluralities of indicators were combined into a comprehensive index, and the results were showed by signal lights which are simple and clear. It is easy to analyze the development trend through analyzing the changes of signal lights. The BP neural network was used to predict indicators with the constant domestication of data according to the error curve, making the prediction results becoming

more accurate. The early-warning system for evaluation has been developed respecting the theory of environment-economy development, so the final results can have a clear meaning in terms of environment-economy system. The above analysis shows that the environment-economy development of Dalian is in the stable state. The empirical results can better fits the present development of Dalian city, and provide decision makers with an effective basis for the formulation of development policies.

Acknowledgments

The authors acknowledge the financial support of the National Science and Technology Major Project (Water Pollution Control and Treatment Major Project (NO. 2012ZX07505-001-04)).

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