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Evaluation model of county cycle economy based on PCA—BP neural network *

Yemei Fang , Jiuping Xu†

School of Public Administration, Sichuan University, Chengdu 610064, P. R. CHINA

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Abstract. In order to evaluate the developed status of the county cycle economy, we collect a large number of index data to set up original index system by expert interview and the documentary review methods. Then, we combine the principal component analysis (PCA) with the BP neural network to set up the evaluation model in this paper. We can get some typical and representative indexes and standardized index data from the original index system by use of the principal component analysis. Thirdly, we input the standardized index data to the BP neural network and train it until we are satisfied the output result, at last we can get the output results of BP neural network by use of the trained BP neural network. So, we can know that the developed level of this county cycle economy is between the good and the better.

Keywords: principal component analysis, neural network, BP model, cycle economy, evaluate

1 Introduction

It is a brand-new economical movement pattern for the humanity realizing the sustainable development to develop cycle economy. The central concern motivating interest in cycle economy is that current human activities may degrade the environment to the point that serious negative consequences emerge. Such consequences could halt improvements in the standard of living as measured in the usual economic terms, or actually worsen overall quality of life. The foundation of conventional economics is an isolated, circular exchange of value between firms and households. The physical environment does not directly enter into this cycle. Of course, issues such as resource use and pollution control are major topics in economics, and a large of literature on environmental economics exists. However, this does not make up for the failure to recognize that the economy is fundamentally connected to the environment.

The research on cycle economy can go far back to the sixties of the 19th century[1]. In 1960's, people reminded that the use of resource in economic program will lead to exhaust of resource. In 1970's and early 1980's, the international community began to carry out environmental control motion organically. In 1989, The United Nations Environment Program (UNEP) adopted the concept of cleaner production, which refers to goods, processes and services in the framework of sustainable development. In the 1993, Robert Solow, a Nobel prize winner, notes that the central concept of sustain ability is the preservation of productive capacity for the indefinite future. Solow outlines two important design features of sustainable civilization: "The claim that a feature of the environment is irreplaceable, that is, not open to substitution by something equivalent but different, can be contested in any particular case, but no doubt is sometimes true. The calculus of trade-offs does not apply. We are going to have to keep depending on physical and other special indicators in order to judge the economy's performance with regard to the use of environmental resources."[8] The cycle

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† Corresponding author. Tel:+86-28-85418522; *E-mail address*: xujiuping@openmba.com.

economy first appeared in ≪ The Recycle Economic and Waste Disposal Management Law ≫ in Germany in 1996. From 1990's, people provided the concept of "Ecomaterial [4], material reduce[2] stretch responsibility of producer, design for environment, ecological benefit, ecological industrial park[3]". At present, the cycle economy already became a new economical tidal current and the tendency in many countries[17], many experts demonstrate "prevent pollution in the headstream" [24]that it can bring the production and the consume into the organic sustainable development frame in different lays and present many cleaner production technology in different industry[23].

This paper combines the PCA with the BP neural network to set up a model to evaluate the development of county cycle economy. Firstly, large amount of the indexes data reflecting the growth situation of county cycle economy were collected, and the evaluating indexe collection of the county cycle economy set up. This model can choose typical and representative indexes from a lot of indexes which reflect developed state of cycle economy. And we can judge the real developed level of the county cycle economy. Thirdly, the BP neural network model was adopted to evaluate the developed situation of the county cycle economy. This paper provide a method from qualitative analysis to quantitative analysis and then from the quantitative analysis to qualitative analysis at last.

The rest of this paper is organized as follows. In section 2, we establish the evaluation model based on principal component analysis and BP neural network. In section 3, we apply this model to deal with the actual question about analysis of county cycle economy planning. Next, The presentation of conclusion is in section 4.

2 Evaluation model

It is basis and prerequisite of new development strategy to describe county cycle economy objectively and exactly. And the evaluating process of cycle economy is from quantitative analysis to qualitative analysis.

2.1 Evaluation model of county cycle economy based on PCA

In this section, we use the principal component analysis to deal with the index data. There is inherent alternation between indexes, and they influence each other. If the original data are not dealt with and pick up the eigenvalues, the veracity of identifying information will be doubtable before the BP neural network evaluates the county cycle economy[16]. In this section, we use PCA to choose the independent indexes from the index system which is inherent relation with each other to input BP neural network[21].

Step 1. Standardize the original indexes

The normal standardization is usually used between the standardizes methods of the principal component analysis[17]. This method does not only calculate trouble, but also the range of the standardized variable is uncertain and it can not reflect the economical significance of the variable. Therefore, this paper adopts the following method to standardize data. According to the different characteristics of the indexes , they are divided into smaller and thus better indexes and bigger and thus better indexes.

For the bigger and thus better indexes, the standardized formula[6]

$$x_{ij}^{*} = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}}, (i = 1, 2, \cdots, n, j = 1, 2, \cdots, p) \tag{1}$$

For the smaller and thus better indexes, the standardized formula[6]

$$x_{ij}^{*} = \frac{\max x_{ij} - x_{ij}}{\max x_{ij} - \min x_{ij}}, (i = 1, 2, \cdots, n, j = 1, 2, \cdots, p) \tag{2}$$

This method not only calculates easily, but also controls the range of the standardized variable easily, which is between 0 and 1.

Step 2. Calculate the standardized symmetric Correlation matrix R, the eigenvalues and the eigenvectors of R.[15]

Sample mean and sample covariance matrix can easily be calculated from the data. Eigenvectors and eigenvalues can be calculated from the covariance matrix. The first eigenvector having the largest eigenvalue points to the direction of largest variance (right and upwards) whereas the second eigenvector is orthogonal to the first one (pointing to left and upwards). The standardized sample correlation coefficient matrix is:

$$R = \frac{1}{n}(X^*)' X^* = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1p} \\ r_{21} & r_{22} & \cdots & r_{2p} \\ \vdots & \vdots & & \vdots \\ r_{p1} & r_{p2} & \cdots & r_{pp} \end{bmatrix} \tag{3}$$

where

$$r_{ij} = \frac{1}{n-1}\sum_{t=1}^{n} x_{ti}y_{tj} \qquad (i = 1, 2, \cdots, p; j = 1, 2, \cdots, p) \tag{4}$$

According to the equation $|R - \lambda_j I| = 0$, we can get the p latent root of R λ_j $(j = 1, 2, \cdots, p)$, and the corresponding eigenvectors U_j, $U_j = (U_{1j}, U_{2j}, , \cdots, U_{pj})$, $(j = 1, 2, \cdots, p)$.

Step 3. Calculate the contribution ratio and the accumulative contribution ratio of the covariance matrix[11].

The contribution ratio v_k of the principal component suggests the proportion of the principal component to the whole covariance, that is to say, the information of the p variable which were gotten by the kth principal component is most in the whole information. The formula of the calculating the contribution ratio[17]:

$$v_k = \frac{\lambda_k}{\lambda_1 + \lambda_2 + \ldots + \lambda_p} \qquad (p = 1, 2, \cdots, n; k = 1, 2, \cdots, p) \tag{5}$$

The formula of the accumulative contribution ratio[17]:

$$\sum_{k=1}^{p} v_k = \frac{\lambda_1 + \lambda_2 + \ldots + \lambda_k}{\lambda_1 + \lambda_2 + \ldots + \lambda_p} \qquad (p = 1, 2, \cdots, n; k = 1, 2, \cdots, p) \tag{6}$$

In general, we choose these principal components which reflect 85% of the variance[17].

$$\sum_{k=1}^{n} v_k \geqslant 85\% \tag{7}$$

Step 4. Get the principal component[11].

Given the volume of information of m principal component was the 85% to the whole information, we get them. That is to say, there are m principal component gotten.

Step 5. Calculate the matrix, get a new matrix.

According to the matrix, we can get the main data which integrated the other factor. So, we can use the lower dimensional principal component as the input sample to the neural network.

2.2 Evaluation model of county cycle economy based on BP neural network

In this section, we use the above statistic index data as the input of BP neural network. The neural network can not simplify the dimension which is as input information to the neural network. When the dimension is larger, the network structure is not only complicated, but also the training time is very long. Therefore, this section introduces the result of principle analysis into the neural network, simplifies the dimension of the input information, reduces the complex of the network system and improves the the ability of anti-interference[11].

2.3 The structure of model

Network configuration has three layers: (1) the input layer, according to the county cycle economy indexes system, we can get rid of superabundant indexes and use the remain indexes as the input variable of the neural network by the principle component analysis. (2) the hidden layer, according to the above methods, we can endue the nodus number of the hidden lay with a bigger number at first, then,we can get suitable the nodus number of the hidden lay when the network adopted by itself many times. (3) the output layer, the nodus number of output lay is three. The county cycle economy evaluation model is a process from quality to quantity. We can get an evaluating conclusion by analysing the output result of the neural network. This paper classes three grades of the county cycle economy, that is the better, the good and the worse. In the model, the output vector (001), (010), (100) denoted these three grades.

2.4 The algorithm step of model

Step 1. Establish the evaluating indexes system of the county cycle economy by expert interview and the documentary review methods.

Step 2. Get the input variable of neural network by the principal component analysis to choose the main indexes from all the indexes.

Step 3. Choose representative samples and collect interrelated indexes data and statistic data.

Step 4. Train the network according to the above algorithm of BP neural network.

Step 5. Judge that whether the trainparam epochs exceed the set or the trainparam goal reach the demand. If not, please back to Step 4. otherwise, stop.

Step 6. Put data of test samples into the trained neural network model, then, calculate the output, at last,evaluate the result,if the evaluating effect is satisfied, we will adopt this network to evaluate the level of this county cycle economy.

Step 7. Put data of evaluate sample into the tested neural network to evaluate grade of this county cycle economy.

3 Application of evaluation model

We can evaluate this county cycle economy by the PCA—BP neural network evaluation model. Firstly, we statistic the original data of many areas (Table 3). Secondly, the neural network had five input valuable, that is to say, the number of input nodus is five, three output nodus and ten hidden nodus. SO, the network structure is five—ten—three. We can divide the data into two parts, Part I is used to train the network as learning samples in order to get perfect neural network connection weight. So we can get that the system accuracy is 0.0001 and the rate studying is 0.005. The part II is used to test the network. We can denoted (001), (010), (100)as the output of neural network. And they suggest the development level of the cycle economy. Let (001) be the better status, (010) be the good status, (100) be the worse status. We can evaluate the developing status of county cycle economy by the neural network which is tested finally.

3.1 Index system

Through the expert interview and the documentary review[12, 17, 22], the indexes collection Table1 which reflects the status of the county cycle economy has been found. This paper adopts thirty-two indexes about the national economy counts indexes system of the county cycle economy initially[18–20]. They are related with the main aspect of national economy and social development such as national output value, international trade, industrial structure, resource utilization, demotic life, ecological comeback and harmonious society and so on[12]. It is beneficial to improving the rate of the right and reducing the training time and simplifying the network structure when the information which input to the neural network is dealt with by the principal component analysis.

Table 1. The original index system of the evaluation model of county cycle economy

first-index	second-index	index unit
Reduced index	Volume of Industrial Dust Emission	ton
	Rate of Industrial Waste Water up to the Standards for Discharge	%
	Facilities for Treatment of Waste Gas	set
	Volume of Sulphur Dioxide Emission	ton
	Volume of Soot Emission	ton
	Volume of Industrial Waste Water up to the Discharge Standards	10 000 tons
	Total Volume of Water Consumed by Industry	10 000 tons
	Volume of Solid Industrial Wastes Produced	10 000 tons
	Volume of Solid Industrial Wastes Accumula	10 000 tons
	Volume of Solid Industrial Wastes Discharge	10 000 tons
	Volume of Industrial Waste Water Discharged	10 000 tons
	Consumption of Chemical Fertilizers	10 000 tons
	Natural Gas Consumption	10 000 cu.m
	Fuel Coal Consumption	10 000 tons
harmless index	Rate of Waste Water Discharged from Daily Life Dispose	%
	Capacity of Facilities for Treatment of Waste Gas	
	Facilities for Treatment of Waste Water	set
	Volume of Industrial Waste Water Treated	10 000 tons/day
	Volume of Solid Industrial Wastes Treated	10 000 tons
	Total Volume of Industrial Waste Gas Emission	10 000 std.cu.m
Reused and resourceful index	Rate of Industrial Reused Water	%
	Rate of Comprehensive Utilization of Solid Industria Wastes	%
	Volume of Comprehensive Utilization of Solid Industrial Wastes	10 000 tons
	Output Valve of Products Made from Waste	
	Water,Waste Gas and Solid Wastes	10 000 yuan
integrated index	Gross Industrial Output Value	10 000 yuan
	Energy consumption of GDP per 10 000yuan	
	Total Sown Area	10 000 hectares
	Forest—coverage Rate	%
	Gross Domestic Product	100 million yuan
	Per Capita GDP	yuan
	Total Investment in fixed Assets	100 million yuan
	Total Sown Area	

3.2 Standardized index data

In this section, according to the above method, we dealt with indexes above by use of the principal component analysis. And we can get the following statistic index data (Tab. 2).

In Tab. 2, X_1denotes Energy consumption of GDP per 10 000yuan. X_2 denotes Rate of Industrial Waste Water up to the Standards for Discharge. X_3 denotes Rate of Comprehensive Utilization of Solid Industria Wastes. X_4 denotes Per Capita GDP. X_5 denotes Volume of Sulphur Dioxide Emission.

3.3 Evaluation result

We use this evaluation model to evaluate the process of this county cycle economy and we can get the following result. It proves that this model is exercisable and scientific. From the output result of the BP neural network (Tab. 3), we can know that the development of this county cycle economy is between the good and the better.

4 Conclusion

In this paper, we develop the evaluation model to make some studies of county cycle economy. We combine the principal component analysis with BP neural network to set up model to evaluate county cycle

Table 2. The statistic index data

Sample	X_1	X_2	X_3	X_4	X_5
1	0.1830	0.3799	0.2499	0.0611	0.3556
2	0.4024	0.7241	0.3421	0.8356	0.9422
3	1.0000	1.0000	0.6679	0.8900	1.0000
4	0.5854	0.7241	0.7368	0.9941	0.9970
5	0.8049	1.0000	0.3556	0.6129	0.9818
6	0.7928	0.8625	1.0000	0.97828	0.9651
7	0.5733	0.8276	0.6855	1.0000	0.9520
8	0.4999	0.7932	0.5395	0.3920	0.9483
9	0.1452	0.7243	0.7109	0.6768	0.9148
10	0.2196	0.6553	0.5530	0.2842	0.8389
11	0.0000	0.0000	0.2105	0.2276	0.6869
12	0.2927	0.3448	0.4078	0.0000	0.1976
13	0.2317	0.0000	0.0000	0.0157	0.0000
14	0.2073	0.2586	0.5026	0.1413	0.3465

Table 3. Output results of bp neural network

sample	type	level	output of sample	deducible output of neural network	evaluating result
1	training sample	good	0 1 0	0.1256 0.9493 0.0000	good
2	training sample	better	0 0 1	0.0000 0.0001 0.9999	better
3	training sample	better	0 0 1	0.0000 0.0003 0.9999	better
4	training sample	better	0 0 1	0.0000 0.0.0001 0.9999	better
5	training sample	better	0 0 1	0.0000 0.0067 0.9952	better
6	training sample	better	0 0 1	0.0000 0.0002 0.9998	better
7	training sample	better	0 0 1	0.0000 0.0001 0.9999	better
8	training sample	good	0 1 0	0.0004 0.9922 0.0060	good
9	training sample	better	0 0 1	0.0000 0.0032 0.9959	better
10	training sample	good	0 1 0	0.0037 0.9948 0.0003	good
11	test sample	better	0 0 1	0.0000 0.0052 0.9968	better
12	test sample	worse	1 0 0	0.9942 0.0078 0.0000	worse
13	test sample	good	0 1 0	0.0053 0.9925 0.0045	good
14	evaluate sample			0.0029 0.3056 0.6121	between good and better

economy, and we set up an integrate index system which contains all aspects of cycle economy. The result of evaluation model shows that the developed status of this county cycle economy is between the good and the better, that is to say, the development of this county cycle economy needs strength in order to arrive further goal. Through the analysis of the evaluating result, it can help the local government to establish the economical, societal and environmental policies and help the local government to plan the future stratagem about county cycle economy. We also need to do further study on the evaluating county cycle economy based on this paper, for example, we need to subdivide the index system which associates with the every aspect of county cycle economy and we can get more accurate evaluating method and model to construct sustainability of the cycle economy system.

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Appendix: The algorithm step of model

Different algorithm methods have been developed[14]. They include different versions of error backpropogation and other methods[10, 13]. Given the input nodus x_i, the hidden nodus y_j, the output nodus z_l, Each neuron j in the hidden layer sums up its input nodus, the network weight between the input nodus and the hidden nodus w_{ji}, the network weight between the hidden nodus and the output nodus v_{lj},when the expected value of the output nodus is t_l,the algorithm of the model as following[7].

The output formula of the hidden nodus

$$y_j = f\big(\sum_{i=1}^{n} w_{ji}x_i - \theta_j\big) = f(net_j)$$

where $net_j = \sum\limits_{i=1}^{n} w_{ji}x_i - \theta_j, (i = 0, 1, \cdots, n)$.

The computing formula of the output nodus

$$z_l = f\big(\sum_{j=1}^{n} v_{lj}y_j - \theta_l\big) = f(net_l)$$

where $net_l = \sum\limits_{j=1}^{n} v_{lj}y_j - \theta_l, (j = 0, 1, \cdots, n)$.

The error of the output nodus

$$E = \frac{1}{2}\sum_{l=1}^{n}(t_l - z_l)^2 = \frac{1}{2}\sum_{l=1}^{n}\left(t_l - f\big(\sum_{j=1}^{n} v_{lj}y_j - \theta_l\big)\right)^2 \tag{8}$$

$$= \frac{1}{2}\sum_{l=1}^{n}\left(t_l - f\left(\sum_{j=1}^{n} v_{lj} f\left(\sum_{i=1}^{n} w_{ji}x_i - \theta_j\right) - \theta_l\right)\right)^2 \tag{9}$$

According to the law of the amending the network weight and parameter, the differential coefficient of the output nodus was gotten by error function

$$\frac{\partial E}{\partial v_{lj}} = \sum_{k=1}^{n}\frac{\partial E}{\partial z_k}\frac{\partial z_k}{\partial v_{lj}} = \frac{\partial E}{\partial z_l}\frac{\partial z_l}{\partial v_{lj}}$$

E is the function of a number of nodus z_k, but only one nodus z_l is related with the weight v_{lj}, and the nodus z_k are independent each other, where

$$\frac{\partial E}{\partial z_l} = \frac{1}{2}\sum_{k=1}^{n}\left[-2(t_k - z_k)\frac{\partial z_k}{\partial z_l}\right] = -(t_l - z_l)$$

$$\frac{\partial z_l}{\partial v_{lj}} = \frac{\partial z_l}{\partial net_l}\frac{\partial net_l}{\partial v_{lj}} = f'(net_l)y_j$$

$$\frac{\partial E}{\partial v_{lj}} = -(t_l - z_l)f'(net_l)y_j$$

Given the error of input nodus is

$$\delta_l = (t_(l) - z_l)f'(net_l)$$

Then, $\frac{\partial E}{\partial v_{lj}} = -\delta_l y_j$.

The differential coefficient of the hidden nodus was gotten by error function

$$\frac{\partial E}{\partial w_{ji}} = \sum_{l}^{n}\sum_{j}^{n}\frac{\partial E}{\partial z_l}\frac{\partial z_l}{\partial y_j}\frac{\partial y_j}{\partial w_{ji}}$$

The error E is the function of a number of the output nodus z_l, for each weight w_{ji}, there is a hidden nodus y_j corresponding to it. Where

$$\frac{\partial E}{\partial z_l} = \frac{1}{2}\sum_{k=1}^{n}\left[-2(t_k - z_k)\frac{\partial z_k}{\partial z_l}\right] = -(t_l - z_l)$$

$$\frac{\partial z_l}{\partial y_j} = \frac{\partial z_l}{\partial net_l}\frac{\partial net_l}{\partial y_j} = f'(net_l)\frac{\partial net_l}{\partial y_j} = f'(net_l)v_{lj}$$

$$\frac{\partial y_j}{\partial w_{ji}} = \frac{\partial y_j}{\partial net_j}\frac{\partial net_j}{\partial w_{ji}} = f'(net_j)x_i$$

Then

$$\frac{\partial E}{\partial w_{jl}} = -\sum_{l=1}^{n}(t_l - z_l)f'(net_l)v_{lj}f'(net_j)x_i = -\sum_{l=1}^{n}\delta_l v_{lj}f^{'}(net_j)x_i = -\delta_j^{'}x_i$$

Given the error of hidden nodus is

$$\delta_j^{'} = f'(net_j)\sum_{l=1}^{n}\delta_l v_{lj}$$

Then

$$\frac{\partial E}{\partial w_{ji}} = -\delta_j^{'} x_i$$

Thanks to the amending weight Δv_{lj}, Δw_{ji} decline direct ratio to error function, so

$$\begin{aligned}
&\Delta v_{lj} = -\eta\frac{\partial E}{\partial v_{lj}} = \eta\delta_l y_j \\
&v_{lj}(k+1) = v_{lj}(k) + \Delta v_{lj} = v_{lj}(k) + \eta\delta_l y_j \\
&\delta_l = -(t_l - z_l)\cdot f^{'}(net_l) \\
&\Delta w_{ji} = -\eta^{'}\frac{\partial E}{\partial w_{ji}} = \eta^{'}\delta_j^{'} x_i \\
&w_{ji}(k+1) = w_{ji}(k) + \Delta w_{ji} = w_{ji}(k) + \eta^{'}\delta_j^{'} x_i \\
&\delta_j^{'} = f^{'}(net_j)\cdot\sum_{l}\delta_l v_{lj}
\end{aligned}$$

The error of the hidden layer $\delta_j^{'}$, the error value $\sum\limits_{l}\delta_l v_{lj}$ suggested that the error value δ_l of the output nodus z_l should be the error value of the hidden nodus through the weight v_{lj} propagated backwards to the nodus y_j and small changes are made to the connection weights in each layer.

The parameter θ is also the variable,which must mend when the weights were adjusted. The law is the same as the the adjust of the weights, that is

$$\begin{aligned}
&\Delta\theta_l = \eta\frac{\partial E}{\partial\theta_l} = \eta\delta_l \\
&\theta_l(k+1) = \theta_l(k) + \eta\delta_l \\
&\Delta\theta_j = \eta^{'}\frac{\partial E}{\partial\theta_j} = \eta^{'}\delta_j^{'} \\
&\theta_j(k+1) = \theta_j(k) = \eta^{'}\delta_j^{'}
\end{aligned}$$

It is obvious that the arithmetic is the iterative process. It calculates the grads and adjusts the weight until the output and the calculated output error less than a certain or the the iterative times less than a certain by the use of the input samples. So we can get an expectant convergence evaluating model. Therefore the train is over and the evaluating model set up.