Indexed in
Scopus Compendex and Geobase Elsevier,
Geo-Ref Information Services-USA, List B of Scientific
Journals, Poland, Directory of Research Journals

International Journal of Earth Sciences and Engineering

www.cafetinnova.org
ISSN 0974-5904, Volume 09, No. 05
October 2016, P.P.2166-2171

Evaluation of Ecological Competitiveness in Jiangsu Province

WEI TANG
School of Business, Hohai University, Nanjing 211100, China
School of Business, NanJing XiaoZhuang University, Nanjing 211171, China
***Email:** 1650598520@qq.com*

Abstract: In light of such current characteristics of Jiangsu province as rapidly-developing economy and society, increasingly prominent constraints on resources and environment, as well as grave damage to ecology, this paper builds up an index system for evaluation of ecological competitiveness (EC) in this province. The index system comprises four dimensions: economic development, social harmony, ecological health, and environmental friendliness. Another contribution is a revised version of technique for order of preference by similarity to ideal solution (TOPSIS). The modified TOPSIS is used in combination with the entropy method to assess the comprehensive evolution of 2004-2013 EC levels in Jiangsu province. The research result shows: social harmony and ecological health, both steadily operating, are in the similar track of development. Their vertical projection distances witness an overall tendency of gradual decrease. As a comparison, the vertical projection distances for economic growth and environmental friendliness fluctuate apparently and similarly. This phenomenon indicates that economic expansion is directly related to the evolution of EC levels as a major cause to EC upheaval. The trend of steadily narrowed vertical projection distance of comprehensive EC from 2004 to 2013 is a reflection of a steady rise in EC levels and a gradually enhanced capacity of sustainable development for Jiangsu province under long-term governance against the increasingly prominent constraints on resources and environment.

***Keywords:** ecological competitiveness; modified TOPSIS; evaluation research; Jiangsu province*

1. Introduction

Modern industrial civilization brings about unprecedented physical wealth and mental wealth. However, due to predatory behaviors of large-scale resource exploitation as well as the preservation of traditional lifestyles and mode of production, conflicts between human beings and the ecological system escalated in mid-20th century. Accordingly, a train of serious ecological and environmental problems occurred at the global level. In the face of a growing ecological threat, an emerging recognition strikes humankind: in order to turn regional competitions to good advantage so that leading to future economic growth, it is necessary to achieve sustainable development, whose motive and fuel, however, rests on the proper way to realize economic growth transformation and the pursuit for higher-stage coordination between economic society and the ecological system.

As a whole, systematic studies on EC are rare and preliminary. EC has not become a foreign concept or a system for targeted research. Nevertheless, there are comprehensive foreign studies discussing the way towards sustainable development from the perspective of global problems arising from resources and environment as well as the response of environmental changes to the expansion of ecological society [1-5]. Most of such studies contain the thought of EC, and can be seen as the theoretical basis and methods for EC reference. Domestic research into EC evaluation is still at the preliminary stage in its small amount. EC-oriented investigations concern an integral assessment on the quality of regional ecology and environment to a great extent, serving as measurement of potentials for sustainable development at the regional level. Main techniques for them include AHP, composite-index appraisal law, fuzzy synthetic evaluation technique, gray theories, and strategic environmental assessment (SEA) [4-5,8]. Despite the reasonable amount, empirical EC research is scattered and unsystematic. Existing EC evaluation indices selected are strongly subjective but arbitrary. In addition, related empirical studies mostly remain at the regional level, homogeneous in terms of EC evaluation. Given this, we first review present-stage research achievements. Then, according to the characteristics of economic society progress and ecological environment in Jiangsu province, we establish a targeted evaluation index system to gauge the conditions of EC level, aiming at revealing the law of EC evolution in this province. Finally, we propose some measures targeting at EC improvement. This is of great theoretical and practical significance for relevant government departments to formulate specific development policies to the advantage of local EC intensification.

2. Research area

Located at coastal areas in eastern China, Jiangsu province serves as one of the core regions in Yangtze River Delta. As of 2013, it had a total GDP of 5,916.175 billion yuan, ranking 2nd nationwide with the national GDP share of 10.4%. From 1978 to 2013, the annual average GDP growth rate was 12.4%, higher than the national counterpart. Apart from economic fruits, departments and sectors in Jiangsu province attach great significance to environmental and ecological protection. They stick tightly to “ecological red-line”, and improve ecological environment with efforts to tentatively avoid the occurrence of severe environmental pollution. However, as the provincial economy develops rapidly, ecological problems should be considered seriously. Pollution to aquatic environments is grave. Air contamination escalates.

The volume of industrial solid wastes and household refuse remain at a high level. Double constraints on resources and environment will continue challenging Jiangsu province in the future time. Ecological issues have added weight to restrictions on sustainable economic and social development in Jiangsu province.

3. Establishment of the evaluation index system and corresponding data source

3.1 Establishment of the evaluation index system

EC theory has an enriched connotation. The strongly synthetic discipline of EC evaluation covers a wide range from economy, society, ecology to environment. In this section, based on a systematic analysis of EC evaluation projects at home and abroad, guided by the principle of establishing EC evaluation index system, this paper employ AHP to build up an assessment index system for Jiangsu’s EC. With quantitative analysis, qualitative analysis and expert consultation [2-3, 4-6], we refer to related studies [7-8] before determining four dimensions for the system: economic development, social harmony, ecological health, and environmental friendliness. The purpose is to exhibit major evaluation indices for all aspects of EC. Meanwhile, with the aid of hierarchical decomposition, the EC evaluation index system is divided into three layers (target layer, system layer, and index layer), as shown in Table 1, so that each index and their relationships are highlighted.

Table 1: *The EC evaluation index system and weight*

Target layer	System layer	Weight	Index layer	Unit	Attribute	Weight
EC evaluation	Ecological development	0.135	GDP per capita	Yuan	+	0.047
			The growth rate of tertiary production	%	+	0.049
			The increment in industrial output value	10^8yuan	+	0.041
			Grain production per capita	kg	+	0.030
	Social harmony	0.252	Population growth rate	‰	-	0.062
			The registered urban unemployment rate at the year end	%	-	0.021
			Urban residents’ per capita disposable income	Yuan	+	0.046
			Urbanization rate	%	+	0.040
			Rural residents’ per capita housing area	M^3	+	0.031
			Per capita daily water consumption	Ton	+	0.040
	Ecological health	0.541	Population density per km2	people	-	0.032
			Urban green area	Hectare	+	0.035
			Green coverage rate in urban built-up area	%	+	0.022
			Water resource per capita	M^3	+	0.026
			Forest coverage rate	%	+	0.107
			Forest area per capita	Mu	+	0.098
	Environmental friendliness	0.072	Comprehensive utility rate for industrial solid wastes	%	+	0.029
			The volume of waste water discharged	10^4ton	-	0.052
			The volume of waste water discharged per ten thousand GDP	Ton	-	0.031
			The volume of ammonia nitrogen discharged per ten thousand GDP	Kg	-	0.034
			The volume of SO2 emitted	Kg	-	0.032
			The elastic coefficient of energy consumption	%	-	0.030
			he proportion of investment in environmental protection acceptance projects in GDP	%	+	0.065

3.2 Data source

The paper's main data sources are: Jiangsu province statistic yearbook (2004-2014), Jiangsu province environmental conditions statement (2004-2013), China environmental statistic yearbook (2013), China statistic yearbook (2004-2014), China energy statistic yearbook (2005-2013), national economy and social development statistic statements and environmental conditions statements from government departments of prefectures and municipals under Jiangsu province.

4. Research approach

4.1 Revised TOPSIS

4.1.1 TOPSIS and its limitations

TOPSIS is a multi-criteria decision analysis method, which was originally developed by Hwang and Yoon in the book Multiple Attribute Decision Making: Methods and Applications in 1981. TOPSIS is a technique for order of preference by approaching ideal solution. The fundamental principle of TOPSIS is: an optimal solution (the positive ideal solution) and a poorest solution (the negative ideal solution) are preset, allowing for characteristics of a specific research objective. The relative closeness of each alternative in the objective space is calculated based on the concept that an alternative is more similar to the best option if it has shorter geometric distance from the positive ideal solution and longer geometric distance from the negative ideal solution. Accordingly, the order of preference for it is higher. In this way, all alternatives for the objective are compared and ordered. Traditional TOPSIS receives social attention as a feasible approach to solving some multi-criteria decision-making problems. However, with inherent drawbacks, TOPSIS produce less objective, less accurate, and even irrational evaluation results. Below are major restrictions of traditional TOPSIS:

(1) In specific applications, this method ignores evaluation index attributes. Instead, evaluation index weights are predetermined subjectively and randomly to help assess the objective. In this case, the reliability of evaluation result remains to be discussed.

(2) This method is founded on Euclidean distance. The relative closeness of an alternative to the best option is measured by its Euclidean distance from the positive ideal solution and Euclidean distance from the negative ideal solution. Nevertheless, a situation exists in practical research that an alternative is both near to the positive ideal solution and the negative ideal solution in terms of Euclidean distance. Thus, when Euclidean distance is used to appraise the quality of various alternatives, the obtained result may lose efficacy.

4.1.2 Modified TOPSIS

To overcome the said limitations, this paper revises TOPSIS.

On the one hand, in order to embody the weight and influences of every evaluation index, we adopt the proposed entropy method to gauge index weight, which also weakens the effect of subjective factors on evaluation results. During traditional TOPSIS-based calculation, the normalization matrix multiplies weight so that forming a weighed normalization matrix

$$Y' = (y_{ij}')_{m\times n} \quad (=1,2,\ldots,;\ =1,2,\ldots,\ ) \tag{1}$$

$$y_{ij}' = w_j \times y_{ij} \quad (=1,2,\ldots,;\ =1,2,\ldots,\ ) \tag{2}$$

Where w_j is the j th evaluation index's weight determined by the entropy technique.

On the other hand, to address problems arising from Euclidean distance, this paper refers to relevant documents and accordingly revises TOPSIS from this perspective: the positive ideal solution and the negative ideal solution are regarded as two points (A and B, for example) in a three-dimensional space (the decision set). We join A and B, and generate some planes with the line segment AB as the normal vector, so that vertical projection distance replaces Euclidean distance. Specifically, X and Y is a pair of arbitrary points in the space. C and d are two planes whose normal vector is the line segment AB, and X and Y falls onto them. P and Q are the points of intersection between the planes and the line segment AB. Thus, PQ represents the vertical projection distance between X and Y. The corresponding sketch map is shown in Figure 1.

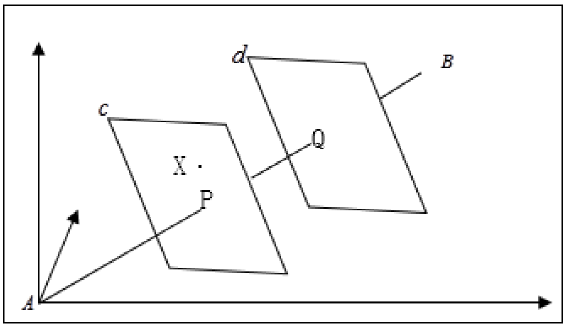

Figure 1: *The sketch map of vertical projection distance*

We assume *A*, *B*, *X* and *Y* correspond to vector *a*, *b*, *x* and *y* respectively. Thus, the vertical projection distance PQ between X and Y is

$$PQ = \frac{|(a-b)*(x-y)|}{\|a-b\|} \tag{3}$$

Where * is the vector's inner product.

For easy calculation, we let the point A be the origin of coordinates. The positive ideal solution becomes

(0,0,…,0). Then, we calculate the decision-making weighed matrix

$$T = (y_{ij}^{'} - D^{+})_{m\times n} \quad (i=1,2,\ldots,m;\ j=1,2,\ldots,n) \quad (4)$$

Accordingly, the negative ideal solution becomes $D_i^{'-} = t_{kj}$,where t_{kj} satisfies $|t_{kj}| > |t_{ij}|$ the condition(k , i =1,2,…, m ; j =1,2,…, n).

Since the norm between A and B is a constant of all evaluation schemes, our work is reduced to a mere calculation of $|(a-b)*(x-y)|$, i.e. the vertical projection distance of each evaluation alternative to the ideal solution S_i , which is expressed as

$$S_i = |D_i^{'-} - T_i| = \sum_{j=1}^{n} D_i^{-} \times t_{ij} \quad (i=1,2,\ldots,m) \qquad (5)$$

It is easy to prove that based on the vertical projection distance, an alternative that approximates the positive ideal solution is far from the negative ideal solution [9]. An alternative with smaller vertical projection distance to the positive ideal solution is better, and its number of order is smaller; reversely, an alternative with larger vertical projection distance to the positive ideal solution is worse, and its number of order is bigger.

The modified TOPSIS gains advantage over traditional TOPSIS in that the former one effectively improves the objectiveness and accuracy of evaluation process and result. The revised version provides scientific guidance to EC evaluation at the regional level. The corresponding evaluation steps are:

(1) Supposing there are m alternatives for the research objective, and each alternative includes n evaluation indices. The evaluation index value is represented by x_{ij} (i =1,2,…, m ; j =1,2,…, n).Then, we obtain a matrix of m lines and n rows $X = (x_{ij})_{m\times n}$.

(2) With different attributes, evaluation indices differ from each other in relation to dimensions and orders of magnitude. Given this, we normalize each evaluation index value, and obtain a normalized matrix (=1,2,…,; =1,2,…,).

(3) The entropy method is in combination with the proposed first modification method to measure evaluation index weight. which also weakens the effect of subjective factors on evaluation results. During traditional TOPSIS-based calculation, the normalization matrix $Y = (y_{ij})_{m\times n}$ multiplies weight so that forming a weighed normalization matrix $Y^{'}$:

(4) Based on the weighed normalization matrix $Y^{'} = (y_{ij}^{'})_{m\times n}$, we obtain positive ideal solutions Y^{+} and negative ideal solutions Y^{-} for finite evaluation alternatives, as well as the latest weighed matrix.

(5) According toz the proposed second modification method, we calculate the vertical projection distance S_i of all evaluation alternatives from the positive ideal solution. Their distances are based to order their quality. The order is analyzed in this paper.

4.2 The entropy method

Entropy is an expression of the disorder of a system, and can measure the volume of effective information about it. Larger information entropy means a higher degree of system disorder, and a lower utility value of information; vice versa. The entropy theory is used in this paper to determine the weight of each evaluation indices, and the calculation steps are:

Supposing that independently evaluate n indices in each of the m alternatives. Then, a multi-criteria evaluation matrix is built up $X = (x_{ij})_{m\times n}$, where is the raw value of the j th index in the i th alternative.

We first normalize raw index data using the following formulas.

The normalization formula for positive indices(+) is

$$X_{ij}^{'} = \frac{x_{ij} - \min x_{ij}}{\max x_{ij} - \min x_{ij}} \qquad (6)$$

The normalization formula for negative indices(-) is

$$X_{ij}^{'} = \frac{\max x_{ij} - x_{ij}}{\max x_{ij} - \min x_{ij}} \qquad (7)$$

Where $X_{ij}^{'}$ is the normalized evaluation index value, and x_{ij} is the raw index value.

Then, we calculate the information entropy of the ith index E_i :

$$E_i = -1/\ln(m)\sum_{i=1}^{n}\frac{q_{ij}}{q_j}\ln(\frac{q_{ij}}{q_j})$$

(i =1,2,…, m; j=1,2,…, n) (8)

Where q_{ij} the normalized value of raw is x_{ij} , q_j is the sum of all normalized index values in the j th year. We let $\frac{q_{ij}}{q_j}$ =0, when $\frac{q_{ij}}{q_j}\ln(\frac{q_{ij}}{q_j})$ =0.

Finally, according to the entropy theory, after the information entropy E_i of the i th index is obtained, we acquire the weight of the i th index

$$Q_i = (1 - E_i)/(n - \sum_{i=1}^{n} E_i) \quad (i = 1, 2, \ldots, n) \tag{9}$$

Where Q_i is the weight of the i th index, E_i is the information entropy of the i th index, n is the number of evaluation indices. When $\sum_{i=1}^{n} Q_i = 1$, $Q_i \in [0,1]$.

5. Evaluation result and analysis

The modified TOPSIS method and the entropy theory are used to calculate the weight of each evaluation index before constructing a weighed normalization matrix. Accordingly, we obtain the positive ideal solutions and the negative ideal solutions of finite alternatives as well as the latest weighed matrix. The vertical projection distances of every alternative from the best option are computed, on whose basis we order EC levels of Jiangsu province from 2004 to 2013 which reflects the corresponding EC level situations. The result is seen in Table 2-3.

Table 2.*Vertical projection distances of every alternatives from the best option*

Year	Economic development	Order	Social harmony	Order	Ecological health	Order	Environmentally friendly	Order
2004	0.0058	9	0.0047	7	0.0242	8	0.0041	7
2005	0.0033	2	0.0048	8	0.0231	6	0.0034	5
2006	0.0050	7	0.0052	9	0.0234	7	0.0041	7
2007	0.0042	6	0.0047	7	0.0226	5	0.0040	6
2008	0.0037	3	0.0034	6	0.0226	5	0.0032	4
2009	0.0055	8	0.0030	5	0.0012	4	0.0042	8
2010	0.0016	1	0.0015	3	0.0008	3	0.0045	9
2011	0.0016	1	0.0016	4	0.0005	1	0.0019	3
2012	0.0039	5	0.0004	1	0.0006	2	0.0008	1
2013	0.0038	4	0.0011	2	0.0006	2	0.0009	2

Table 2 vertical projection distances of every alternatives from the best option.

As can be seen from the composites of EC evaluation, social harmony and ecological health, both steadily operating, are in the similar track of development. As a comparison, the vertical projection distance of economic growth fluctuate apparently, which is mainly caused by the change of tertiary production growth rate and the increment in industrial output value under the action of external macro factors. If seen as a whole, the vertical projection distance of economic growth from 2004 to 2013 tends to decrease year after year. This phenomenon indicates that economic competitiveness has a strong behavior and great potential to develop. The vertical projection distance of environment friendliness presents a similar tendency of change, with strong fluctuations. The change of distance can be divided into three stages: the stage of gradual decrease from 2004 to 2008, the stage of sharp rise from 2009 to 2010, and the stage of plunge between 2011 and 2013. This phenomenon is related to the great rises and falls of investment in environmental protection acceptance, the yearly increasing amount of waste water discharged, and the high level that ammonia nitrogen discharge volume sticks to. This phenomenon indicates that economic expansion is directly related to the evolution of EC levels. Along with economic development, a necessary concern in future time is environmental protection, intensified governance of environmental pollution, and more investment in them.

Furthermore, after the vertical projection distance of four subsystems from the best option is obtained, we acquired the dynamic development situations of overall EC in Jiangsu province from 2004-2013, during which we refer to the weight of these subsystems as well as the calculation steps of the modified TOPSIS. We order the vertical projection value in an ascending sequence, as shown in Table 3.

Table 3.*Dynamic development situations of overall EC in Jiangsu province from 2004-2013*

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Vertical Projection distance	0.0154	0.0144	0.0149	0.0143	0.0138	0.0025	0.0014	0.0010	0.0010	0.0012
Order	9	7	8	6	5	4	3	1	1	2

Table 3 shows that Jiangsu EC finds a stable overall change. The vertical projection distance decreases steadily, hitting the bottom value of 0.001 in 2011 and 2012. The second last vertical projection distance occurs in 2013, and the maximum one happens in 2004 at the value of 0.0154, 15.4 times that of the minimum distance. This result demonstrates a steady rise in overall EC.

Against the backdrop of industrial transformation, structure upgrade, and intensified ecological and environmental protection and control, Jiangsu province bears tremendous economic growth pressure. It is not easy for Jiangsu province to have its EC improved under such conditions, but this province succeeds in doing it. The steady improvement of the ecological competitiveness of Jiangsu Province from 2004 to 2013 is closely related with the long-term eco-environmental protection policy of Jiangsu Province, as well as the improvement of ecological environment quality and ecological competitiveness as the most urgent and important livelihood projects.

6. Conclusion and discussion

This paper constructs an evaluation index system which can reflect the ecological competitiveness of Jiangsu Province comprehensively. Through the use of the improved TOPSIS method and entropy method, the ecological competitiveness of Jiangsu Province in 2004-2013 is evaluated synthetically. The results show that:

(1) From 2004 to 2013, the subsystems of social harmony and ecological health in Jiangsu Province were stable and their development trajectories were basically the same, and the vertical distance was gradually decreasing. The vertical distance of economic development subsystem fluctuates obviously, but on the whole, the vertical distance decreases gradually, which indicates that the economic competitiveness of Jiangsu Province in 2004-2013 is stronger and the development potential is bigger. Similar to the change of the vertical distance of the economic development subsystem, the fluctuation of the vertical distance of the environment-friendly subsystem is relatively strong, which shows that the economic development has direct relationship with the development and change of the ecological competitiveness level. Economic development exerts great effect on the level of ecological competitiveness.

(2) The change of the vertical distance of the ecological competitiveness of Jiangsu Province from 2004 to 2013 is basically stable and displays a steady decrease trend. It shows that ecological competitiveness and the ability of sustainable development are gradually enhanced in Jiangsu Province when the resource and environment are becoming more and more binding.

(3) In order to further enhance the ecological competitiveness of Jiangsu Province, so that leading the future regional economic development, the future several points should draw our attention for improving ecological competitiveness of Jiangsu Province: it remains a necessity to strengthen supervision and management of the ecological environment; the industrial structure should be further adjusted by vigorously developing low-carbon economy; it is suggested to continue optimizing the energy utilization structure, actively developing and utilizing clean energy, aiming at achieving a win-win situation between ecological and environmental protection and economic development.

References

[1] Umberto Colombo. The Club of Rome and Sustainable Development, Futures, Issue 31., 7-11.,2001.

[2] Caldmel, L.K. Political Aspects of Ecologically Sustainable Development, Environment Conservation, Issue 11., 299-308., 1984.

[3] World Commission on Environment and Development, Our Common Future, Oxford: Oxford University Press, 1987.

[4] Liang Wei, Zhang Huiying, Zhu Konglai. Comprehensive Evaluation of Urban Eco-environment Competitiveness based on Fuzzy Mathematics and Gray Theory, China Environmental Science, Vol.33, Issue5. 945-951., 2013.

[5] He Yanxin, Li Jinhua. Ecological Competitions Estimation based on the Strategy of Sustainable Development-A Case Study in Anhui Province, Resources and Environment in the Yangtze Basin, Issue 4., 462-467., 2013.

[6] Ren Zijun, Xu Jian. Establishment and Evaluation on Hefei Urban Ecological Competitiveness, Journal of Anhui Agricultural University, Vol41. Issue3, 491-495., 2014.

[7] Chen Wenjun, Yang Wue, He Zhengchu, Zhou Zhehong. Comparing Urban Eco-competitiveness of Provincial Capitals in Midwestern China Based on Intuitionistic Fuzzy Information. China Soft Science, Issue5., 151-163., 2014.

[8] Zhang LiXiao, Yang ZhiFeng, Chen Bin, Liu GengYuan, Liang Jing. An analysis on Urban Ecological Competition Capability with Biophysical Accounting method, Acta Ecologica Sinica, Issue9,.4344-4351.,2008.

[9] Xu Jianxin, Fan Hua, HU Xiaotao. The Model Combined Entropy Weight with Improved Topsis and Its Application in Groundwater Resource Carrying Capacity Evaluation, China Rural Water and Hydropower, Issue2.,30-33.,2012.