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International Journal of Current Research
Vol. 4, Issue, 11, pp.290-294, November, 2012

INTERNATIONAL JOURNAL OF CURRENT RESEARCH

ISSN: 0975-833X

RESEARCH ARTICLE

USE OF NONLINEAR MAPPING IN REGIONAL COOPERATION LEVEL ANALYSIS OF SHANDONG PENINSULAR URBAN AGGLOMERATION AND TIANJIN BINHAI NEW AREA

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ARTICLE INFO

Article History:
Received 19th August, 2012
Received in revised form
10thSeptember, 2012
Accepted 07th October, 2012
Published online 23h November, 2012

Key words:
Nonlinear mapping (NLM),
Regional cooperation level,
Shandong Peninsular Urban Agglomeration (SPUA), Tianjin Binhai New Area (TBNA).

ABSTRACT

With the rapid development of economy in Tianjin Binhai New Area (TBNA), the regional cooperation has been strengthened in the Areas around the Bohai Sea. As an important part of the Circum-Bohai economic circle, Shandong Peninsular Urban Agglomeration (SPUA) has the regional cooperation advantages in every aspect with TBNA. So it is important to study the regional cooperation level between them. In this study, the clustering analysis was conducted on the regional cooperation level between 8 cities belonged to SPUA and TBNA by the non-linear mapping. The results indicated clearly that Qindao and Dongying have high competitiveness and low cooperation level with TBNA, and Jinan, Yantai and Weihai show relatively tight co-operative relationship with TBNA, whereas Rizhao, Zibo and Weifang exhibit a high complementarity and good cooperation prospects with TBNA. Finally, the detailed development strategies for regional cooperation in study areas were put forward based on the results of the clustering Analysis. Also the non-linear mapping proposed provides a new method for quantitative analysis of the regional cooperation level.

INTRODUCTION

As the exploitation and construction of Tianjin Binhai New Area (TBNA) is brought into national general development strategy layout, TBNA became the third national experimental zone for comprehensive reforms in China after Shenzhen and Shanghai Pudong New Area (PDNA). Shandong Peninsular Urban Agglomeration (SPUA), an important component of the Circum-Bohai economic circle, has good connections with TBNA. With the implementation of the development strategy of the Circum-Bohai economic circle, how to enhance regional economic cooperation and accelerate the integration in the Circum-Bohai economic circle become more and more important (Yan, 2007). Under this background, it is very necessary for economy development of SPUA to set up integral strategy for the regional economic cooperation and long-effect operation mechanism, both which are beneficial to the optimizing resource allocation and advancing regional overall competition. It will be, therefore, very important for SPUA to realize multiplier effect of economic growth and achieve win-win ultimately through active participating in TBNA abutment, widening and deepening economic cooperation between SPUA and TBNA, and conjunct development of resource integration.

However, most of the present studies on regional economy cooperation have been staying on qualitative or half quantitative level all the time (Li *et al*., 2008; He and Zhang, 2006). The limitation of descriptive approach always leads to a great difference between the research results based on the qualitative analyses and the actual situations because it is influenced by subjective factors. There need be further studies by means of accurate and quantitative analysis method. In the present study, according to the economic indices selected which can reflect the regional cooperation level, the clustering analysis on the regional economy cooperation level between the eight cities belonged to SPUA and TBNA is conducted by the non-linear mapping (NLM). The objectives of this study are (i) to evaluate the feasibility of nonlinear mapping method in the study on regional cooperation level and other similar studies, (ii) to offer a scientific regional cooperation strategy of economic persistent development of SPUA and TBNA.

Nonlinear mapping algorithms

Algorithm description

NLM, a classical nonlinear method proposed by Sammon (1969) is a geometrical dimension reduction technique that deals specifically with nonlinear spaces. The algorithms employ nonlinear transformations, which attempt to maintain the inherent structure of the data and visually give the geometry configuration of the data points in a low-dimensional space when the patterns are projected from a high-dimensional space onto a low-dimensional space (Lerner, *et al*., 1998; Li and Liu, 2007). This reduced representation can subsequently be used for a variety of pattern recognition and classification tasks. In the analysis because the NLM only takes data structure, but not data category into account, thus this method has been applied widely in many disciplines of science, from chemistry and physics to social sciences and

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psychology (Dimitris and Victor, 2000; Li and Liu, 2007; Liu, 1994; Lv, *et al*., 1995). The regional cooperation level is also comprehensively affected by many factors (Sun, 2009). When this problem is discussed by NLM, its basic principle is similar to the problems mentioned above. In this paper, we attempt to use the NLM to discuss the problem of regional cooperation and recognize and classify the regions with different cooperation levels according to the positions of different data points in mapping plot, whose aim is to provide scientific basis for developing the regional cooperation.

Realization of mapping process

Suppose that we have n samples, each of which involves p variables, and then every sample represents a point defined in a p-dimensional space designated $X_i = (x_{1i}, x_{2i}, \ldots, x_{pi})$, i=1, 2, …, n. Now let the n sample points in the higher p-dimensional space are mapped onto a lower L-dimensional space (in most cases, L equals to 2 or 3) by constructing a configuration of points in a low-dimensional space to preserve the topology and density of the original data points. To preserve distances between these points as similar as possible to the actual distances in original space during the process of nonlinear mapping transformation, various distance measures and error functions have been designated (Chi *et al*., 2006; Chen *et al*., 1999). In this paper, we define an error function E, which can be used to measure the difference between the distance matrixes of the original and projected spaces, i.e.,

$$E = \frac{1}{\sum_{i<j}^{k} d_{ij}^{*}} \sum_{i<j}^{k} \frac{\left(d_{ij}^{*} - d_{ij}\right)^2}{d_{ij}^{*}} \quad (1)$$

Where d_{ij}^{*} is the distance between any two points X_i and X_j in the original space, and d_{ij} is the distance between two points Y_i and Y_j in the display space. The meaning of the E is to represent how well the present configuration of n points in the original space fits the n points in the display space (Liu *et al*., 2009), and the less the E, the more precise the mapping result to preserve the topological structure of samples in the original space. Next we compute the p-dimension space interpoint distances d_{ij}^{*} by the common Euclidian Distance, defined as

$$d_{ij}^{*} = \sqrt{\sum_{k=1}^{p} \left(x_{ik} - x_{jk}\right)^2} \quad (2)$$

Where i, j=1, 2, …, n. Through the equation (2), we can obtain a symmetric distance matrix D*, namely

$$D^{*} = \left[d_{ij}\right]_{n \times n} \quad (3)$$

In the L-dimensional space, we choose any n initial value points: $Y_i = \left(y_{1i}, y_{2i}, \cdots, y_{Li}\right)$, and then substitute the error function E with them. Note that the error is a function of the $L \times n$ variables y_{ij}, i=1, 2 ,…, n and j=1, 2 ,…, L. The next step in the NLM is to adjust the y_{ij} variables or equivalently change the L-space configuration so as to decrease the mapping error. The values of Y_i for n sample points in the projected space are obtained when the E is minimized using a steepest-descent algorithm. The iterative formula is

$$y_{ij}(m+1) = y_{ij}(m) - \lambda \Delta_{ij}(m) \quad (4)$$

Where m is the iteration number and λ is the learning rate (equals to 0.3 or 0.4), and

$$\Delta_{ij} = \frac{\partial E(m)}{\partial y_{ij}(m)} \Big/ \left| \frac{\partial^2 E(m)}{\partial y_{ij}(m)^2} \right| \quad (5)$$

A case study of regional cooperation between SPUA and TBNA

Selection of the study area

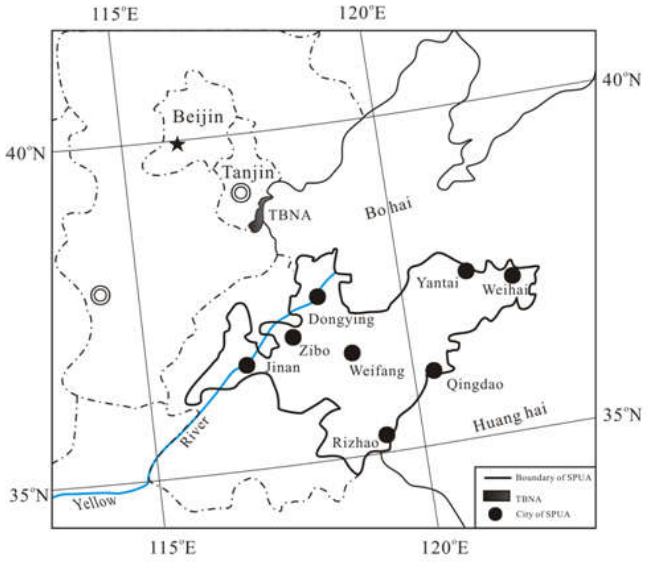

Fig. 1. The distribution of Shandong Peninsular Urban Agglomeration and Tianjin Binhai New Area

TBNA is situated at the east coast of Tianjin city (Fig.1), having an area of 2.3×10^3 km^2. With the rapid development of economy in TBNA (In 2010, the total GDP is 503.1 billion Yuan), extensive exchanges and cooperation in various fields have been carried out among the provinces in the Circum-Bohai Region, and remarkable results have been achieved (Tian, 2007; Li, 2007; Dong, 2006). As an important component of the Circum-Bohai economic circle, SPUA covers an area of 7.3×10^4 squares kilometers, taking up 46.5% of the total area of Shandong province (Fig.1). SPUA has the natural location superiority in regional cooperation with TBNA, including abound resources, good traffic conditions, strong industrial base, and active trade development. Only in 2010, the GDP of SPUA was 217.06 billion Yuan, accounting for about 67.0% of the total in Shandong province. This means that SPUA is the most important element in promoting Shandong Province economical development. And also it is the bridgehead for strengthening regional cooperation between Shandong Provinces and the TBNA. In recent years, the effective eco-economics construction in the Yellow River Delta and the blue economic zone formation in the Shandong Peninsula have started up in Shandong Province. And this may provide an unprecedented opportunity with wide market prospect for the multiaspect economic cooperation with the TBNA.

Data source and selected variable index

With regard to availability and accuracy of raw data acquisition and convenience for transversal comparison, we selected four kinds of indices involving 17 variables (Table 1) which can most unlimitedly reflect cooperation level, to evaluate the region economic cooperation level between the SPUA and the TBNA using NLM method. The statistical data used in this paper are obtained from "A brilliant course-The reform and the open policy in Tianjin for 30 years", "Tianjin Statistical Yearbook" (2011), TBNA Statistical Yearbook" (2011), and "the Shandong Statistical Yearbook" (2011). These indices are relevant to the foundation and conditions of regional cooperation. Among them the scale index reflects the extent of region cooperation level; the domestic/foreign capital index not only can embody the superior or inferior of investment environment, but also is an important reference for the economy development of export-oriented city. The industrial value-added index is the propelling force for the regional economy development and other index may reflect the foundation of the regional cooperation. According to the selected indices, the data obtained are listed in the table 2.

Cluster analysis of the regional cooperation level

Table 3 The two dimensional results obtained by Nonlinear mapping

Region	y_{i1}	y_{i2}	Region	y_{i1}	y_{i2}
TBNA	-3.0101	3.3322	Yantai	-1.6507	-3.3469
Jinan	-1.9505	-1.8566	Weifang	-3.667	-4.9587
Qindao	-1.7312	-0.9675	Weihai	-7.0204	-2.5588
Zibo	-4.961	-4.3158	Rizhao	-9.3611	-2.2707
Dongying	-7.4331	-0.9047			

According to the NLM mentioned above, the analysis of the regional cooperation level between the SPUA and the TBNA was carried out in the DPS (Data Processing System) software developed by Tang and Feng (2007). During the process of the NLM analysis, the maximum permissible error was set to 0.05 and the dimension set was equal to 2. After 5000 iterations when the mapping error is 0.01, the 17 indices reflecting regional cooperation levels in the original space

Table 1. The selected variable index and their classification

Index types	Index meaning	Index code
Scale index	Non-agricultural population(×10⁴ human)	1
	GDP(100 million yuan)	2
	GDP per capita (yuan)	3
	Investment in fixed assets (100 million yuan)	4
	Total exports (100 million US dollars)	5
Foreign capital index	Number of direct utilization of foreign capital contract (n)	6
	Actually utilized foreign capital (100 million US dollars)	7
	Number of foreign and Hong Kong, Macao and Taiwan investment enterprises (n)	8
	Total value of industrial output of foreign and Hong Kong, Macao and Taiwan investment enterprises (100 million yuan)	9
Domestic capital index	Number of domestic enterprises (n)	10
	Total value of industrial output of domestic enterprises (100 million yuan)	11
Industrial value-added index	The value-added of the first industrial (100 million yuan)	12
	The value-added of the secondary industry (100 million yuan)	13
	The value-added of the third industrial (100 million yuan)	14
Other index	Transaction value of markets with individual turnover exceeding RMB 100 million (100 million yuan)	15
	Passenger capacity (ten thousands human)	16
	The value of business transactions of postal and telecommunication (100 million yuan)	17

Table 2. The data of index variables[§]

Index code	TBNA	SPUA							
		Jinan	Qindao	Zibo	Dongying	Yantai	Weifang	Weihai	Rizhao
1	92.2	430.2	478.4	181.7	79.3	311.0	407.2	122.9	100.8
2	3810.7	3340.9	4853.9	2445.3	2059.0	3701.8	2707.2	1733.2	864.7
3	321386	50219	57251	54229	102370	52683	30338	68614	31451
4	2502.7	1655.4	2458.9	1009.6	1095.6	2222.2	1890.5	1165.5	631.9
5	197.1	30.5	269.2	30.6	17.6	198.3	62.0	68.2	16.3
6	315	74	650	36	15	259	79	99	25
7	57.6	9.8	21.9	3.9	1.7	10.9	6.8	5.5	3.8
8	968	225	2243	209	58	1142	511	702	116
9	4004.2	377.4	2919.4	766.0	366.9	3516.8	995.8	1590.3	380.0
10	991	1776	3433	3133	825	2659	4322	1350	838
11	3491.8	3504.1	6458.8	5376.6	3983.2	5560.5	5083.3	3294.5	1519.1
12	7.4	187.1	230.3	87.8	74.7	285.9	302.0	136.3	87.3
13	2569.9	1433.5	2420.1	1535.8	1521.9	2227.3	1526.1	1001.0	471.9
14	2385.5	1720.3	2203.5	821.6	462.3	1188.6	879.2	595.9	305.5
15	518.4	384.0	904.4	328.8	40.1	208.7	254.0	22.6	198.3
16	396.1	11246	19418	37250	3859	30332	20402	14586	3953
17	13.50	164.6	233.7	89.1	57.0	146.8	160.4	67.1	42.2

[§]: Various variables in this table have the same units as the ones in the Table 1.

were successively mapped into two indices (Table 3) in the two-dimensional space when the original spatial structure of the data was maintained unchanged. Hence it is not difficult to obtain the distributed scatter diagram of each region (Fig.2). Based on the very low mapping error we can think that the sample points in two-dimensional space indicated entirely or almost entirely the information of the original sample points in high dimensional space. The different shape symbols in Fig. 2 represented the different classifications of regional cooperation levels. It should be pointed out, however, that the points coordinate values obtained by NLM in accordance with the original data of 17 indices has little practical significance except to show the relative position among points.

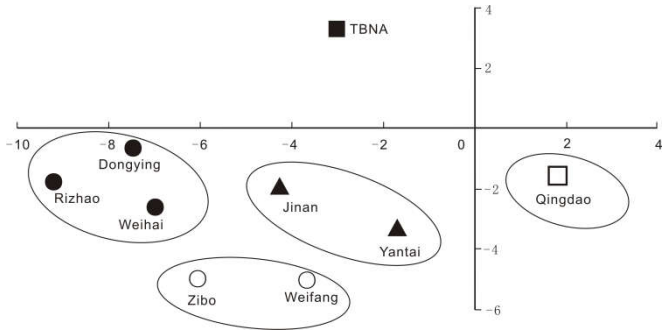

Fig 2. Two-dimensional plane of NLM for the regional cooperation level between SPUA and TBNA

Generally, the distance among sample points in Fig.2 is nearer, their similar degree is higher, and the competitive relationship each other may possibly be existed. The judgment of the cooperation level between the SPUA and the TBNA, therefore, may be realized by analyzing the Euclidean Distance of the sample points after non-linear mapping in the high dimensional space. Namely, the shorter the distance, the smaller the interregional difference, and the stronger the competition. On the contrary, the longer the distance, the bigger the interregional difference, and the better the cooperative prospects due to the stronger complementarity. Accordingly, the correlations of the sample points, which reflect the regional cooperation levels, may be showed directly with the two-dimensional plan. According to the results of the NLM clustering analysis mentioned above, the regional cooperation levels between SPUA and TBNA could be classified into following four types:

- Qingdao belongs to the first group because its regional cooperation level with the TBNA is well above the ones of others of the SPUA.
- Jinan and Yantai are the second group, which has high competitiveness with the TBNA. This was mainly due to their good foundation in economic development, prominent characteristics, and the outstanding superiority in foreign capital index and the value-added of the third industrial when compared to other cities of the SPUA.
- Rizhao, Dongying and Weihai are the third group. They have shown a relative close cooperation relation with the TBNA.
- Zibo and Weifang are the fourth group. The reason is that the two cities, in contrast with the third cities group, have obvious differences in foreign capital index and the value-added of the second and third industrial. Thus their regional cooperation levels are easy to improve because of the stronger complementarity with the TBNA.

Development strategies for regional cooperation

In general, the SPUA and the TBNA showed a good foundation and prospect of regional cooperation. But compared with international advanced level, the regional cooperation between the SPUA and the TBNA still has a greater difference, and faces all kinds of difficulties. In order to further strengthen SPUA-TBNA mutual benefit and cooperation and promote joint development, the following suggestions are necessary and also provide valuable information for other parts of the world.

Development strategies for Qingdao as the first group

Currently Qingdao has become a hotspot in investment and development by Shandong Province because of its rich natural resources and good market prospect. Also Qingdao exhibits competition relationship with TBNA due to the relatively small difference in the economic development levels, similar industrial structure, and its special geographical position. On the one hand, with the fast development of high and new technology industries (e.g., aerospace, electronic information, biology pharmacy, automobile, and petrochemical engineering) in TBNA, Qingdao should adopt the transpositive competition strategy with the TBNA through various forms to improve economic benefits in the healthy competition (Ma, 2008). By jointing closely to TBNA, it is quite necessary for Qingdao to energetically develop modern manufacturing industry, especially to strengthen the development of leading industry, including household electric appliance, boats and ships manufacture, petrochemical industry, and new material. Thus, the two regions can mutually promote and unceasingly drive the economic development of SPUA by the upgrade of industry. On the other hand, TBNA should not enter for the competition with Qingdao in these projects for exploiting resources and infrastructure construction, and should make use of the head start advantage in regional development to accelerate development of telecommunication, trade, tourism, education, culture, Hi-tech and urban construction.

Development strategies for Jinan and Yantai as the second group

Jinan and Yantai are at an intermediate place for industrial transfer from east China and south China to north China, from which to TBNA the nearest land distance is 80 km and the marine distance is 110 km. The good geological location provides more strategic opportunities for the two cities to accept market radiation, expand exchanges and cooperation, gather production factors, and attract foreign capital, which is also the potential of the economic society development in Shandong Province. As an important component of the Circum-Bohai economic circle and an important passageway for Shandong Peninsula jointing to TBNA, the two cities have built a comparatively close cooperation relation with the TBNA. Jinan locates at the position of connecting the West with the East in Shandong Peninsula, on the regional cooperation of Jinan and TBNA we should emphasize the development of four industries including transport and communication facilities, machinery equipment, electronic information and bio-engineering to form the R&D and distributing center of the hi-tech industries, the information

center and the national logistics hinge, which connecting the West with the East. In Yantai, the four pillar industries, namely machinery, electronic information, food processing and gold industry, have already became the engine of regional economy development. Among them, the food processing relying on agriculture is the superiority industry. Thus the two places have supplementary cooperation space in terms of the characteristics of the remarkable agricultural endowments difference and the distinctive agriculture areal features (Li and Liang, 2009).

The development strategies of the third group

As main ports, Dongying and Rizhao should structure the fast distributing transport system to develop port-vicinity logistics and port-vicinity industry. Also expanding the inland hinterland and reducing jointing channel with the TBNA should be energetically done with Northwestern Shandong as its principal body. Food, rubber products and machinery industry are the most preponderant industries in Weihai. When participating in regional economic cooperation with TBNA, Weihai should have its own clear position and look for the breakthrough points in cooperation to actively accept the all-directional radiations in information, finance, and logistics and so on.

The development strategies of the fourth group

Weifang and Zibo have the advantages of lower manpower cost, convenient traffic and so on. They have obvious differences and complementarity with TBNA in the economic structure, so there are large promotion spaces in the regional cooperation. The two cities and TBNA should widely strengthen economic cooperation to complement one another so as to promote economic jointing by the exportation of primarily processed products and raw material to TBNA and the importation of deeply-processed products, funds, technology and talents from TBNA. To be specific, Weifang and Zibo should energetically develop the textile-clothing and the petrochemical-pharmaceuticals industries, respectively. The efficient circulation and fast convergency of production factors including talents, materials, funds, information and so on should be impelled to promote industrial cluster development based on the main railway lines.

DISCUSSIONS

Regional cooperation level is comprehensively influenced by lots of factors, and to some extent, there appears to be a correlation among various factors. This brings up the difficulties to appraise the regional cooperation level objectively, comprehensively and effectively. In this study, the mapping plane with the approximate topology structure of high-dimensional space of original region cooperation level was obtained by the NLM method. In the mapping plane, the approximate clustering of regional cooperation level was obtained clearly, which really reflected the difference and change of the regional cooperation level. The analysis of regional cooperation level with the NLM compared to traditional clustering has two main advantages. One is that we can visually and intuitively inspect the approximate image of high-dimensional sample points in the plane; the other is, by preserving the distances of the original samples on the projected map, that NLM are able to represent the topology and structural relationships in the data set in a unique and faithful manner. And thus the classification results are truer and avoid the false combination caused by human factors during the process of system clustering. It indicated that NLM method was reasonable and effective in the research of regional cooperation level. Although in most cases projection does lead to some loss of information, the amount of distortion induced by NLM is minimal compared to other dimensionality reduction techniques. Besides, due to the limitations of data acquisition, however, there was only the data in 2010 and lack of the dynamic analysis of regional cooperation levels in our study. Therefore, it is a further direction to study the dynamic change of regional cooperation level based on adequate data.

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