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Intelligent Optimization on Correlation Entropy Matter-element Model of Innovation and Reform Pilot Area

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Abstract. In this paper, the correlation entropy matter element model, which is used to evaluate comprehensive competitiveness of innovation and reform pilot area, is Intelligent optimized. After analyzing the connotation of "regional strategy" of Chinese innovation evolutionary path, we build a comprehensive competitiveness evaluation system of the pilot area by combining internal relations and differences among the comprehensive innovation and reform pilot area, the national high-tech Development Zone, and the indigenous innovation demonstration zone. Through using composite correlation entropy matter-element model of grey correlation, this paper evaluates development of eight regions (those are Beijing-Tianjin-Hebei, Sichuan, Anhui, Guangzhou, Shanghai, Wuhan, Xi'an, Shenyang etc.) from four dimensions of support vector ability, innovation ability, social contribution, export earning power, and comprehensive competitiveness of the eight regions is ranked. Finally, countermeasures and suggestions are proposed for advantages and shortcomings of the eight pilot zones.

Key-words: Chinese innovation evolutionary path, regional strategy, comprehensive innovation and reform pilot area, innovation-driven.

1. Introduction

National innovation ability has become the important core of the national competitiveness, and most developed countries and some developing countries have integrated innovation-driven into national strategies. The United States continuously developed the 2009 edition, 2011 edition and 2015 version of "American Innovation Strategy". The British released Our Growth Plan:

Science and Innovation" in 2014. Japan and South Korea launched "Comprehensive Strategy of innovation in science and technology in 2014", and the "Korea industrial innovation strategy in 2015". India, as a developing country, also put forward the national strategy of "from the office of the world towards an innovative country". According to Michael Porter's national development stage theory, national economic driving forces are factor-driven, investment-driven, innovation-driven and wealth-driven [1]. At present, China is in the period of transition from factor-driven and investment-driven to innovation-driven. In order to conform to the needs of national development stage, China has risen innovation-driven as the national strategy after the 18th national congress of the CPC, and it also presents that the innovative country would have been built by 2020. However, China ranks only No. 29 of 141 economies in the "2015 Global Innovation Index (GII) report" released by the World Intellectual Property Organization in 2015, which means the gap to be an innovation oriented country is still large.

Since the reform and opening-up, China's economic development has basically followed the economic version of "region strategy" evolution path of "Special Economic Zone–Economic and Technological Development Zone–High and New Tech Industrial Development Zone-Free Trade Zone". It also follows the law of economic internal development, which is "reform-development-internationalization". After 30 years of development, China's economy has made world-noted achievements. The total amount of GDP from \$2683 billion in 1978 rapid promotes to the \$102821 billion in 2015, and world ranking from 15th in the world jumps to the second place only lower than the United States. "Region Strategy" is an effective measure that Chinese government follows the growth pole theory and centre-edge development theory, and it achieves the key breakthrough. Poland also puts forward its *Regional Innovativeness Strategies* (RIS), and the basic aim of Regional Innovativeness Strategies is to support regional or local authorities and other regional development organizations in defining and implementing an effective system of supporting innovativeness in the region [2]. In the aspect of innovation evolution path, China has also adopted the "region strategy" as the carrier of innovation policy system, as shown in figure 1, forming the evolutionary path of "National High-Tech Industrial Development Zone (abbreviated as the High-Tech Zone) – National Indigenous Innovative Demonstration Zone (abbreviated as the Demonstration Zone) – Comprehensive innovation and reform pilot area (abbreviated as the Pilot Area)". In 1988, China set up the first High-Tech Zone in Zhongguancun, and by 2015, it has set up 145 high-tech zones totally. China Torch Center statistics report shows that the proportion of GDP of the High-Tech Zone accounted for that of the country is 10.38% in 2014, and the high-tech enterprises in the High-Tech Zone accounted for 31.8% of all enterprises in high-tech zones, accounting for up to 36.3% of the national high-tech enterprises. In addition, employees in the high tech enterprises accounted for 49.8% of enterprises' employees in High-Tech Zone, accounting for up to 36.3% of those of the national high-tech enterprises.

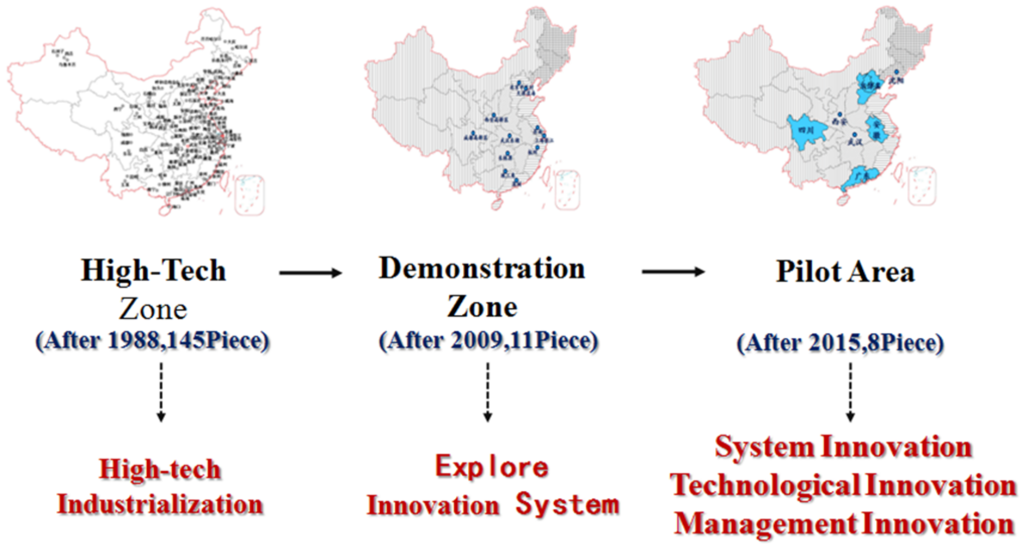

Fig. 1. China innovation evolutionary path (color online).

2. Literature Review

The comprehensive innovation and reform pilot area is a new thing, about which the domestic and foreign research is still blank. However, in essence, the comprehensive innovation and reform pilot area is a continuation of the high-tech zone and the independent innovation demonstration zone. Therefore, to study the comprehensive innovation and reform pilot area, we should trace back to the research of the high-tech zone and the independent innovation demonstration zone. Studies on the high-tech zone at home and abroad are very extensive, and most of the related results are concentrated in the space growth poles, industrial clusters and innovation systems of the high-tech zone. From the perspective of spatial growth pole, some scholars (Boudeville (1966), Chia (2009)) consider that the high-tech zone is the economy and technology engine of specific geographic space that spreads outward through various channels, eventually produces effects of varying intensity to the whole economy. The effect covers both the structural relationships between economic variables and the spatial structure of economic space [3-4]; Based on the dual economic structure theory and regional economic gradient theory, some scholars (Friedman (1964), Alessandro (2011), Montoro (2011), He (2011), Alessandro (2011), Jongwanich (2014)) propose that the high-tech zone as the growth pole will cause a cumulative cycle of causes and effects, leading to faster development of developed regions and slower development of backward regions, and finally form a non-equilibrium structure of the spatial dual economic [5-10].Wang Shengguang (2012) believed that the development of high-tech zone for 20 years had largely achieved dualistic value as economic zone and innovative area, and that two kinds of value became important support to enhance national and local innovation [11]. Wang Song (2011) held that high-tech zone laid the foundation for the cultivation of national strategic emerging industries, but the overall development trend of the high-tech zone existed Matthew effect phenomenon, which could be found in the two directions between the South area and North area and developed cities and less developed cities [12]. Tian Xinbao (2013) thought that during the period of completing the first pioneering, high-tech zone had made great achievements in regional distribution and industrial upgrading, but it still shown deficiency in the management, construction of hardware and software environment and development orientation and technology level. So, it was urgent to realize the “second pioneering” [13]. Xie Jialong (2013) proposed that under the development trend of high input and high output, some secret worries of national high-tech zone were hollow, namely inefficiency of conversion, vacuousness of core technology and imbalance of spatial development, which had become more and more obvious, being the key factors that were constraint to the subsequent development impetus to upgrade. Thus, it was urgent to explore the experience of promoting growth transformation, balancing regional development, and looking for indigenous innovation development path of high-tech zone with Chinese characteristics [14]. Zhang Jiangfu (2014) thinks that the innovation ability of the national high-tech zone is mainly embodied in the three principal component factors and the input of scientific and technical personnel and funds, technology innovation activities, innovation efficiency [15].

In 2009, China chose two high-tech zones that were Zhongguancun of Beijing and Wuhan East Lake as National Indigenous Innovation Demonstration Pilot Zones. Then until the end of 2015, China had approved a total of 11 indigenous innovation demonstration zones, and the carrier of the demonstration zones also included Shenzhen, Hangzhou and other cities, Changsha-Zhuzhou-Xiangtan and the Pearl River Delta city group, and Sunan Area of the economic zone. This demonstration zones as a forerunner, explored the experience and making a demonstration in the aspect of promoting indigenous innovation and high-tech industry development. Theorists mainly focused on the research of connotation, function and selection mechanism of the national indigenous innovation demonstration zone. Hu Shuhua (2009) held that the indigenous innovation demonstration zone was in an area that had the most intensive knowledge and technology, and the most preferential policies in the country. It was also the focusing demonstration area which maximized the conversion of scientific and technological achievements into practical productive by virtue of system innovation and technological innovation, together with optimized soft environment and material environment, It was given four important roles: being the vanguard of the 56 national high-tech zones, carrying historical mission of exploring national indigenous innovation development path under the new situation, representing the highest level of the national indigenous innovation aggregation zone, and striving to the commanding height of the world high-tech industry[16]. Wang Song (2011) believed that the national indigenous innovation demonstration area candidate would present approximately cross type spatial layout in the geographical distribution map of Chinese high-tech zones, only in this way could they support the balanced development of high-tech zones in the future. Xie Jialong (2013) thought that the indigenous innovation demonstration zone should become an important carrier of promoting technological progress and improving indigenous innovation ability, become a powerful engine of driving the regional economic structure adjustment and economic growth mode transformation, and become a service platform of helping high-tech enterprises going out to participate in international competition. It also should be a frontier to seize the commanding heights of world high-tech industry. By using comprehensive index, factors index and some specific indicators information, Zhou Hongyu (2015) constructed the innovation ability evaluation model of national indigenous innovation demonstration zone. Then he put forward the suggestion that construction process of the national indigenous innovation demonstration zone should be combined with the environment of local economic and science development. in addition, it should make full use of comparative advantages, identify the starting point and focus, strengthen the sense of urgency and responsibility, and dock the “Beijing-Tianjin-Hebei collaborative development”, “the

Yangtze River Economic Belt", "Belt and the Road" and other national development strategy layout to become an innovation-driven development pioneer [17]. Kangjuan Lv (2016) obtains the gradient distribution of East, middle and West, the highest in the East and the weakest in the West, by researching on the innovation efficiency of China's high-tech industry [18].

Establishing innovation and reform pilot area with regional as the carrier is a continuation of regional innovation theory. Scholars have studied high-tech zones, science parks and other specific areas from the aspects of innovation connotation, function, carrier and operating mechanism of innovation. However, there is no study involving in the object like the comprehensive innovation and reform pilot area with urban agglomerations, provinces, cities and other multi-carrier attributes. Besides, it is the theoretical innovation of this paper to evaluate the plural subjects at the same latitude.

3. Comprehensive competitiveness evaluation system of comprehensive innovation and reform pilot area

In order to accelerate the process of innovation-driven development, China selects eight areas of Beijing-Tianjin-Hebei, Sichuan, Anhui, Guangzhou, Shanghai, Wuhan, Xi'an, Shenyang as the comprehensive innovation and reform pilot area again in September 2015. The goal is to achieve the transformation to innovation-driven development. The core is to promote scientific and technological innovation, and the main direction is to get rid of the institutional obstacles. However, theoretical research is still blank. The pilot area is a new thing, and theoretical research has not yet defined its concept. When China issued some relevant documents, six requirements of the selection criteria of the pilot area are put forward, including that: (1) innovation resources and innovation activity are centralizing. It has strong ability in science and technology and undertakes many projects. What's more, number of R&D stuff, invention patent and the scientific papers ranks in the top; (2) economic development steps into innovation-driven transformation period, and the proportion of intellectual property intensive industry and the intensity of R&D investment is in the forefront; (3) it has set or been taken into all kinds of national innovation and reform pilot area coordinated by the nation, such as the national indigenous innovation demonstration area, national comprehensive reform pilot area and the free trade pilot zone; (4) the reform of the system and mechanism is in the forefront, and it has rich experience, strong ability of demonstration; (5) it can play an important role in stabilizing growth and adjusting the structure; (5) it attaches importance to the intellectual property protection, improves the working mechanism on combating infringement and counterfeiting and has sound institutions etc.

3.1. Comprehensive competitiveness index system of pilot area

Ahmed R(2016) believes that weaken in the size and complexity of the regional model are also effective [19]. Hu Shuhua (2009) proposed the "four-three structure" model of regional innovation system. Wang Song (2011) constructed comprehensive competitiveness evaluation model of high-tech zone, based on the theory and the core functions of the innovation system. Xie Jialong (2013) built the CIAE selection model of indigenous innovation demonstration zone from the dimensions of carrier support, indigenous innovation, agglomeration and radiation, and external expansion. From function orientation, high-tech zone focuses on providing a place for high and new technology industry, but indigenous innovation demonstration zone focuses on improving the ability of indigenous innovation and exploring the institution building of indigenous innovation. Compared with the high-tech zone and demonstration zone, function of pilot area is more comprehensive. It takes institutional innovation as a breakthrough, and strengthens the ability of technological innovation and management innovation.

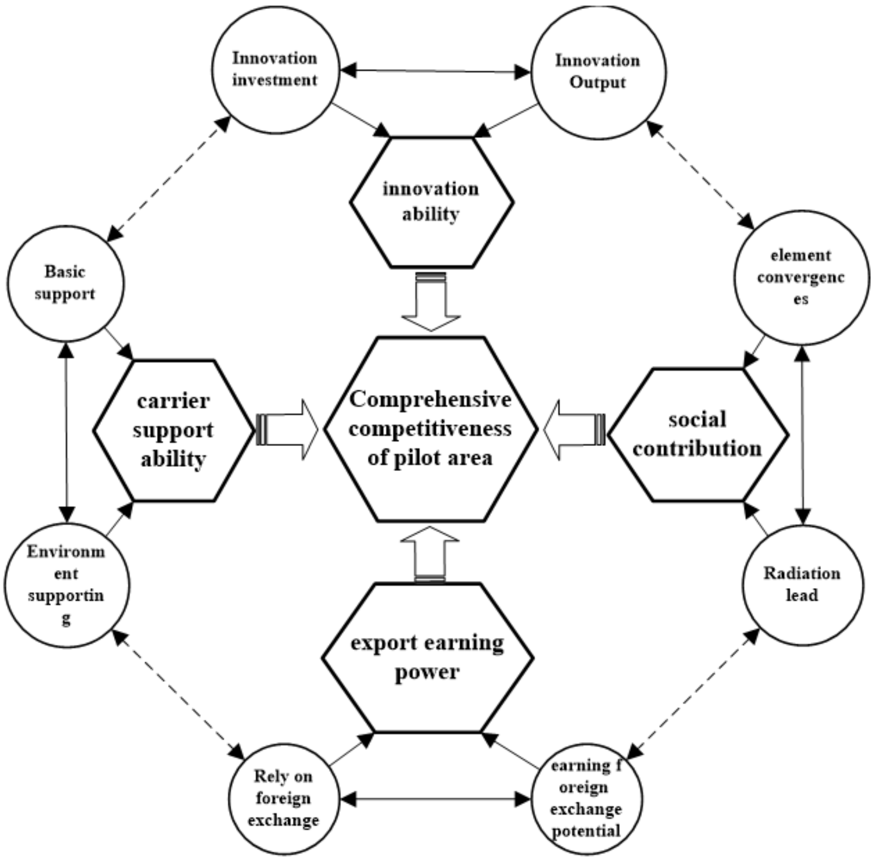

Fig. 2. The framework of comprehensive competitiveness evaluation system of pilot area.

Based on the research on high-tech Zone and demonstration area conducted by Wang Song and Xie Jialong, this study revises the index system and evaluates the competitiveness of the pilot area from dimensions of the innovation ability, the carrier support ability, the social contribution and export earning power, combining with new function of pilot area. Then it makes comparative analysis on comprehensive ability of the pilot area, and provides theoretical support for the pilot area in innovation and development to figure 2 out advantages.

Based on the theory and empirical test, it chooses competitiveness evaluation standard, which is a four-layer and four-dimensional index system. It covers 4 first-grade indexes, 8 second-grade indexes and 36 third-grade indexes. Given that the carriers of pilot area have economic zone, urban group and city, and that the difference of these carriers scale is big, it takes into account quantitative index and qualitative index, together with absolute index and relative index, choosing the evaluation index. It's continuation and bold attempt of existing research results and ensures the scientificity and feasibility of the index system.

Table 1. Comprehensive competitiveness evaluation index of pilot area

First-grade index	Second-grade index	Third-grade index	The calculation formula of index
Carrier support ability B_1	Basic support C_1	D_1 Enterprise scale	Year-end total assets / enterprises' number
		D_2 The scale of employees	(employees at the beginning year-end employees)/2
		D_3 Asset-liability ratio	Year-end liability/ year-end asset 100%
		D_4 Geographical position	coast$\rightarrow$inland, eastern$\rightarrow$western, the geographical advantage decline
		D_5 The number of Productivity Promotion Center	The number of provincial and municipal of Productivity Promotion Center is missing, so based on the national standard
	Environment supporting C_2	D_6 Policy support	Innovation and venture capital funds, guarantee funds, taxation and other incentives
		D_7 Park Innovation Culture	Cultural values the spirit of innovation, failure tolerance, knowledge sharing
		D_8 The completeness of local regulations	Sophistication and high-tech zones related to local administration, finance, science and technology in areas such as legislation
		D_9 Professional service quality	Technology incubators, financial, legal, accounting and other intermediary service organizations
		D_{10} Risk investment support	Ease of obtaining venture capital
		D_{11} the basic supporting environment	Supporting horizontal green park, road traffic, living environment.

Table 1. Comprehensive competitiveness evaluation index of pilot area

First-grade index	Second-grade index	Third-grade index	The calculation formula of index
Innovation ability B_2	Innovation investment C_3	D_{12} average stock fund of R&D	Expenditure $\times$ (1+ funds average annual growth rate) / (average annual growth rate of + funding reduction rate), the rate of reduction using 15%
		D_{13} Expenditure intensity of R&D	R & D expenditure / total revenue
		D_{14} the scale of scientific and technology personnel	Number of scientific and technological activities personnel
		D_{15} The structure of talent Investment	Scientific and technological activities PERSONS / Average number of employees
		D_{16} per capita R&D funds of scientific and technology person	R & D expenditure / number of scientific and technological activities personnel
	Innovation output C_4	D_{17} Income scale of technology	Technical income
		D_{18} The output structure of income	Technical income / Total operating income
		D_{19} per R&D technology to create income funds	Technical income / R & D expenditure
		D_{20} the proportion of New product revenue	Sales of new products / regional product sales revenue
		D_{21} The relative amount of business incubator graduation	Graduated in the number of enterprises incubator / MAX (all participating regions Incubator graduate companies number)
		D_{22} Profitability (net profit rate)	Net profit / total revenue

Table 1. Comprehensive competitiveness evaluation index of pilot area

First-grade index	Second-grade index	Third-grade index	The calculation formula of index
SOCIAL contribution B_3	Element convergences C_5	D_{23} The concentration of high-tech personnel	Number of scientific and technological activities personnel/ Provincial Science and Technology Park, where the number of active personnel
		D_{24} the concentration of capital and factor	End assets / total assets over the area size and scale
		D_{25} Spatial aggregation density	$0.5 \times$ (number of enterprises / park area) (100 / BMAX) + $0.5 \times$ (total revenue /park area) (100 / GMAX)
		D_{26} Incubation density	Incubated enterprises number / Number of incubators
	Radiation lead C_6	D_{27} Export pulling power	Region's total export volume of export / Hotel
		D_{28} Employment absorptive capacity	Persons Employed / Park, where the provinces the number of urban practitioners
		D_{29} Tax contribution	Tax paid / tax revenue of the province tax paid / tax revenue of the province
		D_{30} Environmental improvement	Yuan industrial added value to the city's comprehensive energy onsumption prevail
EXPORT earning power B_4	Rely on foreign exchange C_7	D_{31} Exports per capita	Export volume / Average number of employees
		D_{32} growth of Export earning	Year export volume / year export volume -1
		D_{33} Export dependence	Export volume / total industrial production
	Earning foreign exchange potential C_8	D_{34} parking opening	On foreign capital limits settled factories threshold level
		D_{35} The per capita amount of utilization of foreign capital	The actual use of foreign investment /annual average number of employees
		D_{36} The degree of utilization of foreign capital	The actual utilization of foreign capital / total assets at the end of year

3.2. Composite correlation entropy matter-element model for comprehensive competitiveness evaluation of pilot area

According to the information theory, quantity and quality of information is one of the key factors determining evaluation accuracy and reliability in the evaluation. Thus, entropy is an ideal scale to test the comprehensive competitiveness of the pilot area. Combined with the correlation knowledge of grey system, this paper comprehensively measures the comprehensive competitiveness on the basis of revising the matter-element analysis of multivariate data quantitative measure.

(1) Constructing composite element of comprehensive competitiveness.

If there are M pilot zones with N indices and their corresponding weight value to measure, it is called N dimensional complex matter element of M pilot zones, denoted as R_{mn} . Due to the measuring project are 8 pilot zones, and the number of implementation indicators is 36, that is M=3, N=36

$$S = \begin{bmatrix} & M_1 & M_2 & \cdots & M_m \\ C_1 & x_{11} & x_{21} & \cdots & X_{m1} \\ C_2 & x_{12} & x_{22} & \cdots & X_{m2} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ C_n & x_{1n} & x_{2n} & \cdots & X_{mn} \end{bmatrix} \tag{1}$$

In the formula, M_i is the i -th measure sample of the pilot area, C_j is the j -th measure index of the pilot area, and the corresponding value is x_{ij} .

(2) Optimization of the index calculation value.

According to table 1, it gets all third-grade index value of the eight pilot zones. But given that different pilot zones have different execution units of measurement indices, calculation of the indexes is influenced heavily by dimension, so it should eliminate the dimension and optimize the index value.

According to the value, evaluation index can be divided into three types, namely cost index, benefit index and interval index. The cost index refers to the index whose evaluation value is the smaller the better. The benefit index refers to the index whose evaluation value is the bigger the better. The interval indexs evaluation value should be in a relatively suitable. In the evaluation indexes of this report, D4 and D33 is interval index. D30 is cost index. Other indexes are benefit index. Because the dimension of all kinds of indexes is not uniform, direct participation calculation will produce great error. It is unable to complete the comparative analysis directly. Therefore, it should use the method with non- dimension. J^{+}={benefit index}, J^{-}={cost index}, J^{interval}={interval index}, then:

$$\mu_{ij} = \left(x_{ij} - \min_{1 \le i \le n} x_{ij} \right) \Big/ \left(\max_{1 \le i \le n} x_{ij} - \min_{1 \le i \le n} x_{ij} \right), (i = 1, 2, L, n; j \in J^{+}) \tag{2}$$

$$\mu_{ij} = \left(\max_{1 \le i \le n} x_{ij} - x_{ij} \right) \Big/ \left(\max_{1 \le i \le n} x_{ij} - \min_{1 \le i \le n} x_{ij} \right), (i = 1, 2, L, n; j \in J^{-}) \tag{3}$$

$$u = \begin{cases} 1 - \left[max\left\{ c_i^j - x_{ij}, x_{ij} - c_2^j \right\} \Big/ max\left\{ c_i^j - \max_{1 \le i \le n} x_{ij}, \min_{1 \le i \le n} x_{ij} - c_2^j \right\} \right], v_{ij} \notin \left[c_1^j, c_2^j\right] \\ 1, v_{ij} \in \left[c_1^j, c_2^j\right] \end{cases} \tag{4}$$

(i=1, 2, L , n; $j \in j^{interval}$)

After standardized, R_{mn} is:

$$\underset{\sim mn}{R} = \begin{bmatrix} & M_1 & M_2 & L & M_m \\ C_1 & \mu_{11} & \mu_{21} & L & \mu_{m1} \\ C_2 & \mu_{12} & \mu_{22} & L & \mu_{m2} \\ M & M & M & O & M \\ C_n & \mu_{1n} & \mu_{2n} & L & \mu_{mn} \end{bmatrix} \tag{5}$$

To optimize the index based on the above formula, it is equivalent to optimize the original third-grade indexes calculated values into evaluation data without dimension, which eliminates cross influence among indexes with different uncertainty of pilot area competitiveness and ensures consistency of evaluation data.

(3) Determining the weight coefficient of evaluation index

Because statistical criteria of the pilot zones is relatively inadequate at present and the evaluation index contains lots of qualitative indicators, weight information of the measure index cannot be given explicitly, combined with the fuzzy nature of human thinking. In order to improve objectivity of evaluation process, it uses correlation entropy method to determine weight coefficient of each measure index.

Firstly, calculate the grey correlation coefficient of $\underset{\sim mn}{R}$, establish reference sequence $Y_0 = \{y_1, y_2, L, y_n\}^T$, $(y_j = \max\limits_{1 \le i \le n} \mu_{ij}, j = 1, 2, L, n)$, construct the sequence $@GRF = [y_0\ \underset{\sim mn}{R}]$ and the reference sequence $\Delta_i = |Y_0 - Y_i|$, obtain difference sequence, then the grey correlation coefficient of item j measure index Cj of $\underset{\sim mn}{R}$ is:

$$\zeta_{ij} = \frac{\min\limits_i \min\limits_j \Delta_i + \rho \max\limits_i \max\limits_j \Delta_i}{|\mu_{ij} - y_i| + \rho \max\limits_i \max\limits_j \Delta_i} \tag{6}$$

Where, ρ is resolution coefficient, to weaken the distortion of the measurement index correlation coefficient which is caused by the biggest absolute difference? Under normal conditions, ρ =0.5.

Then, calculate entropy of measure index. Entropy is a function of measurement uncertainty in information theory. The bigger the entropy is, the more information the index obtains. So the entropy of item j of index Cj is:

Text above
Text below

$$F_j = -(\ln m)^{-1} \sum_{i=1}^{m} \frac{\zeta_{ij}}{\sum_{i=1}^{m} \zeta_{ij}} ln \frac{\zeta_{ij}}{\sum_{i=1}^{m} \zeta_{ij}}, (i = 1, 2, \mathrm{L}, m; j = 1, 2, \mathrm{L}, n) \tag{7}$$

Finally, determine the weight of the measure index coefficient. According to deviation degree $k_j = 1 - F_J$, the weight of item j of index Cj is $\omega = k_j \Big/ \sum_{j=1}^{n} k_j$. Construct the weight of the pilot zones competitiveness evaluation index:

$$R_{\omega j} = \begin{bmatrix} & C_1 & C_2 & L & C_n \\ \omega_j & \omega_1 & \omega_2 & L & \omega_n \end{bmatrix} \tag{8}$$

(4) Evaluate the results of comprehensive competitiveness

$\underset{\sim mn}{R}$ and $\underset{\omega j}{R}$ constitute compound correlation entropy matter element $\underset{\sim mH}{R}$:

$$\underset{\sim mH}{R} = \begin{bmatrix} & M_1 & M_2 & L & M_m \\ H_i & H_1 & H_2 & L & H_m \end{bmatrix}$$
$$= \begin{bmatrix} & M_1 & L & M_i & L & M_m \\ H_i & -\sum_{j=1}^{n} P(\omega_j \mu_{1j}) ln P(\omega_j \mu_{1j}) & L & -\sum_{j=1}^{n} P(\omega_j \mu_{ij}) ln P(\omega_j \mu_{ij}) & L & -\sum_{j=1}^{n} P(\omega_j \mu_{mj}) ln P(\omega_j \mu_{mj}) \end{bmatrix} \tag{9}$$

Where, $P(\omega_j \mu_{mj}) = \omega_j \mu_{ij} \Big/ \sum_{j=1}^{n} \omega_j \mu_{ij}, i = 1, 2, L, m; j = 1, 2, L, n, H_i$, is the measure value of item i pilot zone.

The bigger the value is, the better the comprehensive competitiveness evaluation effect. Then, this paper ranks the 8 pilot zones according to the evaluation value.

4. Empirical analysis

4.1. Determination of the weight coefficients

According to the comprehensive competitiveness index system of the pilot zones established in table 1, and the (1) – (9) operation steps, the paper uses software programming Matlab7.0 to calculate the innovation capacity, carrier supporting capacity, social contribution capacity, export capacity and the comprehensive competitiveness ranking of these eight pilot zones based on their 2014 statistical data. It depends on publication data from “China Torch Statistical Yearbook 2015”, “China Statistical Yearbook of science and technology 2015”, “China Statistical Yearbook 2015” and regional data of official website, in which D6, D7, D8, D9, D10, D11 and other qualitative indicators originate from “China City Competitiveness Report 2015”.

As table 2 shows, the carrier supporting capacity is the most influential factor in comprehensive competitiveness evaluation of the pilot zones, and it fully reflects selection standard of the pilot zones of China. Weight of the carrier supporting capacity is up to 0.3099, which puts more emphasis on weight of environment support. Innovative capacity ranks the second with weight of 0.5314, and innovation output accounts for 0.5314 in the dimension of innovation capacity. This stresses importance on the level of industrialization of science and technology of the pilot zones. Social contribution capacity is embodied in convergence of regional elemental resources and ability of radiation to the regional economy. The coefficient of social contribution is 0.2224. Export capacity measures the level of global competitiveness of the pilot zones whose coefficient is 0.1686.

Table 2. Pilot zones comprehensive competitiveness evaluation index weight of each level

<table>
<tr><td>Competitiveness</td><td colspan="11">Carrier Support Ability
B_1</td></tr>
<tr><td>Weight</td><td colspan="11">First: 0.3099</td></tr>
<tr><td>Sub-criterion layer</td><td colspan="5">Basic support
C_1</td><td colspan="6">Environment supporting
C_2</td></tr>
<tr><td>Weight</td><td colspan="5">0.4510</td><td colspan="6">0.5490</td></tr>
<tr><td>Scheme layer</td><td>D_1</td><td>D_2</td><td>D_3</td><td>D_4</td><td>D_5</td><td>D_6</td><td>D_7</td><td>D_8</td><td>D_9</td><td>D_{10}</td><td>D_{11}</td></tr>
<tr><td>Weight</td><td>0.2014</td><td>0.1926</td><td>0.2029</td><td>0.1995</td><td>0.2036</td><td>0.1647</td><td>0.1671</td><td>0.1673</td><td>0.1671</td><td>0.1647</td><td>0.1691</td></tr>
<tr><td>Competitiveness</td><td colspan="11">Innovation Ability
B_2</td></tr>
<tr><td>Weight</td><td colspan="11">Second:0.2991</td></tr>
<tr><td>Sub-criterion layer</td><td colspan="5">Innovation investment
C_3</td><td colspan="6">Innovation Output
C_4</td></tr>
<tr><td>Weight</td><td colspan="5">0.4686</td><td colspan="6">0.5314</td></tr>
<tr><td>Scheme layer</td><td>D_{12}</td><td>D_{13}</td><td>D_{14}</td><td>D_{15}</td><td>D_{16}</td><td>D_{17}</td><td>D_{18}</td><td>D_{19}</td><td>D_{20}</td><td>D_{21}</td><td>D_{22}</td></tr>
<tr><td>Weight</td><td>0.1971</td><td>0.2020</td><td>0.1978</td><td>0.2019</td><td>0.2013</td><td>0.1726</td><td>0.1752</td><td>0.1748</td><td>0.1744</td><td>0.1291</td><td>0.1738</td></tr>
<tr><td>Competitiveness</td><td colspan="11">Social contribution
$\mathbf{B_1}$</td></tr>
<tr><td>Weight</td><td colspan="11">Third: 0.2224</td></tr>
<tr><td>Sub-criterion layer</td><td colspan="6">element convergences
C_5</td><td colspan="5">Radiation lead
C_6</td></tr>
<tr><td>Weight</td><td colspan="6">0.4943</td><td colspan="5">0.5057</td></tr>
<tr><td>Scheme layer</td><td>D_{12}</td><td>D_{13}</td><td colspan="3">D_{14}</td><td>D_{15}</td><td>D_{12}</td><td colspan="2">D_{13}</td><td>D_{29}</td><td>D_{30}</td></tr>
<tr><td>Weight</td><td>0.2474</td><td>0.2491</td><td colspan="3">0.2489</td><td>0.2546</td><td>0.2513</td><td colspan="2">0.2488</td><td>0.2537</td><td>0.2461</td></tr>
<tr><td>Competitiveness</td><td colspan="11">Export earning power
B_4</td></tr>
<tr><td>Weight</td><td colspan="11">Fourth: 0.1686</td></tr>
<tr><td>Sub-criterion layer</td><td colspan="6">Rely on foreign exchange
C_7</td><td colspan="5">earning foreign exchange potential
C_8</td></tr>
<tr><td>Weight</td><td colspan="6">0.5076</td><td colspan="5">0.4924</td></tr>
<tr><td>Scheme layer</td><td colspan="2">D_{31}</td><td colspan="2">D_{32}</td><td colspan="2">D_{33}</td><td colspan="2">D_{34}</td><td colspan="2">D_{35}</td><td>D_{36}</td></tr>
</table>

4.2. Analysis of the 8 pilot zones' advantages and disadvantages

1) Comparison of the carrier support capacity

As shown in figure 3, China positions Shanghai as a global influence innovation centre. As a result, Shanghai ranks first with 0.661. The carrier supporting capacity of Shanghai supports a significant advantage. From the second level indicators, environmental support capacity is an important factor in Shanghai. Shanghai owns open environment, inclusive innovation atmosphere and perfect financial service system. All these help Shanghai establish innovation environment. But it should be noted that the Shanghai is weak in foundation support because of small scale of high-tech enterprises. Beijing-Tianjin-Hebei region ranks the second with 0.635. This region has obvious advantages over other zones, but it is weak in environmental support capacity. How to play a more effective mechanism for collaborative development of Beijing Tianjin Hebei region remains a critical challenge. Followed with Shanghai and Beijing Tianjin Hebei region are Sichuan, Anhui, Guangdong, Wuhan, Shenyang and Xi'an. These regions are relatively balanced in foundation support capacity and environmental support capacity. They should take their respective advantages to promote the regional carrier support capacity.

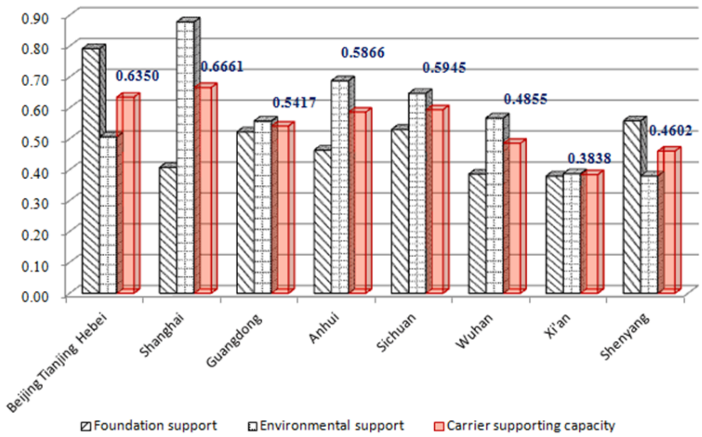

Fig. 3. Comparison of the carrier support capacity of 8 Pilot Zones (color online).

(2) Comparison of the innovation capacity

As shown in figure 4, Beijing-Tianjin-Hebei region has an absolute advantage in terms of innovation capability. Compared with other regions, its innovation output is much higher than innovation input. Beijing is the most intensive area of Chinas science and education resources, and the stock of science and technology is rich in resources. Tianjin puts focus on the development of high-tech industries in recent years relying on the coastal national independent innovation demonstration zone. As is shown in Tianjin government work report 2015, science and technology in small and medium-sized enterprises in Tianjin reached 72000, and fostered small giant 3400 enterprises. Its gross output value accounted for more than 48% of the proportion of the industry. R&D expenditures accounted for the proportion of GDP increased to 3%. These promote the regional innovation capacity vigorously. Followed with Tianjin are Guangdong, Shanghai, Xi'an, Wuhan, Anhui, Sichuan and Shenyang. These regions are facing the same problem, which is lack of scientific research institutions. This leads to gap between basic research and market demands, resulting in a high input and low output dilemma.

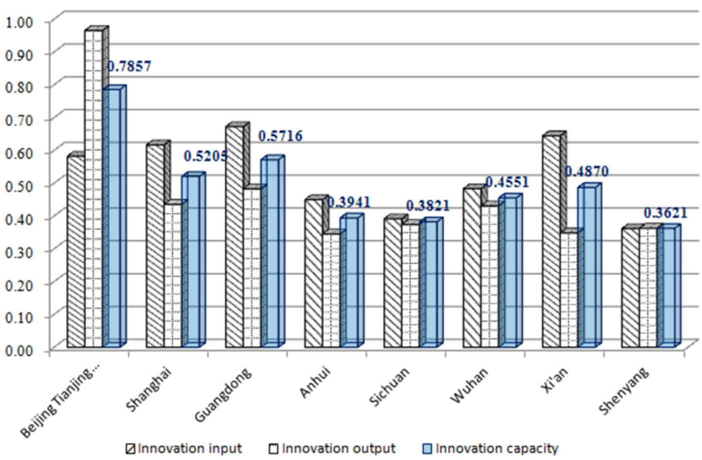

Fig. 4. Comparison of the innovation capacity of 8 Pilot Zones (color online).

(3) Comparison of the social contribution capacity

As shown in figure 5, Wuhan ranks the first in social contribution capacity. In recent years, Wuhan's industrial transformation has accelerated, changing from traditional steel, heavy equipment based industrial structure to the "car-light-material-service". Wuhans advantages of science and education resources cluster to high-tech enterprises. Human concentration, capital concentration and spatial agglomeration of Wuhan high-tech enterprises are in a leading position. This plays a significant role in stimulating Wuhan's export, employment, tax and environmental improvement. Wuhan Optics Valley has built China's largest optical fiber and cable, optical and electronic devices, laser industry research and production base. It has the largest optical fiber and cable production in the world, accounting for 25% of the world's market and 60% of the nation's market. Shanghai is second only to Wuhan because of its lack in factor agglomeration. Followed with Wuhan and Shanghai are Anhui, Sichuan, Beijing Tianjin Hebei region, Shenyang and Guangdong.

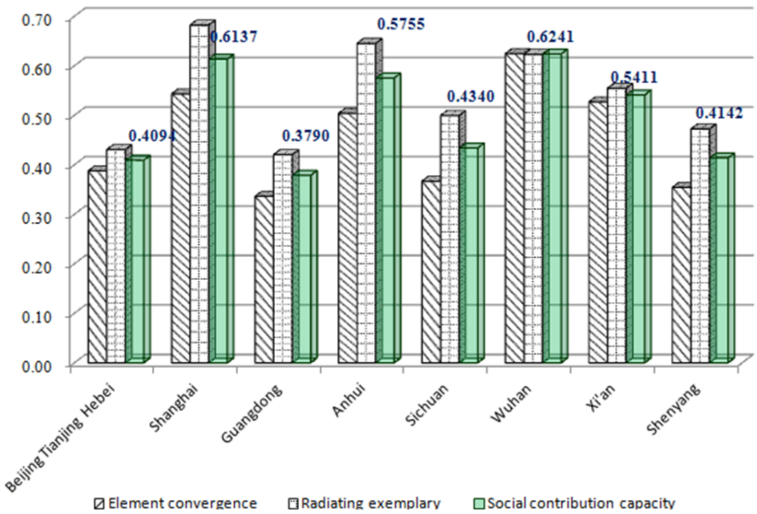

Fig. 5. Comparison of the social contribution capacity of 8 Pilot Zones (color online).

(4) Comparison of the export capacity

Guangdong ranks the first with 0.7104 in export capacity. Relying on Hong Kong and Macao, Guangdong is the representative of China's export-oriented economy, whose economy is foreign trade oriented. But with weakness of global economy, foreign trade oriented economy in Guangdong is facing the challenge. Upgrading of foreign trade oriented economic structure is the focus of exploration in Guangdong experimental area. From the current point of view, Shenzhen, Dongguan and other cities in the front end, continue to promote transformation and upgrading of processing trade. At present, cross-border business, being a new force, suddenly rises. In 2015, Guangdong's cross-border e-commerce import and export reached 16.73 billion yuan at an increase of 3.6 times. The scale ranked the first in the country. Shanghai has the most advantage in terms of potential foreign exchange. Transforming potentiality into benefits in the future is the most important work. Followed Guangdong and Shanghai are Shenyang, Wuhan, Beijing-Tianjin-Hebei region, Anhui, Sichuan and Xi'an.

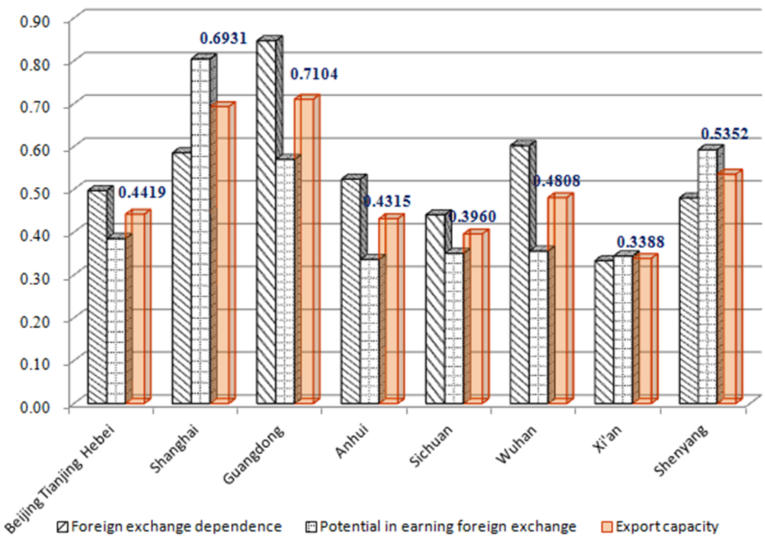

Fig. 6. Comparison of the export capacity of 8 Pilot Zones (color online).

4.3. Comprehensive competitiveness analysis

As is shown in table 3, Shanghai which is China's most open area, ranks the first in the eight pilot zones from the point of comprehensive competitiveness. In carrier support capacity, social contribution capacity, export capacity and other dimensions, the ranking of Shanghai is also in the front. There is only a slight lack of innovation capacity. To make science & technology enterprises stronger and bigger has become the focus of exploration in Shanghai. Beijing-Tianjin-Hebei region ranks the second. Social contribution capacity and export capacity are the short boards. Collaborative development between Beijing, Tianjin and Hebei has risen to national strategy. Clarifying functional orientation of the three regions, and realizing non-main function of Beijing area are focus work of the pilot zones. To seize the second batch of national service trade innovation opportunities, Tianjin should integrate domestic and foreign resources to enhance export of Beijing-Tianjin-Hebei region. Guangdong ranks the third. Carrier support capacity and social contribution capacity are the short boards to Guangdong. Transformation and upgrading industrial structure is the only way to enhance the competitiveness of Guangdong. With help of the national policy, Guangdong should achieve gradient development, transfer traditional industry to the mainland, develop advanced manufacturing industry vigorously, and keep pace with development trend of world science and technology. Wuhan ranks the fourth and has a balanced capacity in every aspect. In recent years, Wuhan has made great achievements in transformation and upgrading of industrial structure. But as an inland city, Wuhan is still lagging behind the coastal cities in terms of innovation and environmental construction. To seize opportunity of national policy to enhance soft power of innovation in Wuhan is of great importance. Anhui ranks the fifth. Innovation capacity and export capacity are weak. Anhui has been incorporated into the development strategy of the Yangtze River Delta city group in the Yangtze River economic belt development strategy. Docking industrial division of the Yangtze River delta system should play a great role in development of the Yangtze River economic belt. Sichuan ranks the sixth. The largest advantage is the carrier support capacity. The world's top

500 companies have nearly 300 options in Sichuan layout. Development potential of Sichuan has been recognized by the world. Subjected to regional restrictions, Sichuan perform poorly in innovation, social contribution, export capacity and other dimensions. Sichuan should fully grasp the strategic opportunity of the Yangtze River economic belt, and absorb scientific and technological resources with its regional cultural advantages. Xi'an ranks the seventh. Carrier support capacity and export capacity become its short boards. But with promotion of the Belt and Road strategy, Xi'an ushers in new opportunities. Shenyang ranks the eighth. As the only selected city in the northeast, Shenyang has shouldered heavier responsibilities. In recent years, as a traditional old industrial base, its economy is declining, transition pressure is huge. Thus, emerging industries inoculation needs breakthrough urgently.

Table 3. Comprehensive competitiveness rank of 8 Pilot Zones

Pilot zones	Comprehensive competitiveness	RK	Carrier support ability	RK	Innovation ability	RK	Social contribution	RK	Export earning power	RK
Beijing Tianjin Hebei	0.5974	2	0.6350	2	0.7857	1	0.4094	7	0.4419	5
Shanghai	0.6155	1	0.6661	1	0.5205	3	0.6137	2	0.6931	2
Guangdong	0.5429	3	0.5417	5	0.5716	2	0.3790	8	0.7104	1
Anhui	0.5004	5	0.5866	4	0.3941	6	0.5755	3	0.4315	6
Sichuan	0.4618	6	0.5945	3	0.3821	7	0.4340	5	0.3960	7
Wuhan	0.5064	4	0.4855	6	0.4551	5	0.6241	1	0.4808	4
Xi an	0.4421	7	0.3838	8	0.4870	4	0.5411	4	0.3388	8
Shenyang	0.4333	8	0.4602	7	0.3621	8	0.4142	6	0.5352	3

5. Conclusion

Comprehensive innovation and reform pilot zones are important explorations for China to adapt to development of innovation driven stage. Eight pilot zones are located in the East, Middle, West and Northeast four major economic plates. The characteristic difference between regions has great difference. This paper constructs evaluation model of comprehensive competitiveness of the pilot zones from four dimensions, namely carrier support capacity, innovation capacity, social contribution capacity and export capacity. According to the national and regional strategic positioning requirements, the paper explores the key and difficulty of the eight pilot zones, and put forward countermeasures and suggestions. It is a theoretical exploration under the situation that a clear perception over comprehensive innovation and reform pilot zones has not yet formed. The main conclusions are as follows.

(1) With the change of national development stage from elements of investment-driven to innovation driven, the evolution path of Chinese regional innovation follows the evolution trend from high-tech industrialization to technological autonomy, relaxation of innovation system, technological innovation, management innovation and integration of system innovation.

(2) From the four dimensions of carrier support capacity, innovation ability, social contribution and export earning power, this paper selects structural indicators to scientifically and effectively measure the comprehensive competitiveness of multi subject.

(3) The comprehensive competitiveness of eight comprehensive innovation reform pilot zones presents significant geographical differences. Overall, it presents echelon transition pattern from east to midland to west. But the fluctuation direction and range of carrier support capacity, inno-

vation ability, social contribution and export earning power and other four dimensions is almost unanimous. There appears the phenomenon of synchronous disequilibrium between the comprehensive competitiveness of the experimental area.

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