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Evaluation on Integrated Innovation Capability of Regions Based on Principal Component Analysis

EVALUATION DE LA CAPACITE D'INNOVATION INTEGREE BASEE SUR L'ANALYSE DES COMPOSANTS PRINCIPAUX

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Abstract: The main carriers of national innovation capacity are the regions which gather the technology, economy, and culture, and the strength of regional innovation capacity indicates the strength of the national innovation capability, so the key to the improvement of the national innovation capacity is to enhance the innovation capacity of every region. Using statistics and statistical software SPSS V17.0 Statistics for principal component analysis, and to analyze and sort the innovation capability for our country's 15 provinces and municipalities, evaluate the results and put forward policy recommendations related, to provide better ideas for economic development of every region.
Key words: comprehensive evaluation; innovation capability of regions; integrated innovation capability; principal component analysis

Résumé: Le porteur principal de la capacité d'innovation nationale sont les régions qui rassemblent la technologie, l'économie et la culture, et la puissance de la capacité d'innovation nationale indique la puissance de la capacité d'innovation nationale, par conséquent la clé de l'amélioration de la capacité d'innovation nationale est de renforcer la capacité d'innovation de chaque région. On utilise les statistiques et le logiciel statistique SPSS V17.0 pour effectuer une analyse des composants principaux, afin d'analyser et classer la capacité d'innovation des 15 provinces et des municipalités de notre pays, évaluer les résultats et proposer des conseils appropriés, et fournir de meilleures idées pour le dévelopement économique de chaque région.
Mots-clés : évaluation complete; capacité d'évaluation de region; capacité d'innovation intégrée; analyse de composants principaux

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1. INTRODUCTION

After nearly 30 years of reform and opening up, China's overall development has made great achievements, integrated national strength and people's living standards improved significantly. But as human society entered into the 21st century, this improvement will change with increased competition situation at any time, so we should have a dominant position in the national competition to remain invincible in the competition. And now the competition between countries mainly focuses on innovation capability, which has become the foundation and source of a higherproductivity, and enhancing national competitiveness and improving living standards, innovation capability has become a key to maintain long-term strength of economic growth and enhance sustained integrated national strength. The main carriers of national innovation capacity are the regions which gather the technology, economy, and culture, and the strength of regional innovation capacity indicates the strength of the national innovation capability, So the key to the improvement of the national innovation capacity is to enhance the innovation capacity of every region (ZHOU & YU, 2008). To improve the regional innovative capability, at first we should analyze and compare the regional innovation capability, and identify the gap between them and implement the corresponding policies and measures to enhance their innovation capabilities. From the national perspective, the qualitative analysis and evaluation of regional innovation capability can not summarize the status of the regional innovation, and it is more difficult to find regional innovation capability discrimination (WEI et al., 2009). However, through the quantitative analysis we can understand the regional innovation dynamics and innovation changes to promote every region to understand and grasp the situation of their regional innovation and the status in the country, also to promote regional innovation activities carried out.

2. SETTING UP THE INNOVATION CAPABILITY INDEX SYSTEM

The scientific and reasonable index system is the key to success of the evaluation of the regional innovation (SHI & MA, 2007). In this paper, from four aspects of knowledge level, science and technology development level, economic strength and institutional environment to evaluate the regional innovation capability and evaluation index selected based on scientific, systematic, representative and operational principles (LI, 2006), we select 28 terms of 2 level indicator to the real evidence and analysis of regional innovation capacity.

Specific evaluation index system in Table 1.

Table 1: Innovation ability evaluation index system

Goal layer	rule layer	index layer	Vari-able	Unit
The evaluation of regional innovation capability	Knowledge	college enrollment in the proportion of the total population	X1	person per 10000person
		the number of person in regional S&T activities	X2	person
		the proportion of the number of university R&D staff in the total population	X3	person per 10000person
		the number of academic papers published	X4	piece
		the number of scientists and engineers in ten of thousands of people	X5	person per 10000person
		the proportion of college educated population	X6	percent

To be continued

Continued

Goal layer	rule layer	index layer	Vari-able	Unit
The evaluation of regional innovation capability	Science and technology development	regional R&D Expenditures	X7	100 million yuan
		the number of three kinds of patent applications received	X8	unit
		the number of three kinds of patent applications accepted	X9	unit
		total output value of industrial enterprises above designated size	X10	100 million yuan
		large and medium industrial enterprises in R&D funding	X11	100 million yuan
		the number of enterprises with S&T institutions in large and medium enterprises	X12	unit
		industrial total industrial output value of large and medium enterprises	X13	100 million yuan
		large and medium enterprises financing of new product development	X14	100 million yuan
		medium and large enterprises output value of new products	X15	100 million yuan
		sales of new products of medium and large enterprises	X16	100 million yuan
	Economic strength	per capita GDP	X17	yuan
		the number of high-tech industries	X18	unit
		the number of large and medium enterprises	X19	unit
		ten of thousands of people with industrial enterprises	X20	unit
		the sales of high-tech products	X21	100 million yuan
		the total output value of high-tech industries	X22	100 million yuan
		per capita disposable income of residents	X23	yuan per year
		the proportion of the tertiary industry in the total GDP	X24	percent
		volume of business in technology market	X25	100 million yuan
	Institutional environment	per capita expenditure on national financial education	X26	yuan
		funding for regional science and technology activities	X27	100 million yuan
		the proportion of the research funding raising on the total GDP	X28	percent

3. PRINCIPAL COMPONENT ANALYSIS AND EVALUATION MODEL

Principal component analysis is a statistical method of dimension reduction, its basic idea is to change the original random vector with its components related into the new random vector with its components not related by means of an orthogonal transformation, which manifests that changing the covariance matrix of original random vector into diagonal matrix in algebra,and in the geometry it manifests that changing the original coordinate system into new orthogonal coordinate system, making it point to sample point p orthogonal directions which spread most, then reduce the dimension of the multi-dimensional variable system, to change it into low-dimensional variable systemsgvb with a high precision (LUO & XING, 1987). This dimension reduction transform make the question simple, intuitive, and these few new variables unrelated with each other, also they can provide most information of the original index. The calculation steps of principal component analysis are as follows:

Firstly,standardization of collection of the original index data with p-dimensional random vector $x=(x_1,x_2,...,x_p)^T$, n samples $x_i=(x_{i1},x_{i2},...,x_{ip})^T$, $i=1,2,\ldots,n$, $n>p$, constructing the sample matrix, and change the array of the sample matrix as the following standard transformation: $Z_{ij}=\frac{x_{ij}-\bar{x}_j}{s_j}, i=1,2,...,n; j=1,2,...,p$, among them, $\bar{x}_j=\frac{\sum_{i=1}^n x_{ij}}{n}, s_j^2=\frac{\sum_{i=1}^n(x_{ij}-\bar{x}_j)^2}{n-1}$, may be standardized matrix Z.

Secondly, seek the correlation coefficient matrix with standardized matrix Z: $R=[r_{ij}]_p xp=\frac{Z^TZ}{n-1}$, which $r_{ij}=\frac{\sum z_{kj}\cdot z_{kj}}{n-1}, i,j=1,2,...,p$.

Thirdly, calculate the eigenvalues and eigenvectors of R:

According to the characteristic equation $|R-\lambda I|=0$, we can calculate the eigenvalues λ_i, and descending order those eigenvalues calculated: $\lambda_1\geq\lambda_2\geq\lambda_3\geq\ldots\geq\lambda_p$, at the same time, we can find out the corresponding eigenvectors u_1, u_2, …, u_n, from which we can find out the main component: **Y=UX**,

That

$$\mathbf{U}=(\mathbf{u_1},\cdots,\mathbf{u_p})=\begin{bmatrix} u_{11} & u_{12} & \cdots & u_{1p} \\ u_{21} & u_{22} & \cdots & u_{2p} \\ \vdots & \vdots & & \vdots \\ u_{n1} & u_{n2} & \cdots & u_{n} \end{bmatrix}$$

Fourthly, to determine the number of principal components: The purpose of using PCA is to reduce the number of variables, it is generally not with the P principal components, and with m <P principal components, usually taking m that the principal components with eigenvalues more than one;

Fifthly, to determine the linear integrated evaluation function:

$F=\alpha1Y1+\alpha2Y2+\ldots+\alpha mYm$, where $\alpha i=\lambda i/\sum\lambda i$, i=1, 2, …, m.

4. REAL EVIDENCE ANALYSIS OF REGIONAL INNOVATION CAPABILITY ASSESSMENT

4.1 The evaluation process

In this paper, targeting China's 15 provinces and cities, based on the original statistical data of the year of 2008, we evaluate the integrated innovation capability of 15 provinces and cities. Data mainly from: China Statistical Yearbook 2009[3], China Statistical Yearbook on Science and Technology 2009 and China Population and Employment Statistics Yearbook 2009. Specific evaluation process is as follows:

Firstly, using statistical software SPSS Statistics V17.0 (LU, 2000) to analyze, inputing the original data（omitted）,and standardize them:

Secondly, carrying through PCA with the standardized data, then we can get the correlation coefficient matrix（omitted）, explanatory total variance（Table 2）, scree plot（Figure 1）, component matrix and the rotation component matrix （Table 3）, component score coefficient matrix（Table 4）.

Thirdly, according to the score matrix and the evaluation function to calculate the integrated innovation capability score of the provinces and the score of the principal components, then order them（Table 5）.

[3] National Bureau of Statistics of China. *China Statistical Yearbook 2009 [M]*. Beijing: China Statistics Press, 2009 Edition in September.

Table 2: Explanatory total variance

Component	Original eigenvalues			Extract to sum the square			Rotate to sum the square		
	Total	Variance Percent	Accumulation Percent	Total	Variance Percent	Accumulation Percent	Total	Variance Percent	Accumulation Percent
1	15.852	56.613	56.613	15.852	56.613	56.613	14.567	52.024	52.024
2	9.045	32.302	88.916	9.045	32.302	88.916	10.192	36.400	88.424
3	1.117	3.990	92.906	1.117	3.990	92.906	1.255	4.481	92.906
4	.729	2.602	95.508						
5	.624	2.228	97.736						
6	.269	.962	98.698						
7	.110	.391	99.089						
Notice: Just to write out the components which are greater than 0.1.									

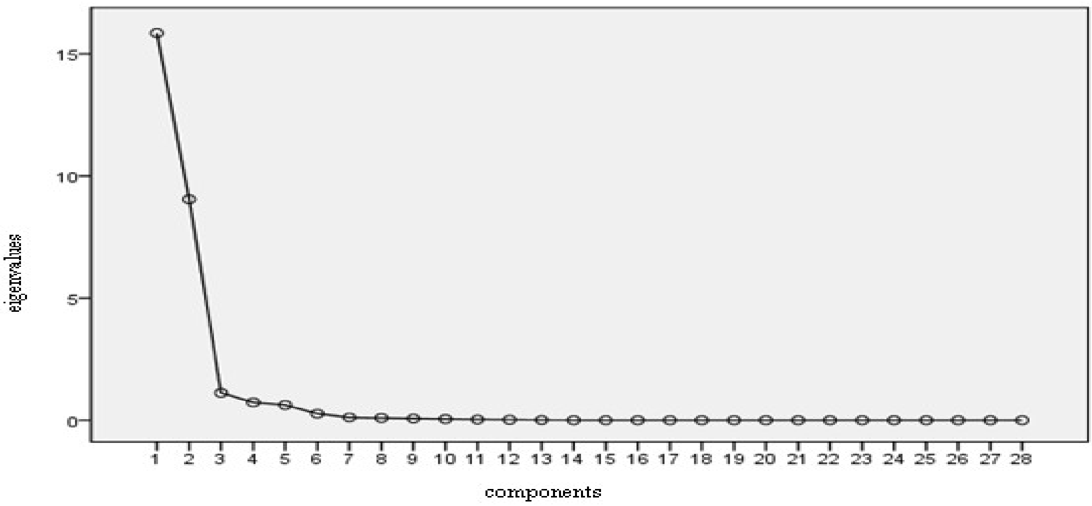

Figure 1 Scree plot

Table 3: Component matrix and the rotation component matrix

	Component matrix			The rotation component matrix				Component matrix			The rotation component matrix		
	Component			Component				Component			Component		
	1	2	3	1	2	3		1	2	3	1	2	3
X1	.323	.776	.246	-.012	.844	.235	X15	.954	-.245	.095	.970	.146	.131
X2	.949	-.078	-.188	.912	.294	-.157	X16	.955	-.228	.105	.964	.161	.140
X3	.318	.938	.041	-.072	.988	.025	X17	.670	.600	.393	.370	.818	.397
X4	.536	.767	-.192	.205	.912	-.197	X18	.898	-.343	-.138	.966	.030	-.102
X5	.468	.867	-.068	.099	.980	-.077	X19	.816	-.542	-.031	.963	-.183	.008
X6	.384	.896	.150	.002	.977	.137	X20	.706	-.342	.575	.761	-.034	.605
X7	.958	.147	-.150	.832	.505	-.125	X21	.906	.004	-.166	.840	.353	-.139
X8	.945	-.252	-.019	.969	.133	.017	X22	.851	-.269	-.231	.897	.079	-.198
X9	.907	-.295	.003	.950	.080	.038	X23	.728	.505	.331	.463	.752	.339

To be continued

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Component matrix				The rotation component matrix			Component matrix				The rotation component matrix		
X10	.831	-.505	-.003	.961	-.143	.035	X24	.385	.826	-.224	.044	.907	-.234
X11	.877	-.417	-.032	.971	-.044	.006	X25	.425	.840	-.285	.077	.936	-.294
X12	.752	-.471	.154	.869	-.141	.190	X26	.473	.829	.159	.109	.950	.151
X13	.858	-.472	-.047	.975	-.103	-.008	X27	.940	.168	-.150	.807	.517	-.126
X14	.885	-.446	-.015	.988	-.068	.024	X28	.396	.858	-.108	.037	.943	-.119

Table 4: Component score coefficient matrix

	Component				Component				Component		
	1	2	3		1	2	3		1	2	3
X1	-.039	.088	.217	X11	.072	-.019	-.021	X21	.067	.023	-.143
X2	.075	.016	-.161	X12	.050	-.027	.144	X22	.082	-.006	-.199
X3	-.028	.103	.034	X13	.075	-.026	-.034	X23	-.011	.071	.296
X4	.014	.090	-.172	X14	.072	-.022	-.006	X24	.005	.092	-.201
X5	-.006	.099	-.062	X15	.057	.001	.092	X25	.012	.094	-.255
X6	-.032	.101	.131	X16	.055	.002	.100	X26	-.025	.097	.140
X7	.062	.039	-.129	X17	-.024	.080	.351	X27	.060	.041	-.129
X8	.067	-.001	-.010	X18	.079	-.012	-.116	X28	-.006	.096	-.098
X9	.065	-.006	.009	X19	.074	-.034	-.020				
X10	.071	-.029	.004	X20	.004	-.013	.517				

Table 5: The ranking of comprehensive score of the provinces

ordinal number	province	comprehensive score	order	the first component	order	the second component	order	the third component	order
1	Beijing	0.81	**3**	-0.26	6	2.98	1	-1.53	15
2	Tianjin	-0.12	7	-0.65	11	0.60	3	1.64	1
3	Liaoning	-0.26	8	-0.36	8	-0.16	6	0.35	5
4	Shanghai	0.57	**4**	0.03	5	1.40	2	1.49	3
5	Jiangsu	1.12	**2**	1.92	2	-0.12	5	-0.20	8
6	Zhejiang	0.56	**5**	0.86	4	-0.09	4	1.61	2
7	Fujian	-0.39	9	-0.46	9	-0.39	10	0.58	4
8	Shandong	0.40	6	0.94	3	-0.51	11	0.30	6
9	Henan	-0.47	11	-0.32	7	-0.80	15	0.02	7
10	Hubei	-0.41	10	-0.49	10	-0.28	8	-0.40	9
11	Guangdong	1.15	**1**	2.16	1	-0.32	9	-1.24	14
12	Guangxi	-0.78	13	-0.84	13	-0.72	13	-0.40	10
13	Yunnan	-0.81	15	-0.86	14	-0.73	14	-0.80	12
14	Shanxi	-0.56	12	-0.75	12	-0.24	7	-0.57	11
15	Gansu	-0.81	14	-0.92	15	-0.62	12	-0.84	13

4.2 The analysis of the evaluation results

There can be seen in Table 2 that the eigenvalues of the first three principal components is greater than one, so we chose the three principal components, while the first two principal components take up a large proportion of variance; The rotation component matrix in Table 3 shows that the proportion of the 28 indicators account for the principal component focused on the first two principal components, in which the first principal component F1 mainly includes: large and medium enterprises financing of new product development, industrial total industrial output value of large and medium enterprises, large and medium industrial enterprises in R&D funding, the number of high-tech industries, the number of large and medium enterprises, the number of three kinds of patent applications received, total output value of industrial enterprises above designated size, medium and large enterprises output value of new products, sales of new products of medium and large enterprises, the number of three kinds of patent applications accepted, the number of person in regional S&T activities, the total output value of high-tech industries, the number of enterprises with S&T institutions in large and medium enterprises, the sales of high-tech products, regional R&D Expenditures, funding for regional science and technology activities, and ten of thousands of people with industrial enterprises, for a total of 17 indicators, which can be defined as the basis for innovation development components; the second principal component F2 mainly includes: the proportion of the number of university R&D staff in the total population, the number of scientists and engineers in ten of thousands of people, the proportion of college educated population, per capita expenditure on national financial education, the proportion of the research funding raising on the total GDP, volume of business in technology market, the number of academic paperspublished, the proportion of the tertiary industry in the total GDP, college enrollment in the proportion of the total population, per capita GDP, per capita disposable income of residents, for a total of 11 indicators, which can be defined as the potential for innovation development components.

From Table 5, which is the sequencing of the provinces of the integrated innovation and of the principal components, we can see that the top five of the integrated innovation are Guangdong, Jiangsu, Beijing, Shanghai, Zhejiang, they all belong to the eastern region, and the last five are Yunnan, Gansu, Guangxi, Shanxi , Henan, except the central region Henan, the rest are in the western region; However the first five of the the basis for innovation development components are Guangdong, Jiangsu, Shandong, Zhejiang, Shanghai, belong to the eastern region, and the last five are Gansu, Yunnan, Guangxi, Shanxi, Tianjin, except for the Tianjin in the eastern region, the rest are in the western region; the top five of the potential for innovation development components are Beijing, Shanghai, Tianjin, Zhejiang, Jiangsu, they all belong to the eastern regions, respectively, the last five Henan, Yunnan, and Guangxi, Gansu, Shandong, except the eastern region of Shandong, others are in the western region.

CONCLUSION ANALYSIS

Through the innovation capability evaluation and analysis of the 15 provinces of China, we can see that,on the whole, there are differences of the economic growth between the central and western region and the eastern region of China in 2008: The East is higher than the West. The quantitative analysis result is coincidence with our economic development status, the 11th five-year plan of the national economic and social development just to point out (ZHANG & HOU, 2008) "The eastern region should lead in raising capability of independent innovation, lead to carry out the optimization and upgrading of economic structure and the transformation of economic growth pattern, and the first to improve the socialist market economic system, pioneer to lead and help the central and western regional development in the development and reform." The first development of the reform and opening up is the eastern region, beacause of the earlier development in those regions, its basic innovation capability is relatively stronger than other regions, which makes its integrated capability in the front compared to others in the order, on the contrary, the central and western regions are instability. However, from the rankings of each principal component,we can see that, some central and western provinces such as Henan, Hubei and other provinces have a better basis of innovation capability development, so these regions can take measures to gradually increase its level of development of innovation potential, such as increasing its investment of scientific research and technology, and enhancing its innovation capability of scientific research to improve its integrated innovation capability. The slower development provinces of westernsuch as Yunnan, Gansu and other areas, it is integrated innovation capability and innovation capability of every principal component are more rearward position in the order, so they should develop its economic strength at first, and on this basis, increase investment of scientific research to improve the integrated innovation capability.

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