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EVALUATION OF INDEPENDENT INNOVATIVE CAPACITY OF HIGH-TECH ENTERPRISES IN SHANDONG PROVINCE

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Abstract On the basis of establishment of evaluative index system for independent innovative capacity of high-tech enterprises, five principal factors used for evaluation are obtained by means of carrying out factor analysis, and comprehensive ranking of independent innovation capacity of different cities in Shandong province is achieved through calculation of composite score, at last, classification and comparison of difference of independent innovative capacity among high-tech enterprises in 14 cities of Shandong province is carried out by means of cluster analysis.

Keywords High-Tech enterprises; Independent innovative capacity; Index system

1 Introduction

The experience of economic development of all over the world proves that independent innovative capacity has become the pivotal element of deciding the future fate of enterprise due to its importance in having a strong relationship to success in market competition. Indubitably, as an important solid support for independent innovation, high-tech enterprise marked by knowledge and technology intensive should make great contribution to promoting economic development and social progress. So, how to evaluate independent innovative capacity of high-tech enterprise accurately has received great attention because of its capacity not only to assist enterprises in getting a thorough understanding of their innovative capacity and achieving sustainable development, but also to assist region to improve economic development and industry structure readjusting.

The purpose of this paper is to evaluate the overall independent innovative capacity of high-tech enterprises in Shandong province by making use of evaluative indices for independent innovative capacity of high-tech enterprises. The data of empirical study is drawn from a questionnaire survey among high-tech enterprises in Shandong province during February to May 2008. We designed questionnaire by means of interviewing and revised it through survey in small scale. We sent out 400 questionnaires by post, email and personal, about 277 enterprises return their questionnaire, representing a response rate of 69.25 percent.

2 Establishment of Evaluative Index System

Research on how to build a comprehensive evaluation index system of independent innovative capacity has emerged as an underlying theme, various domestic and foreign literatures have researched it at different levels, such as national level, regional level and enterprise-level. In all of these researches, Porter and Scott’s study series attract much attention. They introduced a novel framework of the determinants of national innovative capacity in 2001, drawing on their previous research, they constructed an innovative capacity index system composing of human capital investment, innovation policy, cluster-specific environment and the quality of linkage in 2002, then they using the data from the 2001 global competitiveness report to assess the innovative capacity of 75 countries. In 2004, they provided the more detailed explanation for index, they redefined the quality of linkage as connection between nation’s common innovation infrastructure and a cluster, they found that nation’s common innovation infrastructure, and innovative environment of a cluster, their connection and company innovation orientation had reciprocal causation relationship.

Among these literatures, researcher constructed different Index system for different types of company. He Benlan et al (2008) constructed index system for large and medium-sized industrial enterprise; Zhang Ying et al (2005) also proposed an index system for small and medium-sized enterprise. Academia has gradually reached assent on the first order index nowadays, but has different viewpoints on the second order. Human resource has significant impact on innovation capacity of company (Tufan Koc 2007), an empirical research including 91 small and medium-sized software development companies was conducted, and study reveals that the human resource impacted the innovation capacity positively (O'Connor, Roos 2006); the number of new products is a good substitute for patent application because the former has the homogenous quality in measuring innovation activity

(Raffaele Paci, Stefano Usai 1999). Index system of innovation capacity of high-tech enterprise should comprise five crucial determinants which are laws and policy, market environment, resource background, service surroundings, technology and culture circumstance (Yangdong Qi et al 2008).
In order to rank the enterprise innovation capacity more systematically and accurately, we employ the first-order indices announced by national statistical bureau; these indices include an array of four variables: potential independent innovation resource, capacity of independent innovation activity, capacity of independent innovation production, independent innovation environment. In order to establish a simply perfect evaluative index system, we select correspondingly 13 second-order indices on the basis of analysis of influence factors of innovation; Table 1 presents these indices of innovation capacity.

Table 1 Evaluative Indictors of Independent Innovative Capacity

First order index	Second order index	Explanation of index
Potential independent innovation resource	The number of technician of enterprise x_1 Sales income of product x_2 Expenditure of scientific and technological activity x_3	Index comprises the stocking of human resource and economic resource, reflects the potential capacity of enterprise's innovation.
Capacity of independent innovation activity	Devoted intensity of R&D x_4 Devoted intensity of technique acquisition x_5 Devoted intensity of digestive absorption x_6 Devoted intensity of technical reform x_7	Innovation activity includes activity of R&D, technique acquisition, technical reform and technology transfer. This index was measured by the amounts of expenditure on every parts of innovation activity
Capacity of independent innovation production	Quantity of patent application x_8 Quantity of patent of invention x_9 The proportion of sales income of new products x_{10} The number of innovative products x_{11}	This index reflects the synergetic effects exerted by all determinants.
Independent innovation environment	The proportion of government funds on the total financial resource of scientific and technologic activity x_{12} The proportion of loan offered by financial institution on the total financial resource of scientific and technologic activity x_{13}	The index reflects effects exerted by the external environment on the independent innovation capacity

3 Data Analysis

Ordinary, the comprehensive evaluation of innovation capacity can be obtained by analysis of difference among evaluated objects on the total indices; Tang Qiong et al (2008) and Tang Yanzhao (2004) applied respectively the comprehensive evaluation method and fuzzy comprehensive evaluation method for independent innovation capacity of enterprise. In addition, factor analysis also can be used to reduce attributes space from a larger number of variables to a smaller number of factors. This paper extracts the principal components of indices by use of factor analysis, and then computes the composite scores of independent innovation capacity of enterprises in Shandong province.

3.1 Factor analysis

This paper uses SPSS software packet to process data, the sample mainly comes from 14 cities, which are Jinan, Qingdao, Weihai, Yantai, Weifang, Zibo, Laiwu, Zaozhuang, Heze, Dezhou, Dongying, Liaocheng, Binzhou and Linyi. Due to restrictions on data collection, the potential limitation is that sample cannot represent high-tech enterprises in all regions of Shandong province comprehensively because of lacking of sample data from 3 cities: Tai'an, Jining and Rizhao.
Result of KMO test is 0.692 with a significant Bartlett test of sphericity ($p<0.000$), if factor analysis is conducted, the factor extracted will account for fare amount of variance. According to the standard that the amount of variance explained by extracted factors is greater than 85%, finally we extracts five principal components, we found that the amount of variance explained by 5-factors model is 87.8% by calculating. It proves that factor analysis is reasonable. Table 2 presents the result of factor analysis.

Table 2 Rotated Factor Loading Matrixes

	Principal components				
	1	2	3	4	5
x_1	.963	.079	.030	.061	.066
x_2	.962	.058	-.013	.09	-.028
x_3	.941	.023	.005	.127	-.111
x_4	.219	.781	.433	-.231	.131
x_5	.054	-.079	.020	.904	-.018
x_6	.617	.069	-.022	-.138	.447
x_7	.150	.915	-.140	.130	.015
x_8	.579	.431	-.195	.071	-.099
x_9	-.172	.039	.888	.047	-.165
x_{10}	-.483	.107	.648	.218	-.123
x_{11}	.576	-.084	.326	-.203	-.163
x_{12}	.021	-.454	-.004	.368	-.014
x_{13}	-.072	.055	.092	.004	.909

The first factor F1 is marked by high loading on the x_1, x_2, x_3 (>.94), the amount of variance explained by F1 is .32, it is the largest one, we would thus conclude that F1 has the most significant effect on innovation capacity of enterprise. Variables composing of F1 include the number of technician (x_1), sales income of product (x_2) and expenditure of scientific and technological activity (x_3). This factor reflects potential innovation resource of enterprise, so we call it as innovation resource factor.

The second factor F2 is marked by high loading on the x_4, x_7 (>.78), the amount of variance explained by F2 is .247. x_4 represents the devoted intensity of R&D, x_7 represent devoted intensity of technical reform, so we call F2 as innovation activity factor.

The third factor F3 is marked by high loading on the x_9, x_{10} (>.64), the amount of variance explained by F3 is .124, the former variable reflects the quantity of patent of invention, the latter variable reflects the proportion of sales income of new products, so we call f3 as innovation production factor.

The fourth factor F4 have high loading (.904) on the x_5, the amount of variance explained by F4 is .099, this variable reflects devoted intensity of technique acquisition, and it proves that technique acquisition is prerequisite for independent innovation. So we call this independent factor as technique acquisition for innovation factor.

The fifth factor is marked by high loading on the x_{13} (.909); the amount of variance explained by F5 is .088. This variable reflects the proportion of loan offered by financial institution on the total financial resource of scientific and technologic activity. We call F5 as innovative environment factor. But another variables reflecting the proportion of government funds on the total financial resource of scientific and technologic activity does not get involved in the model, it shows that government funds could not play a significant effect on assisting high-tech enterprises in innovation.

3.2 Calculation of composite score

We use contribution rate of variables variance for calculating weights to calculate composite score on the basis of factor analysis, then comprehensive ranking of independent innovation capacity of different cities in Shandong province is achieved. The formula is this:

$$F = \sum_{i=1}^{n} \frac{\lambda_i}{\sum_{i=1}^{n} \lambda_i} fac_i \tag{1}$$

The symbol λ_i is the Eigen value of factor i. We take the numerical result into formula for calculating. The formula is this:

$$F = 0.365F1 + 0.281F2 + 0.141F3 + 0.113F4 + 0.1F5 \tag{2}$$

We obtained finally the composite score of independent innovation capacity of 14 cities in Shandong province by calculating, as reported in table 3. We find that enterprises coming from big cities (Qingdao, Jinan) with strong comprehensive strength, they lead this ranking. Correspondingly, enterprises coming from underdeveloped area (Dezhou, Zaozhuang) do not have the strength to compete with the former in independent innovation. This conclusion is consistence with the general recognized. But it worth noting that some cities (Heze, Laiwu, Liaocheng) pay much attention on the development of high-tech enterprises and give them tremendous assistance for independent innovation in spite of relatively weak comprehensive economic strength, so independent innovation capacity of enterprise in these cities catch up with and surpass other region's enterprises. Take Heze as an example, industrial output value of high-tech enterprises accounts for 18.19% of all above-scale enterprises in 2007, contribution rate of scientific and technological progress to economic growth reaches 43%. Table 3 presents the overall ranking.

Table 3 Overall Ranking of Independent Innovation Capacity of High-Tech Enterprises of 14 Cities in Shandong Province

Cities	Composite Score	Score of Innovation Resource factor	Score of Innovation activity factor	Score of Innovation production Factor	Score of Innovation Technique Acquisition Factor	Score of Innovation Environment Factor
Qingdao	0.345245	0.45293	0.39815	0.2579	0.17231	0.1221
Jinan	0.28335	0.43784	0.40235	0.0392	0.11834	-0.08422
Weihai	0.247857	0.11318	0.44445	0.18511	0.4851	0.00739
Zibo	0.192519	0.24665	0.45582	-0.03993	0.04211	-0.24722
Dongying	0.166086	0.25293	0.40142	0.02113	-0.23404	-0.15565
Yantai	0.120017	0.16679	0.06712	0.07381	-0.0575	0.36368
Weifang	0.102287	0.21234	-0.11658	0.16718	0.19742	0.11661
Laiwu	0.063647	-0.12445	0.31299	0.1211	-0.20248	0.26926
Heze	-0.09936	0.02526	-0.37995	0.00128	0.05976	-0.08748
Liaocheng	-0.13408	-0.20875	-0.06679	-0.16382	-0.02478	-0.13218
Linyi	-0.14594	-0.14169	-0.38325	-0.09875	-0.02181	0.29862
Dezhou	-0.2935	-0.46267	-0.34239	-0.14666	0.01081	-0.08963
Binzhou	-0.38733	-0.4734	-0.58973	-0.19795	-0.04321	-0.16027
Zaozhuang	-0.4608	-0.49697	-0.60362	-0.21968	-0.50193	-0.22102

3.3 Cluster analysis

In order to getting more understanding on the difference and similarity of independent innovative capacity of high-tech enterprises in Shandong province, this paper also uses hierarchical clustering method to classify cities by forming or segmenting cities into many sub-clusters. Graph 1 presents dendrogram letting me visualize the history of cluster formation:

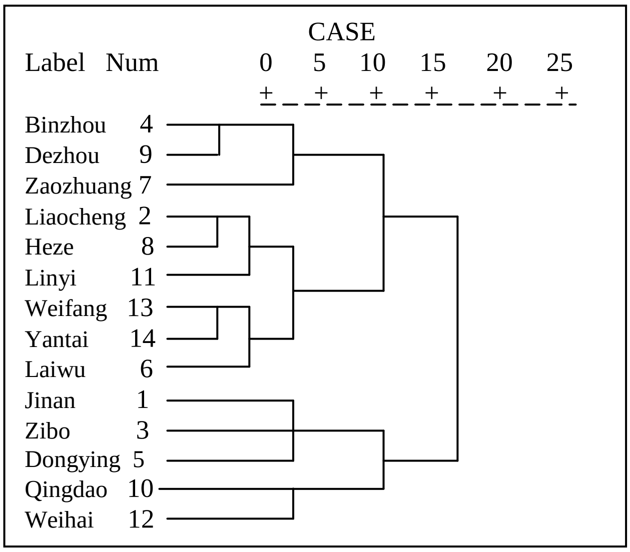

Figure 1 Dendrogram of Independent Innovative Capacity of High-Tech Enterprises of 14 Cities in Shandong Province

In the above dendrogram, the sub cluster IDs are listed along y-axis, the x-axis measure inter-cluster distance. According to dendrogram, it is the most appropriate classification that segments 14 cities into 3 sub clusters, Jinan, Zibo, Dongying, Weihai, Qingdao have the smaller inter-cluster distance, so they are joined in a cluster 1. Liaocheng, Heze, Linyi, Weifang, Yantai and Laiwu are joined in sub cluster 2; Binzhou, Dezhou and Zaozhuang are joined in sub cluster 3. We can find that cities in cluster 1 resides in the forefront of ranking, cities in cluster 2 have ordinary rating in this charts, cities in cluster 3 rank last. It can be seen that there exist significant difference among clusters. The result of hierarchical cluster analysis is credible.

Although hierarchical cluster has advantages in classification of a given data set, there is an obvious lack in generalization and description the feature of each cluster. In order to make up for the deficiencies, this paper also uses K-Means clustering analysis. Firstly, we standardize the variables, then we uses K-Means clustering algorithm to classify data set with standardized variables, the result is showed in Table 4.

Table 4 Final Cluster Center of Clustering Process

	Cluster		
	1	2	3
Z score (innovation resource factor)	.90054	.11009	-1.26329
Z score (innovation activity factor)	.78311	.00906	-.99022
Z score (innovation production factor)	.80517	.15668	-1.20231
Z score (innovation technique acquisition factor)	.88949	-.39961	-.61236
Z score (innovation environment factor)	-.08513	.68670	-.75197

Table 4 shows the variable value at the cluster center. Another important output of K-Means clustering is data summary, which shows how many observations there are in each cluster, as shown on the Table 5. According to the outputs, cluster 1 includes Jinan, Zibo, Dongying, Qingdao and Weihai, cluster 3 includes Binzhou, Dezhou and Zaozhuang, the other cities form cluster 2. It is consistence with the result of hierarchical cluster analysis.

Table 5 Data Summary

Cluster	1	5.000
	2	6.000
	3	3.000
Valid		14.000
Missing		.000

According to the outputs of K-Means cluster analysis, now we can draw a conclusion that:

Cluster 1: This cluster rank first, as the result of leadership in four of the five factors. Firstly, high-tech enterprises in these cities possess very rich potential innovation resource so that they hold an advantage in this field. Secondly, high-tech enterprises in these cities are equipped with strong capacity of innovative activity; this advantage renders them able to actively engage in R&D activity, technical reform, technique acquisition and technology transfer. Thirdly, possessing strong capacity of innovation production makes enterprises to transform research achievement into practical productive forces more smoothly; it is embodied in many aspects, including increasing in the number of invention patent and the proportion of sales income of new products. Fourthly, in comparison with cities in the other clusters, high-tech enterprises in these cities have more capacity of technique acquisition; they place the equal emphasis on R&D and technique acquisition. Lastly, value of innovative environmental indicator of high-tech enterprises in these cities is at middle level, it means that financial institution gives limited financial support for innovation.

Cluster 2: This cluster rank second, as the result of leadership in one of the five factors. Although the other factors including resource of independent innovation and capacity of independent innovative activity and production of independent innovation and technique acquisition of independent innovation continues at middle level, factor of innovation environment well in excess of the other clusters. Six cities are closely bunched together in the second tier. The most striking finding is that this cluster demonstrates considerable strength in terms of funding support, in other words, enterprises have more convenient access to external financial support.

Cluster 3: This cluster lags behind the ranking, as the result of straggler in all of the five factors. In comparison with the other clusters, the gap between the values of the same factor is greater than 1, the sharp difference between cluster 1 and cluster 3 at all of factors demonstrates itself obviously. This cluster includes 3 cities, which are positioned at 12th, 13th, and 14th respectively in overall ranking.

4 Discussion on Evaluation Result

Drawing on the above result of data analysis, the overall situation of independent innovative capacity of enterprises in Shandong province is mingled fear and hope.

Hope: Despite the weak comprehensive economic strength, Heze and Liaocheng register good performance in independent innovative capacity. The pattern highlights their challenges in evolving a path toward economic development with the advent of the knowledge-base economy. Development of high-tech enterprises has a strong positive relationship to optimization and upgrading of industrial structure as well as increase in total economic outputs. So it can be predicted that high-tech industry would replace conventional industry and become a pillar industry.

Fear: Independent innovative capacity of enterprises varies across cities within the province-wide. According to composite score presented on the third column of table 3, average composite score of cluster 1 is 62.7 percentage points higher than that of cluster 3, 21 percentage points higher than that of all clusters, in contrast, average composite score of cluster 3 is 25 percentage points lower than that of all clusters. On the face of it, it is very serious that innovation capacity unevenly distributed across cities of Shandong province. Imbalance in regional economic development will be exacerbated if things continue this way without any effective solution. The gap between coastal developed areas and inland under developed areas could not be conducive to comprehensive coordination and sustainable development of province’s economic.

In short, expanding economic scale of high-tech industry, enhancing efficiency of scientific and technological progress contribution to economic growth, improving general capacity of independent innovation of enterprises, narrowing the gap among inter-cities are the direction for future work of government and enterprises. The problems needed to be solved urgently are differentiated according to different situation facing each cluster. The biggest problem which enterprises of cluster 1 faced is short of effective external financial support; but the problem which enterprises of cluster 2 faced arises from internal; both external and internal innovation factors for enterprises of cluster 3 should be enhanced simultaneously.

5 Conclusion

This paper provides a comprehensive evaluation for independent innovative capacity of high-tech enterprises of 14 cities in Shandong province for the first time, an insight into the strength and challenges facing high-tech enterprises in 14 cities, a factual basis for development of high-tech industry. In addition, our empirical study would become the reference for future studying using data set from other provinces. However, due to the difficulty of data collection, our empirical study was confined to the scope of Shandong province so that could not achieve the overall ranking of all the country, this limitation provides meaningful direction for future research.

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