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Factor analysis-based estimation of technological innovation capabilities of high-tech enterprises in a certain area

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ABSTRACT

In this paper, an evaluation system on industry technological innovation capabilities is set up and the positive analysis about technological innovation capabilities of high-tech enterprises in a certain area are made based on factor analysis. The results show that high-tech enterprises in this area have low technological innovation capabilities, and the endogenous independent innovation of these industries, as well as the innovation external environment constructions, need to be emphasized.

Key words: high-tech; technological innovation capabilities; factor analysis

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INTRODUCTION

With the development of knowledge-based economy, the high-tech enterprise, as an important industry that boosts a new round of economic growth, plays an increasingly dominant role in the national economic development [1-3]. High-tech enterprise is a knowledge and technology-intensive industry, which is characterized by high R&D investment and large proportion of R&D personnel [4-7]. The influence of innovation capability on its development is obvious. Researchers have adopted different methods to study the innovation capacity of the high-tech enterprise[2-3]. However, meticulous and deep-going positive analyses about the high-tech industries in this area are rare. Based on the reality, the innovation capacities of the enterprises in this area are estimated, and the problems existed in their development are examine [8-12]. By providing some references for policy making, it is significant for the healthy development of high-tech enterprises.

THE ESTABLISHMENT OF EVALUATION INDEX SYSTEM FOR TECHNOLOGICAL INNOVATION CAPABILITIES OF HIGH-TECH ENTERPRISES

The technological innovation capacity is a comprehensive system constituted by several elements; it is the sum total of various internal conditions, based on which the enterprises, as the behavioral agent of technological innovation activity, can practice and accomplish the technological innovation activity [4]. However, in academia, no consensus has been reached as to how to objectively and effectively estimate the technological innovation capacities. After reading a large number of literatures and consulting the existed indices, combining with the technological innovation process and component, as well as the data accessibility, we attempt to set up the estimation index system from aspects of support capacity, investment capability, transformation capacity and output capacity of the technological innovation. By drawing reference from previous studies, and adhering to the principle of scientificity, systemacity and feasibility, thirteen second-class indices are determined after repeated screening, see Tab.1.

Tab.1 Estimation Indices for Innovation Capabilities of High-tech Enterprises

	First class index	Second class index
The technological innovation capabilities of High-tech enterprises	support capacity	The proportion of microelectronic control equipment cost in the original cost of manufacturing equipments t1
	investment capability	R&D personnel intensity t2
		The proportion of new product development expenditure in sales income t3
		R&D investment intensity t4
		Investment intensity of science and technology activity t5
		The proportion of external funding in the total amount of funding raised for science and technology activity t6
	transformation capacity	The absorption capacity t7
		The proportion of technological transformation expenditure in sales income t8
		The number of invention patent ownership per thousand people t9
		The number of invention patent application per thousand people t10
	output capacity	New product productivity t11
		The new products contribution rate of scientific and technical personnel t12
		The proportion of new products sales income in the total products sales income t13

FACTOR ANALYSIS MODEL OF HIGH-TECH INNOVATION CAPABILITY MEASUREMENT AND EVALUATION

Model Construction

Suppose that $Z=(Z_1,Z_2,\cdots,Z_m)$ is the evaluation index vector of m enterprises, and $F=(F_1,F_2,\cdots,F_p)$ is unobservable index vector, we get:

That is $Z=AF+U$, in which $U=(U_1,U_2,\cdots U_m)$ is the special factor, and F_i is the i th common factor; and the following conditions are met: (1) $p \le m$; (2) $COV(F,U)=0$; (3) $E(F)=0,\ \ Cov(F)=(1^{\cdot}\cdot.1)_{p\times p}=I_p$.

The Determination of Factor Loading Matrix

Based on the principal components analysis, the factor loading matrix is calculated in this paper. Suppose the covariance of $Z=(Z_1,Z_2,\cdots,Z_m)$ is Σ. The Eigenvalue of Σ is $\lambda_1 \ge \lambda_2 \ge,\cdots,\lambda_m \succ 0$, and the corresponding eigenvector is $e_1,e_2,\cdots,e_m$ (standard orthonormal basis).

Therefore, $\Sigma = (\sqrt{\lambda_1}e_1',\cdots,\sqrt{\lambda_p}e_p')' m\sum_{i=1}\lambda_i e_i e_i' = (\sqrt{\lambda_1}e_1,\cdots,\sqrt{\lambda_m}e_m)(\sqrt{\lambda_1}e_1',\cdots,\sqrt{\lambda_m}e_m')'$ When there are p F_i the special factor is 0. So $Z=AF$ and A is a factor loading matrix, and $A=(\sqrt{\lambda_1}e_1,\cdots,\sqrt{\lambda_m}e_m)$.

Factor Rotation

In this paper, the varimax orthogonal factor rotation method is adopted. First of all, the condition where P=2 is considered

Suppose factor loading matrix A= $\begin{Bmatrix} a_{11}\ a_{12} \\ a_{21}\ a_{22} \\ \cdots\ \cdots \\ a_{m1}\ a_{m2} \end{Bmatrix}$, and T is the orthogonal matrix, $T=\begin{Bmatrix} \cos\theta,-\sin\theta \\ \sin\theta,\cos\theta \end{Bmatrix}$. Let $B \triangleq (b_{ij})=AT$. To simply B structure, the square values of the elements in the two columns of the rotated factor loading matrix need to polarize towards 0 and 1. So V_1 and V_2, the sample variances of $(b_{11}^2,\cdots,b_{m1}^2),(b_{12}^2,\cdots,b_{m2}^2)$, , need to be as large as possible. The orthogonal rotation angle need to meet the requirement: $V_1 + V_2 \Box V = \max$, that is $V = \sum_{J=1}^{2}\left[\frac{1}{m}\sum_{i=1}^{m}(b_{ij}^{2})^{2} - (\frac{1}{m}\sum_{i=1}^{m} b_{ij}^{2})^{2}\right]$ =max.

Generally, if there are p common factors, successive rotation of every two common factors are needed. In fact, when the common factor $P \succ 2$, two are picked out, and matched and rotated.

The Calculation of Factor Score

To set the regression equation with common factor as independent variable and the original variable as dependent variable: $F_j = \beta_{j1}Z_1 + \beta_{j2}Z_2 + \cdots + \beta_{jm}Z_m$, $j = 1, 2, \cdots, p$, $\beta_j = A_j^{'} R^{-1}$. By the least square regression method, the estimate value of F can be obtained. In the expression $F = A^{'} R^{-1} Z$, A is factor loading matrix, $A^{'}$ is the transpose of a rotated factor loading matrix; R is the correlation matrix of the original variable; R^{-1} is the inverse matrix of R; Z is the original variable vector.

Thus, the technological innovation capacity scores of high-tech enterprises in this area are $W_i (i = 1, 2, \cdots, m)$ which is obtained from the weighting scores of each factor. The equation for evaluation is $W_i = a_1F_1 + a_2F_2 + \cdots + a_pF_p / \sum_{i=1}^{p} a_i$, in which $a_i = \lambda_i / \sum_{i=1}^{p} \lambda_i$

POSITIVE ANALYSIS ABOUT THE INNOVATION CAPABILITIES OF HIGH-TECH INDUSTRIES IN A CERTAIN AREA

Based on the evaluation index system in Tab.1, five high-tech sub-industries are studied in a certain area. Data collected from China Statistics Yearbook on High Technology Industry (2000-2011) are organized and standardized with SPSS18.0. Then, the observed value of Bartlett's test of sphericity (Tab.2), the eigenvalue and contribution rate of rotated principal component(Tab.3), as well as the rotated factor loading matrix(Tab.4), are obtained through factor analysis.

Tab. 2 KMO and Bartlett's Test

KMO value		.557
Bartlett's test of sphericity	chi-squared approximations	480.951
	degree of freedom	78
	significance	.000

As shown in Tab.2, the results of KMO test and Bartlett's test of sphericity indicate that: KMO value is 0.557 which lies between 0.5-1; the observed value of test statistics is 480.951; and probability p is approximate to 0.000.

It means that correlations exist among variables, and it is feasible to conduct factor analysis on the original variable.

Tab.3 Eigenvalue and Contribution Rate of Principal Components

Principal component	Eigenvalue	Contribution rate	The accumulative contribution rate
F1	3.630	27.923	27.923
F2	2.221	17.081	45.004
F3	2.099	16.148	61.151
F4	1.546	11.890	73.042

From the eigenvalue and contribution rate of principal component in Tab.3, we know that eigenvalues of the first four principal components are all above 1, and the contribution rate of each of the four decreases in sequence; and their accumulative contribution rates reach to the point of 73.042%. It means that the basic content of the first four principal components contains the information of 13 specific indices. Thus the first four principal components, F1、F2、F3、F4, whose interpretabilities for original information are 27.923%, 17.081%, 16.148% and 11.890% respectively,can be extracted.

To make the loading of each main factor clearer, the original factor loading matrix is rotated. From Tab.4 the rotated principal component loading matrix, we know that the first principal component F1 has substantial loading on indices of R&D investment intensity (t4), R&D personnel intensity (t2), the proportion of new product development expenditure in sales income (t3), and investment intensity of science and technology activity (t5).

Since these four indices account for the technological innovation investment capacity of the enterprises, F1 can be regarded as representative of technological innovation investment factor. The second principal component F2 has substantial loading on indices of the new products contribution rate of scientific and technical personnel(t12)，new product productivity (t11)， and the proportion of new products sales income in the total products sales income (t13). Since these three indices account for the technological innovation output capacity of the enterprises, F2 can be regarded as representative of technological innovation output factor. The third principal component F3 has substantial loading on the index of the proportion of microelectronic control equipment cost in the original cost of manufacturing equipments (t1). Thus, F2 can be regarded as representative of technological innovation support factor. The fourth principle component F4 has substantial loading on the index of number of invention patent ownership per thousand people (t9). So we name F4 as technological innovation transformation factor.

Tab.4 The Rotated Principal Components Loading Matrix

	Component			
	F1	F2	F3	F4
R&D investment intensity t4	.932	-.158	-.112	-.016
R&D personnel intensity t2	.931	-.160	-.083	.065
The proportion of new product development expenditure in sales income t3	.925	.000	-.082	.059
The proportion of external funding in the total funding raised for science and technology activity t6	.597	-.031	.263	-.154
The new products contribution rate of scientific and technical personnel t12	-.114	.906	-.136	-.051
New product productivity t11	-.161	.896	-.019	.270
The proportion of new products sales income in the total products sales income t13	-.026	.772	.382	.083
The proportion of microelectronic control equipment cost in the original cost of manufacturing equipments t1	-.298	.080	.844	.401
The absorption capacity t7	-.099	-.089	.224	.825
The number of invention patent ownership per thousand people t9	.026	.159	-.173	.745
The number of invention patent application per thousand people t10	.056	.147	-.233	.544
Investment intensity of Science and technology activity t5	-.096	.003	.402	-.184
The proportion of technological transformation expenditure in sales income t8	.401	.070	.447	-.219

In further analysis about the innovation capacity of the five high-tech sub-industries in this area, we set up a comprehensive evaluation model in which the synthetic weighting method is adopted to calculate the scores of the four principal factors that are weighted by the percentage of the eigenvalue of each principal factor in the sum eigenvalues of the four extracted factors.

$Z=0.3823*F1+0.2339*F2+0.2210*F3+0.1628*F4$

Bases on this model, the scores of technological innovation capability of the high-tech enterprises in five industries in this area are calculated out. As is shown in Fig.1.

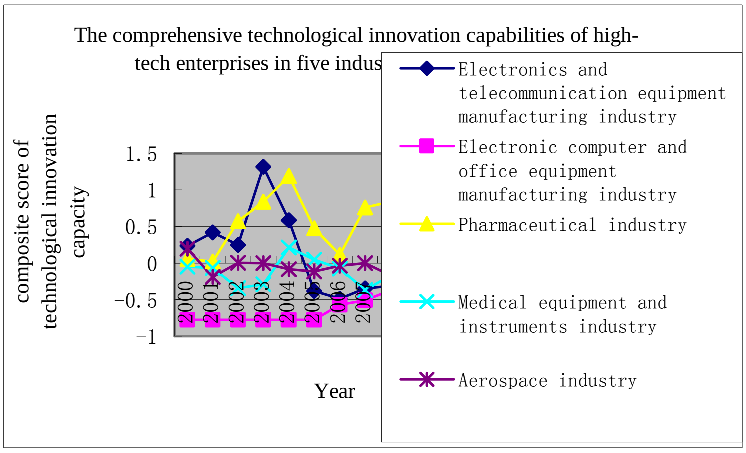

Fig.1 The Comprehensive Technological Innovation Capability of High-tech Enterprises in Five Industries in Certain Area

To specify the actual technological innovation capacity situations of the five high-tech sub-industries, data of average indices values from 2000 to 2011 are analyzed. The scores of the average values of each factor, as well as the composite scores of technological innovation capacity are ranked in Tab.5

Tab.5 The principal components score of the five high-tech sub-industries in certain area

High-tech industry	f1	position in the order	f2	position in the order	f3	position in the order	f4	position in the order	Composite score	rank
Electronics and telecommunication equipment manufacturing industry	-0.526	4	-0.056	5	0.968	1	-0.326	3	-2.398	4
Electronic computer and office equipment manufacturing industry	-0.612	5	0.0818	1	0.051	2	-0.367	5	-4.719	5
Aerospace industry	0.110	1	-0.019	4	-0.037	4	-0.358	4	-1.553	3
Medical equipment and instruments industry	0.042	2	0.031	2	-0.095	5	-0.278	2	-0.885	2
Pharmaceutical industry	0.0157	3	0.0006	3	0.014	3	-0.021	1	-0.0241	1

The principal factor scores of high-tech sub-industries indicate that pharmaceutical industry has the strongest technological innovation capacity, and is followed by medical equipment and instruments industry, aerospace industry, electronics and telecommunication equipment manufacturing industry, and electronic computer and office equipment manufacturing industry. This is consistent with the results derived from Fig.1.

The technological innovation capacity of pharmaceutical industry ranks the first. It takes the lead of all other industries in terms of the technological innovation transformation factor, and its innovation support factor, innovation investment factor and innovation output factor all rank the third, which means that it maintains a balanced development regarding all aspects of technological innovation.

The composite score of medical equipment and instruments industry ranks the second. The innovation investment factor, innovation output factor and innovation transformation factor of the medical equipment and instruments industry all occupy the second place, and its innovation support factor rank the fifth. Though the innovation support factor is not ideal, the innovation of this industry performs well. It means this industry has good innovation potential. If the support factor is intensified, the medical equipment and instruments industry will have greater innovation potential.

The comprehensive ranking of aerospace industry is the third. Its innovation investment factor occupies the first place; but it lags far behind other industries in terms of innovation factor, innovation support factor, and innovation transformation factor, which all occupy the fourth place.

The innovation capability of electronics and telecommunication equipment manufacturing industry ranks the fourth, and that of electronic computer and office equipment manufacturing industry ranks the fifth. But both innovation investment factor and innovation transformation factor of the two industries fall behind others. It means that, though large amount of money has been invested in innovation, the effect is not obvious.

CONCLUSION

Form the above analysis, it can be concluded that: First, the high-tech enterprises in this area have low technological innovation capabilities, which are unstable and is not on a good increasing trend. Second, technological innovation capability gaps exist among the five sub-industries. The technological innovation capability of pharmaceutical industry is much higher than that of electronic computer and office equipment manufacturing industry and electronics and telecommunication equipment manufacturing industry. Third, technological innovation capabilities of the five sub-industries have different supports, as well as different reasons that lead to bottlenecks of development.The technological innovation capability of pharmaceutical industry ranks the first among the five. It is mainly due to the fact that, as a traditional industry in this area, it has advantages over the others in terms of the guaranteed investment and employees, as well as strong scientific achievement transformation capability. But the results of data analysis show its investment factor, output factor and support factor are all on an average level. Technological innovation output and transformation factors of medical equipment and instrumentation manufacturing industry are on an uptrend, but its support factor shows a decreasing trend, which sets back the improvement of innovation capability. The innovation investment factor of aerospace industry plays a supporting role for its innovation capability improvement; the transformation factor used to constrain its innovation capability, but it is on an uptrend in recent years, which means that the innovation transformation capability of this industry is also enhancing. The innovation capacity of electronic computer and office equipment manufacturing industry is relatively weak. Except the innovation output factor which improves greatly in 2010 and 2011, and turns back to a decreasing trend in 2012, all other factors set back its innovation capability improvement. All aspects of the innovation capability of the electronic and telecommunication equipment manufacturing industry are the weakest of the five sub-industries, and the decreasing trend of innovation capacity of this industry is not optimistic.

Based on the results of above analysis, the following suggestions are made concerning the innovation ability of high-tech enterprises in this region: First, the endogenous innovation of high-tech enterprises needed to be emphasized. First of all, we should increase support for innovation, raise enterprise-centered R&D spending, promote independent R&D capabilities of the high-tech enterprises, and drive them into high-end value chain. The innovation capabilities improvement of high-tech enterprises will promote economic restructuring and the transformation of development pattern. Then, we should improve the absorption capacity of high-tech enterprises. Good absorption capability is the key to their innovation capability improvements. We also need to motivate the R & D personnel, to foster organizational learning capability, to increase re-innovation investment after absorption, and to promote the transformation from dominant technology-import pattern to independent innovation pattern. Third, technological innovation output capability need to be strengthened. Poor innovation output from high innovation investment will lead to the wastes of resources. High-tech enterprises in this area are just in such a predicament. To promote their innovation output capabilities, the enterprises need to break through the original boundaries, to enhance cooperation with the outside world, to combine independent R&D with cooperative innovation, and to take advantage of their own merits. Second, a favorable external environment needs to be created for technological innovation of high-tech enterprises. In this process, the government plays an important role. First of all, by formulating industrial policy, the government need to improve the system of industrial technology and provide guidance for independent R&D. Then, improve the supporting service system of innovation; strengthen industry-university-institute cooperation; build effective information transmission mechanism, technological achievement transformation bases, as well as technical service center to facilitate technology cultivation and proliferation. Thirdly, increase financing support for high-tech enterprises. The government can set up fund raising institution of independent innovation, or introduce venture capital to provide financial backup for R&D and technological marketization. In addition, the leverage effect of tax policy should be given full play to guarantee enterprise financing by means of loan, tax reliefs, subsidy, etc.

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