Factor Analysis-Based Appraisal of the Innovation Performance of China's Hi-Tech Industry

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Abstract: It has become an irreversible trend in the global economy for enterprises to shift from the factor-driven development pattern to the innovation-driven development pattern in recent years. The hi-tech industry is characterized by frequent updates and rapid changes and is demanding in respect of independent R&D and innovation capability, so the hi-tech industry becomes the core subject for practicing the innovation-driven development pattern. Therefore, that how to promote the healthy, rapid and efficient development of the hi-tech industry has gradually attracted a lot of attention and been actively explored in all sectors. To solve the problem, exploration into the innovation performance of the hi-tech industry is of the greatest importance. Hence it is crucial to find a reasonable method of innovation performance appraisal and appraise the performance of China's hi-tech industry objectively by the method.

1. Introduction

Hi-tech industry is often used in reference to the aggregation of enterprises that, on the basis of high technology, are engaged in one or more high technologies and related R&D and production of products and technology services. The hi-tech industry made an outstanding contribution to the alleviation of the employment pressure, the maintenance of social stability and the integration into globalization. Despite the rapid growth, segments of the hi-tech industry performed differently and in some areas of China the hi-tech industry hit a bottleneck to growth and dropped. Meanwhile, the hi-tech industries in developed countries remained booming and generally weighed heavily. By contrast, it is obvious that China's hi-tech industry doesn't weigh very much and is poorly structured. It is of great significance to foster, improve and optimize the hi-tech industry and realize optimization and upgrade of the industrial structure according to China's strategy of building an innovative country that practices sustainable development. We can see that it is an important approach to boosting national economy to promote the development of the hi-tech industry.

2. Appraisal of Innovation Performance of the Hi-tech Industry

2.1 Development of an Indicator System

It is difficult to appraise an innovation system, an industrial innovation system in particular. The currently mostly used methods are theoretical deduction and case study. The methods facilitate the study of innovation system's internal structure, but they lack operability relatively, so scholars are trying to find a quantitative method of innovation system appraisal in order to appraise the innovation performance.

In view of the availability of data, an in-depth analysis is conducted by drawing lessons from research methods at home and abroad and taking the characteristics of China's hi-tech industry into consideration. According to the analysis, the following indicators are selected for the appraisal of the hi-tech industry's innovation performance: newly increased fixed assets (M1), funds for development

of new products (M2), output of new products (M3), export delivery (M4), full time equivalent of R&D personnel (T1), internal expenditure of R&D funds (T2), patent applications(T3), patents for inventions (T4), researchers (T5), technological transformation expenditure (T6), technological introduction expenditure (T7), digestion & absorption expenditure (T8), enterprises with R&D (S1), R&D personnel (S2), corporate funds (S3), and governmental funds (S4) Thus, we get the system of indicators for appraising the innovation performance of China's hi-tech industry, as shown in Table 1.

Table 1. Performance Appraisal System

Primary Indicator	Secondary Indicator	Unit	Serial Number
Market Factors	Newly increased fixed assets	10 thousand RMB	M1
	Funds for development of new products	10 thousand RMB	M2
	Output of new products	10 thousand RMB	M3
	Export delivery	10 thousand RMB	M4
Technology Factors	Full time equivalent of R&D personnel	Person-year	T1
	Internal expenditure of R&D funds	10 thousand RMB	T2
	Patent applications		T3
	Patents for inventions		T4
	Researchers		T5
	Technological transformation expenditure	10 thousand RMB	T6
	Technological introduction expenditure	10 thousand RMB	T7
	Digestion & absorption expenditure	10 thousand RMB	T8
Social Motive Factors	Enterprises with R&D		S1
	R&D personnel		S2
	Corporate funds	10 thousand RMB	S3
	Governmental funds	10 thousand RMB	S4

2.2 Standardization of Indicator System

With the innovation performance of the hi-tech industry as the objective of the appraisal, 496 data for the 16 indicators regarding China's 31 provincial-level regions in 2016 are selected for analysis. In order to compare the variables and eliminate impact resulting from any observed dimensional discrepancy or order of magnitude, the observed sample data is processed into standard non-dimensional data. The standard data are shown in Appendix A.

2.3 Test of Indicator System

First, compute the correlation coefficient matrix to test the indicators. Input the indicators of the sample into SPSS17.0 and get the coefficient matrix of the sample. We see that most correlation coefficients are greater than 0.05. This implies that factors are linearly independent of each other, i.e. the factors contain no overlapping information. Second, conduct KMO and Bartlett's test. The results are shown in Table 2.

Table 2. KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.758
Bartlett's Test of Sphericity	Approx. Chi-Square	1237.329
	Df	120
	Sig.	.000

The KMO is 0.758. It indicates that the sampling is adequate. Bartlett's Test of Sphericity shows that the correlation matrix is not an identity matrix. Therefore, it is appropriate to use factor analysis here.

2.4 Calculation of Eigenvalues and Their Percentage and Accumulative Percentage

To reduce originally multidimensional variables to a few factors by synthetic dimension reduction

is at the core of a factor analysis. Factor extraction methods include principal axis factoring, principal component analysis, unweighted least squares, generalized least squares, maximum likelihood, etc. Principal component analysis will be used for factor extraction here. See Table 3 and 4 below for the extraction of the original variables corresponding to the communalities.

Table 3. Communalities

	M1	M2	M3	M4	T1	T2	T3	T4
Initial	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Extraction	0.573	0.959	0.954	0.843	0.985	0.989	0.975	0.772
	T5	T6	T7	T8	S1	S2	S3	S4
Initial	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Extraction	0.966	0.614	0.769	0.956	0.844	0.984	0.969	0.976

Extraction Method: Principal Component Analysis.

Table 4. Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Accumulative %	Total	% of Variance	Accumulative %	Total	% of Variance	Accumulative %
1	11.892	74.328	74.328	11.892	74.328	74.328	11.792	73.698	73.698
2	1.266	7.914	82.242	1.266	7.914	82.242	1.325	8.282	81.981
3	.967	6.046	88.288	.967	6.046	88.288	1.009	6.307	88.288
4	.916	5.728	94.015						
5	.441	2.753	96.769						
6	.211	1.318	98.086						
7	.112	.697	98.783						
8	.087	.547	99.330						
9	.052	.325	99.655						
10	.035	.220	99.876						
11	.009	.057	99.933						
12	.008	.052	99.985						
13	.002	.010	99.994						
14	.001	.004	99.998						
15	.000	.002	100.000						
16	7.413E-5	.000	100.000						

Extraction Method: Principal Component Analysis.

In the process of analysis, principal component analysis is used as the factor extraction method and 3 factors are selected. The accumulative percentage of variance explained reaches 88.288%, which indicates that the 3 factors extracted are adequate to interpret the innovation performance of the 31 provincial-level regions. As we can see, Factor 1 accounts for 74.328% of the variance, the highest, Factor 2 for 7.914%, and Factor 3 for 6.046%. After the rotation, Factor 1 accounts for 73.698% of the variance, Factor 2 for 8.282%, and Factor 3 for 6.307%. The 3 factors largely integrate information of the 16 indicators; thus, the 16 indicators are reduced to 3 integrative factor indicators.

2.5 Calculation of Factor Scores and Composite Scores

Table 5 shows the loadings of the 3 factors after rotation. As we can see, the loadings of M2, M3, T1, T3, S2 and S3 onto Factor 1 are comparably large, that is, Factor 1 has considerably great effect on these 6 indicators, so we can define Factor 1 as Market Factor. Similarly, the loadings of T2 and T5 onto Factor 2 are relatively large, so we can define Factor 2 as Technology Factor. The loadings of T8 and S5 onto Factor 3 are relatively large, so we can define Factor 3 as Social Motive Factor. In Table 5, we can see that with regard to the 3 factors' interpretation of overall objectives, Factor 1 is the most important.

Table 5. Component Matrix^a

	Component		
	1	2	3
M1	.719	-.126	-.201
M2	.970	-.126	.051
M3	.967	-.131	.039
M4	.880	-.201	-.168
T1	.983	.099	-.089
T2	.937	.333	.000
T3	.953	-.207	-.155
T4	.804	-.216	-.282
T5	.941	.277	-.052
T6	.761	-.004	.184
T7	.833	-.004	.276
T8	.537	-.085	.813
S1	.896	-.198	-.032
S2	.981	.130	-.076
S3	.983	-.031	.032
S4	.385	.909	-.046

Extraction Method: Principal Component Analysis.
a. 3 components extracted.

Table 6. Factor Score Coefficient Matrix

	Component		
	1	2	3
M1	.060	-.099	-.208
M2	.082	-.099	.052
M3	.081	-.104	.040
M4	.074	-.159	-.173
T1	.083	.078	-.092
T2	.079	.263	.000
T3	.080	-.164	-.160
T4	.068	-.170	-.291
T5	.079	.219	-.054
T6	.064	-.003	.190
T7	.070	-.003	.285
T8	.045	-.067	.840
S1	.075	-.156	-.033
S2	.082	.102	-.079
S3	.083	-.025	.033
S4	.032	.718	-.048

Extraction Method: Principal Component Analysis.

Table 6 shows the matrix of coefficients used to calculate the scores of the 3 factors from original variables. Thus, we can get the linear combinations of the 3 factors and the 16 indicators. The results of F1 are shown below. The calculation methods for F2 and F3 are the same.

$$F1=0.060M1+0.082M2+0.081M3+0.074M4+0.083T1+0.079T2+0.080T3+0.068T4+0.079T5+0.064T6+0.070T7+0.045T8+0.075S1+0.082S2+0.083S3+0.032S4;$$

Assign raw data of China's 31 provincial-level regions in 2016 to variables in the equations above and we get the factor score of each provincial-level region, as shown in Table 7.

In Table 7 we can see each region's status with regard to each of the 3 factors. Jiangsu is far ahead of other regions in respect of the market of the hi-tech industry, which is largely indebted to its geographical advantage. As China's political and economic center which represents China's highest level in hi-tech areas, Beijing enjoys incomparable technology advantage. As home to a large number of China's institutions of higher learning and scientific research, Shanghai has undoubted capacity for coordination and collaboration, which brings high collaborative effectiveness.

After we figure out the factor scores, we can work out the composite score of each provincial-level region by weighting each factor score according to how much its % of the variance accounts for the total of the 3 factors' % of the variance and adding the weighted factor scores up, as illustrated by the following formula:

$$F=(73.698*F1+8.282*F2+6.307*F3)/(73.698+8.282+6.307)$$

According to the composite score formula above, we can get each provincial-level region's total score and rank, as shown in Table 8.

As shown in Table 8, Jiangsu, Guangdong and Shandong take first, second and third places respectively in China's hi-tech industry with their comprehensive advantages in market, technology and social motive. However, large gaps are seen among other regions in respect of their composite scores. As we can find from the analysis above, apart from the northern, eastern and southern coastal economic zones, most regions ranks low on the list of the innovation performance of the high-tech industry. It indicates that China's hi-tech industry is poor at structure and comprehensive strength,

which is attributed to national policy, economic input and geological conditions. It can be concluded from the analysis of the indicators and factors that in terms of the innovation performance of the hi-tech industry, there are gaps among China's provincial-level regions and that China's hi-tech industry is poor-structured.

Table 7. Factor Score of the Provincial-Level Regions

	F1	F2	F3
Beijing	0.39992	1.11477	-0.0787 0
Tianjin	0.21359	0.06691	0.24075
Hebei	0.19693	0.05784	0.59808
Shanxi	0.11511	0.04931	0.28753
Inner Mongolia	0.06860	0.03583	0.10533
Liaoning	0.23697	0.18391	0.13487
Jilin	0.07903	0.10016	-0.0153 7
Heilongjiang	0.11888	0.13607	0.11003
Shanghai	0.47979	0.19057	0.93864
Jiangsu	0.92232	-0.00491	0.09060
Zhejiang	0.53759	0.01143	0.22425
Anhui	0.17345	0.05470	0.04732
Fujian	0.20254	0.01582	0.09355
Jiangxi	0.09982	0.02971	-0.0200 7
Shandong	0.59156	0.13027	0.48292
Henan	0.22095	0.10396	0.04962
Hubei	0.24763	0.17321	0.10834
Hunan	0.22509	0.03192	0.18818
Guangdong	0.95801	-0.13916	-0.2983 0
Guangxi	0.07712	0.04688	0.01651
Hainan	0.00657	0.00594	0.00027
Chongqing	0.12655	0.02063	0.09557
Sichuan	0.21427	0.32475	0.12513
Guizhou	0.03745	0.01794	-0.1561 1
Yunnan	0.05072	0.04740	0.10541
Tibet	0.00000	0.00000	0.00000
Shaanxi	0.17486	0.26817	-0.1042 8
Gansu	0.06513	0.02098	0.37857
Qinghai	0.00877	0.00638	0.02517
Ningxia	0.01670	0.00219	0.03530
Xinjiang	0.02622	0.02612	0.00088

Table 8.Total Score and Rank of the Provincial-Level Regions

	F	Rank
Beijing	0.43279	6
Tianjin	0.20177	12
Hebei	0.21254	10
Shanxi	0.12125	17
Inner Mongolia	0.06815	24
Liaoning	0.22470	8
Jilin	0.07427	22
Heilongjiang	0.11986	18
Shanghai	0.48544	4
Jiangsu	0.77592	1
Zhejiang	0.46585	5
Anhui	0.15330	16
Fujian	0.17724	14
Jiangxi	0.08468	20
Shandong	0.54053	3
Henan	0.19773	13
Hubei	0.23070	7
Hunan	0.20433	11
Guangdong	0.76534	2
Guangxi	0.06995	23
Hainan	0.00606	30
Chongqing	0.11440	19
Sichuan	0.21826	9
Guizhou	0.02179	27
Yunnan	0.05431	25
Tibet	0.00000	31
Shaanxi	0.16367	15
Gansu	0.08338	21
Qinghai	0.00972	29
Ningxia	0.01666	28
Xinjiang	0.02440	26

3. Conclusion and Suggestion

An innovation performance appraisal system is being explored for China's hi-tech industry during the process of the industry's continuous development. The essence of the appraisal system is to appraise the performance of the hi-tech industry in each phase by qualitative and quantitative techniques. The exploration of a better appraisal system aims to enrich relevant theories in academic circles and develop and select better performance appraisal system for enterprises in practice so as to improve the innovation activities and performance of China's hi-tech industry with a better appraisal system. Moreover, a better appraisal system will facilitate research on gaps between regions with regard to China's hi-tech industry, strategically contributing to China's balanced and sustainable development.

Based on factor analysis, the innovation performance of China's hi-tech industry is appraised and

analyzed herein. It is found during the analysis that in the innovation performance appraisal system, the market factor and technology factor influence China's hi-tech industry remarkably while social motive factor isn't given full play to. The following suggestion is made for this situation. In terms of market factor, the government should continue to offer preferential policy and enterprises should advance their capacity for export delivery and new product sales. With regard to technology factor, upholding "independent R&D", "go global" and "bring in" strategies, enterprises should improve their capacity for introducing, transforming, digest and absorbing advanced technology from abroad while applying it; with endogenous R&D as the staple, training of personnel of the hi-tech industry should be strengthened and enterprises should be encouraged to apply for patents in order to improve the capacity for industrial technology innovation in terms of quality. In respect of social motive factor, China's hi-tech industry doesn't make enough use of results of collaboration among enterprises, higher-learning institutions and research institutes, so China should apply the results via scientific research alliance mechanism efficiently and effectively to promote social motives; and the utilization rate of governmental funds and corporate funds should be increased. Improvements based on the 3 factors above will definitely facilitate optimized structure and rapid growth of China's hi-tech industry and at the same time promote balanced and sustainable development of China's hi-tech industry in all the regions.

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Appendix A

Serial Number	M1	M2	M3	M4	T1	T2	T3	T4	T5	T6	T7	T8	S1	S2	S3	S4
Beijing	0.027	0.175	0.221	0.090	0.560	0.958	0.134	0.095	0.764	0.212	0.325	0.025	0.125	0.603	0.380	1.000
Tianjin	0.132	0.168	0.280	0.083	0.167	0.266	0.136	0.074	0.212	0.178	0.381	0.244	0.108	0.190	0.239	0.091
Hebei	0.133	0.135	0.112	0.012	0.178	0.180	0.065	0.029	0.281	0.352	0.217	0.661	0.128	0.203	0.171	0.056
Shanxi	0.009	0.094	0.059	0.004	0.131	0.103	0.041	0.027	0.182	0.244	0.116	0.299	0.060	0.147	0.105	0.026
Inner Mongolia	0.013	0.047	0.053	0.000	0.068	0.073	0.016	0.010	0.099	0.249	0.050	0.077	0.041	0.070	0.073	0.018
Liaoning	0.151	0.272	0.185	0.038	0.243	0.334	0.098	0.051	0.354	0.431	0.104	0.160	0.101	0.280	0.301	0.137
Jilin	0.044	0.028	0.133	0.001	0.128	0.087	0.025	0.013	0.207	0.050	0.018	0.019	0.033	0.143	0.061	0.060
Heilongjiang	0.016	0.096	0.052	0.001	0.176	0.142	0.037	0.033	0.272	0.152	0.098	0.134	0.051	0.183	0.112	0.078
Shanghai	0.116	0.419	0.479	0.370	0.389	0.561	0.237	0.171	0.474	0.255	1.000	1.000	0.230	0.395	0.448	0.301
Jiangsu	1.000	1.000	0.836	0.722	0.916	1.000	0.711	0.272	0.794	1.000	0.590	0.457	1.000	0.909	1.000	0.241
Zhejiang	0.104	0.485	0.573	0.096	0.647	0.575	0.522	0.167	0.489	0.468	0.349	0.369	0.929	0.641	0.613	0.100
Anhui	0.130	0.230	0.172	0.003	0.183	0.189	0.175	0.061	0.217	0.172	0.073	0.116	0.165	0.209	0.167	0.074
Fujian	0.126	0.175	0.188	0.111	0.220	0.198	0.132	0.045	0.196	0.152	0.381	0.083	0.230	0.224	0.208	0.035
Jiangxi	0.304	0.078	0.068	0.011	0.098	0.100	0.028	0.011	0.130	0.094	0.120	0.024	0.075	0.117	0.094	0.035
Shandong	0.185	0.703	0.765	0.116	0.551	0.783	0.374	0.152	0.639	0.622	0.409	0.561	0.476	0.615	0.845	0.123
Henan	0.123	0.200	0.149	0.004	0.292	0.245	0.135	0.053	0.345	0.282	0.099	0.107	0.285	0.320	0.242	0.065
Hubei	0.093	0.243	0.211	0.028	0.281	0.307	0.132	0.069	0.377	0.274	0.311	0.103	0.184	0.318	0.271	0.129
Hunan	0.120	0.156	0.211	0.003	0.208	0.216	0.152	0.187	0.256	0.574	0.097	0.230	0.203	0.243	0.212	0.054
Guangdong	0.441	0.821	1.000	1.000	1.000	0.943	1.000	1.000	1.000	0.374	0.911	0.270	0.742	1.000	0.998	0.137
Guangxi	0.045	0.052	0.086	0.007	0.095	0.072	0.026	0.017	0.133	0.205	0.006	0.019	0.073	0.114	0.063	0.030
Hainan	0.003	0.005	0.008	0.000	0.011	0.006	0.004	0.005	0.010	0.003	0.000	0.005	0.007	0.013	0.003	0.006
Chongqing	0.034	0.115	0.230	0.004	0.104	0.115	0.113	0.045	0.136	0.114	0.231	0.073	0.109	0.129	0.106	0.042
Sichuan	0.113	0.143	0.136	0.034	0.240	0.307	0.105	0.054	0.319	0.509	0.123	0.140	0.091	0.289	0.153	0.315
Guizhou	0.002	0.035	0.029	0.001	0.040	0.033	0.030	0.018	0.056	0.112	0.021	0.009	0.030	0.049	0.028	0.014
Yunnan	0.000	0.034	0.021	0.001	0.062	0.050	0.017	0.017	0.085	0.093	0.089	0.032	0.048	0.081	0.034	0.035
Tibet	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Shanxi	0.516	0.114	0.082	0.005	0.210	0.252	0.057	0.033	0.320	0.171	0.056	0.037	0.079	0.218	0.108	0.276
Gansu	0.001	0.025	0.032	0.000	0.059	0.047	0.019	0.008	0.089	0.077	0.097	0.424	0.034	0.067	0.033	0.032
Qinghai	0.002	0.004	0.001	0.000	0.010	0.010	0.002	0.001	0.014	0.008	0.011	0.029	0.007	0.014	0.009	0.004
Ningxia	0.000	0.012	0.009	0.001	0.015	0.012	0.007	0.004	0.015	0.056	0.022	0.029	0.022	0.020	0.012	0.003
Xinjiang	0.001	0.025	0.023	0.000	0.038	0.029	0.012	0.008	0.062	0.033	0.000	0.009	0.021	0.044	0.025	0.015