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Evaluation of innovation ability of high-tech enterprises based on catastrophe progression method

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Previous researches have utilized analytic hierarchy process, factor analysis and other methods in investigating innovation ability; however, these have been found to have a common problem that is either too subjective or involves a complex calculation procedure. Application of catastrophe progression method in this paper on innovation ability evaluation of high-tech enterprises helps to avoid these problems. The research results show that the innovation ability of Chinese high-tech enterprises keeps enhancing from the Interior West to the Eastern coastal region, with creativity and innovation efficiency closely related.

Key words: Catastrophe progression method, innovation ability, high-tech enterprise.

INTRODUCTION

Since the concept of innovation was first introduced by the famous economist Schumpeter in 1912, many scholars have done a lot of researches about innovation. Wei and Xu (1995) argue that innovation is both a systematic capacity and a combination of product and process innovations that is deeply influenced by the enterprise's innovation strategy. Liu (2006) argues that the essence of enterprise innovation system is the unity of enterprise system innovation and technological innovation that includes not only its own system of technological innovation, but also other relevant systems to promote technology innovation. It is a system network that centers on technological innovation axis. In addition, Weiqiang (1995), Gao (1998) and Bai (2002) also studied the innovation from different perspectives. Presently, the domestic and foreign scholars mainly use factor analysis method, data envelopment analysis (DEA) method, principal component analysis (PCA), analytic hierarchy process (AHC), and neural network method. By analyzing the factors influencing the effect of high-tech enterprise's technological innovation capability, Cheng and Chen (2015) established the evaluation index system of technological innovation capability for high-tech enterprises and evaluated a chemical fiber enterprise technology innovation ability using the analytic hierarchy process and the evaluation index system, as well as analyzed the results. Hou et al. (2009) used the principal component analysis to evaluate and analyze the innovation ability of 31 provinces and cities across China in 2008. Also, Liu (2006) used the DEA method to evaluate the innovation performance of private science and technology enterprises in Anhui Province on the

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basis of building a private technology enterprise innovation performance evaluation index system. Su and Zhang (2002) partly expanded the enterprise technological innovation capability evaluation method based on the construction of index system of enterprise technological innovation capability by using artificial neural network method on the evaluation of enterprise technological innovation capability.

On the basis of establishing the factor analysis model of measuring and evaluating the technological innovation capability of enterprises, Bai et al. (2008) uses factor analysis to evaluate the technological innovation capability of 15 enterprises in Zhejiang Province. Qian Xuesen (1982) thinks that the above methods are subjective or complex in calculation, while catastrophe progression method is a comprehensive one which first decomposes the main bodies assessed through many levels, generates mutation fuzzy membership function by the catastrophe theory and fuzzy mathematics and then obtain a parameter through integrated quantitative operation of normalized formula to get the total membership function. Its biggest feature is that it only needs to determine the relative importance of each evaluation index (Qian, 1982), and no longer needs to design the weights of the indexes, which greatly reduces the subjectivity and research process without losing its scientific nature and rationality, eventually making the operation simple and accurate. This is the greatest feature compared to other methods. The catastrophe progression method has not been applied before to the evaluation of innovation capability of high-tech enterprises.

BASIC THEORY AND EVALUATION STEPS OF CATASTROPHE PROGRESSION METHOD

Basic theory of catastrophe progression method

Dou (1994) points out that catastrophe theory is the theoretical basis of catastrophe progression method and a new branch of mathematics, which is founded by France mathematician Rene Thom and focuses on the mutation (change) which includes not only the mechanics of topology, the basis of calculus, but even including the Singularity Theory and mathematical theories such as structural stability. It is called "calculus mathematics after another revolution." Catastrophe progression method is a comprehensive method which first decomposes the main bodies assessed through many levels, generates mutation fuzzy membership function by the catastrophe theory and fuzzy mathematics and then obtains a parameter through integrated quantitative operation of normalized formula to get the total membership function. Its biggest feature is that it only needs to determine the relative importance of each evaluation index (Dou, 1994), and no longer need to design the weights of the indexes, which greatly reduces the subjectivity and research process without losing its scientific nature and rationality as well as making the operation simple and accurate. Through different conditions of catastrophe model analysis and comparative study, Rene Thom summed up that when the state variable is less than 2 and the control variable less than 4, various mutations can be summed up as 7 standard mathematical models.

Evaluation steps of catastrophe progression method

Establishing evaluation index system

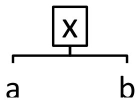
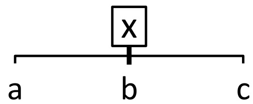
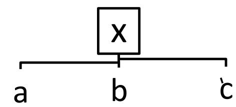
Dou (1994) also points out, according to the evaluation objectives, that the evaluation index is decomposed through multiple levels from top to bottom, and then arranged in inverted goal tree hierarchy. Based on the principle of catastrophe progression method, only the bottom indicator data is needed to calculate the index value step by step until the target value is calculated at its highest level. Normally, mutation of some state variables of the system control number cannot be more than 4, compared to common cusp, swallowtail catastrophe and butterfly mutation system control variables which are 2, 3 and 4, respectively. Therefore, the number of sub indexes for each single index decomposition cannot be greater than 4 (Dou, 1994).

As required by the principle of catastrophe progression method, all parameters need to be first classified according to the logic of contradictions within the system, distinguish between major and minor contradictions, and then break down major and minor contradictions to finally get the quantitative index. According to this principle, the indexes in the evaluation model are decomposed in turn. To reduce its subjectivity, this paper used the entropy method to calculate the weights of the indexes at different levels, and the importance of the indexes at different levels is determined according to the size of the weights, so as to construct an evaluation index system. After the evaluation index is determined, the evaluation index data is treated with dimensionless method in order to avoid the inequality of the indexes due to the difference between the dimension and the dimension unit.

Determining type of indicators at all levels of the system model

In this paper, as the importance of each index on the same system differs, we need to first determine the major and minor aspects and mutations of the index system subsystem model type. The program is a prerequisite for establishing evaluation system of catastrophe progression method. In order to judge the mutation membership function according to the corresponding mutation series normalization formula, the catastrophe

Table 1. The model of mutation series formula and illustration.

Parameter	The cusp catastrophe system	The swallowtail catastrophe system	The butterfly mutation system
Model	F(x)=x4+ax2+bx	$F(x)=x^5+ax^3+bx^2+cx$	F(x)=x6+ax4+bx3+cx2+dx
Normalized formula	$x_a = a^{1/2}, x_b = a^{1/3}$	$x_a = a^{1/2}, x_b = a^{1/3}, x_c = c^{1/4}$	$x_a = a^{1/2}, x_b = a^{1/3}, x_c = c^{1/4}, x_d = d^{1/5}$
Diagram			

model subordinate to the index at different levels is determined. Methods to determine the mutation model is decomposed into two superior index system corresponding to the cusp catastrophe model; the index system is divided into three indexes and the corresponding swallowtail superior index is decomposed into four indexes system corresponding to the butterfly catastrophe model. Table 1 shows the catastrophe progression, system model, formula and diagram. Here the entropy method is used to calculate the weight of each index, the importance of the sort by weight index (the principal aspect of a contradiction) corresponding to the main control variables, and the secondary indicators (conflict on the secondary side control variables corresponding to secondary) model.

Conducting of comprehensive evaluation using normalization method

In the case of multiple targets, Fuzzy theory think if A_1, A_2,......,A_n are fuzzy sets, the strategies to meet the above targets are: $C=A_1 \cap A_2 \cap \cdots\cdots \cap A_n$. The membership function is: $U_{C(X)}$, $UA_{n(X)}$ is the membership function of evaluation index of Ai, and $U_{C(X)}$ is the minimum of membership function of Ai (Evaluation index) (Lu Fang, 2008).

Assuming that A_1 and A_2 are different alternatives, if the membership function exists, it means that A_1 is better than A_2. Thus, the X value on the basis of the "same object of the control variables corresponds to the “minimax” principle, and if there are complementarities among the indexes, we usually use its average as substitution. In the final comparison of each scheme, according to the principle of “minimax”, that is, according to the total evaluation index score, each evaluation object will be sorted.

"Complementary" and "Non-Complementary" principles are two crucial criteria for target evaluation when using catastrophe progression method. If there is no obvious interrelationship between the control variables (such as a, b, c, etc.) of a system, the minimum value of the mutation series corresponding to each control variable should be selected when calculating the system state variable x, that is, "Non-Complementary "minimax" principle. If there is a clear interrelationship between the control variables of a system, the "averaging" principle in the "complementary" principle should be followed. Theoretical studies have shown that only when the above principles are followed, the requirements of the divergent equations in the catastrophe theory can be met. According to this, we first calculate the number of mutations of the control variables on the evaluation index by the normal formula, and use the obtained mutation series as the control variable of the index; thereafter, the number of evaluations of the evaluated units was obtained by taking the number of stages. This score is the evaluation of the innovation capability of high-tech enterprises.

INNOVATION ABILITY EVALUATION OF HIGH-TECH ENTERPRISES

Construction of index system

Based on the "China Enterprise Innovation Capability Analysis Report" and the shortcomings of application from Shen and Lei (2006), Lu Fang (2008), Wu Feng et al. (2010), and Chen and Chen (2006), this paper constructs the evaluation index system of innovation ability, which includes two aspects: innovation output and innovation input ability, as shown in Figure 1. According to the evaluation procedure of the mutation series method, the four secondary indicators like the innovation output, the innovation resource and the innovation activity and innovation environment of the enterprise are decomposed one by one, and the third-level indexes which can be further decomposed can be quantified to stop decomposition. The innovation ability evaluation system is constructed into an inverted tree-like multi-level target evaluation structure, and is being ranked by the importance of the index. In order to sort the importance of indicators, this paper uses the entropy weight method to calculate the weights of each index from bottom to top, and then sort the indexes according to the weight to reduce the subjectivity of the links. The main indicators are the former ones and secondary indicators the latter

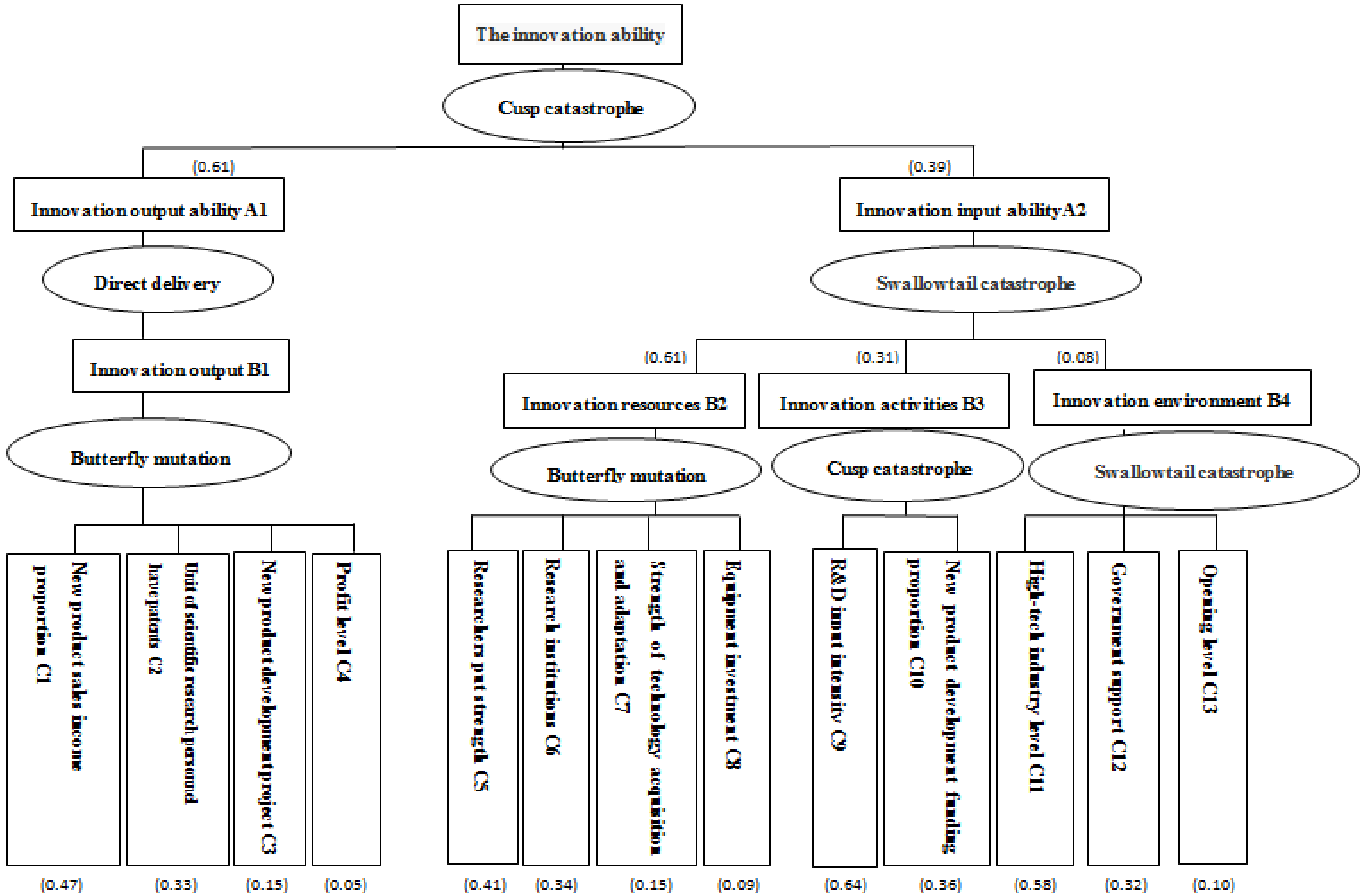


Figure 1. The high-tech enterprises ' innovation capability evaluation index system.

ones. Ultimately, we will build a complete evaluation index system for the high-tech enterprise innovation ability.

Determination of the mutation system type

According to the mutation sequence method, to evaluate the steps, we will determine the level of evaluation parameters of the mutation system type from top to bottom:

First-level index system: The innovation capability of high-tech enterprises includes two first-level indicators of innovation output and input. According to the principle of mutation series method, it corresponds to the cusp mutation system, and there are obvious interrelations and effects between indicators. The control variables are denoted as A1 and A2, respectively.

Secondary indicators system: First-level indicators of innovation output only decompose one secondary indicator, so it can be directly delivered. Innovation investment can be divided into three secondary indicators. According to the principle of mutation series method, it corresponds to the swallowtail mutation system, and there are obvious interrelations and effects between the indicators, which is the complementary type, with the control variables denoted as B2, B3, and B4.

Third-level index system: Secondary index will be decomposed into four third-level indexes, which correspond to the butterfly mutation system. There is no obvious interrelationship among the indexes, and the control variables are labeled C1, C2, C3 and C4.

Innovation resource will be decomposed into four third-level indexes, which correspond to the butterfly mutation system. Here, there is no obvious interrelationship among the indexes, and the control variables are labeled C5, C6, C7 and C8.

Innovation resource will be decomposed into two third-level indexes, corresponding to the butterfly mutation system. Here, there is no obvious interaction between the indexes, and the control variables are marked as C9, C10.

Innovation resources will be decomposed into three third-level indexes, corresponding to the swallowtail mutation system. There is a clear correlation between the indicators, which falls under the complementary type, and control variables are marked as C11, C12 and C13.

Data processing

The research data of this paper are derived from the "China High-Tech Statistical Yearbook (2011 - 2015)" and "China Science and Technology Statistical Yearbook (2011 - 2015)" and the relevant data of 29 provinces (autonomous regions and municipalities) were collected. Since some of the data are from Qinghai Province and Tibet Autonomous Region, the study does not include these two provinces. According to the evaluation principle and requirements of the mutant series method, the control variable is restricted to between 0 and 1, in view of the different indicators in the evaluation system with different dimensions and dimension units. In order to eliminate the non-generability of the resulting indicators, this paper uses the range transformation method to carry on the dimensionless processing to all the evaluation indexes [83]. The dimensionless processing procedure is as follows:

Positive indicators:

$$y_{ij} = \frac{x_{ij} - \min\limits_{1\le j\le n} x_{ij}}{\max\limits_{1\le j\le n} x_{ij} - \min\limits_{1\le j\le n} x_{ij}} \tag{1}$$

i = 1, 2,……,m (m is the index number), j = 1, 2, ……, n (n is the number of objects).

Innovation ability evaluation

Using the normal formula of the mutation series method to calculate and evaluate the innovation ability of high and new technology enterprises, this paper takes the data of Guizhou High-tech Enterprises as an example to illustrate the calculation process.

Third-level index system

The third-level indicators of innovation output B1 will be decomposed into new product sales revenue ratio (C1), unit of scientific research personnel owned by all the invention patents (C2), new product development projects (C3) and profit levels (C4); all of which are the butterfly mutation model, given as

$$x_{c_1} = \sqrt{c_1} = \sqrt{0.335} = 0.579, \quad x_{c_2} = \sqrt[3]{c_2} = \sqrt[3]{0.112} = 0.48,$$
$$x_{c_3} = \sqrt[4]{c_3} = \sqrt[4]{0.041} = 0.449, x_{c_4} = \sqrt[5]{c_4} = \sqrt[5]{0.541} = 0.88,$$

This is a non-complementary system. So, according to the principles of "non-complementary, minimax", the index value of innovation output (B1) is equal to $\min(x_{c1}, x_{c2}, x_{c3}, x_{c4},) = \min(0.579, 0.48, 0.449, 0.88) = 0.449$.

The third-level indicators of innovation resources (B2) will be decomposed into the strength of researchers (C5), the number of scientific research institutions (C6), the strength of technology acquisition and transformation (C7) and the strength of equipment investment (C8); all of which are also the butterfly mutation model, given as

$$x_{c_5} = \sqrt{c_5} = \sqrt{0.864} = 0.930, x_{c_6} = \sqrt[3]{c_6} = \sqrt[3]{0.014} = 0.239,$$
$$x_{c_7} = \sqrt[4]{c_7} = \sqrt[4]{0.172} = 0.644, x_{c_8} = \sqrt[5]{c_8} = \sqrt[5]{0.264} = 0.766,$$

This is a non-complementary system. So, according to the principles of "non-complementary, minimax", the index value of innovation resource (B2) is equal to $\min(x_{c5}, x_{c6}, x_{c7}, x_{c8},) = \min(0.580, 0.239, 0.644, 0.766) = 0.$

The third-level indicators of the innovation activities (B3) will be decomposed into the intensity of R&D input (C9), the proportion of new product development costs (C10), all of which are the cusp catastrophe model, given as

$$x_{c_9} = \sqrt{c_9} = \sqrt{0.683} = 0.827, x_{c_{10}} = \sqrt[3]{c_{10}} = \sqrt[3]{0.265} = 0.643,$$

This is a complementary system. So, in accordance with the principle of "complementary mean", the index value of innovation resources (B3) is equal to $x_{B_3} = (x_{c_9} + x_{c_{10}})/2 = (0.827 + 0.643)/2 = 0.735,$

The third-level indicators of innovation activities (B4) will be decomposed into the high-tech industry development level (C11), the government support (C12) and the level of opening (C13); all of which are the swallowtail mutation model, given as

$$x_{c_{11}} = \sqrt{c_{11}} = \sqrt{0.131} = 0.362, x_{c_{12}} = \sqrt[3]{c_{12}} = \sqrt[3]{0.368} = 0.7$$
$$x_{c_{13}} = \sqrt[4]{c_{13}} = \sqrt[4]{0.003} = 0.233,$$

This is a complementary system. So, in accordance with the principle of "complementary mean", the index value of the innovation resources (B4) is equal to $x_{B_4} = (x_{c_{11}} + x_{c_{12}} + x_{c_{13}})/3 = (0.362 + 0.717 + 0.233)/3 = 0.$

Secondary index system

The first-level indicators of index system is innovation output ability (A1), which only decomposes one secondary indicator, that is the innovation output (B1), making the link to be directly transferred as $x_{A_1} = x_{B_1} = 0.449$.

The first-level indicators of index system is innovation input ability (A2), which is the dovetail mutation system that consist of the second level of indicators, including the innovation activities (B2), the innovation resources (B3) and the innovation environment (B4), given as:

$$x_{B_b} = \sqrt{x_{B_2}} = \sqrt{0.645} = 0.803, x_{B_c} = \sqrt[3]{x_{B_3}} = \sqrt[3]{0.735} = 0.902,$$
$$x_{B_d} = \sqrt[4]{x_{B_4}} = \sqrt[4]{0.437} = 0.813,$$

This is a complementary system. So, in accordance with the principle of "complementary mean", the index value of the innovation input (A2) is equal to

$$x_{A_2} = (x_{B_b} + x_{B_c} + x_{B_d})/3 = (0.803 + 0.902 + 0.813)/3 = 0.839.$$

First-level index system

The innovation capability of high-tech enterprises is decomposed into two primary indexes: innovation output (A1) and innovation input (A2), according to the requirements of mutation series method. Because there is a cusp mutation model, then

$$x_{A_a} = \sqrt{x_{A_1}} = \sqrt{0.449} = 0.670, x_{A_b} = \sqrt[3]{x_{A_2}} = \sqrt[3]{0.839} = 0.9943,$$

In the same manner as described above, we will calculate respectively the other provinces and autonomous regions of the two indicators of innovation and output (B1), innovation resources (B2), innovation activities (B3) and innovation environment (B4) and first-level indicators of innovation and production (A1) and innovation into the results of A2. Results of the final evaluation of the innovation capability system of the high-tech enterprises in the 29 provinces and municipalities are directly under the central government and autonomous regions and are shown in Table 2.

Evaluation and analysis of enterprise innovation capability

It can be seen from Table 2 that the innovation ability of the high-tech enterprises in the eastern provinces is better than that in the central and western regions. In addition to Sichuan Province, the top ten are the eastern provinces and cities while the last five are from the western region. But the western region also has a strong ability to innovate, such as Sichuan Province which ranked sixth in the country. Ranking 18, Guizhou's high-tech enterprises in the western region is weak in innovation capacity and is at a lower level. The national high-tech enterprise innovation ability as a whole keeps increasing from the western inland to the eastern coastal areas.

As shown in Figure 2, the innovation capacity of high-tech enterprises in 29 provinces (autonomous regions and municipalities directly under the central government) is mainly concentrated in the three regions: the regional areas in the eastern coastal region (I), the central and southwestern parts of the region (II) and the northwest inland, the southwest and northeast region (III). The

Table 2. Results of 29 provinces nationwide city innovation ability evaluation of high-tech enterprises.

Area	Innovation output	Ranking	Innovation input	Ranking	Innovation ability	Ranking
Guangdong	0.865312	1	0.863551	2	0.941248	1
Beijing	0.844628	2	0.841137	5	0.931500	2
Zhejiang	0.834124	3	0.845605	3	0.929468	3
Jiangsu	0.792298	4	0.840955	6	0.917004	4
Tianjin	0.789376	5	0.722750	26	0.892945	5
Sichuan	0.719047	6	0.816499	15	0.891311	6
Anhui	0.713864	7	0.821620	13	0.890755	7
Shanghai	0.682641	10	0.843145	4	0.885468	8
Fujian	0.702301	9	0.802531	18	0.883665	9
Shandong	0.679318	11	0.810132	17	0.878214	10
Hunan	0.667964	12	0.822208	12	0.877060	11
Chongqing	0.702635	8	0.749669	23	0.873330	12
Shaanxi	0.605602	18	0.903247	1	0.872427	13
Hubei	0.641365	17	0.839917	7	0.872180	14
Hainan	0.650369	14	0.817121	14	0.870674	15
Liaoning	0.646445	16	0.811103	16	0.868305	16
Yunnan	0.654004	13	0.790111	20	0.866591	17
Guizhou	0.598527	19	0.839454	8	0.858490	18
Henan	0.649315	15	0.726891	25	0.852466	19
Hebei	0.587847	20	0.801571	19	0.847818	20
Jiangxi	0.545724	22	0.786339	21	0.830867	21
Heilongjiang	0.498141	25	0.834681	10	0.823667	22
Shanxi	0.585413	21	0.674114	28	0.820972	23
Jilin	0.525425	23	0.746825	24	0.816069	24
Ningxia	0.472158	28	0.839052	9	0.815160	25
Gansu	0.474538	27	0.823034	11	0.813005	26
Xinjiang	0.493290	26	0.769437	22	0.809344	27
Guangxi	0.501352	24	0.700941	27	0.798182	28
Inner Mongolia	0.341278	29	0.589241	29	0.711276	29

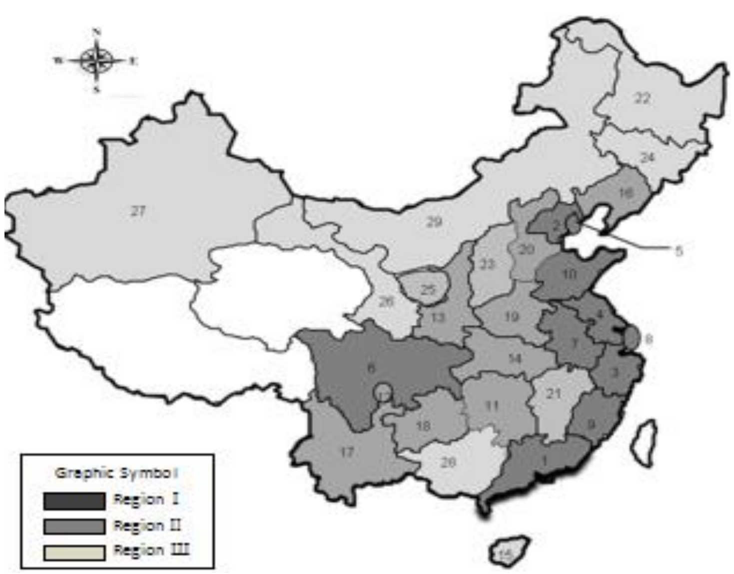


Figure 2. 29 provinces (municipalities and autonomous regions) distribution area of high-tech enterprises' innovation capability.

provinces of the region I are mainly provinces and cities in the eastern coastal region, the most of which rank top ten in terms of innovation capacity. They are Shandong (10), Fujian (9), Shanghai (8), Anhui (7), Tianjin (5), Jiangsu (4), Zhejiang (3), Beijing (2) and Guangdong (1). However, there are inland provinces such as Sichuan (6) squeezed into the top ten.

Most cities in Region III are in inland, with enterprise innovation capacity ranking in the last ten, such as Xinjiang (27), Ningxia (25), Inner Mongolia (29), Gansu Province (26), Shanxi (23), Guizhou (20) and Jiangxi (21) in the Yangtze River Basin, Guangxi (28) and Heilongjiang (22). The 10 provinces, autonomous regions and high-tech enterprises are at a lower state in the country's ability, and their innovation capacities are poor. The provinces of Region II are mainly located in the central and southwestern parts of the country, with enterprise innovation capacity ranking mainly concentrated in 11 to 19, such as Shaanxi (13), Henan (19), Guizhou (18), Yunnan (17), Liaoning (16), Hainan (15), Hubei (14), Chongqing (12). The nine provinces, the city's high-tech enterprise innovation capability in the country is located in the middle and the level of innovation is better.

In order to quantify the innovation efficiency of each region, the innovation efficiency (innovation efficiency = innovation output / innovation input) of high-tech industry in each region is calculated according to the data in Table 2, as shown in Table 3.

As can be seen from Table 3, the area of the bold font is located in Area I in Figure 3, with the first echelon of innovation capacity, the top ten in innovation capacity, and most of its innovation efficiency also high. Only the innovation efficiency of Shandong and Shanghai fell out of the top ten. Similarly, the area represented by the black normal font is located in Area III in Figure 3, where the innovation capacity is weak and its innovation efficiency is also ranked after twenty. The area represented by the oblique font is located in Area II in Figure 3. The innovation capacity is located in the middle of the country, and the innovation efficiency in most areas is similar to that of its innovation capacity. Only the innovation efficiency of Shaanxi and Guizhou is relatively low.

From the chart it can be seen that innovation and innovation efficiency are closely related to the specific trend shown in Figure 3. Innovation efficiency and innovation capacity of the relationship between the level of innovation and efficiency directly affect the number of innovation and output, as well as the size of innovation

SUGGESTIONS AND COUNTER MEASURES

As shown in Figure 2 and Table 3, the innovation capability of high-tech enterprises in China can be divided into three regions, with differences in innovation output, innovation investment and innovation efficiency. Therefore, considering the three aspects above, the present study makes some targeted suggestions to enhance the innovation ability of high-tech enterprises in the three regions.

Proposal and countermeasures of Region I

The innovation efficiency and innovation output of high-tech enterprises in this area are high; as a result, the high-tech enterprises in this area should set up enterprise innovation resource base, increase innovation investment, and also keep up the potential development that is innovation-driven. To be specific, improvements can be made in the following aspects:

1) Formulating the evaluation mechanism of innovation talents within enterprises: The enterprises should regularly evaluate the innovation level of employees, judging by the dimensions such as the engagement and the achievement in innovation activities. Evaluation results should be matched with the salary and welfare, according to which the innovation talents at different levels are better distinguished, and the higher the rating scale they have, the better benefits they enjoy.

2) Setting up enterprise innovation fund base which includes special funds for innovation talents and scientific research: Special fund for talents is specially used for the training and introduction of high-level creative talents. Regular innovative training to employees should be regularly conducted within the enterprise, and quantified evaluation should be applied in training performance and results which are included in the performance of employees' participation in innovation activities. The enterprises would evaluate the early innovation achievements of the high level innovative talents being introduced into the enterprises according to the evaluation system. On the basis of the evaluation results, besides some preferential treatment prescribed by the company, the talents also enjoy a one-time high subsidy in terms of housing, traffic etc. Setting up special funds for scientific research is to ensure the flow of funds for R&D activities of enterprises. The enterprises themselves should continue to invest in scientific research, and the support of policy-based financial institutions is also essential. As shown in the previous research results, little support for innovation from financial institutions is achieved. Therefore, banks and other financial institutions should optimize the loan risk compensation mechanism for enterprises’ developing innovative project, and provide more financial support for enterprise innovation activities under the premise of safeguarding the bank's own interests.

3) Setting up enterprise R & D Department: According to the evaluation results of the innovative talents, the high-level innovative talents should establish the enterprise scientific research department which is responsible for

Table 3. The country's 29 provincial high-tech enterprise innovation efficiency evaluation results.

Area	Innovation input	Innovation output	Innovation efficiency	Innovation efficiency ranking	Innovation capability ranking
Tianjin	0.72275	0.789376	1.092184	1	5
Beijing	0.841137	0.844628	1.00415	2	2
Guangdong	0.863551	0.865312	1.002039	3	1
Zhejiang	0.845605	0.834124	0.986423	4	3
Jiangsu	0.840955	0.792298	0.942141	5	4
Chongqing	0.749669	0.702635	0.93726	6	12
Henan	0.726891	0.649315	0.893277	7	19
Sichuan	0.816499	0.719047	0.880647	8	6
Fujian	0.802531	0.702301	0.875108	9	9
Anhui	0.82162	0.713864	0.868849	10	7
Shanxi	0.674114	0.585413	0.868418	11	23
Shandong	0.810132	0.679318	0.838528	12	10
Yunnan	0.790111	0.654004	0.827737	13	17
Hunan	0.822208	0.667964	0.812403	14	11
Shanghai	0.843145	0.682641	0.809637	15	8
Liaoning	0.811103	0.646445	0.796995	16	16
Hainan	0.817121	0.650369	0.795927	17	15
Hubei	0.839917	0.641365	0.763605	18	14
Hebei	0.801571	0.587847	0.733369	19	20
Guangxi	0.700941	0.501352	0.715256	20	28
Guizhou	0.839454	0.598527	0.712996	21	18
Jilin	0.746825	0.525425	0.703545	22	24
Jiangxi	0.786339	0.545724	0.694006	23	21
Shanxi	0.903247	0.605602	0.670472	24	13
Xinjiang	0.769437	0.49329	0.641105	25	27
Heilongjiang	0.834681	0.498141	0.596804	26	22
Inner Mongolia	0.589241	0.341278	0.579182	27	29
Gansu	0.823034	0.474538	0.576572	28	26
Ningxia	0.839052	0.472158	0.562728	29	25

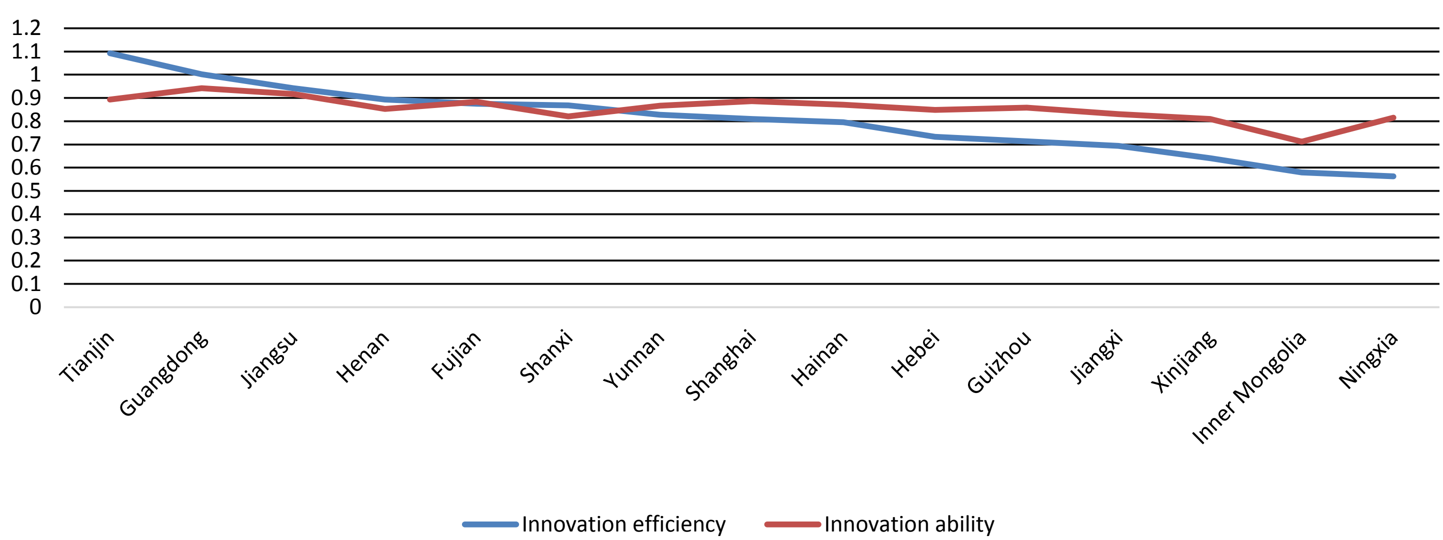


Figure 3. The relationship between innovation efficiency and innovation ability.

enterprise leaders directly. The innovation fund base and the innovative talents evaluation system should ensure the capital and talent, specializing in tackling technology problems on products and services and continuously improving the technological content of products with the service, as well as market competitiveness.

Proposal and countermeasures of Region II

The innovation efficiency and innovation output of the enterprises in the region are generally in the middle level, with investment in innovation relatively small. In particular, the innovation environment is relatively poor. Thus, the region should focus on improving the innovation environment and promoting the industrial development. Specific recommendations are as follows:

i) Strengthening the government's support for high-tech enterprises and establishing a relatively "relaxed" business survival environment: Establishing and constantly improving a motivating and guiding mechanism of the financial funds, such as state-owned investment company investment and other forms of indirect financial expenditure, as well as guiding private capital and other social capital to enter, and constantly enrich and improve the innovation investment system. Establish a set of diversified capital to support the process and innovation of enterprise innovation. To promote or guide the risk of funds and venture capital companies on the role of innovation. On the one hand, it will be good for the enterprise to provide adequate funding for innovation activities; on the other hand, it will establish and improve the risk protection mechanism to minimize the enterprises innovation team, especially to reduce the risk and loss of innovation and their early development.
ii) Adjust the enterprise innovation tax incentives, focus on supporting major technical research, major market development and other key projects and important links so that investment and reinvestment of enterprises engaged in research will enjoy investment credit policy: Due to high cost, financing difficulties, insufficient support efforts and other reasons, many companies lack the funds to carry out systematic R & D activities. A considerable number of high-tech enterprises can only support low-level of technology research and development, which seriously hinders the Guizhou high-tech enterprises from attaining the pace of high-end innovation breakthrough.
iii) Led by the government, enterprises serve as the main body to hold technical seminars and the achievements exhibition exchange meeting on a regular basis. We should strengthen technical and economic exchanges with other regions both at home and abroad to raise the level of exposure to the outside world. From the results of the study, the high degree of openness of Guizhou's high-tech enterprises in the western eight provinces ranked low in the country, ranking 29 among other provinces (autonomous regions and municipalities). It will not only affect the overall high-tech enterprises in Guizhou in expanding the scale of the market, but also affect the process of enterprise technology and the ability to accelerate the improvement of innovation. Therefore, it is necessary to formulate a relatively preferential trade policy, encourage foreign trade and exchange of high-tech enterprises, and hold regularly Chinese and foreign innovation products exhibitions to strengthen the exchanges and cooperation between Guizhou high-tech enterprises and other high-tech enterprises in other regions raising its degree of exposure to the outside world.

Proposal and countermeasures of Region III

The innovation output and innovation efficiency of enterprises in this region are very low, while the innovation investment is relatively high. Therefore, enterprises in this region should improve their innovation efficiency and enhance their capacity for innovation output. To be specific, measures are as follows:

i) The technician should become the owner of the company through the joint-stock reform in enterprises, allow the technical elements to fully participate in the distribution of income, and enhance the determination and motivation of scientific research staff to carry out innovative activities. The enterprises should establish and optimize the supporting incentive mechanism for technician, and increase satisfaction of technicians in welfare and occupation career, which is the fundamental path to guarantee that the enterprises would get more resources of high-quality innovative talents.
ii) Integrate innovative resources to build an innovation platform with enterprise as the main bodies. For the current high-tech enterprises in Guizhou Province, the characteristics of innovative environment and different institutions include having the resources; hence, it is necessary to build an innovation cooperation platform joined by many parties. High-tech enterprises will provide the innovation platform with necessary machinery and equipment. Universities, Research institutes, as well as university science and technology parks will provide the platform for human resources; financial institutions and governments can provide financial support for the platform to ensure that there is sufficient funding for innovation activities. Guide the advantages of multi-resources into the scientific and technological innovation cooperation platform, which is similar to the stereoscopic structure. In this way, not only can they give full attention to their own characteristics and advantages, but will also enjoy high efficiency, low cost of implementation of innovative activities, which is more conducive to the

sharing of innovative achievements and utilization.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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