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Applying Grey Relational Analysis to Evaluate the Factors Affecting Innovation Capability:

Evidence from Chinese High-Tech Industries[1]

APPLICATION DE L'ANALYSE RELATIONNELLE GRIS D'ÉVALUER LES FACTEURS AFFECTANT LA CAPACITÉ D'INNOVATION:

PREUVE EN PROVENANCE DE LA HAUTE TECHNOLOGIE DE L'INDUSTRIE CHINOISE

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Abstract: For the studies on the innovation capability, there are many limitations in using traditional statistical techniques. The grey system theory proposed in this paper is to supplement the limitations of using traditional techniques and it is more suitable to figure out the significance of influencing factors for facilitating innovation capability. Based on the statistical data from Chinese high-tech industries, over the period 2006-2008, this paper used fifteen indicators affecting the innovation capability, and it applied grey relational analysis to find out the significant factors. The results show that expenditure and persons engaged in science and technology activities are the significant factors affecting innovation capability within Chinese high-tech industries, and the efficiency for input-output of resources is less significant factor, which implies that the efficiency for input-output within Chinese high-tech industries is lower, and its effect to facilitate Chinese high-tech industrial innovation capability is insignificant. In order to facilitate Chinese high-tech industrial innovation capability, the government and enterprises should pay enough attentions to not only the expenditure and personnel engaged in science and technology activities, but also enhancing the efficiency for input-output of technology resources.
Key words: Innovation capability; Grey relational analysis; Chinese high-tech industries

Résumé: Pour les études sur la capacité d'innovation, il ya beaucoup de limitations dans l'utilisation de techniques statistiques traditionnelles. La théorie des systèmes de gris proposées dans ce document est de compléter les limites de l'utilisation des techniques traditionnelles et il est plus approprié pour comprendre l'importance de facteurs d'influence pour faciliter la capacité d'innovation. Basé sur les données statistiques du chinois industries de haute technologie, sur la période 2006-2008, ce papier utilisé quinze indicateurs affectant la capacité d'innovation, et l'a appliqué l'analyse relationnelle grise pour découvrir les facteurs significatifs. Les résultats montrent que les dépenses et les personnes engagées dans des activités scientifiques et technologiques sont des facteurs importants qui affectent la capacité d'innovation au sein chinoise industries de haute technologie, et l'efficacité pour les entrées-sorties de ressources est un facteur moins important, ce qui implique que l'efficacité d'entrées-sorties au sein chinoise industries de haute technologie est plus faible, et son effet de faciliter chinoises de haute technologie capacité d'innovation industrielle est insignifiante. Afin de faciliter chinoises de haute technologie capacité d'innovation industrielle, le gouvernement et les entreprises devraient payer des attentions assez pour non seulement les dépenses et le personnel engagé dans les activités

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scientifiques et technologiques, mais aussi améliorer l'efficacité des entrées-sorties de ressources technologiques.

Mots clés: La capacité d'innovation; Gris analyse relationnelle; De la haute technologie de l’industrie chinoise

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INTRODUCTION

Ample theories and empirical studies provided a lot of evidence that innovation capability from high-tech industries in one country will enhance the national innovation capability. In this regard, the relevant issues on exploring the influencing factors for facilitating innovation capability has been attracted enough attentions of government officers and scholars. In the firm level, some scholars established some indicators for assessing the innovation capability (XIA, 2005), and in the industrial level, particularly in high-tech industrial level, less research on evaluating the innovation capability is found, a minority of research related assessing the efficiency for innovation in industrial level used input indicators and output indicators to estimate the innovation efficiency of each industry. As for the influencing factors for facilitating innovation capability in Chinese high-tech industries and assessing the significance of each influencing factor, less corresponding research was found.

With the rapid growth of Chinese economy, Chinese industrial innovation has been attracted attentions of scholars from many counties and regions all over the world. Generally, As for the relevant research on innovation for the Chinese high-tech industries, there are two directions: a) the research on the relationship between innovation performance and technological channels, such as FDI, exports, imports, and so on (LIU, Buck T., 2007); b) the research on the efficiency for innovation of industries (LI, 2009).

Previous research techniques used frequently on the related studies were the factor analysis and regression analysis, OLS with fixed effects and OLS with random effects methods. Multivariate statistical methods need a large of number of data to analyze, and the distribution of the data must be the normal distribution. However, traditional multivariate statistical methods could have a hard time obtaining a persuasive explanation. According to what was mentioned above, multi-attribute method may be used to solve the problems (Felix T. CHAN S., CHUNG S. H., 2005). In order to supplement the limitations from the research methods above, this paper proposes using grey relational analysis to evaluating the influencing factors in facilitating innovation capability within Chinese high-tech industries. The grey system theory proposed by Deng has been extensively applied in a lot of fields and get excellent performance, such as financial institutions, advertising agencies, management (KUNG, CHENG, 2004; LIN, HSU P. F., 2001; LIN, YANG, 1999; TU, LIN, FANG, 2001), and so on.

This paper was organized as follows: The introduction was followed by a brief discussion of the theory of innovation in industry level. In section 2 the research design, including research variables and data procuring were given. In section 3 the methodology was provided. In section 4 the empirical results were given, In section 5 some conclusions with valuable advices were put forward.

1. RESEARCH DESIGN

1.1 Research Variables

There were many indicators used by scholars to evaluate innovation capability for enterprises level, and there were less studies on evaluating the innovation capability for industries level, and there were three types indicators for evaluate innovation capability for enterprises, such as input indexes, output indexes, efficiency indicators, and so on. This paper used three above types of indicators affecting innovation capability in Chinese high-tech industries, as for the detailed information of indicators, please refer to Table 1.

1.2 Data Procuring

According to the classed criteria from the China Statistics Yearbook on High Technology Industry, the high-tech industries mainly include five general industries, such as manufacture of medicines, manufacture of aircrafts and spacecrafts, manufacture of electronic equipment and communication equipment, manufacture of computers and office equipments, manufacture of medical equipments and measuring instrument. In order to enhance the accuracy of the research results, this paper applied the relevant statistical data of five general high-tech industries, over the period 2006-2008. All the data came from China Statistics Yearbook on High Technology Industry. Due to the limitation of the length of this paper, the correlative original data was omitted.

2. METHODOLOGY

The methodology used in this paper was grey relational analysis, which is a quantitative analysis to explore the similarity and dissimilarity among factors in developing dynamic process (DENG, 1989). The theory proposes a dependence to measure the correlation degree of factors, the more similarity develop, the more factors correlate. It uses the grey relational grade to measure the relation degree of factors. The related methods and theories of the grey relational analysis were described as follows:

Table 1: The Synthetic Weighing of Three Years, 2006-2008 (takes mean)

	Synthetic effect weighing	Year 2006	Year 2007	Year 2008	Total period	Rank
X_1	Funds for S&T activities	0.3191	0.327	0.3407	0.3289	1
X_2	Intramural expenditure for R&D	0.3185	0.3259	0.3357	0.3267	2
X_3	Expenditure on technical renovation	0.1649	0.1904	0.2883	0.2145	11
X_4	Expenditure on technology import	0.3080	0.3081	0.3152	0.3104	5
X_5	Expenditure on technology absorption	0.2862	0.2643	0.2866	0.2790	6
X_6	Expenditure on purchase of domestic technology	0.2095	0.1495	0.1817	0.1802	14
X_7	Personnel for scientific and technologic (S&T) activities	0.3108	0.3083	0.3387	0.3193	4
X_8	Scientists and engineers in S&T personnel	0.3149	0.3135	0.3421	0.3235	3
X_9	Scientists and engineers to personnel for S&T activities ratio	0.2247	0.1852	0.2091	0.2063	12
X_{10}	Sales revenue from new products to funds for S&T activities ratio	0.2446	0.2608	0.1869	0.2308	10
X_{11}	Sales revenue from new products to personnel for S&T activities ratio	0.2542	0.2564	0.1862	0.2323	8
X_{12}	Owning inventive patent to funds for S&T activities ratio	0.1723	0.1302	0.1077	0.1367	15
X_{13}	Owning inventive patent to personnel for S&T activities ratio	0.1533	0.221	0.218	0.1974	13
X_{14}	Industrial output value of new products to funds for S&T activities ratio	0.2453	0.2636	0.1856	0.2315	9
X_{15}	Industrial output value of new products to personnel for S&T activities ratio	0.2546	0.2585	0.1872	0.2334	7

(1) The basic model of grey systems theory. The original series formed by $P(X)$ is:

$$x_i = (x_i(1), x_i(2), x_i(3), \cdots, x_i(k)) \in X \quad (1)$$

Before calculating the grey relational grade, we must perform data processing (Hsia K. H., CHEN M.Y., CHANG M.C., 2004), which is called grey relational generating. So, the series data can be treated with the following three situations and the linearity of normalization to avoid distorting the normalized data.

If the expectancy is larger-the-better, then it can be expressed as follows:

$$x_i^*(k) = \frac{x_i^{(0)}(k) - \min x_i^{(0)}}{\max x_i^{(0)}(k) - \min x_i^{(0)}(k)} \quad (2)$$

If the expectancy is smaller-the-better, then it can be expressed by

$$x_i^*(k) = \frac{\max x_i^{(0)} - x_i^{(0)}(k)}{\max x_i^{(0)}(k) - \min x_i^{(0)}(k)} \quad (3)$$

If the expectancy is nominal-the-better, then the target value can be expressed by

$$x_i^{(0)}(k) = 1 - \frac{\left|x_i^{(0)}(k) - OB\right|}{\max\left\{\max x_i^{(0)}(k) - OB, OB - \min x_i^{(0)}(k)\right\}} \quad (4)$$

Where

$x_i^{(k)}$: values generated from grey relational generating operation;

$\min x_i^{(0)}(k)$: The minimum value of $x_i^{(0)}(k)$ or the smallest factor in the i th sequence;

$\max x_i^{(0)}(k)$: The maximum value of $x_i^{(0)}(k)$ or the largest value in the i th sequence;

OB: The chosen value of $x_i^{(0)}(k)$ or the chosen value in the i th sequence.

(2) Grey relational grade. In the grey relational space which is denoted by $\{P(X);\Gamma\}$, the sequence $x_i(k)=(x_i(1), x_i(2), \cdots, x_i(k)) \in X$ exits, the grey relational coefficient are $\gamma(x_0(k), x_i(k))$ and expressed as follows:

Partial analysis: When there is only a sequence $x_0(k)$ to be the reference sequence and the others are comparable sequence, the definition of the grey relational grade is as follows:

The grey relational grade $\Gamma_{0i}=\Gamma\left(x_0(k), x_i(k)\right)=\dfrac{\bar{\Delta}_{\max}-\bar{\Delta}_{0i}}{\bar{\Delta}_{\max}-\bar{\Delta}_{\min}}$, (5)

Where:

a) x_0 represents referable sequence, x_i represents comparable sequence.

b) $\bar{\Delta}_{0i}=\|x_{0i}\|_\rho=\left(\sum_{k=1}^{n}[\Delta_{0i}(k)]^2\right)^{\frac{1}{2}}$.

c) $\Delta_{0i}=\|x_0(k)-x(k)\|$: The (k) difference's absolute value between x_0 and x_i.

d) $\Delta_{\min}=\forall_{j\in i}^{\min}\forall^{\min}k\,\|x_0(k)-x_i(k)\|$.

e) $\Delta_{\max}=\forall_{j\in i}^{\max}\forall^{\max}k\,\|x_0(k)-x_i(k)\|$.

Global grey relational analysis: When sequence $x_i(k)$ could be the referable sequence and others are the comparable sequences, the definition of the grey relational grade is as follows:

If $\Gamma_{ij}=\Gamma(x_i, x_j)=1-\dfrac{\bar{\Delta}_{ij}}{\Delta_{\max}}$, then is could be get $m\times m$ grey relational grades $r(x_i, x_j)$, after putting all of the grey relational grades in order, then we are in a position to get a $m\times m$ matrix, it is called grey relational matrix R as follows:

$$R=\begin{bmatrix}\Gamma_{11} & \Gamma_{12} & \Gamma_{13} & \cdots & \Gamma_{1m}\\ \Gamma_{21} & \Gamma_{22} & \Gamma_{23} & \cdots & \Gamma_{2m}\\ \Gamma_{31} & \Gamma_{32} & \Gamma_{33} & \cdots & \Gamma_{3m}\\ \vdots & \vdots & \vdots & \ddots & \vdots\\ \Gamma_{m1} & \Gamma_{m2} & \Gamma_{m3} & \cdots & \Gamma_{mm}\end{bmatrix} \quad (6)$$

After getting the matrix model, every element is the weighting of grey relational grade and the method of getting weighting is as follows:

a) Getting the grey relational matrix R;

b) Calculating the characteristic weighting of the grey relational matrix R;

c) Calculating the characteristic vector quantity P and P^{-1}, $RP=diag\{\lambda_1,\lambda_2,\lambda_3,\cdots,\lambda_m\}$;

d) Choose the largest characteristic vector corresponding to the largest value $\lambda_{\max}$,and the value $\lambda_{\max}$ is the weighting.

The weighting in terms of grey relational matrix could explain the significant evaluation in a system, this paper applied globalization grey relational analysis to evaluate the influence degree of influencing factors.

3. EMPIRICAL RESULTS

In order to explore the relationship between influencing factors and innovation capability in Chinese high-tech industries, this paper employed grey relational analysis to evaluate the significant degree of influencing factors. Before calculating the grey relational grade, this paper performed data pre-processing in order to make sure how to deal with each variable data. The selected fifteen indicators using the expectancy were larger-the-better effect. Based on the grey relational analysis discussed in this paper, this paper employed a program by using Matlab toolbox programming language in windows platform. Then we could get three 15×15's grey relational matrix, Due to the length of this paper, the grey relational matrices for the data in the year 2006 was reported in appendix A, the grey relational matrices for the data in the year 2007 and 2008 were omitted. This paper calculated the weighting λ of grey relational matrix and the corresponding characteristic vector of largest weighting. The characteristic vector is considered as weighting of each variable.

After taking means for the weighting of each indicators, over the period 2006-2008, we could get the top eight indicators affecting the innovation capability as follows: funds for S&T activities (X_1), intramural expenditure for R&D (X_2), scientists and engineers in S&T personnel (X_8), personnel for scientific and technologic (S&T) activities (X_7), expenditure on technology import (X_4), expenditure on technology absorption (X_5), industrial output value of new products to personnel for S&T activities ratio(X_{15}) sales revenue from new products to personnel for S&T activities ratio (X_{11}).

CONCLUSIONS

This paper used fifteen influencing factors as research variables and through the globalization grey relational analysis to find out the significant influencing factors affect facilitating the innovation capability of Chinese high-tech industries, over the period 2006-2008. The descriptions of research results were as follows:

Firstly, through using globalization grey relational analysis, the research results showed that the top five affect facilitating innovation capability of Chinese high-tech industries of fifteen influencing factors are: funds for S&T activities (X_1), intramural expenditure for R&D (X_2), scientists and engineers in S&T personnel (X_8), personnel for scientific and technologic (S&T) activities (X_7), expenditure on technology import (X_4). So, we could find that human resources and expenditure on science and technology are the most significant influencing factors for facilitating innovation capability within Chinese high-tech industries. Therefore, in order to facilitate innovation capability within Chinese high-tech industries, it is suggested to promote the input resources on scientists and technicians and expenditure on science and technology activities. Government and enterprises should provide the guarantee for expenditure input, what is more, government and enterprises should establish effective mechanism for attracting and reserving person with strong skill capability, particularly those with core technology and capability.

Secondly, through the research results, we could find that input-output efficiency indicators, such as sales revenue from new products to funds for S&T activities ratio, owning inventive patent to funds for S&T activities ratio, owning inventive patent to personnel for S&T activities ratio, industrial output value of new products to funds for S&T activities ratio, industrial output value of new products to personnel for S&T activities ratio, etc, were insignificant influencing factors for facilitating innovation capability of Chinese high-tech industries. It is shown that the input-output efficiency within Chinese high-tech industries is lower, which did not make great contribution to facilitate innovation capability within Chinese high-tech industries. So, the problems of increasing the efficiency of input-output should attract more attentions of Chinese government officers and scholars, because the efficiency of input-output will not be another significant influencing factor until its efficiency is larger. In addition, we could find that grey system theory is suitable for evaluating the relationship between influencing factors and innovation capability and is an important technique for government and scholars to find out the more objective and successful influencing variables.

Appendix A. Grey Relational Grade Matrix for the İndicators in Year 2006

R=[1.0000 0.9729 0.4385 0.9361 0.7902 0.4743 0.9242 0.9533 0.3932 0.3890 0.4153 0.2843 0.2105 0.3907 0.4175;

0.9729 1.0000 0.4244 0.9445 0.7665 0.4588 0.9061 0.9308 0.4021 0.4053 0.4316 0.2797 0.2110 0.4071 0.4338;

0.4385 0.4244 1.000 0.3898 0.5671 0.6145 0.4836 0.4622 0.2288 0.0000 0.0336 0.1822 0.1991 0.0031 0.0354;

0.9361 0.9445 0.3898 1.0000 0.7327 0.4225 0.8931 0.9161 0.3645 0.3878 0.4112 0.2567 0.1717 0.3895 0.4134;

0.7902 0.7665 0.5671 0.7327 1.0000 0.6145 0.8086 0.8088 0.3754 0.2853 0.3150 0.3333 0.2623 0.2866 0.3169;

0.4743 0.4588 0.6145 0.4225 0.6145 1.0000 0.5169 0.4974 0.3085 0.1999 0.2257 0.3751 0.2975 0.2023 0.2266;

0.9242 0.9061 0.4836 0.8931 0.8086 0.5169 1.0000 0.9657 0.3578 0.3457 0.3709 0.2805 0.1922 0.3478 0.3730;

0.9533 0.9308 0.4622 0.9161 0.8088 0.4974 0.9657 1.0000 0.3666 0.3577 0.3831 0.2821 0.1961 0.3595 0.3852;

0.3932 0.4021 0.2288 0.3645 0.3754 0.3085 0.3578 0.3666 1.0000 0.4986 0.5293 0.5381 0.7085 0.4997 0.5300;

0.3890 0.4053 0.0000 0.3878 0.2853 0.1999 0.3457 0.3577 0.4986 1.0000 0.9572 0.3008 0.2745 0.9938 0.9546;

0.4153 0.4316 0.0336 0.4112 0.3150 0.2257 0.3709 0.3831 0.5293 0.9572 1.0000 0.3134 0.3000 0.9584 0.9965;

0.2843 0.2797 0.1822 0.2567 0.3333 0.3751 0.2805 0.2821 0.5381 0.3008 0.3134 1.0000 0.6379 0.3008 0.3124;

0.2105 0.2110 0.1991 0.1717 0.2623 0.2975 0.1922 0.1961 0.7085 0.2745 0.3000 0.6379 1.0000 0.2750 0.2999;

0.3907 0.4071 0.0031 0.3895 0.2866 0.2023 0.3478 0.3595 0.4997 0.9938 0.9584 0.3008 0.2750 1.0000 0.9558;

0.4175 0.4338 0.0354 0.4134 0.3169 0.2266 0.3730 0.3852 0.5300 0.9546 0.9965 0.3124 0.2999 0.9558 1.0000]

According to global grey relational analysis method, the maximum λ =7.7552, therefore, eigenvector for each factor is as follows:

[0.3191 0.3185 0.1649 0.3080 0.2862 0.2095 0.3108 0.3149 0.2247 0.2446 0.2542 0.1723 0.1533 0.2453 0.2546]

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