

Technology innovation evaluation model based on factor analysis

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Abstract. According to the bad effect of the existing evaluation model of technology innovation in practical application, an evaluation model of enterprise technology innovation is proposed based on factor analysis. On the basis of the elements in input-output process, the multi-index comprehensive evaluation method is adopted. The multiple statistical indicators that described something considered different aspects and different dimension are converted to the relative value of the dimensionless. Then according to the different forms of innovation unit, two cases that with no intermediate inputs and intermediate input are for two-stage evaluation. Simulations show that the proposed evaluation model has better effect in the evaluation of enterprise technology innovation, which is deserved to be promoted.

1 INTRODUCTION

In practice, the evaluation of enterprise technological innovation ability is the feedback to the performance of enterprise technology innovation, and plays a very important role in the enterprise management of technology innovation, which makes the enterprise technology innovation process, completed a positive feedback mechanism with open loop to closed-loop [Cooke & Uranga & Etxebarria, 2012.]. So, how to objectively and systematically and really evaluate the innovation ability of enterprise technology, to find out the influencing factors of enterprise technology innovation, the method which combines qualitative and quantitative is used to regulate and guide on the improvement of enterprise technology innovation. And provide the scientific basis for the enterprise and other decision makers, which is a very meaningful evaluation of science and technology [Wu, 2014].

The evaluation researches of enterprise technology innovation are mainly in the following respects. Clark [Clark, 2007] put forward that the technological innovation ability can measure from two aspects, which are product innovation and process innovation. Product innovation is the integrated embodiment of the enterprise industry development cycle, product development efficiency and comprehensive its product quality, and process innovation is the integrated embodiment of the enterprise production process equipment development, production test, batch production. From the perspective of organizational behavior, Larry E.westPha thinks that enterprise technology innovation is the comprehensive ability of the organizational, adaptive and innovative and technology and the information [Larry &Yung & Garry, 2014]. Seven Muller thinks that technology innovation is the integrated ability of product development, improving production technology, reserve capacity and organization[Seven, 2013]. Burgelman thinks that technology innovation ability is consisted by the available resources, understanding of industry competitors, understanding of environmental capacity, the company's organizational culture and structure and pioneering strategy, etc[Burgelman, 2011]. From the enterprise technology innovation behavior subjects, Bartonthinks that technology innovation ability is consisted by the skills of technicians and senior technicians, technical system, management ability, values, etc [Barton, 2011]. From the four big directions as the external environment, investment and manufacturing and output of technological innovation, Ren Shulin establishes an evaluation index system for industrial technology innovation ability[Ren, 2006]. From the innovation resources allocation, explore capacity, innovation found support and the innovation output, Wang designs a set of evaluation index system of technology innovation which is suitable for Chinas high and new technology industry[Wang, 2007]. Wu Youjun builds up the evaluation in-

dex system of industrial technology innovation [Wu, 2014]. Wang Shicai et al. set the target layer, criterion layer and index layer by innovation comprehensive evaluation of quantitative technology, and formulate the fifth evaluation set of expert evaluation [Wang, 2012]. Chen Xiaohong et al. establish a dynamic evaluation model of innovation system based on the total factor productivity and the BP neural network [Chen, 2011]. Liu Jinshu et al. analyze the industrial technology innovation ability evaluation target and evaluation content, and further to determine the components of industrial technology innovation ability [Liu, 2007].

According to the demand of the enterprise technology innovation evaluation, an evaluation model of technological innovation is put forward based on factors analysis, and simulations show its good performance.

2 MULTI-INDEXES COMPREHENSIVE EVALUATION BASED ON FACTORS ANALYSIS

Based on high technology industry evaluation index system of technology innovation, technology development and technology transformation stage, there are a variety of input elements and a variety of output results in its input and output process. The multi-index comprehensive evaluation method is adopted, which can make statistical indicators convert to the relative evaluation value of dimensionless, and synthetically the value to get a whole for the matters.

(1) Standardization of the sample data

The essence of standardization is transforming the sample for standardization data with zero average and 1 variance. Set there are n samples, p indicators while get the data matrix $X = (X_{ij})_{n \times p}$, $i = 1, 2, \dots, n$ means No. i sample, $j = 1, 2, \dots, p$ means the No. j index, X_{ij} means the No. j index value of the No. i sample, the matrix is $Z = (z_{ij})_{n \times p}$ after standardization.

$$z_{ij} = \frac{x_{ij} - \bar{x}_j}{S_j} \quad (1)$$

In the equation (1),

$$S_j^2 = \frac{1}{n-1} \sum_{i=1}^n (x_{ij} - \bar{x}_j)^2 \quad (2)$$

$$\bar{x}_j = \frac{1}{n} \sum_{i=1}^n x_{ij} \quad (3)$$

(2) Complete the correlation matrix of index data

Each element in correlation matrix is expressed by the corresponding coefficient of correlation. Assume that r_{jk} is the correlation coefficient of index k and index j , while the correlation matrix can be expressed as $R = (r_{jk})_{p \times p}$.

(3) According to the correlation matrix R to determine the composition

p characteristic roots λ_g can be obtained by the characteristic equation $|\lambda I_p - R| = 0$. λ_g in order of size is $\lambda_1 \geq \lambda_2 \geq \dots \geq \lambda_p \geq 0$, it is the main component of variance, it is the variance of the main component. And its size describes the role of each principal component in the description being the evaluation objects. Each characteristic root corresponds to a feature vector, assuming that the g characteristic vector for $L_g = (l_{g1}, l_{g2}, \dots, l_{gp})$, then the No. g principal component can be represented as the equation (4).

$$F_g = \sum_{i=1}^p \frac{l_{gi}}{\sqrt{\lambda_g}} Z_i \quad (4)$$

(4) According to the variance contribution rate determine the number of principal components

Principal component analysis is to select k principal components ($k < P$) less as far as possible for comprehensive evaluation, and the loss of information as little as possible. Extraction principle of the number of principal components is the cumulative variance contribution ratio to reach a certain percentage, generally require cumulative variance contribution rates of 85% or 90%.

(5) k principal components for comprehensive evaluating

Comprehensive evaluation of multiple indexes is weighted sum for k main components. The weight of each principal component is proportion that the variance contribution rates of the principal component in cumulative variance contribution rates of k principal components, namely the comprehensive evaluation value can be represented as the equation (5).

$$F = \frac{\sum_{i=1}^k \lambda_i F_i}{\sum_{j=1}^k \lambda_j} \quad (5)$$

According to the above method, input indexes and output indexes of the enterprise are for synthetically evaluating respectively, then enterprise technology innovation index and the technical development of output index can be obtained. Accordingly, respectively, the input indexes and output indexes for of technology transfer phase are for comprehensive evaluation, and then technical transformation input indexes and output indexes can be obtained.

3 TWO-STAGE EVALUATION OF ENTERPRISE TECHNOLOGY INNOVATION

When evaluating innovation unit of technology innovation, not only through investigation innovation unit of different forms of the decomposition efficiency, innovation is also a study unit in the overall situation of the whole process of technological innovation, namely the high technology industry technology innovation. According to whether to add other intermediate input, it can be divided into two cases to discuss.

3.1 Two phase evaluation with no intermediate input

Considering two stages are diminishing marginal returns, for the sample points $A(X_{jk}, I_{jk}, Y_{jk})$ in the system, $A_1(X_{jk}, I_{jk})$ means sample points that A in the first phase, $A_2(I_{jk}, Y_{jk})$ means sample points of unit A in the second stage.

The input of unit A in the first phase is X_{jk} , and the output is I_{jk} , for this phase, output oriented model can be set up, as shown in the equation (6).

$$\begin{cases} \sum_{i=1}^n \sum_{t=1}^T \lambda_{it} I_{it} \geq \rho_{jk}^1 I_{jk} \\ \sum_{i=1}^n \sum_{t=1}^T \lambda_{it} X_{it} \leq X_{jk} \\ \sum_{i=1}^n \sum_{t=1}^T \lambda_{it} = 1 \end{cases} \quad (6)$$

According to the equation (6), projection point of $A_1(X_{jk}, I_{jk})$ in the first phase front surface can be determined as $A_1^*(X_{jk}, I_{jk}^*)$. Therefore, in the first stage, the technical evaluation of A_1 is $E_{jk}^1 = I_{jk} / I_{jk}^*$.

Suppose the efficiency value of unit A achieve maximum on the first stage, namely the middle output of unit A can achieve ideal value I_{jk}^* in the first stage, while of the sample points of A in the second phase from A_2 to $B_2(I_{jk}^*, Y_{jk})$, therefore, the output oriented model can set up in this phase, such as equation (7).

$$\begin{cases} \sum_{i=1}^n \sum_{t=1}^T \lambda_{it} I_{it} \geq \rho_{jk} Y_{jk} \\ \sum_{i=1}^n \sum_{t=1}^T \lambda_{it} X_{it} \leq I_{jk}^* \\ \sum_{i=1}^n \sum_{t=1}^T \lambda_{it} = 1 \end{cases} \quad (7)$$

According to the equation (7), projection points of B_2 in the second stage edge can be determined as $B_2(I_{jk}^*, Y_{jk}^{**})$, $Y_{jk}^{**} = \rho_{jk} Y_{jk}$. Therefore, if the two stages are effective, the output of unit A can achieve Y_{jk}^{**} , aimed at the system level, technical evaluation of unit A is $E_{jk} = Y_{jk} / Y_{jk}^{**}$.

3.2 Two stage evaluation with no intermediate input

If both phase does not exist the phenomenon of increasing marginal benefit, for the sample points $A(X_{jk}, I_{jk} + M_{jk}, Y_{jk})$, X_{jk} is the input of the first phase, I_{jk} is the middle output, M_{jk} is the applied middle input, Y_{jk} is the output of the second phase, $A_1(X_{jk}, I_{jk})$ means sample points of A in the first phase, $A_2(I_{jk} + M_{jk}, Y_{jk})$ means sample points of unit A in the second stage.

The input of unit A in the first phase as X_{jk} , output as I_{jk} , output oriented model can be set up in this phase, as shown in equation (6).

According to the equation (6), projection points of $A_1(X_{jk}, I_{jk})$ in the first phase surface can be determined as. Therefore, in the first stage, the technical efficiency of A_1 is $E_{jk}^1 = I_{jk} / I_{jk}^*$.

Suppose the efficiency value of unit A is maximum in the first stage, namely the middle output of the unit A can achieve ideal value I_{jk}^* in the first stage, the sample points of A in the second phase from $A_2(I_{jk} + M_{jk}, Y_{jk})$ to $B_2(I_{jk}^* + M_{jk}, Y_{jk})$, therefore, can choose equation (8) in the stage.

$$\begin{cases} \sum_{i=1}^n \sum_{t=1}^T \lambda_{it} Y_{it} \geq \rho_{jk} I_{jk} \\ \sum_{i=1}^n \sum_{t=1}^T \lambda_{it} I_{it} \leq I_{jk}^* + M_{jk} \\ \sum_{i=1}^n \sum_{t=1}^T \lambda_{it} = 1 \end{cases} \quad (8)$$

According to the equation (8), projection points of B_2 can be determined as $B_2^*(I_{jk}^*, Y_{jk}^{**})$ in the second stage edge, $Y_{jk}^{**} = \rho_{jk} Y_{jk}$. Therefore, under the condition of two phases are effective, the output of unit A can achieve to Y_{jk}^{**} . Aimed at the system level, technical evaluation of unit A is $E_{jk} = Y_{jk} / Y_{jk}^{**}$.

4 PERFORMANCE SIMULATION OF ALGORITHM

To verify the validity of the proposed evaluation model, instance simulation test for the model. 30 technical enterprises in province as an example, its statistical data are derived from the 2015China statistics yearbook on high technology industry, the proposed model is adopted to carry out the evaluation of technological innovation, the results shown in figure 1, and the actual result is shown in figure 2.

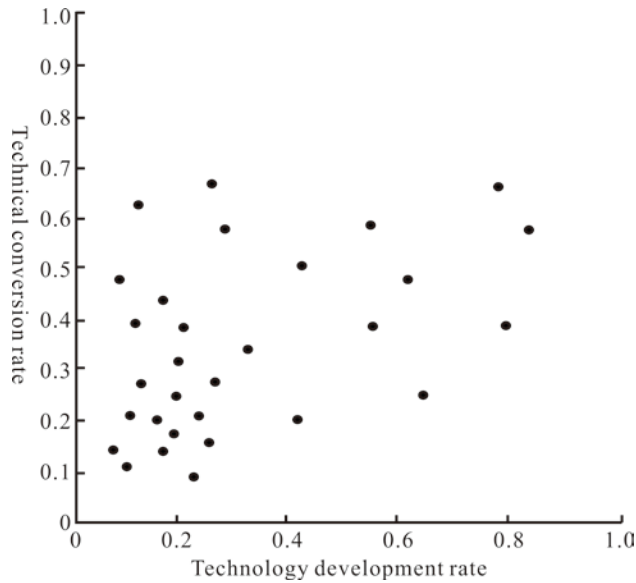


Figure 1. Technology innovation evaluation results of 30 companies

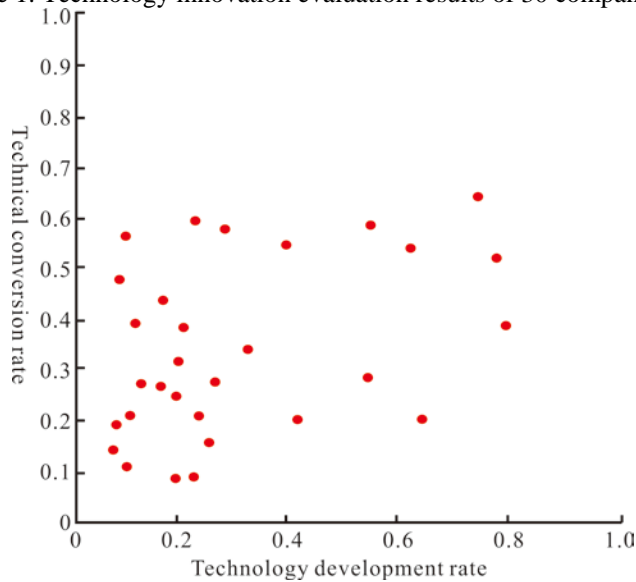


Figure 2. Technological innovation actual results of 30 enterprises

From simulations, the proposed evaluation model has good effect in evaluation of technological innovation.

5 CONCLUSIONS

Technical innovation is the soul of high-tech industries, but from the perspective of the level of high and new technology industry technology innovation, it still has certain gaps compared with the developed countries in our country. Therefore, the study of the formation of high and new technology industry technology innovation level and the evaluation of the level of high and new technology industry technology innovation has important theoretical significance and practical value. According to the demand of the enterprise technology innovation evaluation, an evaluation model of technological innovation is put forward based on factors analysis, and simulations show that the proposed model has good evaluation result.

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