Research on Enterprise Innovation Performance Based on DEA and SNA

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Affected by the national policy and macro economic environment, the domestic large enterprises actively promote strategic transformation to enhance the core competitiveness. Evaluation of the innovation performance of the enterprise, this article studies is focused on introducing the basic theory of social network analysis, Based on data envelopment analysis (DEA) was improved, this paper selected 52 manufacturing listed companies as the research object, using DEA and SNA method for manufacturing the innovation performance of listed companies in 2015 were analyzed.

1. Introduction

Enterprise innovation activities are to shift production and application of an organizational knowledge creation process, Bernini (2013) reported that also bring science and technology management methods and the innovation of social and political system. Our country enterprise innovation resources and strength are increased, Clement (2011) reported that the number of national economy and national comprehensive competitive ability also constantly improve, make our country in the world political and economic status continues to rise.

A country's science and technology innovation and innovation activities of big companies have close ties. Jahanshahloo (2015) reported that Affected by the national policy and macro economic environment, actively promote the strategic transformation of China's enterprises to enhance the core competitiveness, Corporate R&D spending, practitioners in the number of R&D personnel, staff education and training for enterprise.

To the enterprise innovation performance, help enterprises to grasp the evaluation itself and the status of the industry innovation, Omarsson (2012) reported that enterprise managers find innovation problems and reasons, further improve the way of enterprise innovation, Ramalho (2010) reported that Macroeconomic research department as well as to country and understand the development of the enterprise innovation path.

2. Theoretical review

2.1 The basic principle and mode of DEA

In 1978, by the American scholar Charnes-Cooper etc. Put forward the concept of data envelopment analysis has been more than 20 years. It is to have multiple outputs as decision unit, the application of mathematical programming model to evaluate the relative effectiveness of decision making units. Since chames waiting C^2R of DEA model, this kind of the production frontier is constructed to unit relative efficiency evaluation method has received the widespread attention, and obtained the rapid development. This article mainly involves C^2R, C^2GS^2 two models. The following will detail the two models.

2.1.1 C^2R Model

Suppose there are n department or unit (Called decision making units DMU), each decision making unit (DMU$_j$) has m kinds of input and output, S corresponding vector, respectively.

$$x_j = \left(x_{1j}, x_{2j}, ..., x_{mj}\right)^T > 0 \,, \, y_j = \left(y_{1j}, y_{2j}, ..., y_{mj}\right)^T > 0 \quad (j = 1, 2...n);$$

The weight coefficient of V , U respectively: $V = \left(v_1, v_2, ...v_m\right)^T$, $U = \left(u_1, u_2, ...u_s\right)^T$. And set

$$x_{ij}, y_{ij}, v_i > 0, v_r > 0, (\text{r=1,2,...,s,i=1,2,...,m})$$

$$
\begin{array}{ccc}
 & & \text{DMU}_1 \quad \text{DMU}_2 \quad \cdots \text{DMU}_j \\
\end{array}
$$

$$
\begin{array}{ccc}
v_1 & 1 & \rightarrow \\
\vdots & \vdots & \vdots \\
v_m & m & \rightarrow \\
\end{array}
\begin{array}{cccc}
x_{11} & x_{12} & \cdots & x_{ij} \\
\vdots & \vdots & \vdots & \vdots \\
x_{m1} & x_{m2} & \cdots & x_{mj} \\
\end{array}
$$

$$
\begin{array}{cccc}
y_{11} & y_{12} & \cdots & y_{1n} \\
\vdots & \vdots & \vdots & \vdots \\
y_{s1} & y_{s2} & \cdots & y_{sj} \\
\end{array}
\begin{array}{ccc}
\rightarrow & 1 & u_1 \\
\vdots & \vdots & \vdots \\
\rightarrow & s & u_s \\
\end{array}
$$

C^2R Modeling Notation

For the first j a decision-making unit efficiency of DMU has a corresponding evaluation index:

(1-1)

$$h_j = \frac{u^T y_j}{v^t x_j}, \, j = 1, 2, ..., n$$

For the linear planning objectives, Set for constraint conditions is h_j, and $j=1,2...n$, which Make up the appraisal DMU$_j$ optimization model (C^2R for short).

$$\max \frac{u^T Y_0}{v^T X_0} = h^*_{j_0}$$

(1-2)

$$
\begin{cases}
\dfrac{u^T Y_j}{v^T X_j} \leq 1, \, j = 1, 2, ...n \\
u \geq 0, v \geq 0
\end{cases}
$$

Among them, the m kind of input power coefficient is $V = \left(v_1, v_2, ...v_m\right)^T$, s kind of input power coefficient

is $U = \left(v_1, v_2, ...v_s\right)^T$ .From fraction by Chames a Cooper transform formula (formula 1-2) can be transformed into equivalent linear programming model (formula1-3) (formula1-4).

(1-3)

$$t_0 = \frac{1}{v^T X_0} > 0$$

$$\omega = tv, \mu = tu$$

$$\max u^T Y = h^*_{j_0}$$

(1-4)

$$
\begin{cases}
\omega^T X_j - u^T Y_j \geq 0, \, j = 1, 2, ...n \\
\omega^T X_o = 0 \\
\omega \geq 0, \mu \geq 0
\end{cases}
$$

Charnes-Cooper also introduces the Archimedes infinitesimal, using the dual model is established of formula to determine the effectiveness of decision making units. Set ε is A less than any positive number (i.e., the Archimedes dimensionless) and greater than zero, the DEA model can be converted to

$$\max \left(u^T Y_0 + \delta u_0 \right) \tag{1-5}$$

$$\begin{cases} \omega^T X_j - u^T Y_j - \delta u_0 \geq 0, \ j = 1, 2, ...n \\ \omega^T X_o = 0 \\ \omega^T \geq 0, \mu^T \geq \varepsilon \bullet e^{\hat{T}} \end{cases}$$

Its dual planning for

$$\min \left[\theta - \varepsilon (e^{\hat{T}} S^- + e^{\hat{T}} S^+) \right]$$

$$\begin{cases} s.t. \sum_{j=1}^{n} X_j \lambda_j + S^- = \theta X_o \\ \sum_{j=1}^{n} Y_j \lambda_j - S^+ = Y_0 \\ \lambda_j \geq 0, \ j = 1, 2, ...n, \\ S^-, S^+ \geq 0 \end{cases} \tag{1-6}$$

In this formula, $e^{\hat{T}} = [1,1,...,1] \in E^m, e^T = [1,1,...,1] \in E^s$, $S^- and\ S^+$ are Slack and remaining variables respectively, m and s dimension Column vector respectively. X_j, Y_j are respectively the first j a decision-making unit DMU_j set of input and output indicators.

2.1.2 C^2GS model

C^2R model judgment on the decision making units in technology and scale effectively at the same time. But in some practical application of DEA method, Due to the input and output indicators for variables, through the relative efficiency may be optimized by the n times because of irrelevant to the actual weight or some weight to 0, which led to the error of judgment. But decision-making unit quantity is large. Therefore, we need further analysis to eliminate the scale under the influence of the relative effectiveness of analysis. C^2GS^2 is based on the C^2R model which only considering the effectiveness of the model, the corresponding linear programming as follow,

$$\min \left[\theta - \varepsilon (e^{\hat{T}} S^- + e^{\hat{T}} S^+) \right] \tag{1-7}$$

$$\begin{cases} s.t. \sum_{j=1}^{n} X_j \lambda_j + S^- = \theta X_o \\ \sum_{j=1}^{n} Y_j \lambda_j - S^+ = Y_0 \\ \sum_{j=1}^{n} \lambda_j = 1 \\ \lambda_j \geq 0, \\ j = 1, 2, ...n, \\ S^-, S^+ \geq 0 \end{cases}$$

3. Based on social network analysis to discriminate DEA analysis

3.1 The basic idea

Each area as individual network, namely basic network nodes, For R&D input and output unit can be used as an effective area of effective area of the reference object (learning), the corresponding weight coefficient of index factor into the value as the weight of the node. Again through the integrated computation of weights, finally get to regional unit as a network node adjacency matrix, by eigenvector center degree value of sorting the sorting of the regional R&D performance, because the center degree value can reflect the impact area unit in the network.

3.2 Analyse process

Using social network analysis method of basic network DEA analysis, the main computational steps are as follows:

The first step: to calculate the relative effectiveness of DEA specifications for all decision-making units.

(1-8)

$$\min \hat{\theta}_k^t$$

$$
\begin{cases}
s.t. \sum_{j=1}^{n} \lambda_{jk}^t x_{ij}^t + s^- = \hat{\theta}_k^t x_{ik}^t, i = 1,...,m \\
\sum_{j=1}^{n} \lambda_{jk}^t x_{rj}^t - s^+ = y_{rk}^t, r = 1,...,s \\
\sum_{j=1}^{n} \lambda_{jk}^t = 1 \\
\theta_k^t, \lambda_{jk}^t \geq 0. j = 1,2,...,n
\end{cases}
$$

The second step: the standardization of k under the condition of DEA segment, smaller effective organization, on the input and output size is usually small, therefore the effective unit of relatively large and easy to get a higher value.

(1-9)

$$IW_{ij}^{t,k} = \frac{\lambda_{jk}^t x_{ij}^t}{\sum_{j \in E}^{n} \lambda_{jk}^t x_{rj}^t}$$

$$0 < IW_{ij}^{t,k} \leq 1$$

Similarly, in DEA detailed t

(1-10)

$$OW_{ij}^{t,k} = \frac{\lambda_{jk}^t y_{ij}^t}{\sum_{j \in E}^{n} \lambda_{jk}^t y_{rj}^t}$$

$$0 < OW_{ij}^{t,k} \leq 1$$

Standardized λ

(1-11)

$$IOW_{jk}^{t,k} = \frac{1}{m+s}(\sum_{i=1}^{n} IW_{ij}^{t,k} + \sum_{i=1}^{n} OW_{ij}^{t,k})$$

The third step, create the base network,

(1-12)

$$A = \left[\sum_{i=1}^{n} IOW_{jk}^t \right]$$

The fourth step is to calculate the characteristics of the network node vector concentration,

$$cI_j = \sum_k A_{ij} I_j \qquad (1\text{-}13)$$

4. Empirical Analysis

4.1 Data Sources

Data in this paper mainly has 52 manufacturing listed companies in 2012 the number of R&D funds R&D intensity of R&D personnel enterprise R&D personnel accounted for the total number of employees than the year-on-year growth rate of sales revenue enterprise patent number on the overall Labor productivity profit total asset-liability ratio, Focusing on automobile appliance pharmaceutical industry, three samples of more than 30 cars home appliance enterprises all the specific conditions of the pharmaceutical industry in DEA analysis section.

4.2 DEA analysis

Enterprise independent innovation is a complicated process, to establish the evaluation index system is the foundation of scientific evaluation system for performance evaluation of enterprise innovation which can specifically to quantitatively analyze the innovation performance.

Table 1: Performance evaluation of listed enterprise innovation

Company Type	Descriptive Index	Combined efficiency	Pure technical performance	Scale performance
Home appliance	max	0.09	0.36	0.25
	min	1	1	1
	average	0.55	0.75	0.66
medical	max	0.06	0.2	0.22
	min	1	1	1
	average	0.41	0.6	0.66
car	max	0.14	0.5	0.17
	min	1	1	1
	average	0.4	0.8	0.48

The comprehensive efficiency of pure technical efficiency and scale efficiency of the enterprise comprehensive analysis of the overall study of the causes of enterprise innovation efficiency is low, pure technical efficiency is not lower than the scale efficiency of enterprise has 41 Therefore, as a whole, 2014 listed companies innovation efficiency is low, mainly due to low scale efficiency.

5. Results and Conclusion

According to the results of DEA analysis, in 2012 the innovation performance of listed companies in our country as a whole is low The comprehensive efficiency innovation good or better accounted for only 25% of the total, achieve DEA efficient enterprises only 11, 21.5% of the total it shows that the enterprise resource allocation ability resources use efficiency there is a big problem Comprehensive efficiency of the pharmaceutical industry and automobile industry average at around 0.4, DEA efficient enterprise less, furthermore, the enterprise production efficiency due to technical factors, namely each decision-making unit inputs in optimal scale has a better production efficiency So overall high pure technical efficiency of listed companies in our country.

According to the above conclusions, in order to promote the innovation efficiency of large enterprises in our country, from the industry and enterprise three levels of government, should give full play to the functions of the

government, clear the government positioning, establish the market position, give full play to the function and role of market economy to actively support the innovation of the enterprise research and development, form industry level also need to change the development mode actively, take concrete and effective policies and measures to enhance the support of an application for a patent for new drug research and development and, forming a batch of internationally competitive high-tech.

References

Asava-vallobh, N., Gronberg, T. J., & Jansen, D. W. (2013). Introducing a new DEA methodology for environmental inputs. Applied Economics Letters, 20(17), 1592-1595. doi: 10.1080/13504851.2013.826865

Bernini, C., Guizzardi, A., & Angelini, G. (2013). DEA-Like Model and Common Weights Approach for the Construction of a Subjective Community Well-Being Indicator. Social Indicators Research, 114(2), 405-424. doi: 10.1007/s11205-012-0152-3

Clement, J. P., Valdmanis, V. G., Bazzoli, G. J., Zhao, M., & Chukmaitov, A. (2011). Response to modeling and notation of DEA with strong and weak disposable outputs. Health Care Management Science, 14(4), 391-391. doi: 10.1007/s10729-011-9162-y

Chen, H. C., Hsu, S. Y., Chang, T. L., & Yang, S. L. (2010). Applying DEA and Taguchi methods in plant selection and optimal layout to increase commerce management environment quality. African Journal of Business Management, 4(18), 4079-4085.

Ding, J. J., Feng, C. P., Bi, G. B., Liang, L., & Khan, M. R. (2015). Cone ratio models with shared resources and nontransparent allocation parameters in network DEA. Journal of Productivity Analysis, 44(2), 137-155. doi: 10.1007/s11123-014-0420-0

Huang, C., Dai, C., & Guo, M. (2015). A hybrid approach using two-level DEA for financial failure prediction and integrated SE-DEA and GCA for indicators selection. Applied Mathematics and Computation, 251, 431-441. doi: 10.1016/j.amc.2014.11.077

Jahanshahloo, G. R., Soleimani-damaneh, M., & Ghobadi, S. (2015). Inverse DEA under inter-temporal dependence using multiple-objective programming. European Journal of Operational Research, 240(2), 447-456. doi: 10.1016/j.ejor.2014.07.002

Krivonozhko, V. E., Forsund, F. R., & Lychev, A. V. (2015). Terminal units in DEA: definition and determination. Journal of Productivity Analysis, 43(2), 151-164. doi: 10.1007/s11123-013-0375-6

Ma, J. H., Zhang, Q., & Ma, C. Y. (2012). The optimization of state-owned enterprise group development model based on the method of DEA. Frontiers of Manufacturing and Design Science Ii, Pts 1-6, 121-126, 2343-2347. doi: 10.4028/www.scientific.net/AMM.121-126.2343

Omarsson, B., Bjarnason, E. H., Haughey, S., Ingolfsson, O., & Field, T. A. (2012). Bond formations and rearrangement reactions in DEA experiments. Xxvii International Conference on Photonic, Electronic and Atomic Collisions (Icpeac 2011), Pts 1-15, 388. doi: Artn 05202010.1088/1742-6596/388/5/052020

Ramalho, E. A., Ramalho, J. J. S., & Henriques, P. D. (2010). Fractional regression models for second stage DEA efficiency analyses. Journal of Productivity Analysis, 34(3), 239-255. doi: 10.1007/s11123-010-0184-0

Sueyoshi, T., & Goto, M. (2012). Returns to Scale, Damages to Scale, Marginal Rate of Transformation and Rate of Substitution in DEA Environmental Assessment. Energy Economics, 34(4), 905-917. doi: 10.1016/j.eneco.2012.04.003

Sun, X. Y., Zhou, L., & Liu, Q. G. (2012). An Approach for Evaluating Journals of Universities or Colleges Based upon Multi-layer Efficiency DEA. International Conference on Solid State Devices and Materials Science, 25, 678-686. doi: 10.1016/j.phpro.2012.03.143

Ting, C. T., & Huang, C. W. (2012). Measuring the Effectiveness of Mutual Learning for Taiwan's Tourist Hotels with the DEA Approach. Cornell Hospitality Quarterly, 53(1), 65-74. doi: 10.1177/1938965511425364

Tokic, D. (2012). Managed Futures for Long-Term Investors: A DEA Ranking Analysis. Australian Economic Review, 45(4), 422-440. doi: 10.1111/j.1467-8462.2012.00699.x