Research on Fuzzy Dynamic Evaluation Approach for ERP Benefits-application in China

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Abstract

This paper puts forward a new dynamic approach to evaluate Enterprise Resource Planning (ERP) benefits. In this paper, essential financial indicators are used to calculate the effect of sample enterprises which have executed ERP implement for more than 5 years in China. The method we proposed in this paper is based on the fuzzy statistical analysis and fuzzy rule based decision support system. According to the yield study, we find that it is different from our expectation, there is a positive impact in the first few years after the ERP implement; but then, the trend of the ERP performance will be downside to be negative as time goes by, it is surprising, we think it may be caused by marketing environment changes; at last, the trend of the ERP performance will be stable and a little rise. We think the trend fits the actual situation more, and prove the effectiveness of our approach.

Keywords*: ERP, Fuzzy Dynamic Evaluation, The ERP Performance.*

1. Introduction

In recent years, ERP has been applied to company management by many companies because of its function to reduce operating costs, shorten cycle times and improve customers' satisfaction. For example, in China there are some enterprises such as Lenovo, Hang Zhou Iron and Steel Group Company, Haier and Hongta Group Company has invested large amounts of money in ERP. Opinion of ERP advocates is that the positive benefits of ERP will increase firm's financial performance and enhance competitiveness.

But as many companies in China had no scale and competence advantage, lack technology and service innovation[18], after performing ERP, many enterprises found the phenomenon that they got little even negative benefit from it.

To conduct ERP, enterprises have to invest huge capital charges and long-term efforts with the difficult implementation and slow effect. All of above may reduce the benefits of ERP implementation. It is estimated that about 95% of the enterprises have not performed the improvement of company finance after conducted the ERP[1]. ERP adoption success is not guaranteed[15]. The time lag problem and the business cycle also induce the failure of applying ERP. In fact, in years after performing ERP, it may contribute to a considerable sum of corporate budget[19]. Many researchers argue that a longer time horizon after implementation analysis is preferred[2,3,4].

On the other hand, enterprises which perform the ERP are unable to examine its profitable improvement. Since to calculate the ERP performance accurately is hard, it is influenced by some impacts such as economic conditions, transportation and political policy. So it is hard to found an appropriate evaluation approach on ERP performance.

In fact, experts present some approaches in detecting and testing procedures for ERP performance. Among them, t-test and event study method are mostly used[5,6,7,4]. Although all these procedures are easy to perform, the disadvantages of them are also obviously. Because the decimal cost/benefit comparison comes from that calculate the ERP benefits can not be immediately identified, but costs can instead5. On the other hand, an explicit statistical model also means lack of structure change, it makes investigating statistical properties of the models and making forecasts difficult.

In this paper, we present an integrated testing procedure to evaluate the ERP performance, our evaluation approach contains a single financial factor effect and a single company's performance

evaluation. The ERP impact of time and impact of company size from fuzzy rule base are are proposed for the testing hypothesis of ERP impact; in section 3, we give an empirical research about ERP impact on China; in section 4, we give out our conclusions.

2. modelling

2.1. Previous methods

It is obvious that when enterprises increase investment in the computer/technology, then companies' administration and benefit will gain positively help. And many researches have proven it; improving investment in the computer/technology will reduce growth in operating expense, increase cost efficiency and return on assets, and some other indicates[8]. Evaluation process of ERP systems needs to take many criteria into account[16,17].This paper summarizes the essential factors which every factor has 2 elements: 1. Analysis of operation: (1.1) Accounts Receivable Turnover; (1.2) Inventory turnover; 2. Analysis of profitability: (2.1) Pretax profit to sales; (2.2) Gross profit ratio; 3. Analysis of investment return: (3.1) Return on total assets; (3.2) Return on common equity;4. Analysis of growth rate: (4.1) Sales Growth Rate; (4.2) Gross Profit Growth Rate, as financial performance evaluation indicators to evaluate the ERP. Table 1 shows the relationship between factors and elements[9,10,11,12,13,14,4].

Table 1. The relationship between factors and elements

Factors	Elements
Analysis of operation	Accounts Receivable Turnover Inventory turnover
Analysis of profitability	Pretax profit to sales Gross profit ratio
Analysis of investment return	Return on total assets Return on net assets
Analysis of growth rate	Sales Growth Rate Gross Profit Growth Rate

In Table 1, Accounts Receivable Turnover = Net Revenue/average accounts receivable;
Inventory turnover = Cost of GoodsSold / average s inventories;
Pretax profit to sales = Pre-tax income/ revenues;
Gross profit ratio = Gross profit/ revenues;
Return on total assets = Earning Before Interest and Tax (EBIT)/average assets;
Return on net assets = Profit after tax/ Working capital;
Sales Growth Rate = Sales of Current period-Sales of Base period/Sales of Base period;
Gross Profit Growth Rate = Gross Profit of Current period -Gross Profit of Base period/Gross Profit of Base period.

2.2. Design of Evaluations

If we want to calculate the performance improvements with a new system, then a long term evaluation is necessary. Base on this, this paper think that the changes in enterprise performance from 1 years before ERP implementation, and to 1,2,3,4 and 5years after ERP implementation.

By observing n_t enterprises' financial indicates, this paper evaluate the ERP performance with fuzzy logic rule base. In the research, we define the degree of financial linguistic fluctuation to be{very down (very non-efficient) = [–1,- 0.5), down (non-efficient) = [-0.5, -0.1), unchanged (medium) = [-0.1, 0.1], high (efficient) = (0.1, 0.5], very high(very efficient) = (0.5, 1]}. The basic purpose to design the evaluation approach is that to calculate the steady state behavior after ERP, this paper applies median filter tool. Median filter tool is a robust statistics comparing with mean filter, since little changes of certain factors may derive from noise, but when we use mean filter tool, little changes may effect our evaluation result. And why this paper thinks 1.3 times and 1.1 times of median filter as the threshold values of linguistic degree is that we confirm it base on general practical experience and human thought. The procedure below shows how the evaluation process is.

Algorithm for a single factor's evaluation procedure

Step 1: denote n_t as the number of enterprises at time t; let x_{ijt} be the i[th] standardized financial feature of j[th] firm at t year, where i=1,2,…m, meaning the number of features, j=1,2,… n_t. Measure $\Delta x_{ijt} = x_{ijt} - x_{ij0}$, then $m_{it} = \underset{1\le j\le n_t}{median}\left|\Delta x_{ijt}\right|$.

Step 2: compute $l(\Delta x_{ijt})$ the i[th] financial linguistic variable of j[th] firm at t year.

$$l(\Delta x_{ijt}) = \begin{cases} 1 & if \Delta x_{ijt} > 1.3m_{it} \\ 0.5 & if\ 1.1m_{it} < \Delta x_{ijt} \le 1.3m_{it} \\ 0 & if\ -1.1m_{it} \le \Delta x_{ijt} \le 1.1m_{it} \\ -0.5 & if\ -1.3m_{it} < \Delta x_{ijt} < -1.1m_{it} \\ -1 & if \Delta x_{ijt} < -1.3m_{it} \end{cases} \quad (1)$$

Step 3: compute $\overline{x_{it}} = \frac{1}{n_t}\sum_{j=1}^{n_t} l(\Delta x_{ijt})$, it means the financial linguistic value for the average of n_t firms.

Step 4: calculate $x_t = \sum_{i=1}^{m} w_i \overline{x_{it}}$, meaning the weighted ERP performance of a factor, and w_i indicate the weight of the i[th] feature, we have $\sum_{i=1}^{m} w_i = 1.$

Step 5: get the result according to fuzzy rule base:

If $x_t > 0.5$, then we say the ERP performance of this factor is "very high" which means very efficient up to year t;

If $0.1 < x_t \le 0.5$, it is high, i.e. efficient up to year t;

If $-0.1 \le x_t \le 0.1$, it represents unchanged, i.e. medium up to year t;

If $-0.5 \le x_t < -0.1$, it means non-efficient up to year t;

If $x_t < 0.5$, it means very non-efficient up to year t.

Algorithm for macro evaluation procedure

Step 1: denote X_{it} as the weighted ERP performance of the i[th] factor.

Step 2: compute $X_t = \sum_{i=1}^{m} W_i X_{it}$, meaning the weighted performance of the macro-ERP, and W_i indicate the weight of the i[th] feature, we have $\sum_{i=1}^{m} W_i = 1.$

Step 3: get the result according to fuzzy rule base:

If $X_t > 0.5$, then we say the macro-ERP performance is "very high" which means very efficient up to year t;

If $0.1 < X_t \le 0.5$, it is high, i.e. efficient up to year t;

If $-0.1 \le X_t \le 0.1$, it represents unchanged, i.e. medium up to year t;

If $-0.5 \le X_t < -0.1$, it means non-efficient up to year t;

If $X_t < 0.5$, it means very non-efficient up to year t.

A test of a financial factor's ERP benefit

Step 1: denote y_{it} as the i[th] standardize financial feature of a firm at t year, compute $\Delta y_{it} = y_{it} - y_{i0}$, and $m_{it} = \underset{1 \le j \le n_t}{median} \left| \Delta x_{ijt} \right|$.

Step 2: compute $l(\Delta y_{it})$ the i[th] feature of linguistic value at t year.

$$l(\Delta y_{it}) = \begin{cases} 1 & if \Delta y_{it} > 1.3 m_{it} \\ 0.5 & if\ 1.1 m_{it} < \Delta y_{it} \le 1.3 m_{it} \\ 0 & if\ -1.1 m_{it} \le \Delta y_{it} \le 1.1 m_{it} \\ -0.5 & if\ -1.3 m_{it} < \Delta y_{it} < -1.1 m_{it} \\ -1 & if \Delta y_{it} < -1.3 m_{it} \end{cases} \quad (2)$$

Step 3: get $y_t = \sum_{i=1}^{m} w_i l(\Delta y_{it})$ meaning the weighted ERP performance of a factor, and w_i indicate the weight of the i[th] feature, we have $\sum_{i=1}^{m} w_i = 1$.

Step 4: get the result according to fuzzy rule base:

If $y_t > 0.5$, then we say the macro-ERP performance is "very high" which means very efficient up to year t;

If $0.1 < y_t \le 0.5$, it is high, i.e. efficient up to year t;

If $-0.1 \le y_t \le 0.1$, it represents unchanged, i.e. medium up to year t;

If $-0.5 \le y_t < -0.1$, it means non-efficient up to year t;

If $y_t < 0.5$, it means very non-efficient up to year t.

Fuzzy Weight Decision for ERP Factors

Researches in the past showed that people gave every factor an equal weight in the evaluation process. That means all factors have the same effect on the universe domain. But, we think different weight will contribute to a more accurate evaluation, i.e. different factors have different effect on project. Then what we get will reflect the real situation. This paper uses the fuzzy set theory and sampling survey technique to get fuzzy weight of each factor. Especially, we get an appropriate fuzzy weight with using fuzzy memberships and multiple values assignment. Below we give a definition of fuzzy weight.

Definition: Fuzzy Weight (Data with Multiple Values)

Denote U as a finite set, and define $L = \{L_1, L_2, \cdots, L_k\}$ as k-linguistic factors on U, and $\{FS_i = \frac{m_{i1}}{L_1} + \frac{m_{i2}}{L_2} + \cdots + \frac{m_{ik}}{L_k}, i = 1,2,...,N\}$ as a sequence of random fuzzy sample on U,

let m_{ij} ($\sum_{j=1}^{k} m_{ij} = 1$) be the membership with respect to L_j. Then we denote the fuzzy weight as:

$$FW = \frac{\frac{1}{N}\sum_{i=1}^{N} m_{i1}}{L_1} + \frac{\frac{1}{N}\sum_{i=1}^{N} m_{i2}}{L_2} + \cdots + \frac{\frac{1}{N}\sum_{i=1}^{N} m_{ik}}{L_k}, i = 1,2,..., N\} \quad (3)$$

We survey questionnaire to 7 experts with the universe set U = {factor 1, factor 2, factor 3, factor 4}. Then we get the fuzzy sample below showed in Table 2:

Table 2. Fuzzy Sample Survey

	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**
F_1	0.4	0.1	0.2	0.3
F_2	0.2	0.1	0.2	0.5
F_3	0.3	0.2	0.3	0.2
F_4	0.3	0.2	0.4	0.1
F_5	0.3	0.1	0.2	0.4
F_6	0.2	0.2	0.4	0.2
F_7	0.5	0.1	0.3	0.1
Total	2.2	1	2	1.8
Weight	0.31	0.14	0.29	0.26

So, the fuzzy weight can be described as:

$$FW = \frac{0.31}{1} + \frac{0.14}{2} + \frac{0.29}{3} + \frac{0.26}{4} \quad (4)$$

3. Empirical research

The survey sampling is performed in China by choosing enterprises which have publicly disclosed ERP implementation for more than 5 years.

Factor 1: Analysis of Operation

The results of accounts receivable turnover and inventory turnover are illustrated at Table 3.

We can find that the dynamic performance of the feature Accounts Receivable Turnover $\overline{x_{it}}$ is efficient ($\overline{x_{i1}}$ = 0.22, $\overline{x_{i2}}$ =0.22, $\overline{x_{i3}}$ =0.19, $\overline{x_{i4}}$ =0.28, $\overline{x_{i5}}$ =0.28). While the dynamic performance of the feature Inventory turnover is efficient in the first 2 years ($\overline{x_{i1}}$ = 0.36, $\overline{x_{i2}}$ =0.11),but the following 3 years, it turns unchanged($\overline{x_{i3}}$ =0.08, $\overline{x_{i4}}$ =0.06, $\overline{x_{i5}}$ =0), the performance turns positive to negative. Then the result of operation performance is always efficient (x_1 = 0.29, x_2 = 0.17, x_3 = 0.14, x_4 = 0.17, x_5 = 0.14), but it has a downside.

Table 3. Dynamic Performance Of Operation After ERP Implementation

Operation performance	T=1	T=2	T=3	T=4	T=5
Accounts Receivable Turnover ($\overline{X_{it}}$)	0.22	0.22	0.19	0.28	0.28
Inventory turnover($\overline{X_{it}}$)	0.36	0.11	0.08	0.06	0
Factor 1: Operation	0.29	0.165	0.135	0.17	0.14

Factor 2: Analysis of Profitability

The results of pretax profit to sales and gross profit ratio are illustrated at Table 4.

We can find that after first year of ERP implementation, the dynamic performance of pretax profit to sales fluctuated, it shows a rising trend the first 3 years from unchanged to efficient, and then itbecomes worse after the succeeding years to non-efficient. The dynamic performance of the feature Gross profit ratio also becomes worse, from efficient to unchanged and to non-efficient. The result of profitability has declined.

Table 4. Profitability after ERP implementation

Profitability performance	T=1	T=2	T=3	T=4	T=5
Pretax profit to sales ($\overline{X_{it}}$)	0.06	0.19	0.28	-0.03	-0.14
Gross profit ratio ($\overline{X_{it}}$)	0.17	-0.03	-0.14	-0.08	-0.31
Factor 2: Profitability	0.115	0.08	0.07	-0.055	-0.22

Factor 3: Analysis of Investment Return

Two financial features of investment return are return on total assets return on net assets.

Results are shown at Table 5.

The results show that, after ERP implementation, return on total assets turns to unchanged from efficient, and return on net assets is always unchanged. The performance of investment return is efficient after the first year of ERP implementation, then it turns to unchanged.

Table 5. Investment Return After ERP Implementation

Investment Return performance	T=1	T=2	T=3	T=4	T=5
Return on total assets ($\overline{X_{it}}$)	0.25	0.06	0.19	-0.11	-0.03
Return on net assets ($\overline{X_{it}}$)	0.06	-0.03	0.08	-0.17	0
Factor 3: Investment Return	0.155	0.015	0.135	-0.14	-0.015

Factor 4: Analysis of Growth Rate

The results of the two financial features, sales growth rate and gross profit growth rate, are illustrated at Table 6.

Table 6. Growth Rate After ERP Implementation

Growth Rate performance	T=1	T=2	T=3	T=4	T=5
Sales growth rate ($\overline{X_{it}}$)	0.22	0.17	-0.25	-0.19	-0.06
Gross profit growth rate ($\overline{X_{it}}$)	0.36	0.19	-0.08	-0.11	-0.08
Factor 4: Growth Rate	0.29	0.18	-0.165	-0.15	-0.07

For sales growth rate, the change is steep. The first 2 year, the performance is efficient; then, the next 2 year, it becomes non-efficient; at 5 year, it becomes unchanged. For gross profit growth rate, the case is similar, from efficient to unchanged. And for factor 4, growth rate, the performance turns to non-efficient after twp year's efficient, then at 5 year, it becomes unchanged.

The Macro ERP Performance

According to these four factors, we will test the macro ERP performance. The fuzzy weight is $FW = \frac{0.31}{1} + \frac{0.14}{2} + \frac{0.29}{3} + \frac{0.26}{4}$.

The results are shown at Table 7.

According to Table 7, we find an interesting result that the first 2 year after the ERP implementation, the macro ERP performance is efficient, then at 3 year after the ERP implementation it turns positive to negative. the EPR implementation does not meet the expected achievement, we can find that after 2-3years the ERP implementation, the trend will be stable, and a little rise.

The reason why our result shows this trend is that we think after the ERP implementation, ERP system will have a positive effect to the firms, so we get efficient result at 1 year and 2 year, but then it goes down, we think it is because that as time goes by, marketing environment has changed, and the ERP system may not adapt to these changes. After system updating, the ERP performance has a little rise, and we believe the ERP performance will be positive effect as time goes by.

Table 7. The Results of Macro-ERP Performance

	T=1	**T=2**	**T=3**	**T=4**	**T=5**
Factor 1: Analysis of Operation	0.29	0.165	0.135	0.17	0.14
Factor 2: Analysis of Profitability	0.115	0.08	0.07	-0.055	-0.22
Factor 3: Analysis of Investment Return	0.155	0.015	0.135	-0.14	-0.015
Factor 4: Analysis of Growth Rate	0.29	0.18	-0.165	-0.15	-0.07
Macro ERP Performance	0.226	0.114	0.048	-0.035	-0.010

4. Conclusions

In this paper, we propose a new way in ERP evaluation, and we give an examination with enterprises in China which have executed ERP implement for more than 5 years. The application of the fuzzy rule base to examine the benefit of ERP implementation is heuristic. From our test, we find that for single features, only account receivable turnover get positive impact, all the others are getting worse.

For 4 factors evaluation of ERP, the ERP performance of operation is efficient, while other 3 factors get worse. The ERP performance of profitability is non-efficiency, investment return factor and growth rate become unchanged.

Suggestions to Chinese enterprises: (1) there are difference between eastern company and western both management and concept, so Chinese enterprises should reform their administration concept and the management system before the ERP implement.(2)ERP system ia a complete system containing human resource, sales and management, so only part of apply of ERP can not reach the expected goal.(3) it is a long term process to put ERP system into use, maybe in short run, the performance is unchanged and even non-efficient, but in long run, we believe it will be better and efficient.

For this study, many firms wouldn't supply us entire information because of business privacy, it makes our study more difficult. Maybe we add more non-financial performance indicators, the result will be more satisfied.

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6. References

[1] S.S. Rao, "Enterprise Resource Planning: Business Needs and Technologies", Industrial Management & Data Systems, vol. 2, no. 100 , pp.81-88, 2000.
[2] T. Davenport , J. Short, In Search of ERP Paybacks, Computerworld, pp.42, 2000.
[3] E. Knorr, "Dawn of the Digital Marketplace", Upside , pp.124,1999.
[4] L. Wah, "Give EPR a Chance", Management Review , pp.20-24,2000.
[5] D.C. Hayes, J.E. Hunton , J.L. Reck, "Market Reaction to ERP Implementation Announcements", Journal of Information Systems, vol. 1, no.15 , pp.3-18, 2001.
[6] R. Poston , S. Grabski, "Financial Impacts of Enterprise Resource Planning Implementations", International Journal of Accounting Information Systems, vol. 2 ,pp.271-294,2001.
[7] J.W. Ross, "Surprising Facts about Implementing ERP", IEEE IT Pro ,pp.65-68, 1999 July/August.
[8] P. Weill, "The Relationship between Investment in Information Technology and Firm Performance: A Study of the Valve Manufacturing Sector", Information Systems Research, vol. 4, no. 3, pp.307-333, 1992.
[9] Benchmarking Partners, "ERP's Second Wave: Maximizing the Value of ERP-Enabled Processes", Deloitte Consulting Study ,1998.
[10] D.H. Bender, "Financial Impact of Information Processing", Journal of Management Information Systems, vol. 2, no. 3 , pp.232-238,1986.
[11] T. Bresnahan , S. M. Greenstein, "The Competitive Crash in Large Scale Computing, in The Mosaic of Economic Growth, Eds., Landau, Taylor, and Wright, Stanford", CA: Stanford University Press ,1996.
[12] E. Brynjolfsson, L.M. Hitt, "Computers and Economic Growth Firm Level Evidence", Unpublished Manuscript ,MIT Sloan School Cambridge, MA, 1993.
[13] Deloitte Consulting, ERP's Second Wave – Maximizing the Value of Enterprise Applications and Processes – A Global Research Report Including Deloitte Consulting's Perspective: Making ERP Spell ROI ,1999.
[14] S. Y. Harris , H.L. Katz, "Organizational Performance and Information Technology Investment Intensity in the Insurance Industry", Organization Science 3,2 ,1991.
[15] J. L. Salmeron , C. Lopez, "Forecasting Risk Impact on ERP Maintenance with Augmented Fuzzy Cognitive Maps" , IEEE TRANSACTIONS ON SOFTWARE ENGINEERING, vol. 38, no. 2 , pp. 439-452, 2012.
[16] A. C. Tolga, "Fuzzy Multi-criteria Method for Revaluation of ERP System Choices Using Real Options", Proceedings of the World Congress on Engineering , pp. 1074-1078,2011.
[17] Wei GW, Zhao XF, Wang HJ, Lin R, "GRA Model for Selecting an ERP System in Trapezoidal intuitionistic Fuzzy Setting", INFORMATION-AN INTERNATIONAL INTERDISCIPLINARY JOURNAL , vol.3, no.4, pp.1143-1148,2010.
[18] Lina Li, "Evaluation Research of Real Estate Enterprise Competitiveness with Linguistic Information", JDCTA: International Journal of Digital Content Technology and its Applications, Vol. 6, No. 4, pp. 245-251, 2012.
[19] Chao-Yen Wu, Hsin-Te Chan, Shi-Hua Wang, "A Study of Applying Modified Grey Relational Analysis Approach to Assessment Enterprise Resource Planning System Providers", JCIT: Journal of Convergence Information Technology, Vol. 7, No. 1, pp. 368-379, 2012