以資料包絡分析法評估 ERP 系統導入後投資效能之研究

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摘要

對於想要獲取商業利益及 ERP 系統效能的企業而言，資訊科技管理已經成爲關鍵的因素之一。本研究使用資料包絡分析法來評估 ERP 持續投資與技術效率之間的關係；基於整體擁有成本的概念，本研究也利用 Tobit 回歸來分析技術效率分數與 ERP 持續投資之間的關係。本研究的結果顯示：(1) ERP 系統的維護支出，對公司的技術效率有明顯的影響。(2) ERP 人員的薪資支出，對公司的技術效率有明顯的影響。(3) ERP 人員的教育訓練支出，對公司的技術效率沒有明顯的影響。(4) 對於持續投資 ERP 系統的公司而言，在技術效率上有正相關的影響。(5) 對於在台灣導入 ERP 系統的公司而言，相較於國際品牌的 ERP 系統，本土的 ERP 系統顯示出較高的技術效率。

關鍵字：企業資源規劃、效能評估、資料包絡分析、系統導入後

The Evaluation of Post Implementation ERP Investment Performance by DEA Approach

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Abstract

The information technology (IT) management has become one of the critical factors that enterprises want to assess the business benefits and performances of ERP systems. This research tries to evaluate the relationship between ERP continuous investment and technical efficiency by using DEA approach. This study also utilizes the Tobit regression to investigate the relationship between efficiency scores and ERP continuous investment based on the concept of total costing ownership (TCO) for technology assets. The research results show as follows: (1)

Maintenance expenses of ERP system whether on line or on the scene, has a favorable impact on company's technical efficiency. (2) Salary expenses of ERP personnel, has a favorable impact on company's technical efficiency. (3) Training expenses of ERP staffs has no significant impact on company's technical efficiency. (4) The company invests on ERP system continuously has positive affect on technical efficiency. (5) The local ERP systems show higher technical efficiency than international brands for those surveyed companies in Taiwan.

Keywords: Enterprise Resource Planning (ERP), Performance Evaluation, Data Envelopment Analysis (DEA), Post Implementation

1. Introduction

Enterprise resource planning (ERP) systems are information systems that support the integration of value-added processes of enterprises. Based on modular software structure and centralized database, information flows in manufacturing, finance, sales, distribution as well as human resources processes can be integrated in real time. This kind of system supports most daily activities including purchasing, sales, finance, human resources and manufacturing resource planning, etc. within a company. The ERP systems have become one of the largest IT investments for many companies during the 1990s (Chung and Snyder, 1999). Hence, the information technology (IT) management has played an important role for company running business in global competitive environment nowadays (Shao and Lin, 2002).

There are many related researches devoted to measure the business value and impact of IT in business performance (Dos Santos, 1991; Feniosky and Shunsuke, 2002; Lee, 2001;Mitra and Chaya; 1996; Mukhopadhyay and Cooper, 1993). The attitude of company toward ERP implementation is a key factor in performance gaining (Davenport, 2000). It is classified into IT projects that companies just allocate enough budgets to keep the systems working and business projects that many resources are devoted to tune business processes or ERP systems to gain more values after system going lives. Ross (1999) and Davenport (2000) suggested that companies have to keep investment continually after system going live in order to get noticeable business performance. It is expensive and time consuming for companies to implement enterprise systems (Davenport, 1998). The companies can take many years to implement enterprise systems, and cost $10 millions for a moderate size company and over $100 millions for a large international enterprise (Mabert et al., 2000). The companies would like to check the expectable benefits after implementing ERP systems. Unfortunately, the implementations of ERP do not promise abundant

business benefits obviously (Deloitte Consulting, 1999; Ross, 1999). Since ERP systems are critical to companies and expensive to acquire, some studies have been devoted to measure the impact of ERP implementation (Rosemann and Wiese, 1999; Shari and Seddon, 2000). Most of the researches are performed with case studies. Rosemann and Wiese (1999) measured the impact of ERP implementations with quantitative data. Their findings regarding to the enterprise performance in the post implementation era is inconclusive.

This study uses the data envelopment analysis (DEA) (UNESCAP, 2000) to measure with technical efficiency in the enterprise performance. We propose investigate the effects of ERP on technical efficiency in a company's production process through a two-stage analytical study. In the first stage, we utilize one output-variables: gross sales, and two input-variables: capital stock and labor expense, to measure the technical efficiency in BCC model in order to identify the best benchmark performers in our surveyed companies. In the second stage, the relationship between efficiency scores and ERP continuous investment is investigated by utilizing the Tobit regression. It is measured with items commonly used in Total Costing Ownership (TCO) of technology assets. The finding results support the arguments of Davenport (2000) and Ross (1999) in that enterprises spend more portion of IT budget in ERP systems gain better performance.

The rest of the paper is organized as following: Section 2 gives an overview of researches concerning DEA on IT and ERP measurement. In Section 3, the theory of DEA, the research methodology and hypothesis, and data collection process is presented. The research results and discussions are described in Section 4. Conclusions are discussed in Section 5.

2. Related works

2.1. Data Envelopment Analysis of IT

Banker et al. (1990) used DEA to evaluate the performance of restaurants deployed new point-of-sale (POS) system that they are better, on average, than those without POS systems. Ranker and Kemerer (1989) used DEA to test software projects exhibit VRS and to identify the optimal project size with respect to maximizing productivity. The merit of Banker and Kemerer is to introduce DEA in software

engineering. Benjamin and Winston (2002) investigated the effects of IT on technical efficiency in a company's production process. Statistical evidence is strongly presented to confirm that IT exerts a significant favorable impact on technical efficiency. Doyle and Green (1994) utilized DEA to benchmark 22 microcomputers. The merit of their paper is to provide a good presentation of DEA and a comparison of DEA with regression analysis.

2.2. Overview of ERP Measurement

The measurement of ERP systems could classify into two dimensions: the implementation stage and the stage after go-live. Somers and Nelson (2001) investigated the impact of critical success factors in the stage of ERP implementation. The result indicated that top management support was the most critical success factor for ERP implementations. Michael and Jens (1999) utilized balanced scorecard approach to measure the ERP implementation project and the business performance of controlling ERP system. Hitt et al. (2002) utilized Standard and Poor's Compustat II database to construct various measures to calculate productivity necessarily, stock market valuation and company performance, and indicated that companies investing in ERP tend to show higher performance across a wide variety of financial metrics. However, it is seldom used DEA to measure the ERP systems. Thus, this paper intends to use DEA to analyze the relationship between technical efficiency and ERP continuous investment.

3. Theoretical Perspectives and Methodologies

3.1. Theory of DEA

Data envelopment analysis (DEA) was developed by Charnes et al. (1978), which is used in non-profit organization and government department originally, and used in profit organization, for example bank, fast food, and IT companies subsequently. In DEA, the organizations under study are named Decision Making Units (DMU). The definition of DMU is rather loose to allow flexibility in its use over a wide range of possible applications. Generally speaking, a DMU is regarded as the entity responsible for converting inputs into outputs and whose performances are to be evaluated. DEA is specialized in measuring performance, which has its base on efficient frontier concept, and developed in portfolio theory during the 1950s is now

being increasing used as a tool for general productivity analysis in diverse fields.

DEA provides a framework both for formulation and interpretation of compound measures that comprehend the multiple performance measures associated with multidimensional nature of infrastructure performance and linking these back to the budgeting process. While making use of efficiency optimization techniques, such as linear programming, recognizing the interconnectivity of planning performance measures and efficiency analysis to identify the best benchmark performers (that have the highest composite efficiency) (UNESCAP, 2000).

3.2. Research Methodology and Hypothesis

Benchmarking Partners, Inc. (1998) indicated that implementing an ERP solution disrupts the equilibrium of the company, creating an environment of chaos during the first few months after go-live. During this period, people try to learn the new system, find the information they need. The research found that this period typically lasts from three to nine months. Also, Deloitte Consulting (1999) indicated that the ERP implementation performance of company will decreased at the first few months and rise after a while as shown in Figure 1.

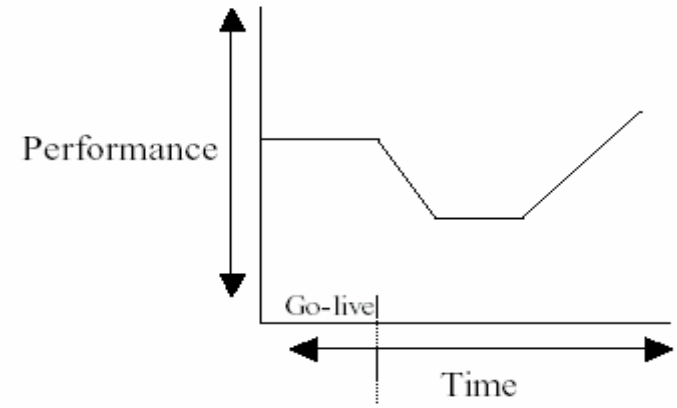

Figure 1: The Trend of ERP Implementation Performance for a Company

ERP lifecycle management is an on-going process. According to Dailey (1998), the whole lifetime of ERP system includes three stages: pre-implementation, implementation and post-implementation. The major lifecycle stages and associated phases are shown in Figure 2. After the initial implementation, companies often revise and re-implement ERP systems repeatedly for systems maintenance.

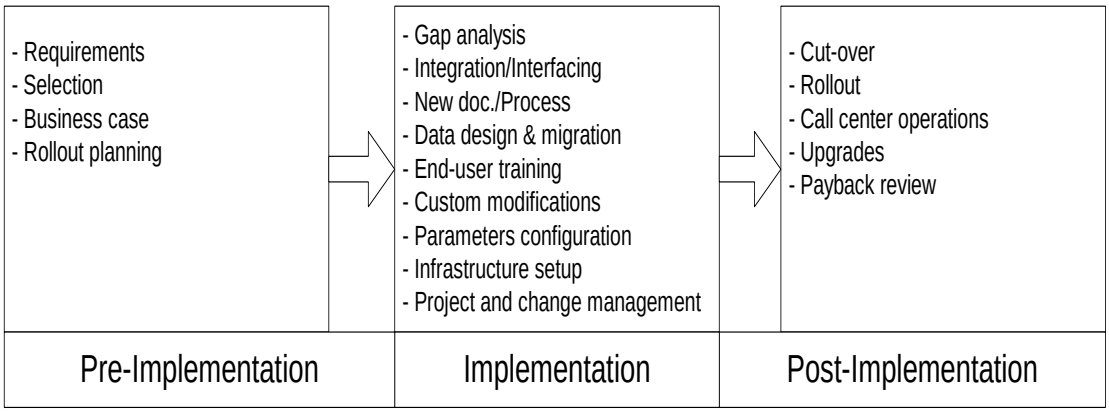

Figure 2: Three Stages of the ERP Lifecycle

Managers want to see the expected results of the investments made in the new system. The issues related to the use and maintenance of ERP systems arises. Issues related to usability, performance measurements, infrastructure management support, upgrading systems and network resource planning are very important in this phase. Once a system is implemented, it must be maintained, because malfunctions have to be corrected, special optimization requests have to be met, and general systems improvements have to be made (Esteves and Pastor, 1999). Thus, this study focused on the use and maintenance phase and proposed an approach to investigate the effects of ERP continuous investment on technical efficiency in a company's production process through a two-stage analytical study.

In first stage, the BCC model is employed to measure the technical efficiency scores for the companies in our sample. We choose gross sales to be the output variables, capital stock and staff expense to be the input variables. The data will be collected from the Taiwan Economic Journal database, and IDEAS software will be used to run BCC model to measure the technical efficiency scores. In order to examine ERP's continuous investment has an impact on technical efficiency in the second stage, we carry on Tobit regression to regressing the scores of technical efficiency, which truncated model is derived from DEA in the first stage.

Mahmood and Mann, (1993) used five ratios to measure an organization's IT investment including: (1) IT budget as a percentage of revenue; (2) value of an organization's IT as a percentage of revenue; (3) percentage of IT budget spent on staff; (4) percentage of IT budget spent on the training of IT staff; and (5) number of PCs and terminals as a percentage of total employees.

Based on the above concept, the present research uses three dependent variables which include percentage of IT budget spent on average annual ERP maintaining expense (Mi), percentage of IT budget spent on average annual personal salary (Si) of ERP maintaining staff and percentage of IT budget spent on average annual training expense (Ti) of ERP staff. The maintaining expense (Mi) identified as debugging and system update whether on line or on the scene. Therefore, the following four hypotheses are implied.

Hypothesis 1: a company's percentage of IT budget spent on average annual ERP maintaining expense (Mi) has a favorable impact on the technical efficiency.

Hypothesis 2: a company's percentage of IT budget spent on average annual personal salary (Si) of ERP maintaining staff has a favorable impact on the technical efficiency.

Hypothesis 3: a company's percentage of IT budget spent on average annual training expense (Ti) of ERP staff has a favorable impact on the technical efficiency.

On the other hand, total costs of ownership (TCO) of technology assets were included: (1) hardware and software cost; (2) tools; (3) development labor; (4) training and education; (5) maintenance and support; and (6) operational labor (CRIMSON, 2002). The present research focused on go-live stage which cost of ERP may aggregating the item 4 to 6 named ERP continuous investment (Ci). The hypothesis 4 is implied:

Hypothesis 4: a company's continuous investment on ERP system has a favorable impact on the technical efficiency.

McCarty and Yaisawarng (1993) suggested that, under this circumstance, the Tobit regression model should be used, because it can account for the censoring of the dependent variable. When the dependent variable is censored, values in range >1 are transformed to particular value =1. We represent the original scores of technical efficiency as TEi, percentage of average annual maintaining expense as Mi, percentage of average annual salary as Si and average annual training expense as Ti, ERP system's maintaining expenditure as Ci, and dummy variable as $\gamma 4$, then the Tobit regression model in the second stage of our study is formulated as:

$$TE^*i = \alpha 0 + \alpha 1Mi + \alpha 2Si + \alpha 3Ti + \varepsilon i,$$
$$TE^*i = \beta 0 + \beta 1Ci + \varepsilon i,$$

$$TEi = 1, \text{ if } TE^*i \geqq 1,$$
$$TEi = TE^*i, \quad \text{if } TE^*i < 1, \quad i = 1,\ldots,n.$$

When the coefficient estimate α_1, α_2, α_3 and β_1 for ERP maintaining expenditures is significantly positive, we could concluded with statistical evidence to corroborate that the ERP continuous investment in ERP continuous improve exerts a positive total effect on the company's technical efficiency.

3.3. Data Collection

The surveyed companies obtained from "Top5000-The Largest Corporations in Taiwan" of China Credit Information Service, there are 956 companies listed in stock market or listed in over-the-counter market. In order to observe the relationship between technical efficiency and ERP continuous investment, we select 46 companies from 956 companies by using the following two rules:

Rule 1: the companies should be listed in stock market or listed in over-the-counter market because accountant must audit these companies' financial report, the data set of financial report will be more reliable.

Rule 2: the companies' ERP system should be used more than 1 year, which is based on the concept of Benchmarking Partners, Inc.

There are many ERP systems available in Taiwan, and many enterprises have already implemented ERP systems for their operations. Among the surveyed companies, there are many different kinds of ERP systems implemented, including two SAP systems, thirteen Oracle systems, eight TIPTOP systems, two Proyoung systems, and so on. If we classify these systems into international and local brands, there are twenty two international brand ERP systems and twenty four local brand ERP systems. Some of the ERP products provide more functions to support the requirements of large-scale enterprises. But for small and medium enterprises, the local ERP product could be the suitable choice. From the questionnaires data, it implies that most small and medium companies in Taiwan select local ERP products for implementation. The related information of these companies is listed in Table 1. Table 1 contains two parts of information: the go live date and brand of ERP systems implemented, and the financial data of surveyed companies that including gross sales, capital stock and labor expense.

Table 1: The Company Profile of 46 Companies

Obs#	Go live date	Brand of ERP system	Gross Sales ($000)	Capital Stock ($000)	Labor Expense ($000)
1	2001.8	SAP	9,478,987	6,845,315	431,668
2	2002.1	OW	85,101,266	126,648,435	1,547,935
3	2001.6	J.D. Edwards	1,914,490	1,677,343	108,582
4	2000.10	TIPTOP	507,096	572,055	18,829
5	2002.2	Fast tech	1,873,601	695,231	29,519
6	2001.9	Oracle	18,436,254	11,446,232	486,814
7	2001.4	QAD	957,582	842,882	33,495
8	2001.1	OW	1,486,863	1,017,894	47,392
9	2001.8	SAP	10,423,370	13,599,906	186,837
10	1998.6	TIPTOP	430,441	613,251	18,138
11	2001.12	Oracle	5,160,116	2,852,296	58,734
12	2000.1	IE	1,158,630	2,418,515	51,056
13	2002.1	TIPTOP	1,140,266	768,299	28,018
14	2001.1	TIPTOP	5,520,431	7,244,157	151,032
15	2002.1	J.D. Edwards	2,296,767	1,133,301	196,588
16	1999.12	Oracle	424,129	835,603	22,669
17	2000.1	OW	1,994,505	1,960,628	33,003
18	1999.12	TIPTOP	2,274,627	3,894,547	67,330
19	2001.1	TeamMax	675,921	752,098	14,814
20	2000.6	OW	795,977	844,702	17,546
21	2001.7	Oracle	49,142,800	11,285,707	995,402
22	2001.1	Peoplesoft	4,458,136	5,724,212	43,266
23	1999.12	Youngton	411,135	357,104	32,606
24	2002.1	Oracle	1,477,164	556,208	67,062
25	2001.1	Oracle	98,861,782	128,927,115	1,928,181
26	2002.2	Oracle	2,745,816	2,396,049	103,591
27	2000.12	TIPTOP	6,023,950	2,402,709	66,906
28	1999.12	Oracle	3,670,429	775,896	40,169
29	2002.1	Oracle	7,906,016	5,725,154	110,277
30	2001.8	SAP	5,860,913	40,100,023	179,567
31	2002.1	OW	3,165,463	1,797,301	155,423
32	2000.1	Iuteutia Movex Steel	11,487,183	5,773,560	168,770

33	2001.12	Oracle	35,690,549	42,283,131	2,156,749
34	1998.12	TIPTOP	2,564,866	405,104	43,684
35	1999.1	IE	2,179,140	958,574	53,489
36	1999.7	Proyoung	1,066,719	931,927	58,762
37	2001.7	OW	1,576,878	1,132,584	25,597
38	2001.1	Oracle	2,600,570	4,135,181	408,480
39	2002.1	OW	2,733,764	1,368,818	34,237
40	1999.10	Oracle	37,874,976	36,248,692	797,017
41	2000.2	OW	1,974,826	3,417,658	52,091
42	1999.11	Oracle	5,553,923	1,234,091	208,542
43	2001.1	TIPTOP	2,427,712	766,447	18,980
44	2002.1	OW	1,010,167	851,233	35,914
45	2001.1	Proyoung	8,692,769	4,790,836	77,786
46	2002.6	OW	10,048,097	4,586,566	596,690

4. Results and Discussions

4.1. Result of First Stage

We use IDEAS software to run BCC model in order to measure the technical efficiency (TEi) scores. The result of first stage is show in Table 2. There are 10 companies TE=1, and 36 companies TE=0 ~ 0.99.

Table 2: Values of TEi

Obs#	TEi	Obs#	TEi	Obs#	TEi	Obs#	TEi
1	0.36	13	0.77	25	1	37	0.67
2	1	14	0.34	26	0.29	38	0.1
3	0.3	15	0.35	27	0.98	39	0.66
4	1	16	0.76	28	1	40	0.86
5	0.87	17	0.54	29	0.69	41	0.34
6	0.61	18	0.28	30	0.29	42	0.89
7	0.67	19	1	31	0.32	43	1
8	0.55	20	0.88	32	0.87	44	0.65
9	0.59	21	1	33	0.32	45	1
10	0.99	22	0.88	34	1	46	0.47
11	0.81	23	1	35	0.58		
12	0.31	24	0.68	36	0.5		

4.2. Result of Second Stage

Tobit regression model is used to determine the correlation between technical efficiency (TEi) and ERP continuous investment (Ci). The estimates of α_1 $\alpha_{2,}$ α_3 and β_1 from the Tobit regression model in the second stage are presented in Table 3 and Table 4. The coefficient estimates of α_1 is observed significantly positive with P < 0.005 (actually P < 0.0001), thereby allowing us to reject the null hypothesis. The coefficient estimates of α_2 is observed significantly positive with P < 0.05, thereby allowing us to reject the null hypothesis. The coefficient estimates of α_3 is observed significantly positive with P > 0.005, thereby couldn't allowing us to reject the null hypothesis. The coefficient estimates β_1 is observed significant positive with P < 0.005 (actually P < 0.0001). We could reject the null hypothesis and conclude that a company's ERP continuous investment has a favorable impact on the technical efficiency.

Table 3: Estimates of α1, α2 andα3

Variable	Coefficient	Standard Error	B/St.Er.	P[|Z| > z]	Mean of X
Constant	0.2759164647	0.29290353	9.420	.0000	
Mi	0.7695403555	0.99501033	7.734	.0000***	0.40869565
Si	0.2165979267	0.10603358	2.043	0.0411*	0.38260870
Ti	0.7676259034	0.16020214	0.048	0.9618	0.13695652

* p < 0.05, ** p < 0.01, *** p < 0.001

Table 4: Estimates of β1

Variable	Coefficient	Standard Error	B/St.Er.	P[|Z| > z]	Mean of X
Constant	0.3123337738	0.43007540	7.262	.0000	
Ci	0.4574902858	0.46221669	9.898	.0000***	0.79130435

* p < 0.05, ** p < 0.01, *** p < 0.001

4.3. Discussions

Hirt and Swanson (1999) presented a new relationship of foundations for maintaining ERP systems. ERP systems, when compared to traditional information system, can indeed give rise to radically different managerial challenges with respect to the maintenance task. The additional complexity arises primarily from the new, prominent roles now played by vendors and often third parties, and the new relationships thus engendered as suggested by the enlarged model. Accordingly, the

challenge to achieve a task fit in maintaining ERP is for any organization a significant one. Through second stage, we realize the ERP continuous investment has a favorable impact on company's technical efficiency, which is aggregated by three variables:

1. Maintenance expenses of ERP system

The cost of ongoing maintenances and future upgrades should be considered before initiating the ERP project. The upgrades of ERP systems are not cheap and easy, it often needs considerable efforts. From our results, maintenance expenses of ERP system, identified as debugging and system upgrade whether on line or on the scene, has a favorable impact on company's technical efficiency. Therefore, it is important to make sure your executive managers commit to a long term and on-going project on ERP implementation, not just for the initial implementation.

2. Salary expenses of ERP personnel

Swartz and Orgill (2001) indicated that the largest area of ERP costs would come from personnel salary: project staffs, back-filled staffs, consultants, recruiters, project managers, and raises for personnel. The requirements and costs for training and mentoring take an important factor for ERP system. From our results, the salary of ERP personnel identified as back-filled staff's salary and maintains staff's salary that has a favorable impact on company's technical efficiency.

3. Training expenses of ERP staffs

The training expenses of ERP staffs, identified as the costs to training ERP experts and end users, has no significant impact on company's technical efficiency. Training and education in the use of ERP system is an important part of ERP implementation, although the hypothesis in this paper is not significantly. While we have discussed the no significant reason with ERP consultants, the reason is mentoring but not consultants unconcerned with old or new employees. The companies need to re-train their staffs in order to achieve higher system performance on ERP systems, but in the mentoring system will increase expenses.

4. Continuous investment on ERP system

After ERP systems implemented successfully, many companies are considering and implementing various extensions to the systems. The extendable external systems could include supplier chain management (SCM), customer relationship management

(CRM), e-business or e-commerce solutions (B2B and B2C), data warehouse (DW), data mining (DM), business intelligence (BI), knowledge management (KM), and so on (Mabert et al., 2000; Tarn et al., 2002; Willis and Willis-Brown, 2002; Jacobs and Bendoly, 2003; Newell et al., 2003; Olhager and Selldin, 2003). By integrating ERP system with these external systems, company can improve the relationships with suppliers and customers and provide competitive advantage for the organization. Under this situation, the accuracy of the data is very important in system process. As the hypothesis 4, the company invests on ERP system continuously has positive affect on technical efficiency.

5. Cultural complications of ERP systems

Davison (1999) indicated that awareness of cultural differences and preferences will certainly improve the assessment of ERP suitability and any subsequent implementation. This implies that a one-size-fits-all or one-business-model-fits-all approach is unlikely to be successful. As the statistic evidence, developers and consultants need to adapt their ERP products and services for different cultural markets.

5. Conclusion

Ross (1999) investigated fifteen ERP implementing companies and indicated that in the earlier of go-live stage. The companies' performance will decrease until they realize how to gain the useful information from ERP systems, train staffs to familiar with ERP systems, and continue improve system functions. Then the companies' performance will be better than before.

In this paper, we present a new methodology to analyze ERP systems and focus on the relationship between ERP continuous investment and technical efficiency. We utilize a two-stage model to analyze, and obtain statistical evidences indicated that ERP continuous investment has a significantly positive impact on the company's technical efficiency. Finally, our findings also support the argument of Davenport (2000) and Ross (1999) in that enterprises spend more portion of IT budget in ERP systems gain better performance.

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