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# Benchmarking of Optimal Efficiency and Decision Making in the Information Services Industry

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## Abstract

**Purpose**－This paper aims at benchmarking the operations of inefficient firms and offering suggestions on how these firms could concentrate their efforts.

**Design/methodology/approach**－The data envelopment analysis (DEA) is used to analyze the operating efficiency of the information services industry. These include firms from the over-the-counter (OTC) market or that are listed on the Taiwan Stock Exchange (TSE). The inefficient firms are apprised of their benchmark values which are customized according to their own characteristics. This is achieved through the contribution of efficient firms in reference sets.

**Findings**－First, firms with a greater scale of business are relatively more efficient than those with a smaller scale of business in this industry, and much more effort is needed to efficiently manage larger firms than smaller ones, but even small firms can still reach optimal performance. Second, the proportion of efficient firms in the TSE group (20%) is slightly higher than that in the OTC group (18.5%). Third, total non-operating revenues as the output should be improved the most; actual capital receipts as the input should be reduced the most, followed by the number of employees. Fourth, firms with a higher price-to-book ratio, higher proportion of major products, higher shareholding ratio of overseas subsidiaries, lower frequent chief officer changes, lower employees' average seniority, and lower average age can reach optimal overall technical

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efficiency even though their scale of operations may be small. Different from other industries, firms in the information services industry have a higher proportion of younger employees who are creative and innovative.

**Practical implications**－The benchmark construction helps inefficient firms to identify the factors impacting on operating efficiency and provides a choice of efficient firms' input or output items to refer to. Based on this, inefficient firms can improve the allocation of their resources to achieve higher operating efficiency.

**Originality/value**－This paper help firms in the information services industry to better identify some of the relevant factors that have an impact, such as features of the industry, the business environment, business sales, and different operating scales. Subsequently, firms will be able to strengthen the allocation of resources to avoid waste and to achieve optimal performance and higher operating efficiency targets.

**Keywords:** data envelopment analysis (DEA), information services industry, operating efficiency, efficiency reference sets

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# 資訊服務產業最佳效率標竿與決策制定

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## 摘要

本文旨在協助資訊服務產業中無效率公司之營運進行標竿設立，以及如何透過資料包絡分析技術對公司提出經營改善之建議。研究結果指出，一、該產業中規模較大的公司，其經營效率相較規模較小的公司來的更好，同時規模大的公司管理者相對的需投入更多的努力以有效管理企業，然而即使是規模小的公司仍有可能達到最佳績效。二、上市公司經營有效率的家數比例（20%）略高於上櫃公司經營有效率的家數比例（18.5%）。三、產出項目的非營業收入總額最需要努力提升，投入項目的實收資本額需要再努力減少，其次是減少員工人數。四、當公司具有較高的市價對帳面價值比，較高的主要產品比例與海外子公司持股比例，以及較低的主管變動頻率，較淺的員工平均資歷與較低的平均年齡時，其可達到最佳整體技術效率；此外，不同於其他產業，資訊服務公司擁有更高比例的年輕員工。最後，本文亦發現無效率公司（無論是高或低營業利潤群），仍會以高營業利潤群中經營有效率的公司為主要學習對象。建立績效標竿公司，可幫助無效率公司找出影響其經營效率的因素，並提供其有效率公司投入或產出項目選擇的參考，同時績效標竿公司亦可作為其他無效率公司效仿學習之標準，如此可改善資源配置，進而達到最佳的經營效率。

**關鍵詞：**資料包絡分析、資訊服務產業、經營效率、效率參考集合

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# 1. INTRODUCTION

The superiority of Taiwan’s (information technology; IT) network is globally recognized and the advent of IT hardware has led to major changes in consumer behavior. The considerable growth in turnover created by online shopping and software and hardware maintenance has encouraged entrepreneurs to pay more attention to the provision of digital content and information services. According to the Standard Industrial Classification in Taiwan (DGBAS 2012), the information services industry includes two categories: 1) computer systems’ design services (e.g., computer software design and computer system integration services); and 2) the supply of data processing and information services (e.g., website portals, providers of data processing services, web hosting and related services, and information providers). The characteristics of this industry include an orientation to (research and development; R&D), knowledge-intensive business, high R&D costs, the necessity for product innovation, an awareness of the need for product marketing, and high advertising costs.

According to the Department of Statistics in the Ministry of Economic Affairs, R.O.C. (Taiwan), the turnover created by the information services industry was NT$132.521 billion in 2003, NT$237.206 billion in 2009, and NT$232.425 billion in 2010 (December 2010 is not included). The turnover shows a positive annual growth rate from 2003 to 2010 (6.2% in 2003, 5.96% in 2009, and 10.54% in 2010) even during the global economic crisis of 2008-2009. The statistics data also reveal that the categories of data processing and information supply services show the biggest turnover of all the industries. In 2010, small- and medium-size enterprises (SMEs; defined as firms with a turnover of less than NT$100 million or which employ fewer than 100 employees) in the information services industry in Taiwan accounted for more than 90% of all businesses.

Although SMEs characteristically show a high degree of adaptability and flexibility in their business model, their weaknesses can threaten their viability. The lack of resources for R&D means that their technology lags behind international standards; the lack of manpower and weak financial structures means that they are unable to obtain sufficient funds to overcome downturns in the industry; the lack of global market information and an international perspective leads to a misjudgment of industry trends and inadequate promotion through marketing. In short, there is still much room for development in Taiwan's information services industry. Traditionally, this industry has been an (original equipment manufacturer; OEM), but now the priority is to encourage economic development and transform it into one that has high added value and is highly competitive. Making the best use of limited input resources in order to achieve maximum output should be the focus of each firm's business strategy. Therefore, this paper aims to identify the performance indicators or characteristics of the industry that should be analyzed in order to improve the business model and strategy. Moreover, it aims to understand how benchmark firms improve the operating performance of Taiwan's information services industry in order to propose policy recommendations.

This paper intends to provide a performance-improvement reference for firms in the information services industry by applying the (data envelopment analysis; DEA) evaluation method. This efficiency analysis can help inefficient (decision making units; DMUs) find the reference sets by which to benchmark performance and can also help inefficient DMUs identify the indicators that require more attention and how this should be done. By emulating the characteristics of benchmark DMUs, inefficient DMUs can improve their allocation of limited resources and enhance operating performance. The analysis of efficiency indicators by DEA can be taken into consideration for future business expansion, and benchmark DMUs can be the standard for other inefficient DMUs. This can be based on the viewpoint of external market appraisal, major product strategy, and firms' internal characteristics, such as their price-to-book ratio, proportion of major products, shareholding ratio of overseas subsidiaries, total number of chief officers' changes, employees' average seniority, employees' average age, and the firms' major products. By combining the firms' attributes and their efficiency analysis, it is possible to deduce the common features of efficient firms and provide a reference for clients and investors concerning developmental strategies in the information services industry. The results of this paper will help firms in the information services industry to better identify some of the relevant factors that have an impact, such as features of the industry, the business environment, business sales, and different operating scales. Subsequently, they can help improve the allocation of resources, avoid waste, and achieve the optimal scale of production and high efficiency.

The remainder of this paper is organized as follows: Section 2 is the literature review; Section 3 presents the DEA model; Section 4 discusses the empirical results; Section 5 offers conclusions and managerial implications.

# 2. LITERATURE REVIEW

## 2.1 Operating Efficiency Evaluation Methods

Chatzoglou and Soteriou (1999) present a theoretical framework to assess the efficiency of the (requirements capture and analysis; RCA) process in software development. They follow a production approach to model the early stages of a software project and use DEA to isolate the effects of exogenous factors, such as the environment or the type of project, on the project's RCA efficiency. Troutt et al. (2000) use DEA and propose a new method for estimating cost efficiencies and benchmark unit costs. They analyze published data from a set of property tax (called rates) collection offices for the London metropolitan area and define a principle of maximum performance efficiency. Stockport, Bradford, Leeds, and the City of London are identified as being cost efficient. The proposed multiple cost driver approach provides management with a benchmarking tool that may help to save costs, improve accuracy, and promote the wider sharing of data.

Kleist (2003) shows that performance measures may be incomplete, inaccurate, or inefficient for application to electronic commerce investments. That study discusses a two-by-two matrix delineating the gap between the quantitative and qualitative performance measures of (management information systems; MIS) and proposes a framework derived from production theory economics for future research in evaluating e-business MIS implementation. According to Lesjak and Vehovar (2005), despite the rapid expansion of e-business, a corresponding evaluation is rarely researched, and thus they apply a causal model (LInear Structural RELation model; LISREL) to investigate how Slovenian telephone companies deal with the need for an evaluation of their e-businesses in 2003. Seol et al. (2007) offer a new framework for benchmarking the service delivery process, using both DEA and a decision tree in the service industry to enable a firm's managers to identify inefficiency in both its service units and in the firm as a whole. This study determines which process should be improved and which should be benchmarked to assess the overall efficiency of an organization.

Montoneri et al. (2011) apply DEA to assess the performance of English writing courses at a university in Taiwan, suggesting that some evaluated classes with high actual values of inputs and outputs have low efficiency. In fact, evaluated classes may refer to different facets of reference sets depending on whether their actual values are located in lower or higher ranges. Their study demonstrates that the benchmarking characteristics of the DEA model can automatically segment all the evaluated classes into different levels based on the indicators fed into the performance evaluation mechanism, and the boundaries are systematically defined by the DEA model according to the statistical distribution. Montoneri et al. (2012) utilize DEA to explore the quantitative learning performance of 18 classes of freshmen students studying a course of English conversation at a university of Taiwan from academic years 2004 to 2006. A learning performance mechanism is designed to identify two inputs and two outputs. The sensitivity study highlights the priority of the richness of course contents over the other evaluated indicators. The performance mechanism can help decision-makers to design educational policies. Lee (2014) explores the operating efficiency of (certified public accounting; CPA) firms from the perspective of industry-specific client groups, by integrating three analysis methods: DEA, an independent sample t test, and multiple-regression analysis. It aims to offer the operators of CPA firms with a reference for improving operating efficiency, identifies important industry-specific client groups for the sustainable operation of the firms, and analyzes the impact of operating efficiency on operating revenue and total revenue.

## 2.2 Operating Efficiency Evaluation in the Information Services Industry

Hand (2001) studies share prices of U.S. companies and web traffic, particularly focusing on the relevance of web-metrics. According to Demers and Lev (2001), web-metrics are major economic indicators in search/portals (gateways to the Internet), e-tail (sales of products online), financial news/services, and content/communities (websites with specific content). Brockett et al. (2004) make a clear distinction between firms selling physical products and those selling digital products. Davila and Venkatachalam (2012) analyze the income of CEOs in relation to performance indicators based partly on web traffic.

Serrano-Cinca et al. (2005) propose a new method for model selection in DEA based on multivariate statistical analysis to assess the efficiency of 40 dot-com firms. In order to preserve homogeneity, only three areas of Internet activities are included: e-tail, content/communities, and search engines/portals. E-tailers are more efficient at generating revenue, while portals/search engines and content/communities are better at attracting unique visitors. This study suggests the impact of the Internet and that revenue is an independent concept. Further studies can include new web-metric indicators such as indices of visitors' buying power by transforming visitors into customers equated to capital. According to Shen (2009), despite the international financial crisis, China's online game industry in 2008 achieved rapid growth in revenue, with the revenue from the top ten operators accounting for over 90% of the entire industry. Shang and Zheng (2009) state that China's online game industry is still in a primal stage, with problems such as smallness of scale, old modes of management, game homogeneity, shortage of talent and virtual fortune exchange, and low rates of product innovation. Lee (2010) applies a DEA model to analyze the efficiency of B2C controls installed by three groups of organizations: financial firms, retail firms, and information services providers. That study uses B2C controls as input and three variables as output: volume, sophistication, and information content. Decision trees are used to identify efficient firms and generate rules for recommending levels of controls. Retail firms and information services providers implement B2C controls more efficiently than financial firms.

Song (2010) uses a DEA model and window analysis to study operating efficiency based on 2002-2008 panel data, collecting 15 Chinese online gaming firms in the Shanghai and Shenzhen Stock Markets as evaluation samples. Liquid assets, fixed assets, staff salaries, administrative expenses, and financial expenses are the selected input indicators; total profit and net investment income are the output indicators. The overall operating efficiency of China's online game industry is good, the degree of concentration has increased gradually, and it is entering an era of oligopolistic competition. Lee and Huang (2015) execute a performance evaluation of 50 information services firms in Taiwan; a proposed operating efficiency and strategy matrix shows that more than half of the firms belonging to quadrant 1 progress both in pure technical efficiency and scale efficiency over the period 2009-2010. These firms are suggested to continue to maintain their policies in R&D, product development, and operating scale.

## 3. DATA ENVELOPMENT ANALYSIS

DEA is a robust evaluation method that is applied to a wide range of fields and industries, such as software projects (Mahmood et al. 1996), high-tech industry (Thore et al. 1996; Kozmetsky & Yue 1998; Lai 2007), information technology investments (Shao & Lin 2002), finance industry (Jemrić & Vujćić 2002; Lin et al. 2009), hotel industry (Hwang & Chang 2003; Wang et al. 2006), branches of banks (Wu et al. 2006), data warehouse operations (Mannino et al. 2008), supplier evaluation and selection (Çelebi & Bayraktar 2008), and the CPA industry (Lee 2014).

## 3.1 Charnes-Cooper-Rhodes (CCR) Model

Farrell (1957) is the first to propose DEA by using a linear programming approach to identify the frontier curves of evaluated units, named DMUs. As a tool that measures the relative efficiency scores of a group of evaluated units. Charnes et al. (1978) expand Farrell's (1957) efficiency measurement concept of multiple inputs and a single output to the concept of multiple inputs and multiple outputs converted to a single virtual input and output by a linear combination. They estimate the efficiency frontier by the ratio of two linear combinations and measure the relative efficiency of each DMU under (constant returns to scale; CRS). Charnes et al. (1978) design the so-called "Charnes-Cooper-Rhodes (CCR) model". The procedure of finding each DMU's target efficiency can be formulated as a linear program by taking multiple inputs and outputs into consideration. The CRS concept means that output directly reflects input (i.e. double inputs produce exactly double outputs). Anderson et al. (2002) indicate that the target efficiency can be obtained by assuming the few inputs that the target DMU needs (called input-oriented), or by assuming the maximum outputs that the target DMU produces (called output-oriented). If the efficiency value equals 1, then the DMU is relatively efficient; if less than 1, then the DMU is relatively inefficient (Lee 2009; Lin et al. 2009; Montoneri et al. 2011, 2012; Lee 2014; Lee & Huang 2015).

Because DEA can deal with multiple inputs and outputs at the same time, the efficiency frontier of DEA is a combination line under the most favorable conditions of each evaluated unit. Therefore, taking this line as the target for other units, it has the function of comparing with each other, and the results of analysis are also more acceptable to each evaluated unit. DEA can be applied to a wide range of businesses and is suitable for general performance evaluation issues. The information services industry of this paper has the characteristics of multiple inputs and multiple outputs, and so it is appropriate to use DEA to evaluate the efficiency of industrial operations. Therefore, this paper employs DEA as a tool for subsequent empirical research and analysis.

## 3.2 Data Resource and Choice of DMU

The research objects of this paper originally include 11 firms listed on the (Taiwan Stock Exchange; TSE) and 29 (over-the-counter; OTC) firms in the information services industry. Of these 40 firms, three are excluded due to a lack of detailed operating expenses. Therefore, the related annual financial statements of 10 TSE-listed and 27 OTC firms in 2009 are used as data references to assess efficiency. Their financial data come from their annual reports, the Taiwan Market Observation Post System (TMOPS) (http://mops.twse.com.tw/mops/web/index), and the Taiwan Economic Journal (TEJ) Data Bank (http://www.tej.com.tw/twsite/).

## 3.3 Definition of Input and Output Items

The DMUs selection is made according to the references of DEA-related research in the information services and the high-tech industries, as well as to the Pearson correlation of statistical analysis. All of the following input and output items are collected from TEJ data. The input items include number of employees (in persons) (I1), actual capital receipts (in thousand NT$) (I2), operating expenses (in thousand NT$) (I3), and total remuneration paid to all employees (in thousand NT$) (I4). The output items include gross operating profits (in thousand NT$) (O1), total non-operating revenues (in thousand NT$) (O2), and market share (O3). The definitions of these items are stated as follows.

### *3.3.1 Input Items*

1. Number of employees (I1) (in persons): the total number of employees of an information services firm.
2. Actual capital receipts (I2) (in thousand NT$): the capital actually raised from the shareholders of the firm; that is, the sum of the book value of a firm's current number of negotiable and preferred stock shares multiplied by their face value.
3. Operating expenses (I3) (in thousand NT$): the marketing, management, and R&D expenses, such as labor costs, rents, advertising expenses, miscellaneous taxes, depreciation, patent royalties, bad debts, sales commission, packing, freight and export, insurance, consultancy, SG&A commodity, and other SG&A expenses.
4. Total remuneration paid to all employees (I4) (in thousand NT$): the salaries of directors, supervisors, managers and employees, duties imposed on all bonuses, incentive payments, severance pensions, severance pay, rewards, business execution costs (such as travel expenses, special expenses, allowances, dormitories, with vehicles in kind), cash bonuses to employees, and stock dividends.

### *3.3.2 Output Items*

1. Gross operating profits (O1) (in thousand NT$): net operating revenue minus operating costs.
2. Total non-operating revenues (O2) (in thousand NT$): equal to the sum of interest revenue, investment or dividend revenue, gains from disposal of investments, turn-around from the loss of falling prices on investments, gains from disposal of assets, turn-around from the loss of falling prices on inventories, gains from turn-around of impairment loss, exchange earnings benefits, and other revenue.
3. Market share (O3): defined as the ratio of the individual firm's net operating revenue to the total amount of all firms' net operating revenues in the information services industry.

### *3.3.3 Correlation Analysis of Input and Output Items*

With the Pearson correlation, a number between -1 and 1 reflects the degree of linear correlation of two variables. The level of significance for the Pearson correlation coefficient (two-tailed test) represents the probability of misjudgments; a lower probability indicates higher accuracy. The significance is suggested to be lower than 0.1. Table 1 summarizes the Pearson correlation coefficients of the input and output items. The values inside parentheses are p values that denote the significant levels. The results show that the inputs and outputs are all significantly positively correlated, reaching a statistically significant level of 1%, thus meeting the principle of equal expansion. As shown in Table 2, the variance inflation factor (VIF) diagnostics among the input and among the output items indicate that there is not a high degree of collinearity among them since the values are distinctly inferior to 10.

Table 1: Pearson correlation coefficients between inputs and outputs[a]

| Outputs / Inputs | Gross operating profits (O1) | Total non-operating revenues (O2) | Market share (O3) |
|---|---|---|---|
| Number of employees (I1) | 0.816 (0.000)[b] | 0.531 (0.001) | 0.682 (0.000) |
| Actual capital receipts (I2) | 0.470 (0.003) | 0.458 (0.004) | 0.522 (0.001) |
| Operating expenses (I3) | 0.952 (0.000) | 0.503 (0.002) | 0.768 (0.000) |

| | | | |
|---|---|---|---|
| Total remuneration paid to all employees (I4) | 0.814 (0.000) | 0.614 (0.000) | 0.652 (0.000) |

Notes: [a] The number of observations is 37.

[b] The value inside parentheses is p value which denote the significant level.

Table 2: Variance inflation factor (VIF) diagnostics among the input and output items

| Dependent variable (Input) | Independent variable (Outputs) | Tolerance | VIF |
|---|---|---|---|
| Number of employees (I1) | Gross operating profits (O1) | 0.548 | 1.823 |
| | Total non-operating revenues (O2) | 0.676 | 1.479 |
| | Market share (O3) | 0.440 | 2.273 |
| Dependent variable (Output) | Independent variable (Inputs) | Tolerance | VIF |
| Gross operating profits (O1) | Number of employees (I1) | 0.147 | 6.780 |
| | Actual capital receipts (I2) | 0.624 | 1.602 |
| | Operating expenses (I3) | 0.159 | 6.278 |
| | Total remuneration paid to all employees (I4) | 0.147 | 6.805 |

# 4. EMPIRICAL RESULTS

## 4.1 Analysis of DEA Efficiency Scores

Table 3 lists the performance indicators of each evaluated DMU. All the DMUs are allocated in one of two levels according to the descending ranking order of gross operating profits (i.e., the O1 value). DMUs that have an O1 value higher than the average O1 value of all the DMUs (NT$578,675 thousand) belong to the high level (denoted as H); those that have an O1 value lower than the average O1 value belong to the low level (denoted as L). The empirical results are presented below.

## 4.2 CCR Efficiency Score, Type, and Level of DMUs

Of the DMUs evaluated, seven (D8, D25, D29, D13, D14, D9, and D12) have a CCR score equal to 1.000 and are considered to be efficient. All the efficient DMUs belong to the high-level group except for D29 and D12 - that is, the O1 values of D29 and D12 are lower than the average O1 value. According to the classification of each DMU’s O1 value, 11 DMUs are in the high-level group and 26 DMUs are in the low-level group. The proportion of efficient DMUs in the high-level group is 5/11=45.5%; the proportion of efficient DMUs in the low-level group is 2/26=7.7%. This paper concludes that firms with a greater scale of business are relatively more efficient than those with a smaller scale of business in the information services industry. However, even small firms can still reach optimal performance. In addition, among the seven efficient DMUs, there are five OTC firms (D25, D29, D13, D14, and D12) and two TSE firms (D8 and D9). Most of the firms in the data studied are in the OTC group. There are ten DMUs in the TSE group of which two are efficient. There are 27 DMUs in the OTC group of which five are efficient. Thus, the proportion of efficient DMUs in the TSE group (2/10=20%) is slightly higher than that in the OTC group (5/27=18.5%). Even though the TSE firms are relatively more rigorous than the OTC firms in terms of operations and quality control, the OTC firms still have quasi-efficient proportion. Moreover, contrary to what is generally assumed to be a fact, the average CCR score of the inefficient DMUs in the TSE group (0.573) is lower than that of the OTC group (0.603).

Of the DMUs, 30 with a CCR score lower than 1.000 can be considered inefficient. D30 is the least inefficient DMU (CCR score=0.791) and D18 (CCR score=0.263) is the most inefficient DMU. The average CCR efficiency score of all the DMUs is 0.595. In addition, D8 is ranked the highest in the TSE group and D25 is ranked the highest in the OTC group. The characteristics of these two firms are similar except that D8's price-to-book ratio and shareholding ratio of overseas subsidiaries (5.78 and 100%) are better than those of D25 (5.69 and 96.8%); D8's employees' average seniority and employees' average age (4 years and 32 years old) are lower than those of D25 (8 years and 34 years old).

## 4.3 Number of References

The "Number of references" listed in Table 3 refers to the "number of times a DMU acts as a peer". This paper notes that only efficient DMUs can be reference DMUs under DEA, and that D8 is the most popular DMU (it is referred to 28 times by other, inefficient DMUs). The efficient DMUs that belong to the low-level group can also be reference DMUs, such as D29. Seventeen inefficient DMUs refer to D29, but none of the inefficient DMUs refers to D12. In fact, the efficient DMUs can reference themselves; for example, D12 is also its reference DMU. This paper chooses to exclude those times that DMUs refer to themselves so as to avoid ambiguity in the table.

Table 3: Efficiency indicators of each evaluated DMU

| DMUs [a] | Type of firms | Level of DMUs | CCR score | Rank in all firms | Rank in TSE group | Rank in OTC group | Number of references | Number of peers | Reference sets [b] |
|---|---|---|---|---|---|---|---|---|---|
| D8 | TSE | H | 1.000 | 1 | 1 | - | 28 | 0 | D8 |
| D25 | OTC | H | 1.000 | 2 | - | 1 | 18 | 0 | D25 |
| D29 | OTC | L | 1.000 | 3 | - | 2 | 17 | 0 | D29 |
| D13 | OTC | H | 1.000 | 4 | - | 3 | 9 | 0 | D13 |
| D14 | OTC | H | 1.000 | 5 | - | 4 | 3 | 0 | D14 |
| D9 | TSE | H | 1.000 | 6 | 2 | - | 2 | 0 | D9 |
| D12 | OTC | L | 1.000 | 7 | - | 5 | 0 | 0 | D12 |
| D30 | OTC | H | 0.791 | 8 | - | 6 | 0 | 4 | D8, D13, D14, D25 |
| D35 | OTC | L | 0.786 | 9 | - | 7 | 0 | 1 | D25 |
| D36 | OTC | H | 0.699 | 10 | - | 8 | 0 | 4 | D9, D13, D25, D29 |
| D34 | OTC | H | 0.667 | 11 | - | 9 | 0 | 2 | D8, D13 |
| D19 | OTC | L | 0.658 | 12 | - | 10 | 0 | 2 | D8, D29 |
| D7 | TSE | H | 0.656 | 13 | 3 | - | 0 | 3 | D8, D13, D29 |
| D17 | OTC | L | 0.587 | 14 | - | 11 | 0 | 2 | D8, D25 |
| D24 | OTC | L | 0.585 | 15 | - | 12 | 0 | 2 | D8, D29 |
| D21 | OTC | L | 0.567 | 16 | - | 13 | 0 | 2 | D8, D29 |
| D23 | OTC | L | 0.565 | 17 | - | 14 | 0 | 3 | D8, D25, D29 |
| D37 | OTC | L | 0.563 | 18 | - | 15 | 0 | 4 | D8, D13, D14, D25 |
| D10 | TSE | L | 0.536 | 19 | 4 | - | 0 | 2 | D8, D25 |
| D32 | OTC | H | 0.528 | 20 | - | 16 | 0 | 3 | D8, D13, D29 |
| D31 | OTC | L | 0.513 | 21 | - | 17 | 0 | 2 | D8, D29 |
| D4 | TSE | H | 0.504 | 22 | 5 | - | 0 | 3 | D8, D9, D25 |
| D15 | OTC | L | 0.493 | 23 | - | 18 | 0 | 2 | D8, D13 |
| D26 | OTC | L | 0.487 | 24 | - | 19 | 0 | 4 | D8, D13, D25, D29 |
| D1 | TSE | L | 0.469 | 25 | 6 | - | 0 | 2 | D8, D25 |
| D6 | TSE | L | 0.437 | 26 | 7 | - | 0 | 3 | D8, D25, D29 |
| D16 | OTC | L | 0.435 | 27 | - | 20 | 0 | 2 | D8, D29 |
| D2 | TSE | L | 0.435 | 28 | 8 | - | 0 | 2 | D8, D25 |
| D11 | OTC | L | 0.385 | 29 | - | 21 | 0 | 1 | D8 |
| D20 | OTC | L | 0.371 | 30 | - | 22 | 0 | 2 | D8, D29 |
| D3 | TSE | L | 0.354 | 31 | 9 | - | 0 | 2 | D8, D29 |
| D33 | OTC | L | 0.352 | 32 | - | 23 | 0 | 3 | D8, D14, D25 |
| D5 | TSE | L | 0.338 | 33 | 10 | - | 0 | 3 | D8, D9, D25 |
| D28 | OTC | L | 0.333 | 34 | - | 24 | 0 | 3 | D8, D25, D29 |
| D22 | OTC | L | 0.330 | 35 | - | 25 | 0 | 4 | D8, D13, D25, D29 |
| D27 | OTC | L | 0.324 | 36 | - | 26 | 0 | 2 | D8, D25 |
| D18 | OTC | L | 0.263 | 37 | - | 27 | 0 | 3 | D8, D25, D29 |
| Average of all the DMUs | | | 0.595 | | | | | | |
| Average of the inefficient DMUs in TSE group | | | 0.573 | | | | | | |
| Average of the inefficient DMUs in OTC group | | | 0.603 | | | | | | |

Note: [a] The evaluated DMUs are sorted firstly by CCR score and secondly by the number of references.
[b] The reference sets order is listed according to DMUs' name.

## 4.4 Number of Peers and Reference DMUs

The column "Number of peers" (between 1 and 4 in this paper) refers to the number of times the inefficient DMUs refer to efficient DMUs; the column "Reference sets" clarifies the DMUs to which the inefficient DMUs refer. These two columns compare DMUs' characteristics. In fact, different items have different referral weightings for each efficient DMU; therefore, the order of the reference sets is listed according to the DMU's name.

## 4.5 Room for Improvement of Output and Input Items (Slack Variable Analysis)

Table 4 shows the room for improvement of the input and output items chosen in this paper. The average values of all DMUs for outputs O1, O2, and O3 are 94.2%, 237.2%, and 94.2%, respectively; those for inputs I1, I2, I3, and I4 are -20.4%, -25.5%, -2.6%, and -17.3%, respectively. The positive values of output items give an idea of the lack of output performance, given the current input resources; the negative or zero values of input items indicate the percentage reduction required under the current output performance. According to the average values, O2 (total non-operating revenues) is the output that should be improved the most for the TSE group as well as for the OTC group; I2 (actual capital receipts) is the input that should be cut the most, followed by I1 (number of employees).

Table 4: Room for improvement (%) of input and output items

| DMU | Type of group | CCR score | Outputs | | | Inputs | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Gross operating profits (O1) | Total non-operating revenues (O2) | Market share (O3) | Number of employees (I1) | Actual capital receipts (I2) | Operating expenses (I3) | Total remuneration paid to all employees (I4) |
| D8 | TSE | 1.000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D25 | OTC | 1.000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D29 | OTC | 1.000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D13 | OTC | 1.000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D14 | OTC | 1.000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D9 | TSE | 1.000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D12 | OTC | 1.000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D30 | OTC | 0.791 | 26.4 | 2503.8 | 26.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| D35 | OTC | 0.786 | 27.3 | 698.7 | 27.3 | 0.0 | -95.7 | -76.5 | -80.5 |
| D36 | OTC | 0.699 | 43.0 | 43.0 | 43.0 | 0.0 | 0.0 | -18.8 | 0.0 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| D34 | OTC | 0.667 | 49.8 | 196.5 | 49.8 | -20.9 | 0.0 | 0.0 | -55.6 |
| D19 | OTC | 0.658 | 51.9 | 51.9 | 51.9 | -74.5 | -36.0 | 0.0 | -59.8 |
| D7 | TSE | 0.656 | 52.5 | 52.5 | 52.5 | -33.6 | 0.0 | 0.0 | -13.1 |
| D17 | OTC | 0.587 | 70.4 | 150.3 | 70.4 | 0.0 | -73.5 | 0.0 | -48.7 |
| D24 | OTC | 0.585 | 70.9 | 70.9 | 70.9 | -42.7 | -43.0 | 0.0 | -29.4 |
| D21 | OTC | 0.567 | 76.5 | 76.5 | 76.5 | -12.0 | -43.0 | 0.0 | -37.2 |
| D23 | OTC | 0.565 | 77.0 | 77.0 | 77.0 | -53.0 | -33.0 | 0.0 | 0.0 |
| D37 | OTC | 0.563 | 77.6 | 134.0 | 77.6 | 0.0 | 0.0 | 0.0 | 0.0 |
| D10 | TSE | 0.536 | 86.4 | 489.8 | 86.4 | 0.0 | -29.5 | 0.0 | -40.5 |
| D32 | OTC | 0.528 | 89.5 | 89.5 | 89.5 | -10.3 | 0.0 | 0.0 | -1.9 |
| D31 | OTC | 0.513 | 94.8 | 94.8 | 94.8 | -20.5 | -64.4 | 0.0 | -26.9 |
| D4 | TSE | 0.504 | 98.3 | 211.8 | 98.3 | 0.0 | 0.0 | 0.0 | -17.8 |
| D15 | OTC | 0.493 | 102.9 | 332.6 | 102.9 | -19.1 | 0.0 | 0.0 | -14.6 |
| D26 | OTC | 0.487 | 105.1 | 105.1 | 105.1 | -42.1 | 0.0 | 0.0 | 0.0 |
| D1 | TSE | 0.469 | 113.2 | 530.5 | 113.2 | -44.9 | -47.5 | 0.0 | 0.0 |
| D6 | TSE | 0.437 | 128.9 | 128.9 | 128.9 | -4.4 | -60.8 | 0.0 | 0.0 |
| D16 | OTC | 0.435 | 129.9 | 129.9 | 129.9 | -69.8 | -64.6 | 0.0 | -56.5 |
| D2 | TSE | 0.435 | 130.0 | 430.4 | 130.0 | -49.9 | -1.0 | 0.0 | 0.0 |
| D11 | OTC | 0.385 | 159.6 | 379.6 | 159.6 | -20.0 | -42.7 | 0.0 | -11.8 |
| D20 | OTC | 0.371 | 169.5 | 169.5 | 169.5 | -20.2 | -54.3 | 0.0 | -36.0 |
| D3 | TSE | 0.354 | 182.5 | 182.5 | 182.5 | -62.6 | -47.5 | 0.0 | -44.7 |
| D33 | OTC | 0.352 | 184.5 | 336.3 | 184.5 | -5.9 | 0.0 | 0.0 | 0.0 |
| D5 | TSE | 0.338 | 196.0 | 196.0 | 196.0 | -47.8 | -71.0 | 0.0 | 0.0 |
| D28 | OTC | 0.333 | 200.1 | 200.1 | 200.1 | 0.0 | -74.8 | 0.0 | -24.5 |
| D22 | OTC | 0.330 | 202.8 | 202.8 | 202.8 | -51.5 | 0.0 | 0.0 | 0.0 |
| D27 | OTC | 0.324 | 208.2 | 230.2 | 208.2 | -49.0 | -13.6 | 0.0 | 0.0 |
| D18 | OTC | 0.263 | 280.1 | 280.1 | 280.1 | 0.0 | -48.8 | 0.0 | -42.1 |
| Average of all the DMUs | | 0.595 | 94.2 | 237.2 | 94.2 | -20.4 | -25.5 | -2.6 | -17.3 |
| Average of the inefficient DMUs | | 0.500 | 116.2 | 292.5 | 116.2 | -25.2 | -31.5 | -3.2 | -21.4 |
| Average of the inefficient DMUs in TSE group | | 0.573 | 123.5 | 277.8 | 123.5 | -30.4 | -32.2 | 0.0 | -14.5 |
| Average of the inefficient DMUs in OTC group | | 0.603 | 113.5 | 297.9 | 113.5 | -23.3 | -31.3 | -4.3 | -23.9 |

The average values of the inefficient DMUs in the TSE group for outputs O1, O2, and O3 are 123.5%, 277.8%, and 123.5%, respectively; those for inputs I1, I2, I3, and I4 are -30.4 %, -32.2%, 0.0%, and -14.5%, respectively. The average values of the inefficient DMUs in the OTC group for outputs O1, O2, and O3 are 113.5%, 297.9%, and 113.5%, respectively; those for inputs I1, I2, I3, and I4 are -23.3%, -31.3%, -4.3%, and -23.9%, respectively. Among 22 inefficient DMUs in the OTC group, nine (representing 40.9%) need to reduce the I2 resource over other inputs. Another nine have to reduce the I1 resource over other inputs. Among eight inefficient DMUs in the TSE group, three (representing 37.5%) need to reduce the I2 resource over other inputs, and another three have to reduce the I1 resource over other inputs. Contrary to what is believed to be a fact, the average room for improvement for different input and output items of the inefficient DMUs in the

TSE group are slightly higher than those in the OTC group except for O2 (total non-operating revenues), I3 (operating expenses), and I4 (total remuneration paid to all employees) - that is, when considering the performance of the items along with scale of operations and capital like O1 (gross operating profits), O3 (market share), I1 (number of employees), and I2 (actual capital receipts), the inefficient DMUs in the TSE group are weaker than those in the OTC group. This paper concludes that much more effort is needed to efficiently manage larger firms than smaller ones. Hastily expanding firms' scale of operations without relative measures to improve performance may easily erode operating efficiency or provoke a fatal crisis in such firms.

## 4.6 Characteristics of DMUs

Table 5 summarizes the characteristics of all the efficient DMUs. It also shows the inefficient DMU with lowest CCR score (D18) and the one with the highest CCR score (D30) in the information services industry. The data are sourced from TMOPS. From the viewpoint of external market appraisal, the efficient DMUs' average price-to-book ratio (5.52) is higher than that of the inefficient DMUs (2.64). The price-to-book ratio equals the share price divided by the book value per common share. The book value per common share is total shareholders' equity divided by the weighted average number of common shares outstanding. The "major product" in Table 5 is defined as those products contributing to the majority of revenues.

From the viewpoint of key product strategy, the efficient DMUs' average proportion of having a major product (89.63%) is higher than that of the inefficient DMUs (58.57%). This finding suggests that firms with a higher proportion of a major product (mostly higher than 80%) allocate more resources to and focus on a single product, thereby indirectly increasing their operating performance. In addition, a firm that focuses on a single product and service can reduce the business risks incurred by non-professionals due to product and service diversities. It can also reduce additional input costs of manpower, equipment, and time spent on related products. Therefore, specialization of products and services in the information services industry can help firms to be relatively more efficient and to improve business performance.

Table 5: Characteristics of some representative DMUs in the sector of information service

| | DMU | Type of firms | Level of DMUs | Price-to-book ratio | Proportion of major product (%) | Shareholding ratio of overseas subsidiaries (%) | Total number of chief officers' changes | Employees' average seniority | Employees' average age | Major product |
|---|---|---|---|---|---|---|---|---|---|---|
| Efficient | D8 | TSE | H | 5.78 | 82.5 | 100.0 | 0 | 4 | 32 | Digital surveillance system |
| | D9 | TSE | H | 3.37 | 88.5 | 100.0 | 0 | 3 | 31 | Digital audio visual equipment |
| | D12 | OTC | L | 2.30 | 97.5 | 100.0 | 1 | 3 | 30 | Online games |
| | D13 | OTC | H | 7.29 | 63.6 | 100.0 | 0 | 4 | 30 | Game machines |
| | D14 | OTC | H | 10.05 | 98.4 | 82.6 | 1 | 3 | 30 | Online games |
| | D25 | OTC | H | 5.69 | 98.2 | 96.8 | 0 | 8 | 34 | Game softwares |
| | D29 | OTC | L | 4.16 | 98.7 | 100.0 | 1 | 3 | 31 | Game softwares |
| Inefficient | D18 | OTC | L | 0.71 | 50.5 | 0.0 | 4 | 8 | 41 | Service of system integration |
| | D30 | OTC | H | 3.50 | 90.4 | 3.5 | 0 | 4 | 30 | Online games |
| Average of all the DMUs | | | | 3.18 | 64.44 | 82.30 | 1.35 | 4.86 | 33.86 | |
| Average of the efficient DMUs | | | | 5.52 | 89.63 | 97.05 | 0.43 | 4.00 | 31.14 | |
| Average of the inefficient DMUs | | | | 2.64 | 58.57 | 78.86 | 1.57 | 5.07 | 34.50 | |

The efficient DMUs' average shareholding ratio of overseas subsidiaries (97.05%) is higher than that of the inefficient DMUs (78.86%). Firms with a higher shareholding ratio of overseas subsidiaries (mostly higher than 90%) have surplus finance, manpower, and technical know-how to invest in overseas subsidiaries. These overseas investment experiences are fed back to the parent firm, which can then improve management and achieve business efficiency.

From the viewpoint of firms' internal characteristics, three indicators are evaluated: the number of changes of chief officers in a year, employees' seniority, and employees' age. The efficient DMUs' average values of these three indicators (0.43, 4.00, and 31.14) are lower than those of the inefficient DMUs (1.57, 5.07, and 34.50). Generally, efficient DMUs have no changes of chief officers in a year or at most one change. Frequent changes of chief officers will result in frequent changes of business strategy and business models, which certainly have a negative effect on operations. Younger employees are probably more energetic and have more innovative ideas, suggesting the major products of those firms are mostly gaming software or online games. Thus, the firms that have fewer changes in chief officers and that have energetic and creative employees can increase operating efficiency.

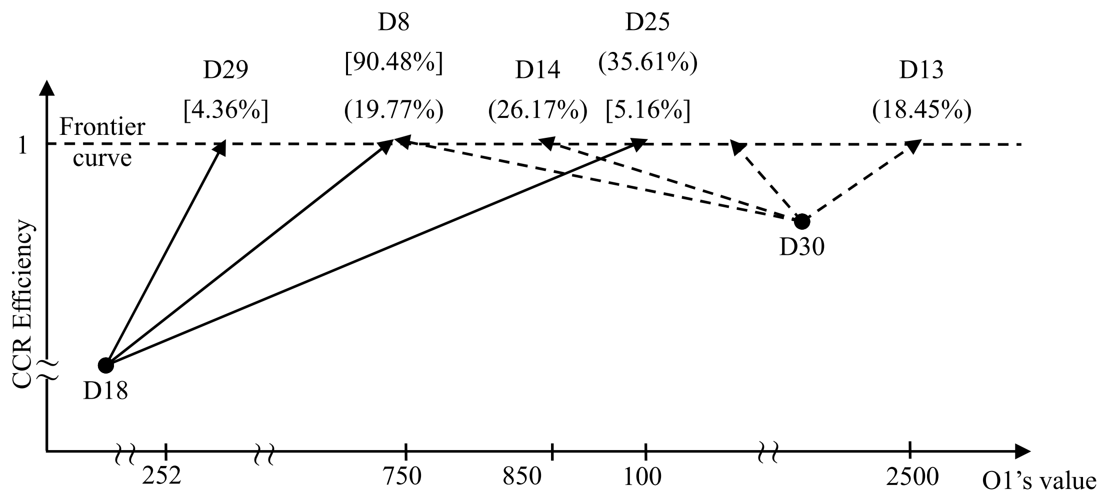
In conclusion, firms with a higher price-to-book ratio (>3.18), higher proportion of major products (>64.44%), higher shareholding ratio of overseas subsidiaries (>82.30%), lower frequent chief officer changes (0 or 1), lower employees' average seniority (<4.86 years), and lower average age (<33.86 years) can reach optimal overall technical efficiency, even though their scale of operations may be small. Examples of this are the efficient DMUs D12 and D29. Gaming software and online games, contributing to about 98% of total profits, are the major products of DMU D29. Different from other industries, firms in the information services industry have a higher proportion of younger employees who are creative and innovative. Younger, creative employees who show potential are of more benefit to firms in the information services industry than employees who have been with the firm for a long time and who have experience in the industry - that is, different industries need different employee characteristics, combinations, and experience.

## 4.7 Analysis of the Reference Set

Table 6 shows the reference sets for the optimal efficiency of two inefficient DMUs; that with lowest CCR score and that with the highest CCR score. Figure 1 illustrates how the inefficient DMUs refer to efficient DMUs and their corresponding contribution in calculating the item's target value. Neither the horizontal axis based on the output O1 (gross operating profits) nor the vertical axis based on the DMUs' CCR efficiency are to scale. This paper finds that the D30 reference set includes four high-level efficient DMUs. D18 refers to two high-level efficient DMUs; the proportion goes up to 95.64% (90.48% to D8 and 5.16% to D25). D18 also refers to the low-level efficient DMUs, but D29 accounts for only 4.36%. This means that the inefficient DMUs (whether of high or low level) still mainly refer to high-level efficient DMUs.

Table 6: Example of two inefficient DMUs' reference set

| | DMU (type, level, O1's contribution) | CCR | DMUs' O1 value (thousand NT$) | Reference sets (Type, Level) | Reference set's O1 value (million NT$) | Reference set's O1 contribution |
|---|---|---|---|---|---|---|
| Inefficient DMU with lowest CCR score | D18 (OTC, L, 0 %) | 0.263 | 87.786 | D8 (TSE, H)<br>D25 (OTC, H)<br>D29 (OTC, L) | 743.303<br>996.823<br>252.108 | 90.48 %<br>5.16 %<br>4.36 % |
| Inefficient DMU with highest CCR score | D30 (OTC, H, 94.332 %) | 0.791 | 1800.065 | D8 (TSE, H)<br>D13 (OTC, H)<br>D14 (OTC, H)<br>D25 (OTC, H) | 743.303<br>2653.274<br>869.078<br>996.823 | 19.77 %<br>18.45 %<br>26.17 %<br>35.61 % |




Note: The values in the square brackets [ ] are the referred percentages of D18's reference set; the values in the parentheses ( ) are the referred percentages of D30's reference set.

Figure 1: Diagram of inefficient DMUs referring to efficient DMUs

Table 6 indicates that the inefficient DMUs with a low CCR score mostly refer to efficient DMUs in the TSE group; it can be seen that up to 90.48% of D18 referrals are to D8 (TSE, H) - that is, it is possible for an inefficient DMU with a low CCR score to rapidly and effectively improve its operating efficiency by referring to the most efficient DMU in the TSE group. The inefficient DMUs with high CCR scores mostly refer to efficient DMUs in the OTC group; it can be seen that up to 80.23% of D30 referrals are to the OTC group (D13, D14, and D25). In fact, D30 is similar to D13, D14, and D25; they all belong to the high-level group of the gross operating profits and all have a major product that focuses on online games or gaming software.

D18 and D30 both refer to the efficient DMUs D8 and D25. D8 is ranked the highest in the TSE group, and D25 is ranked the highest in the OTC group. D8's characteristics are its price-to-book ratio is 5.78, its proportion of major product is 82.5%, its shareholding ratio of overseas subsidiaries is 100%, it has no changes in chief officers, its employees' average seniority is four years, its employees' average age is 32, and its major product is digital surveillance systems. D25's characteristics are its price-to-book ratio is 5.69, its proportion of major product is 98.2%, its shareholding ratio of overseas subsidiaries is 96.8%, it has no changes in chief officers, its employees' average seniority is eight years, its employees' average age is 34, and its major product is gaming software.

D18 (a low-level OTC firm) refers to two high-level DMUs (90.48% to D8 and 5.16% to D25) and to one low-level DMU (4.36% to D29). D18's characteristics are its price-to-book ratio is 0.71, its proportion of major product is 50.5%, its shareholding ratio of overseas subsidiaries is 0%, its chief officers changed four times, its employees' average seniority is eight years, its employees' average age is 41, and its major product is system integration services. This paper finds that D18's performance characteristics (summarized in Table 5) are contrary to those of the efficient DMU D8 and show worse average values of all the evaluated DMUs. This can explain why D18, ranked last, has the worst CCR efficiency among all the DMUs and belongs to the low level from the viewpoint of gross operating profits (O1 value). This comparison shows that it is possible for inefficient DMUs with a low CCR score, such as D18, to effectively progress by referring to the best ranked DMU D8.

D30 (a high-level OTC firm) refers to four efficient, high-level DMUs (35.61% to D25; 26.17% to D14; 19.77% to D8; and 18.45% to D13). D30's characteristics are its price-to-book ratio is 3.50, its proportion of major product is 90.4%, its shareholding ratio of overseas subsidiaries is 3.5%, it has no changes in chief officers, its employees' average seniority is four years, its employees' average age is 30, and its major product is online games. D30's characteristics are generally better than the average values of the inefficient DMUs and are very similar to those of efficient DMUs except for the performance indicator, "shareholding ratio of overseas subsidiaries", which only equals 3.5%. It is for this reason that D30 is the least inefficient DMU and belongs to a high level from the viewpoint of O1.

## 4.8 A Benchmark Construction of Optimal Efficiency for Inefficient Firms

This section provides more comprehensive analysis in order to offer inefficient firms a choice of referrals to the efficient firms' output or input items. In fact, the efficient DMUs of each inefficient firm's reference set make different contributions to the benchmark values of inputs and outputs when forming optimal efficiency. The main contribution to each input/output does not always come from the same efficient DMU. If these contributions are ranked, then inefficient firms will have a source of referrals when formulating their operational improvement policies. This paper proposes steps to be taken for benchmark construction of the inefficient DMUs as follows.

Step 1. Calculate DMUs' relative efficiencies by applying the DEA method to identify the inefficient and efficient DMUs.

Step 2. Identify the efficient DMUs as a reference set for the inefficient DMUs.

Step 3. List each efficient DMU's contributions to inefficient DMUs' input/output benchmark values.

Step 4. Rank each efficient DMU's contributions for each input/output item.

Step 5. List the room for improvement for inefficient DMUs' input/output items.

Step 6. List each input/output item's contribution to calculating inefficient DMUs' relative efficiency.

Step 7. Make suggestions for improvements in inefficient DMUs.

The inefficient DMUs with the lowest and the highest CCR scores (D18 and D30) are chosen as examples of benchmark construction. Table 7 shows the relative data of the benchmark construction steps. This paper uses D18 to explain the proposed benchmark construction.

Table 7: Reference sets' contributions (%) to benchmark optimal efficiency[a]

| | Outputs | | | | | | Inputs | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Gross operating profits (O1) | | Total non-operating revenues (O2) | | Market share (O3) | | Number of employees (I1) | | Actual capital receipts (I2) | | Operating expenses (I3) | | Total remuneration paid to all employees (I4) | |
| | D30's reference set's contributions (%) to inputs'/outputs' benchmark values [b] | | | | | | | | | | | | | |
| D8 | 19.77 | (3) | 2.21 | (2) | 19.77 | (3) | 17.43 | (3) | 17.57 | (2) | 12.38 | (4) | 24.24 | (3) |
| D13 | 18.45 | (4) | 0.42 | (4) | 18.45 | (4) | 16.09 | (4) | 6.72 | (4) | 15.94 | (3) | 23.13 | (4) |
| D14 | 26.17 | (2) | 0.80 | (3) | 26.17 | (2) | 41.01 | (1) | 13.19 | (3) | 27.73 | (2) | 27.11 | (1) |
| D25 | 35.61 | (1) | 96.57 | (1) | 35.61 | (1) | 25.47 | (2) | 62.53 | (1) | 43.94 | (1) | 25.52 | (2) |
| | D30's room for improvement (%) | | | | | | | | | | | | | |
| | 26.4 | | 2503.8 | | 26.4 | | 0 | | 0 | | 0 | | 0 | |
| | D30's Outputs/Inputs contribution (%) in calculating relative efficiency | | | | | | | | | | | | | |
| | 0 | | 0 | | 100 | | 6.5 | | 14.4 | | 25.8 | | 53.2 | |
| | D18's reference set's contributions (%) to inputs'/outputs' benchmark values [b] | | | | | | | | | | | | | |
| D8 | 90.48 | (1) | 15.11 | (3) | 90.48 | (1) | 88.62 | (1) | 83.65 | (1) | 82.28 | (1) | 79.39 | (1) |
| D25 | 5.16 | (2) | 20.93 | (2) | 5.16 | (2) | 4.10 | (3) | 9.42 | (2) | 9.24 | (2) | 2.65 | (3) |
| D29 | 4.36 | (3) | 63.97 | (1) | 4.36 | (3) | 7.28 | (2) | 6.93 | (3) | 8.48 | (3) | 17.97 | (2) |
| | D18's room for improvement (%) | | | | | | | | | | | | | |
| | 280.1 | | 280.1 | | 280.1 | | 0 | | -48.8 | | 0 | | -42.1 | |
| | D18's Outputs/Inputs contribution (%) in calculating relative efficiency | | | | | | | | | | | | | |
| | 94.3 | | 5.7 | | 0 | | 62 | | 0 | | 38 | | 0 | |

Notes: [a] The unit for all the items' benchmark value is in thousand NT$, except for the O3.
[b] The numbers in the parentheses indicate the contributions ranking for each input/output item.

D18's benchmark construction:

Step 1. D18's relative efficiency value is 0.263.

Step 2. The efficient DMUs of D18's reference set are D8, D25, and D29.

Step 3. D8, D25, and D29's contributions to D18's input/output benchmark values are listed in Table 7.

Step 4. D8, D25, and D29's contribution rankings for each input/output item are listed in Table 7.

Step 5. The room for improvement in D18's input/output items is listed in Table 7.

Step 6. D18's input/output item contributions in calculating D18's relative efficiency are listed in Table 7.

Step 7. Managerial suggestions for D18:

1. All D18's output items should be improved equally to 2.801 times.
2. Two of D18's inputs, I1 (number of employees) and I3 (operating expenses), can be maintained at the same level; the input resources of I2 (actual capital receipts) and I4 (total remuneration paid to all employees) should drop by 48.8% and 42.1%, respectively.
3. Only O1, O2, I1, and I3 make a contribution to calculating D18's relative efficiency.
4. Taking into account the I/O items' room for improvement and contribution in calculating efficiency, the items with values not equal to zero should also be improved as a priority in order to increase the DMU's relative efficiency. Therefore, D18 can only make an effort on O1 and O2, specifically on O1, which represents 94.3%.
5. If D18 hopes to rapidly increase its relative efficiency, then it is suggested that it should refer mainly to D8's gross operating profits (O1) up to 90.48%, D25's O1 to 5.16%, and to D29's O1 to 4.36%. After this, it should refer to D29's total non-operating revenues (O2) up to 63.97%, to D25's O2 to 20.93%, and to D8's O2 to 15.11%.
6. If D18 hopes to increase its overall performance in each I/O item in the long term, then its performance improvement measures cannot merely refer to a single efficient DMU. It is suggested that D18 should mainly refer to D8's gross operating profits (O1), market share (O3), and all the input items (I1 to I4) from 79.39% to 88.62%. As for item O2 (total non-operating revenues), D29 is the major model (representing 63.97%) for D18.

The main research contribution of this paper is to successfully construct a benchmark of optimal efficiency for inefficient firms and offer managerial suggestions based on a robust and reliable quantitative efficiency assessment model. The managerial implications of the proposed benchmark construction are presented as follows.

1. When seeking performance improvement measures, inefficient firms cannot merely refer to one single efficient DMU.
2. The benchmark construction can give the inefficient firms concrete ways to emulate the efficient DMUs in a prior order of input/output items. The proportion of reference sets' contributions (percentage) to benchmark optimal efficiency can give the inefficient firms some information about how to prioritize their goals - that is, the inefficient firms can apply the efficient DMUs' business models in prior input/output items to their own business operations and

proceed with an overall integrated plan of improvement. This will ensure a rapid and focused improvement in firm performance. Such an “integrated benchmark construction” can make the planning of operations more sophisticated and complete.

3. Each inefficient firm’s benchmark construction is based on the combination of efficient DMUs in its reference set. This allows managers to take advantage of all corporate resources and to smoothly transfer the efficient firms’ experiences, technical operations, and business models to the inefficient firms. Thus, they can save on costs related to software/hardware and time while independently searching for improvement solutions.

# 5. CONCLUSIONS AND MANAGERIAL IMPLICATIONS

This study categorizes all DMUs in the information services industry into a high- or low-level group according to their gross operating profits. The results of the CCR model show that almost all efficient DMUs belong to the high-level group. The proportions of efficient DMUs in the high-level and low-level groups are 45.5% and 7.7%, respectively. This paper concludes that the firms with a higher scale of business are relatively more efficient than those with a lower business scale in the information services industry. However, it is still possible for small firms to reach optimal performance. The proportion of efficient DMUs in the TSE group (2/10=20%) is slightly higher than that in the OTC group (5/27=18.5%). TSE firms are relatively more rigorous than OTC firms in terms of operations and quality control.

According to the average values of room for improvement, O2 (total non-operating revenues) is the item that should be improved the most among the outputs; I2 (actual capital receipts) is the resource that should be reduced the most among the inputs. The DMUs in the information services industry are more concentrated on their core industry; it is recommended that they diversify their businesses in order to increase total non-operating revenues. Moreover, inefficient DMUs can dismiss excess manpower and transfer capital into other investments to reduce waste of capital.

Regarding the external market appraisal, the efficient DMUs’ average price-to-book ratio (5.52) is higher than that of the inefficient DMUs (2.64). Regarding the major product strategy, the efficient DMUs’ average proportion of major product (89.63%) is higher than that of the inefficient DMUs (58.57%). A firm that focuses on a single product and service can reduce some business risks of non-professionals due to product and service diversities and cut additional input costs. Therefore, strengthening the specialization of products and services in the information services industry can help firms to be relatively more efficient and to improve business performance.

The efficient DMUs' average shareholding ratio of overseas subsidiaries (97.05%) is higher than that of the inefficient DMUs (78.86%). These overseas investment experiences are fed back to their parent firm; such feedback can improve business management and improve the efficiency of business performance. Regarding firms' internal characteristics, a frequent change of chief officers will result in frequent changes of business strategy and model, which will certainly have a negative influence on the firm's operations. Firms in the information services industry have a high proportion of younger, creative employees who are able to acquire novel technologies. Younger, creative employees with potential are of more benefit to firms in the information services industry than employees who have been at the firm for a longer timer and have industry experience.

In the analysis of reference sets, this paper finds that the inefficient DMUs (whether they are in the high- or low-level group) still mainly refer to the efficient DMUs from the high-level group. It is possible for inefficient DMUs to make progress by referring to the highest ranked DMU D8 (the TSE and high-level firm). The characteristics of D30 (the OTC and high-level firm) refer to performances that are better than the average values of the inefficient DMUs and very similar to those of efficient DMUs. As a result, D30 becomes the least inefficient DMU and belongs to the high-level group from the viewpoint of O1 (gross operating profits).

This paper presents a comprehensive analysis and offers inefficient firms a choice of efficient firms' output or input items to refer to in order to formulate their operational improvement policies. The steps for benchmark construction for the inefficient firms are also given. Some suggestions are offered to management based on DEA as a robust and reliable quantitative efficiency assessment model. The inefficient firms can take into account the input/output items that deal with room for improvement and contribution to calculating efficiency. It is concluded that the items with values that are not equal to zero should be improved as a matter of priority in order to ensure a rapid increase in the DMU's relative efficiency. For long-term performance improvement measures, the inefficient firms should refer to the efficient DMUs in their reference set.

The empirical analysis of this paper only discusses an annual performance evaluation. It is suggested that DEA can be used to evaluate the operating efficiency of each evaluated unit at different time periods in the future. From the development process of each period, we can further see whether the unit has made progress or is still lagging behind. In addition, considering the premise of DEA application, the data of input and output items should be very clear. Therefore, the input and output item data used herein are quantitative, and qualitative data such as category variables or dummy variables cannot be used as the measurement basis of input and output items. The results of our performance evaluation may be limited by the attributes and selection of variable data, and so they cannot be considered comprehensively, which is also the research limitation of this paper.

In past studies concerning operating performance, a few researchers have applied DEA in the information services industry. The main contribution of this paper is to show how to construct a benchmark of optimal efficiency for inefficient DMUs and how to emphasize where to put more efforts and by how much through various indicators. The analysis of efficiency indicators by DEA can be used to consider future business expansion. The benchmark DMUs can serve as the standard for other inefficient DMUs to emulate. The results of this paper offer firms in the information services industry a better way to identify those factors that have a greater impact on operating efficiency, such as the features of the industry, the business environment, business sales, and different operating scales. Subsequently, firms will be able to strengthen the allocation of resources to avoid waste and to achieve optimal performance and higher operating efficiency targets.

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