African Journal of Business Management Vol. 6(3), pp. 1164-1176, 25 January, 2012
Available online at http://www.academicjournals.org/AJBM
DOI: 10.5897/AJBM11.743

Full Length Research Paper

Measuring the financing and business performance of the information technology industry

Dong Shang Chang, Po Wen Kuo* and Shou Min Tsao

Department of Business Administration, National Central University, Taiwan, R.O.C.

Accepted 23 June, 2011

Information technology (IT) firms are facing ever-increasing competition and challenges in today's globalized economy, and especially, firms in the advanced emerging market need to focus on improving their performance in order to remain highly competitive to survive. According to the business process of firms and IFRS (international financial reporting standards), this study applies an alternative data envelopment analysis (DEA) technique to explore the financing and business performance, and identify the benchmarks of 50 listed IT firms in Taiwan. A managerial decision-making matrix is constructed based on the derived financing and business efficiencies. The result shows that the firm's efficiency and the firm's market value are highly relevant. The proposed method and the results provide managers with an insight into the efficiency of the individual business processes of IT firms, and it can be applied to more precisely assess industrial benchmarks.

Key words: Data envelopment analysis (DEA), financing performance, business performance, managerial decision-making matrix.

INTRODUCTION

The performance measurement of enterprises has long been an important issue within the management field, since it is a critical decision-making indicator for practitioners and an enhancement to improve the performance of organizations. Besides a financial ratio analysis, the commonly-used frontier production functions of performance measurement fall into two main categories: parametric methods and non-parametric methods (Coelli et al., 1997). Data envelopment analysis (DEA), first introduced by Charnes, Cooper and Rhodes, is one type of non-parametric method. This method does not require any prior assumptions regarding the frontier production function. Therefore, it allows for the simultaneous use of multiple input and output variables, and directly derives the weight of each input and output variable from a linear programming model. Hence, this method has been widely used in recent years to measure the performance of both public and private sector enterprises in terms of operational research, and economic or management literature (Charnes et al., 1997; Cooper et al., 2000).

The operation of firms is a process of creating maximum income with limited resources by using multiple inputs to create multiple outputs.

The traditional DEA method assumes that there is only one phase of the input and output process of all decision-making units (DMUs). However, in reality, the first phase of the financing and profit-creation process of these organizations begins with capital funding from shareholders and debt holders (that is, internal capital and external capital) and the use of this capital to purchase assets, such as inventory, equipment, factories and land, so as to achieve optimal asset allocation.

The second phase begins with the deployment and utilization of the assets purchased to undertake production and operation, and eventually, generate profits.

DEA is a measure of overall performance, but the conventional application of DEA fails to correctly characterize the performance of the two-phase process (Seiford and Zhu, 1999). Traditional studies of DEA view the operation of firms as a whole, ignoring the performance of their component process. Nowadays, most of the measures for evaluating the performance or

*Corresponding author. E-mail: pwkuo@mgt.ncu.edu.tw, pwk_ncu@yahoo.com.tw. Tel: 886-3-4227151/66100. Fax: 886-3-422-2891.

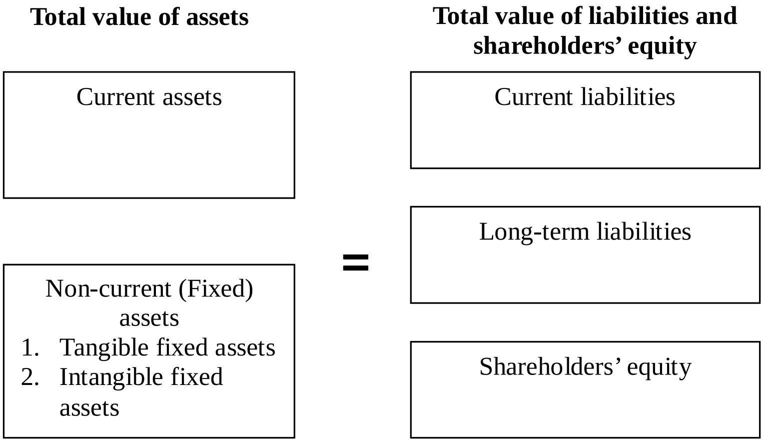

Figure 1. The balance-sheet model of the firm.

efficiency of firms merely consider the inputs and outputs of one phase, and mainly focus on the input of assets and/or expenditure and output of revenue and/or profits. They focus on the firm's business efficiency but ignore the most important phase of the sources of funding, that is, the financing from debt holders and shareholders, and the destination of the funds, that is, the use of the funding to invest in current assets, fixed assets, etc.

The standard accounting equation states that the value of assets is always equal to the liabilities plus the shareholders' equity. The balance-sheet model of the firm is presented in Figure 1 (Ross et al., 1999). The balance sheet is a snapshot of the firm, and the assets of the firm are shown on the left-hand side of the balance sheet. These assets can be classified as being current and fixed (non-current), and before a firm can invest in an asset, it must obtain financing. The forms of financing are represented on the right-hand side of the balance sheet. A firm will issue debt or equity shares. Liabilities are classified as being current and long-term. By definition, the difference between the total value of the assets (current and fixed) and the total value of the liabilities (current and long-term) is the shareholders' equity. The balance sheet "balances" because the value of the firm's assets is equal to the sum of its liabilities and the shareholders' equity.

Logical concerns appear to occur if all the relevant factors of debt capital (liabilities), equity capital (shareholders' equity), assets (current and fixed) and costs or expenses are simultaneously included as input variables. However, this problem can be overcome by breaking down the inputs and outputs of the two phases for measurement purposes. There have been several previous attempts at developing two-phase efficiency measurements of this type. However, none of them resulted in a genuine and continuous two-phase measurement model. Most of the previous studies merely treated the outputs of the first phase as the inputs for the second phase, before going on to evaluate the efficiencies of the two phases. Of course, these are not integrated models (Abad et al., 2004).

This paper models the business process of the funding, investment, production and profit creation of firms by taking the relationship between the balance sheet and income statement into account, and then goes on to develop a two-phase concept. The proposed integrated DEA method can be applied to more precisely assess the financing and business performance. Moreover, the current study contributes to the performance measurement of the productivity theory, operational research, economic and management literature. From a managerial perspective, the proposed method distinguishes the source of inefficiency, and the findings of this study may enable decision-makers to target inefficient phases of the business operating process.

METHODOLOGY

Business processes and economic activities of firms

All business firms engage in following basic kinds of activities: debt, equity, investing and operating. In general, the first phase of the business process of a firm begins with the raising of funds. Firms raise funds (sometimes called capital) from two basic sources: shareholders (equity capital) and debt holders (debt capital). These debt and equity activities are followed by investing and operating activities. From the resource transformation perspective, a firm uses the capital obtained from debt and equity activities to purchase current and fixed assets, such as materials, inventory, equipment, factories and land to enable it to make products or provide services.

IASB and IFRS Foundation issued the discussion paper - Preliminary Views on Financial Statement Presentation in October, 2008. This paper classifies the major economic activities of firms as business (operating and investing) activities and financing (debt and equity) activities. According to the IFRS and Taiwan's generally accepted accounting principles (GAAP), if the utilization of capital can create future economic benefits or provide material benefits beyond the current period, the items purchased are recognized as being assets. If not, these payments are recognized as being

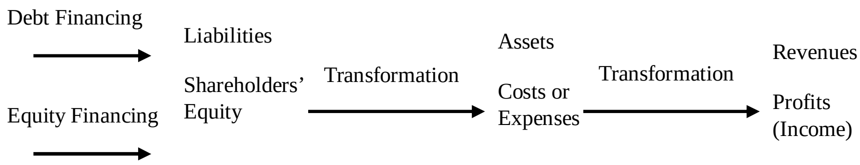

Figure 2. Business processes and resource transformations of firms.

expenses. Debt and equity activities are part of the financing process of firms. Therefore, in this paper the efficiencies measured from the source of capital to the destination of capital are referred to as "financing efficiencies."

In the second phase, firms use the resources to invest, produce and sell products or provide services, as well as incurring expenditure, and eventually to generate income. A firm's net profits are based on the returns on these activities. Since the process of investing, making and selling products and expending to create profits is generally referred to as investing and operating process, this paper refers to the efficiencies measured in this phase as "business efficiencies." Figure 2 shows the basic concept.

Figure 2 illustrates that equity and liabilities are the sources of capital, while assets, costs and expenses are the uses or destinations of the capital. From the perspective of financial statements, on the balance sheet, liabilities can be divided into current and long-term liabilities based on a firm's operating cycle, as well as the assets can be divided into current and non-current assets based on its operating cycle. Revenue from sales of goods and services to customers is reported on the income statement. Costs and expenses can be categorised into costs directly related to the goods sold (cost of goods sold), operating expenses (including selling and administrative costs), non-operating expenses and income tax based on their relative functions. Profits can be categorised into gross profits, operating income, pre-tax profits and net profits.

Data envelopment analysis

The DEA was introduced by Charnes et al. (1978) who extended Farrell's (1957) idea of estimating technical efficiency in terms of the production frontier. The chief characteristic of the DEA method is that it uses envelopment to replace the production function which has traditionally been used in microeconomics (Chang et al., 2008). The DEA incorporates all the inputs and outputs of decision-making units (DMUs) into the space, and searches for their frontier. It is a non-parametric linear programming technique which computes a comparative ratio of outputs to inputs for each DMU, and reports it as a relative efficiency score. Charnes et al. (1994, 1997) and Cooper et al (2000) gives an introduction to the basic DEA models and theoretical extensions.

Since its introduction in the late 1970s, the DEA has been widely used to measure the relative performance of DMUs. The method has continued to gain widespread acceptance as a management tool in many fields (Barros and Leach, 2006; Lin et al., 2010; Chen et al., 2010), and the literature on the DEA continues to expand vigorously (Ahmad et al., 2006). Li et al. (2005) use the DEA to rank the efficiency performance of a set of DMUs. Asmild et al. (2004) apply the DEA model to evaluate the performance of the banking industry, while Brockett (1998, 2004) uses the DEA to measure the performance of the insurance industry. Thore et al. (1994, 1996) apply the DEA to measure the performance of the computer Industry in the U.S., and Yang et al. (2010) use the DEA to evaluate the efficiency of intellectual capital management of Taiwan IC design industry. Lu et al. (2010) propose a DEA model to measure the R and D (research and development) performance of the high technology industry, and Chen et al. (2010) use a super-efficiency DEA to evaluate the performance of the financial and non-financial holding companies.

However, the major applications of the DEA assume that DMUs are involved in the inputs and outputs of only a single phase. The existence of intermediate production processes which produce intermediate outputs is not considered. The overall (single phase) efficiency measure does not provide any insight into the efficiency of individual production processes and their importance in realizing final outputs. Responding to this problem, multi-phase (or multi-stage) DEA methods have been proposed by researchers, such as Charnes et al. (1986), Wang et al. (1997), Seiford and Zhu (1999), Zhu (2000), Luo (2003), Sexton et al. (2003), Abad et al. (2004) and Hwang et al. (2008).

Charnes et al. (1986) describe a two-stage application which arose from the application of the DEA to an analysis of U.S. Army Recruiting Command activities. Wang et al. (1997) use the DEA with a two-stage concept to study the impact of IT investment on banking performance. In the first stage, banks accumulate funds from customers in the form of deposits. In the second stage, they invest in securities and provide loans using funds from the deposits. Seiford and Zhu (1999) propose a profitability and marketability DEA model to evaluate the performance of banks, and Zhu (2000) applies this model to assess the profitability and marketability of Fortune 500 companies. Luo (2003) extends Seiford and Zhu's (1999) study to evaluate the profitability and marketability of large banks. Hwang et al. (2008) follow up the two-stage DEA to measure the profitability and marketability, and efficiency change of non-life insurance companies.

Sexton et al. (2003) apply a two-stage model to the U.S. Major League Baseball. In the first stage, the team's front office utilizes the resources to acquire techniques. In the second stage, the techniques are exercised to achieve game victory. This study treats both total bases gained and total bases surrendered as inputs to the second stage and outputs from the first stage. Abad et al. (2004) propose a two-stage DEA to analyze 30 stocks (listed companies) in the Spanish manufacturing industry. They calculate the projected revenue in the first stage, and feed it as an input into the second stage. In the first stage, a frontier is estimated which ties accounting information to the future firm's performance (assets and operating expenses as inputs and revenue as an output). In the second stage, they calculate an efficiency frontier which traces an idealized relationship between certain accounting information (projected revenues, operating expenses, book value) and market value.

Most of the multi-stage studies did not model the process as a single multi-phase process but as multiple single-stage processes. These studies separate the business process of DMUs or firms into multiple independent phases which are not fully integrated into a single model, before going on to estimate the efficiencies individually.

Chen and Zhu (2001, 2004) propose a single two-phase model which captures the impact of IT on the firm's performance via intermediate variables. According to Chen and Zhu's IT performance model, the present study develops a continuous integrated model based on the business process and considers the decision-maker's specific weight based on the market value of the firm before demonstrating how to apply this model to measure the financing and business efficiency of IT firms in Taiwan.

Integrated two-phase DEA model

The integrated two-phase DEA model is illustrated in a single linear programming model expressed in formula (1):

$$\text{Min} \quad w_1\alpha - w_2\beta$$

$$\text{s. t.} \quad \sum_{j=1}^{n}\lambda_j x_{ij} \le \alpha x_{ij_o},\ i = 1,2,\ldots,m,$$

$$\sum_{j=1}^{n}\lambda_j z_{dj} \ge \tilde{z}_{dj_o},\ d = 1,2,\ldots,D,$$

$$\sum_{j=1}^{n}\lambda_j = 1,\ \lambda_j \ge 0,\ j = 1,2,\ldots,n;$$

$$\alpha \le 1,$$

$$\sum_{j=1}^{n}\mu_j z_{dj} \le \tilde{z}_{dj_o},\ d = 1,2,\ldots,D,$$

$$\sum_{j=1}^{n}\mu_j y_{rj} \ge \beta y_{rj_o},\ r = 1,2,\ldots,s,$$

$$\sum_{j=1}^{n}\mu_j = 1,\ \mu_j \ge 0,\ j = 1,2,\ldots,n;$$

$$\beta \ge 1, \qquad (1)$$

where w_1 and w_2 are user-specified weights reflecting the preference of the two phases' performance, and $\tilde{z}_{dj_0}$ is the dth unknown intermediate measure. Formula 1 presents the integrated two-phase process where the first phase of DMU_j (j = 1, …,n) uses inputs x_i (i = 1, . . .,m) to produce outputs z_d (d = 1, . . .,D), and then these z_d are used as inputs in the second stage to produce outputs y_r (r = 1, . . ., s). It can be seen that z_d are outputs in stage 1 and inputs in stage 2, and w_1 and w_2 are the decision-maker's preferences in each phase. In Formula 1, $\alpha^* \le 1$ or $\beta^* \ge 1$ represents the efficiency scores in phase 1 or in phase 2. If $\alpha^* = \beta^* = 1$, an optimal solution must exist, such as $\lambda_{j0}^* = \mu_{j0}^* = 1$, where (*) represents the optimal value in Formula 1. This indicates that, when $\alpha^* = \beta^* = 1$ the firm is efficient when the two-phase process is viewed as a whole (Chen and Zhu, 2004). The constraints on $\sum_{j=1}^{n}\lambda_j$ and $\sum_{j=1}^{n}\mu_j$ actually determine the returns to scale (RTS) type. If $\sum_{j=1}^{n}\lambda_j = 1$ is added in phase 1 and $\sum_{j=1}^{n}\mu_j = 1$ in phase 2, a two-phase VRS (variable RTS) model is obtained (Cook and Zhu, 2005).

AN EMPIRICAL APPLICATION

Data and measurement of variables

Information technology (IT) firms are facing ever-increasing competition and challenges in today's globalized economy. Especially, firms in advanced emerging markets such as Taiwan need to focus on improving their performance in order to remain highly competitive and survive in such a competitive world. In the past ten years, Taiwan's IT industry has spanned technologies from personal computers to the handset sector, and has also has expanded its territory from Taiwan's Taipei–Hsinchu region to China's Shanghai region (Lee and Saxenian, 2008).This paper applies a multi-stage evaluation approach with the integrated DEA model to evaluate the performance of IT industry in this advanced emerging market, that is, Taiwan's IT industry. The sample consists of 50 IT firms listed on the Taiwan Stock Exchange. The data source was gathered from the Taiwan Economic Journal (TEJ) database, and annual data for the years 2003 and 2004 is used in this paper. According to the business process and IFRS, the first phase of the methodology measures financing efficiency, with input variables of current liabilities, long-term liabilities and adjusted shareholders' equity. These variables represent the sources of debt and equity capital. The intermediate measures are current assets, non-current assets, cost of goods sold and operating expenses, and these variables represent the utilization of the capital. For the second phase, in which business efficiency is measured, the input variables for the model include current assets, non-current assets, cost of goods sold, and operating expenses, all of which represent the utilization and investment of the capital. The output variables are sales revenue, operating income and net income, representing final outputs and profitability. Figure 3 illustrates the financing efficiency and business efficiency. In economics, a distinction is often made between stock magnitudes and flow magnitudes. As assets, liabilities and equity on the balance sheet are the concept of "stocks", representing the status at a specific date of the balance sheet. This is a static perspective. On the other hand, sales revenue, expenses and net profits during the specific period of time are the concept of "flows". This is a dynamic perspective. Therefore, referring to the technique of financial ratio analysis, this paper uses average amounts at the beginning of the year and ending of the year for current assets, non-current assets, current liabilities, long-term liabilities and stockholders' equity to enable the consistency between inputs and outputs on a measurement basis. In addition, the stockholders' equity from the balance sheet signifies a closed amount, and thus, it is modified by the reduction of the net profit contributed in that year for the first phase. Table 1 summarizes the statistics of the raw data.

The empirical model to measure financing and business performance

Let θ_{fe} and θ_{oe} be the financing efficiency in phase 1 and the business efficiency in phase 2 respectively and w_{fe} and w_{oe} be the decision-maker's preference of the performance of each phase. The value-based integrated model is illustrated in the linear programming model expressed in formula (2):

$$\text{Min} \quad w_{fe}\theta_{fe} - w_{oe}\theta_{oe}$$

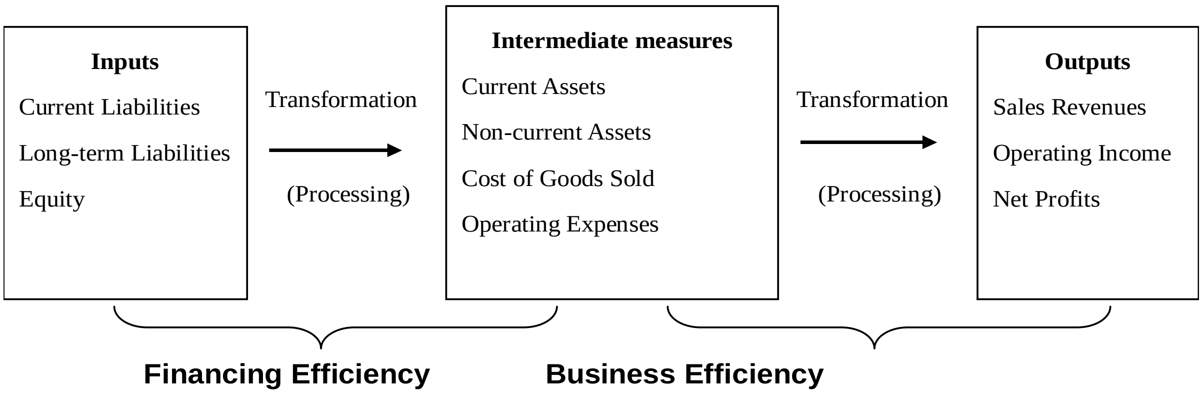

Figure 3. Integrated DEA model.

Table 1. Summary statistics of inputs, intermediate measures and outputs (000s NTD).

Statistics	Maximum	Minimum	Average	Standard deviation
Inputs				
Current liabilities	79,549,618.5	627,909	12,141,187	16,557,891.19
Long-term liabilities	47,512,128.5	14,331.5	5,730,835	9,592,626.23
Equity	294,302,396.5	470,167.5	28,629,918	52,089,124.02
Intermediate measures				
Current assets	166,096,791.5	626,712.5	22,089,652	34,839,777.02
Non-current assets	275,888,244.5	715,916.5	28,052,552	49,716,386.04
Cost of goods sold	394,154,486	1,971,373	45,415,583	77,340,269.41
Operating expenses	23,337,806	53,843	3,020,044	4,226,407.56
Outputs				
Sales revenues	421,669,678	2,057,688	52,014,601	86,254,133.41
Operating income	86,822,778	-1,865,254	3,593,861	12,713,700.33
Net income	91,778,584	-11,629,391	4,210,395	14,726,738.65

s. t. $\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta_{fe} x_{ij_o}$, i = 1,2,…,I;

$\sum_{j=1}^{n} \lambda_j m_{dj} \geq \tilde{m}_{dj_o}$, d = 1,2,…,D;

$\sum_{j=1}^{n} \lambda_j = 1$;

$\lambda_j \geq 0$; j = 1,2,...,n;

$\theta_{fe} \leq 1$

$\sum_{j=1}^{n} \mu_j m_{dj} \leq \tilde{m}_{dj_o}$, d = 1,2,…,D;

$\sum_{j=1}^{n} \mu_j y_{rj} \geq \theta_{oe} y_{rj_o}$, r = 1,2,…,R;

$\sum_{j=1}^{n} \mu_j = 1$;

$\mu_j \geq 0$; j = 1,2,...,n;

$\theta_{oe} \geq 1$ (2)

where n (= 50) is the number of firms and x_{ij}, m_{dj} and y_{rj} are the amount of the ith input consumed, the amount of the dth input/output consumed/produced and the amount of the rth output produced by the jth DMU (or firm), respectively. In phase 1, there are i = 3 inputs- current liabilities, long-term liabilities and equity, and d=4 outputs-current assets, non-current assets, cost of goods sold and operating expenses. In phase 2, d = 4 inputs -current assets, non-current assets, cost of goods sold and operating expenses, and r = 3 outputs -sales revenues, operating income and net income.

Formula 2 shows that the value of θ_{fe} lies between 0 and 1, whereas the value of θ_{oe} is greater than 1. The closer either θ_{fe} or θ_{oe} is to 1, the better the financing or business efficiency of the enterprise in question. Including $\theta_{fe} \leq 1$ and $\theta_{oe} \geq 1$ simultaneously in constraints with the single objective function $w_{fe}\theta_{fe} - w_{oe}\theta_{oe}$ represents that the efficiency scores in phase 1 (θ_{fe}) and phase 2 (θ_{fe}) are interrelated, and stands for the view of an integrated two-phase process. The constraints on $\sum_{j=1}^{n} \lambda_j$ and $\sum_{j=1}^{n} \mu_j$ determine the returns to scale type. Therefore, $\sum_{j=1}^{n} \lambda_j = 1$ and $\sum_{j=1}^{n} \mu_j = 1$ represent the fact that the variable return to scale (VRS) is employed to determine the best practice frontier in phases 1 and 2 in the IT industry.

Value-based model (model 2): Setting the market values as the weights for each phase

In model 1, it is assumed that the decision-maker does not consider the specific weights for financing efficiency and business efficiency, so the weights can be set by $w_{fe} = w_{oe}$ =1. In model 2 (value-based model), for the consideration of weights, this study incorporates the firm's market value to calculate the weights of financing efficiency and business efficiency. The weights are estimated by calculating the ratio of the explained variation to the total variation between the efficiency score and the market value. The weights of financing efficiency (w_{fe}) and business efficiency (w_{oe}) are expressed in formula (3):

$$w_{fe} = \frac{\left[\sum_{i=1}^{n}\left(\theta_{1j} - \bar{\theta}_1\right)\left(P_j - \bar{P}\right)\right]^2}{\left[\sum_{j=1}^{n}\left(\theta_{1j} - \bar{\theta}_1\right)^2\right]\left[\sum_{j=1}^{n}\left(P_j - \bar{P}\right)^2\right]}$$

$$w_{oe} = \frac{\left[\sum_{j=1}^{n}\left(\theta_{2j} - \bar{\theta}_2\right)\left(P_j - \bar{P}\right)\right]^2}{\left[\sum_{j=1}^{n}\left(\theta_{2j} - \bar{\theta}_2\right)^2\right]\left[\sum_{j=1}^{n}\left(P_j - \bar{P}\right)^2\right]} \quad (3)$$

where P_j = Market value of firm j; $\bar{P}$ = Mean of P_j; $\bar{\theta}_k$ = Mean of θ_k, k=1, 2.

In formula (3), *j* represents the firms in the IT industry, while P*j* represents the market value of the firms being evaluated in the industry. A firm's market value (P*j*) is calculated by using its number of outstanding shares multiplied by the market price per share. The computations for θ_1 and θ_2 are illustrated in the linear programming models expressed in formulas (4) and (5):

$$\begin{aligned}
&\text{Min} \quad \theta_1 \\
&\text{s. t.} \quad \sum_{\substack{j=1 \\ j\neq o}}^{n} \lambda_j x_{ij} \leq \theta_1 x_{io},\ i = 1,2,\ldots,I; \\
&\sum_{\substack{j=1 \\ j\neq o}}^{n} \lambda_j m_{dj} \geq m_{do},\ d=1,2,\ldots,D; \\
&\lambda_j \geq 0,\ j \neq o. \qquad (4)
\end{aligned}$$

$$\begin{aligned}
&\text{Min} \quad \theta_2 \\
&\text{s. t.} \quad \sum_{\substack{j=1 \\ j\neq o}}^{n} \lambda_j m_{dj} \leq \theta_2 m_{do},\ d=1,2,\ldots,D; \\
&\sum_{\substack{j=1 \\ j\neq o}}^{n} \lambda_j y_{rj} \geq y_{ro},\ r = 1,2,\ldots,R; \\
&\lambda_j \geq 0,\ j \neq o. \qquad (5)
\end{aligned}$$

For a set of DMUs, the DEA identifies the efficient frontier where all DMUs have a unity score. In order to discriminate the performance among efficient DMUs, a super-efficient DEA model is developed, in which a DMU under evaluation is excluded from the reference set (Andersen and Petersen, 1993; Banker and Gifford, 1988; Banker et al., 1984). Since the efficiency score of the efficient DMU is truncated in 1 in the traditional envelopment DEA model, the super-efficiency model is employed, in which j$\neq$o is added to the constraints of Formulas 4 and 5 to enable the value of θ_1 and θ_2 to be more than 1. The super-efficient model allows for a ranking of the efficient DMUs themselves (Andersen and Petersen, 1993), and the discrimination among the efficient DMUs can make a more reasonable association between θ_k and P_j. Thus, the values of θ_{fe} and θ_{oe} in Model 2 represent the consideration of the firm's market value in the IT industry when measuring the financing and business efficiency.

RESULTS OF MODELS 1 AND 2

The results of model 1 are shown in Figure 4. This model does not consider the market value of each firm in the IT industry and the setting of weights for phases 1 and 2 is the same ($w_{fe} = w_{oe}$ =1). The average scores of financing and business efficiency are 0.982 and 1.191, respectively. The results of the value-based model (model 2) and overall efficiency are shown in Figure 5 (FE, BE and overall). The weights of phases 1 and 2 are 0.499 and 0.462. The average scores of financing and business efficiency are 0.977 and 1.186, respectively. When efficient

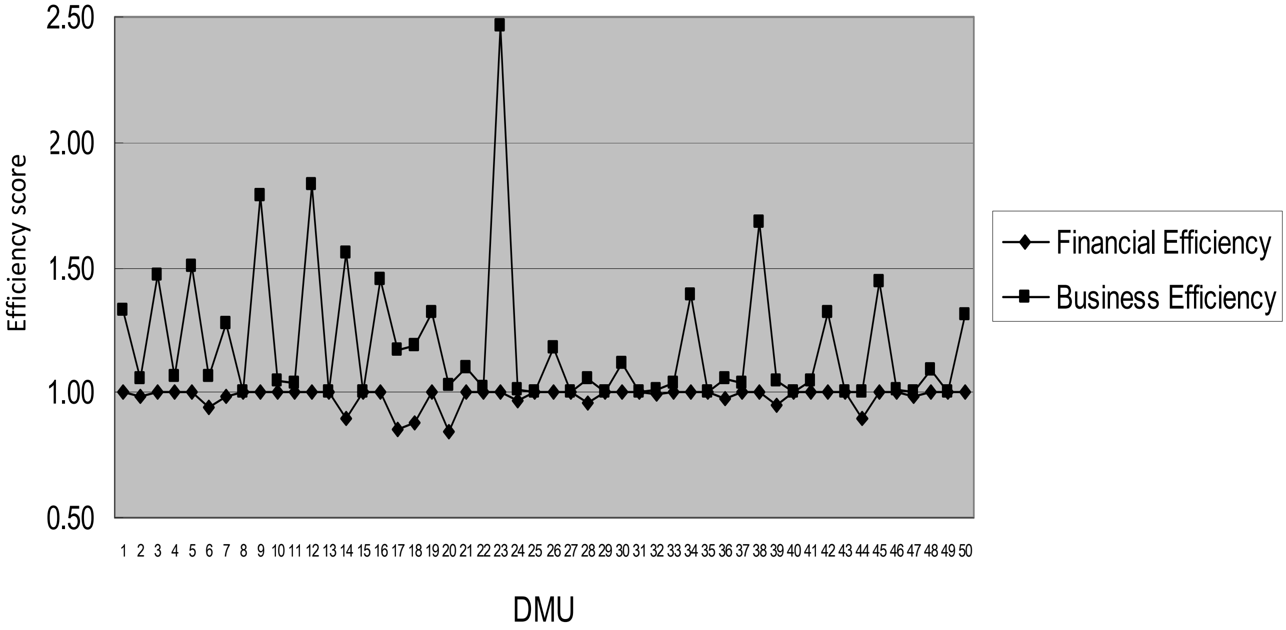

Figure 4. Financing and business efficiency scores of 50 firms (w_{fe} = w_{oe} =1).

firms are excluded from the sample, the average financing and business efficiency scores, are 0.944 (model 1) versus 0.928 (model 2) and 1.252 (model 1) versus 1.245 (model 2). According to Seiford and Zhu (1999), the t-test is applied to the inefficient firms. The results of the t-test show that the mean of the paired differences between the efficiency scores in models 1 and 2 for financing and business efficiency are not significantly greater than zero (p-values are equal to 0.123 and 0.12 in models 1 and 2, respectively). The results of financing efficiency and business efficiency in model 1 are highly consistent with the results in model 2, and this is probably because the weights in model 1 (1:1) are almost equal to the weights in model 2 (0.499:0.462). This result also shows that the firm's efficiency (not only its financing efficiency but its business efficiency) and the firm's value (market value) are highly relevant in Taiwan's IT industry. The results show that there are 11 DMUs displaying the best efficiency in both phases. These best-practice firms include DMU8, DMU13, DMU15, DMU25, DMU27, DMU29, DMU31, DMU35, DMU40, DMU43, and DMU49 (Appendix). This shows that these firms are in the optimal situation of capital utilization and profit making, and are the benchmarks in Taiwan's IT industry. Figures 4 and 5 demonstrate that the variance of business efficiency is greater than financial efficiency in the IT industry.

Comparison with conventional two-stage DEA approach

In order to compare this approach with the conventional DEA approach, Table 2 summarizes the results of this approach and a conventional two-stage and single stage approach. The second and third columns of Table 2 provide summary statistics of efficiency based upon our integrated value-based model. The FE in the second column means financing efficiency (θ_{fe}) and the BE in the third column means business efficiency (θ_{oe}). The fourth and fifth columns summarize the results of efficiency based upon the conventional two-stage DEA in phases 1 and 2, respectively. The last column summarizes the results of overall efficiency based on the single stage DEA approach. The overall efficiency is calculated using an input-oriented BCC model with current liabilities, long-term liabilities and shareholders' equity as the inputs, and sales revenues, operating income and net income as the outputs. The conventional DEA score only considers the single phase efficiency, whereas, θ_{fe} and θ_{oe} measure the efficiency in the context of a two-phase process. It can be seen from Figure 5 that overall efficient firms do not necessarily represent an efficient performance in these two phases when measured by the integrated DEA model.The difference between the integrated model and the conventional two-stage model can be seen in Table 3. The results of the first phase of financing efficiency (FE) and the second phase of business efficiency (BE) calculated by a conventional two-stage (VRS) individually indicate that DMU4, DMU10, DMU20, DMU26 and DMU39 are efficient in both phases. However, these

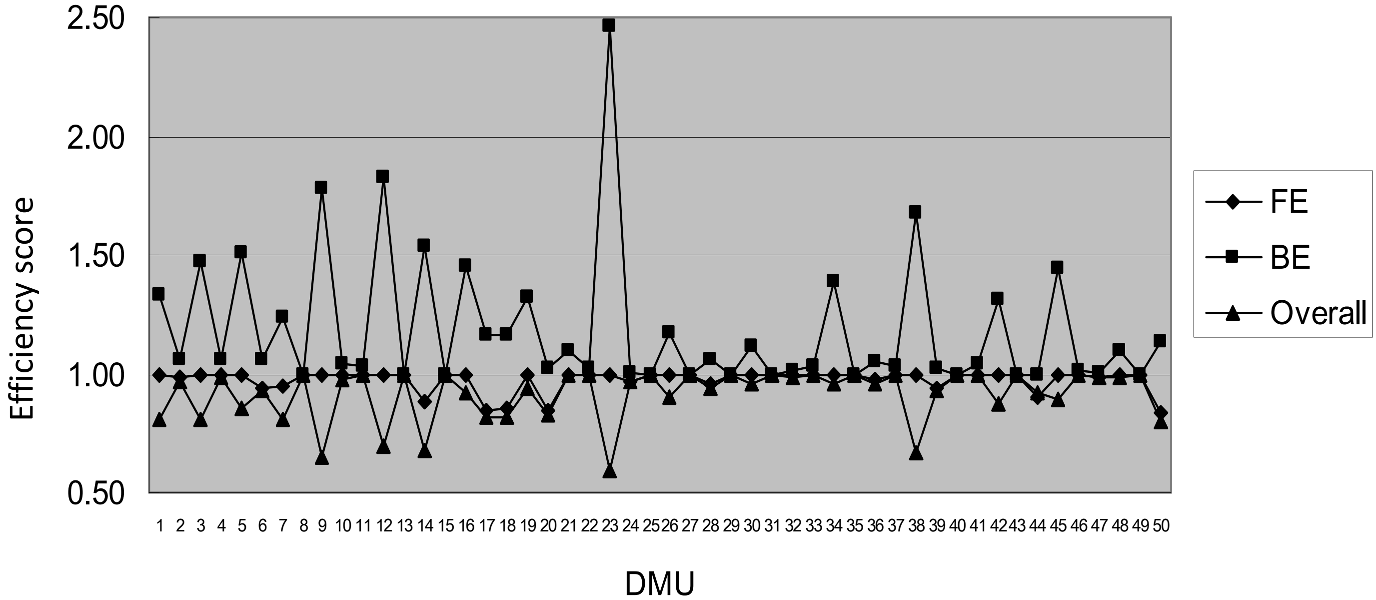

Figure 5. Efficiency scores of FE, BE and overall.
FE: financing efficiency; BE: business efficiency; Overall: overall efficiency.

Table 2. DEA results for integrated model, conventional two-stage model and single-stage model.

	Integrated DEA		Conventional two-stage DEA		Single-stage DEA
	FE (θ_{fe})	BE (θ_{oe})	FE	BE	Overall
Average score	0.9768	1.1860	0.9924	1.0434	0.9161
Standard deviation	0.0470	0.2867	0.0145	0.0593	0.1088
Maximum efficiency score	1	2.4621	1	1.273	1
Minimum efficiency score	0.8358	1	0.9415	1	0.5934
Number of efficient DMUs	34	12	32	18	16

FE: financing efficiency; BE: business efficiency; overall: overall efficiency.

Table 3. Comparison of integrated model and conventional DEA approach.

DMU	Integrated DEA		Conventional two-stage DEA		Single-stage DEA
	FE (θ_{fe})	BE (θ_{oe})	FE	BE	Overall
4	1	1.0642	1	1	0.9823
10	1	1.0436	1	1	0.9727
20	0.8434	1.0253	1	1	0.8305
26	1	1.1743	1	1	0.9
39	0.9388	1.0273	1	1	0.934

FE: financing efficiency; BE: business efficiency; overall: overall efficiency.

DMUs are not overall efficient firms when the two-phase process is viewed as a whole. The integrated model detects inefficiency which is missed by conventional two-stage DEA models. Additionally, the integrated model distinguishes the inefficiency in the first phase from that in the second phase, enabling decision-makers to target

Table 4. Summary statistics of accounting measures for efficiency and inefficiency firms in financing and business performance.

	Total (1)			Financing performance						Business performance						t-statistics (Z-statistics) on the difference	
				Inefficiency (2)			Efficiency (3)			Inefficiency (4)			Efficiency (5)				
	Mean	Median	STD	Mean	Median	STD	Mean	Median		Mean	Median	STD	Mean	Median	STD	(2)-(3)	(4)-(5)
Solvency and financial risk																	
Current Ratio	1.71	1.54	0.71	1.35	1.33	0.56	1.88	1.62	0.71	1.69	1.54	0.73	1.77	1.53	0.68	2.62**(2.75***)	0.32(-0.23)
Leverage (%)	41.49	43.96	13.47	45.62	47.35	10.40	39.54	38.81	14.43	41.30	42.48	13.69	42.09	46.08	13.32	-3.56***(-3.39***)	0.17(0.14)
Profitability and operating efficiency																	
ROA (%)	3.48	5.78	11.17	3.54	5.57	9.88	3.45	5.78	11.87	0.80	4.19	10.85	11.96	11.04	7.51	-0.03(0.06)	3.31***(-3.13***)
ROE (%)	7.53	10.28	19.86	6.92	10.07	19.33	7.81	10.68	20.39	2.11	7.93	18.15	24.68	23.09	15.05	0.15(-0.02)	3.90***(-3.25***)
Deployment and utilization of assets																	
Assets turnover (%)	106.46	87.50	62.50	77.85	76.08	29.45	119.93	108.42	69.45	87.12	77.57	46.22	167.70	175.76	69.53	2.32**(1.75*)	4.64***(-3.52***)
Observations		50			16			34			38			12			

*, ** and *** denote significance at 10, 5 and 1% levels, respectively.

specific inefficient phases of the business process.

Relationship between efficiency performance and accounting measures

In financial statement analysis, solvency and profitability are the two major dimensions of a firm's performance measurement. A solvency analysis focuses on the ability of the firm to pay or otherwise satisfy its current and non-current liabilities, while a profitability analysis focuses on the firm's ability to earn profits, which depends on the efficiency of its operations, as well as its available resources. In terms of accounting ratios for financial statement analysis (single ratio analysis), the current ratio (CR) is often used in evaluating a firm's current position and short-term financial risk (liquidity). Financial leverage (LEV), which is the ratio of total liabilities to total assets, is commonly used to assess a firm's ability to satisfy its non-current position and long-term financial risk. Return on assets (ROA) and return on equity (ROE) present comprehensive accounting measures of the profitability of the firm's performance. In previous studies of corporate finance or financial accounting, ROA and ROE are the two most commonly-used measures of a firms' performance in profitability. Total asset turnover (TAT), the ratio of net sales to average total assets, measures a firm's performance in terms of the utilization of its assets. The concept of turnover is that we invest in assets to sell goods and services and then expect that our investment in assets will be converted or turned over into sales.

In order to examine the relationship between the DEA efficiency performance and the above accounting measures of IT firms, this study then tries to examine the differences in the accounting ratios between efficient and inefficient firms. The results of the t-test are shown in Table 4. Table 4 illustrates that there is a significant difference in CR and LEV, but no significant difference in ROA and ROE, between efficient and inefficient firms in terms of financial efficiency. Table 4 also indicates a significant difference in ROA and ROE, but no significant difference in CR and LEV when efficient and inefficient firms are discriminated by business efficiency. There is a significant difference in TAT between efficient and inefficient firms, both in terms of financing and business efficiency. The numbers in parentheses in Table 4 are the Z-statistics of a Mann-Whitney U test, and it can be seen that the results of the t-test are nearly the same as those of the Mann-Whitney U test. Thus, it can be concluded that financing-efficient firms perform better than financing-inefficient firms in CR, LEV and TAT, and business-efficient firms are superior to business-inefficient firms in ROA, ROE and TAT.

These results imply that the financing and

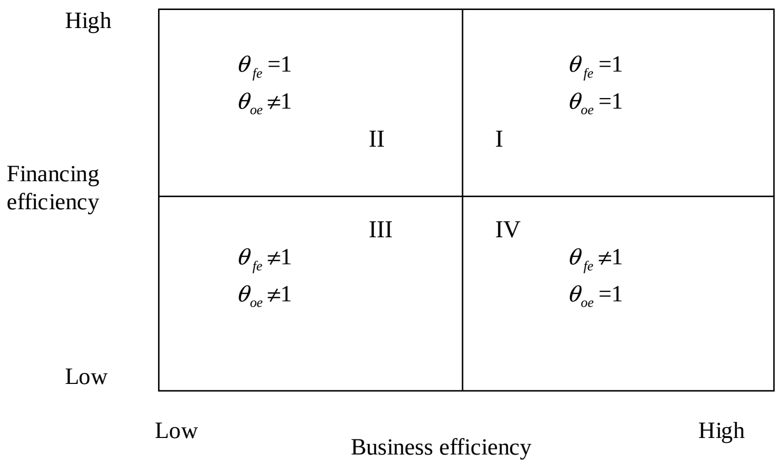

Figure 6. Managerial decision-making matrix.

Table 5. Empirical results of managerial decision-making matrix.

	$\theta_{oe}\neq1$	$\theta_{oe}=1$
$\theta_{fe}=1$	DMU1, DMU3, DMU4, DMU5, DMU9, DMU10, DMU11, DMU12, DMU16, DMU19, DMU21, DMU22, DMU23, DMU26, DMU30, DMU33, DMU34, DMU38, DMU41, DMU42, DMU45, DMU46, DMU48	DMU8, DMU13, DMU15, DMU25, DMU27, DMU29, DMU31, DMU35, DMU40, DMU43, DMU49
$\theta_{fe}\neq1$	DMU2, DMU6, DMU7, DMU14, DMU17, DMU18, DMU20, DMU24, DMU28, DMU32, DMU36, DMU37, DMU39, DMU50	DMU44, DMU47*

* Business efficiency of DMU47 is 1.001.

business efficiency evaluated by the integrated model could correctly characterize an IT firm's solvency and profitability, respectively. Financing efficiency focuses on the measurement of a firm's financial risk, while business efficiency focuses on the measurement of a firm's profitability. In addition, both financing and business efficiency are affected by the deployment and utilization of assets.

Managerial decision-making matrix

By using the results of the financing and business efficiency, this paper develops a matrix for evaluation purposes to provide usable information for decision-making, thereby facilitating the resolution of management issues. The two concepts presented by financing efficiency and business efficiency form a matrix for business activities. The pictorial representation of the managerial decision-making matrix is illustrated in Figure 6, which shows the status of the IT firms in the two vital performance dimensions of financing efficiency as the vertical axis, and business efficiency as the horizontal axis, to form four quadrants.

The empirical result of the business efficiency matrix is presented in Table 5, from which the following managerial implications can be made for IT firms which fall into four different quadrants.

If the IT firm falls into the first quadrant (top right), this indicates that the firm is simultaneously achieving the best financing and business efficiencies, since firms which fall into this area are best-practice, and can be regarded as benchmarks for others in the industry (for example, DMU8, DMU13, DMU15, etc.). These firms should continue to maintain their strength in funding, investing and business activities.

If the IT firm falls into the second quadrant (top left), this indicates that it is not business efficiently, but is financing-efficient (for example, DMU1, DMU3, DMU4, etc.). The managers of the firms in this quadrant should focus on the profit-making process, in order to enhance the efficiency whereby assets and expenses are converted or turned over into sales and profits. These firms should increase their output of sales and decrease their input of assets and reduce costs and expenses to generate higher profits.

If the IT firm falls into the third quadrant (lower left), this indicates that the firm performs poorly, both in financing efficiency and in business efficiency. Therefore, firms in this quadrant must pay attention to both the conversion of capital and the profit-making process (for example, DMU2, DMU6, DMU7, etc.). These double under-achievers should simultaneously focus on their financing and business activities. They should change their funding or financing strategy to increase their liquidity (CR) or decrease their financial risk (LEV), and change their operating or marketing strategy to reduce costs and increase sales in order to create profits. In addition, their deployment and utilization of assets is critical.

If the IT firm falls into the fourth quadrant (lower right), this indicates that the firm performs well in business efficiency, but poorly in financing efficiency. The process of converting internal capital and external capital into assets is inefficient (for example, DMU44 and DMU47). Therefore, firms falling into this quadrant should focus on funding and investing activities and on the process of asset deployment. They should reduce their financing risk and improve their liquidity in order to move themselves into the first quadrant.

Conclusions

This paper proposes a model for evaluating the financing and business performance of firms, based on the data envelopment analysis technique. This concept is innovative, since it takes two phases of firms' activity into account in a single efficiency-measurement model: financing aspects, which relate to the transformation of liabilities and equity in assets and production costs, and business aspects, which are related to the transformation of assets and costs into revenue and profits. Different from the previous model, neither the efficiency of phase 1 nor the efficiency of phase 2 is evaluated independently. Instead, they are put into the same model for evaluation. This developed DEA model can be weighted by market values to measure the two phase efficiency of the financing and business process. The results of financing efficiency and business efficiency in model 1 are highly consistent with the results in model 2. These results show that the firm's efficiency (not only its financing efficiency but also its business efficiency) and the firm's market value are highly relevant in Taiwan's IT industry.

The results also imply that the financing and business efficiency evaluated by the integrated model can correctly characterize an IT firm's solvency and profitability, respectively. The financing efficiency focuses on the measurement of a firm's financial risk, while the business efficiency focuses on the measurement of a firm's profitability. In addition, both financing and business efficiency are affected by the deployment and utilization of assets. A managerial decision-making matrix is constructed based on the derived financing and business efficiencies in order to evaluate the status of the IT firms in the two vital performance dimensions, and obtain some managerial implications for practitioners.

The empirical application could be useful for firms in finding the source of inefficiency, and could help managers, creditors and stockholders to evaluate their firms' financing or business performance. For future studies, the proposed framework, combined with the value-based DEA model, could be extended to different industries or different countries.

A financial ratio analysis could also be conducted on the benchmark firms, enabling inefficient manufacturers to use the results to develop clear targets of accounting measures for improvement. It is hoped that this paper has provided a way forward for firms in their efforts to improve efficiency, and can help managers to more precisely evaluate the financing and business performance of their firms in order to achieve the optimal allocation of assets, liabilities and shareholders' quity, and thus, create the maximum value of the firm.

REFERENCES

Abad C, Thore S, Laffarga J (2004). Fundamental analysis of stocks by two-stage DEA. Manage. Decis. Econ., 25(5): 231-241.

Ahmad N, Berg D, Simons TG (2006). The integration of analytical hierarchy process and data envelopment analysis in a multi-criteria decision-making problem, Int. J. Inform. Technol. Decis. Mak. 5(2): 263–276.

Andersen P, Petersen NC (1993). A procedure for ranking efficient units in data envelopment analysis. Manage. Sci., 39(10): 1261–1264.

Asmild M, Paradi JC, Aggarwall V, Schaffnit C (2004). Combining DEA window analysis with the Malmquist index approach in a study of the Canadian banking industry, J. Prod. Anal., 21(1): 67-89.

Banker RD, Charnes A, Cooper WW (1984). Some models for estimating technical and scale efficiencies in data envelopment analysis. Manage. Sci., 30(9): 1078–1092.

Banker RD, Gifford JL (1988). A relative efficiency model for the evaluation of public health nurse productivity. School of Urban and Public Affairs, Carnegie Mellon University.

Barros CP, Leach S (2006). Performance evaluation of the English premier football league with data envelopment analysis. Appl. Econ., 38(12): 1449–1458.

Brockett PL, Cooper WW, Golden L, Rousseau J, Wang Y (1998). DEA evaluation of the efficiency of organizational forms and distribution systems in the US property and liability insurance industry. Int. J. Syst. Sci., 29(11): 1235-1247.

Brockett PL, Cooper WW, Golden L, Rousseau J, Wang Y (2004). Evaluating solvency versus efficiency performance and different forms of organization performance and marketing in US property-liability insurance companies. Eur. J. Oper. Res., 154(2): 492-514.

Chang DS, Kuo YC, Chen TY (2008). Productivity measurement of the manufacturing process for outsourcing decision: the case of a Taiwanese printed circuit board manufacturer. Int. J. Prod. Res., 46(24): 6981-6995.

Charnes A, Cooper WW, Golany B, Halek R, Klopp G, Schmitz E, Thomas D (1986). Two phase data envelopment analysis approach to policy evaluation and management of army recruiting activities: tradeoffs between joint services and army advertising. Research Report CCS. 532. Center for Cybernetic Studies. The University of Texas at Austin, Texas.

Charnes A, Cooper WW, Lewin AY, Seiford LM (1994). Data Envelopment Analysis: Theory, Methodology, and Application. Kluwer Academic Publishers.

Charnes A, Cooper WW, Lewin AY, Seiford LM (1997). Data Envelopment Analysis: Theory, Methodology, and Application. Kluwer Academic Publishers.
Charnes A, Cooper WW, Rhodes E (1978). Measuring the efficiency of decision-making units. Eur. J. Oper. Res., 2(6): 429-444.
Chen LF, Hsiao CH, Tsai CF (2010). Three-stage-DEA model selections and managerial decision. Afr. J. Bus. Manage., 4(14): 3046-3055.
Chen Y, Zhu J (2001). Measuring information technology's indirect impact on firm performance. Proceedings of 6th INFORMS Conference on Information System and Technology.
Chen Y, Zhu J (2004). Measuring information technology's indirect impact on firm performance. Infor. Technol. Manage. 5(1-2): 9–22.
Chen YC, Chiu YH, Huang CW (2010). Measuring super-efficiency of financial and nonfinancial holding companies in Taiwan: an application of DEA models. Afr. J. Bus. Manage., 4(13): 3122-3133.
Coelli T, Rao D, Battese G (1997). An Introduction to Efficiency and Productivity Analysis. Kluwer Academic Publishers, Boston.
Cook W, Zhu J (2005). Modeling Performance Measurement: Applications and Implementation Issues in DEA. Springer Science + Business Media, Inc., Boston.
Cooper WW, Seiford LM, Tone K (2000). Data Envelopment Analysis. Kluwer Academic Publishers.
Farrell MJ (1957). The measurement of productive efficiency. J. Roy. Stat. Soc., 120(3): 253-290.
Hwang SN, Kao TL (2008). Using two-stage DEA to measure managerial efficiency change of non-life insurance companies in Taiwan. Int. J. Manage. Decis. Making, 9(4): 377-401.
Lee CK, Saxenian A (2008). Coevolution and coordination: a systemic analysis of the Taiwanese information technology industry. J. Econ. Geo., 8(2): 157–180.
Li HY, Zhu J (2005). Ranking the efficiency performance within a set of decision making units by data envelopment analysis, Int. J. Inform. Technol. Decis. Making, 4(3): 345–357.
Lin WC, Liu CF, Liang GS (2010). Analysis of debt-paying ability for a shipping industry in Taiwan. Afr. J. Bus. Manage., 4(1): 77-82.
Lu YH, Shen CC, Ting CT, Wang CH (2010). Research and development in productivity measurement: An empirical investigation of the high technology industry. Afr. J. Bus. Manage., 4(13): 2871-2884.
Luo X (2003). Evaluating the profitability and marketability efficiency of large banks: an application of data envelopment analysis. J. Bus. Res., 56(8): 627-635.
Ross AS, Westerfield RW, Jaffe J (1999). Corporate Finance. McGraw-Hill Publishing Company.
Seiford LM, Zhu J (1999). Profitability and marketability of the top 55 US commercial banks. Manage. Sci., 45(9): 1270-1288.
Sexton TR, Lewis HF (2003). Two-stage DEA: an application to major league baseball. J. Prod. Anal., 19(2-3): 227-249.
Thore S (1996). Economies of scale, emerging patterns, and self-organization in the U.S. computer industry: an empirical investigation using data envelopment analysis. J. Evol. Econ., 6(2): 199–216.
Thore S, Kozmetsky G, Phillips F (1994). DEA of financial statements data: the U.S. computer industry. J. Prod. Anal., 5(3): 229–248.
Thore S, Phillips F, Ruefli RW, Yue P (1996). DEA and the management of the product cycle: the computer industry. Comp. Oper. Res., 23(4): 341–356.
Wang CH, Gopal RD, Zionts S (1997). Use of data envelopment analysis in assessing information technology impact on firm performance. Ann. Oper. Res., 73: 191–213.
Yang CY, Chen TY (2010). Evaluating the efficiency of intellectual capital management for Taiwan IC design industry. Afr. J. Bus. Manage., 4(15): 3366-3373.
Zhu J (2000). Multi-factor performance measure model with an application to Fortune 500 companies. Eur. J. Oper. Res., 123(1): 105-124.

APPENDIX

The names of firms and their corresponding DMUs

DMU1	United MICROELECTRONICS Corp.	DMU26	ACER Incorporated (ACER)
DMU2	Microtek International, Inc.	DMU27	FOXCONN Technology Co., Ltd
DMU3	Advanced Semiconductor Engineering, Inc.	DMU28	CHIN-POON Industrial Co., Ltd.
DMU4	Kinpo Electronics, INC.	DMU29	Inventec Corporation
DMU5	Compeq Manufaturing Co., Ltd.	DMU30	Asustek Computer Inc. (ASUS)
DMU6	Microelectronics Technology Inc.	DMU31	MAG Technology CO., LTD
DMU7	MITAC International Corp.	DMU32	CHROMA ATE INC.
DMU8	Hon Hai Precision IND. Co., Ltd.	DMU33	MUSTEK SYSTEMS INC.
DMU9	CMC Magnetics Corporation	DMU34	Silicon Integrated Systems Corp.
DMU10	Compal Electronics, Inc.	DMU35	KYE Systems CORP.
DMU11	CIS Technology INC.	DMU36	Unitech Printed Circuit Board Corp.
DMU12	Yageo Corporation	DMU37	LINGSEN Precision Industries, Ltd.
DMU13	Pan-International Industrial Corp.	DMU38	Tatung Co.
DMU14	Orient Semiconductor Electronics, Limited	DMU39	Aurora Corporation
DMU15	Taiwan Semiconductor Manufacturing Co., Ltd. (TSMC)	DMU40	Ability Enterprise Co., Ltd.
DMU16	Elitegroup Computer Systems Co. ,Ltd.	DMU41	Gigabyte Technology Co.,Ltd
DMU17	Picvue Electronics, LTD.	DMU42	Micro-Star International Co.,Ltd.
DMU18	OPTO TECH CORPORATION	DMU43	Quanta Computer INC.
DMU19	Behavior Tech Computer Corp.	DMU44	Wintek Corporation
DMU20	Mosel Vitelic INC.	DMU45	VIA Technologies, INC.
DMU21	Systex Corporation	DMU46	Cheng UEI Precision Industry Co., Ltd.
DMU22	Synnex Technology International Corp.	DMU47	Everlight Electronics Co., Ltd.
DMU23	RITEK Corporation	DMU48	Premier Image Technology Corporation
DMU24	SDI Corporation	DMU49	Advantech Co., Ltd.
DMU25	BENQ Corporation	DMU50	PRODISC Technology Inc.