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Data Envelopment Analysis and Financial Ratio: A new approach to estimate the efficiency of Taiwan Computer's Peripheral Industry

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Data Envelopment Analysis and Financial Ratio: A new approach to estimate the efficiency of Taiwan Computer's Peripheral Industry

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Abstract

The goal of this study is to measure the operating efficiency of computer's peripheral industry and to highlight the status of operation performance so that managers can find strategy to improve their performance. In this paper, we used data envelopment analysis (DEA) technique in conjunction with financial indicator to evaluate the efficiency of twelve computer's peripheral companies. We found that company which has good profitability indicator always enjoy high level of efficiency. We also found that technological innovation, differentiation and uniqueness can be complement of *DEA* for the evaluation of an organization performance. Due to high level of competition among the companies in this field, they became a complementary cluster in the overall computer industry in Taiwan.

Keyword: *Performance evaluation, DEA, Financial ratios, Computer's peripheral industry*

1. Introduction

The performance and efficiency quality is an important issue for any business essence in an industry. Since the Taiwan's computer and its peripheral industry has becoming a real global

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business, is essential to evaluate their level of efficiency and give some suggestion for improvement. Traditionally, the level of efficiency among firms has been measure by using conventional financial ratios. Financial ratios have been used continuously as an analytical technique to measure the company's performance and to analyze trends and to compare a firm's financial figures to those of competitors or those of the business sector in which it belongs to. Recently, there have been a number of empirical studies, applying Data Envelopment Analysis (DEA) as an advanced technique to measure efficiency of the company. The application of methodology is based on fact that it's seems to be more efficient compared to conventional financial ratios in term of measuring performance.

This study involves the business evaluation of twelve computer 'peripheral companies over the period 2006-2010, by using the technique of data envelopment analysis in conjunction with standard financial ratio which assesses cost, revenue and profitability efficiency.

The empirical experiment explores that two firms had a brilliant performance in that field. They are better off in term of business-level strategies and business tactic than competitors. Differentiation, uniqueness and technological innovation, have been their key strategy for being a complementary cluster in the overall computer's industry in Taiwan.

The remainder of the paper is structured as follows: Section II, represent a brief literature review. Section III, data acquisition and methodology. Section IV, details the empirical study and illustrates the results of efficiency. Finally, conclusions and summary are given in section V.

2. Literature review

The efficiency measurement of any individual firms is of fundamental importance for policymaking in many areas of economics. The efficiency can be measured in term of minimization of cost or profit maximization. In general, a firm operates with full efficiency if it's able to obtain minimum inputs required to produce any given level of outputs [16]. There have been a number of researches that use nonparametric approach to evaluate the firm performance[16,21,3],but also, there have been employed in large body of literature accounting based financial ratio, including ROA and ROE as a key indicator to evaluate firm efficiency. For instance, the financial ratios are employed to determine firm's solvency, capital structure, profitability, and liquidity. Altman [1] stated in his research paper that firm with poor profitability ratio record is regarded as inefficient. Similarly, Penman [28] investigated the properties of the rate of return on equity (ROE); he concluded that ROE is a pure measure of the firm profitability and performance. McNamara and Duncan [25] investigated the association between ROA and firm performance. They found that firm performance is a function of the prior year ROA.

Since the introduction of data envelopment analysis, by Charnes *et al.*,[11] it has been extensively applied in performance evaluation of the, schools[29,33] hospital and health care[32,9] airports performance[6],air force maintenance units[31], power plant[30],advertising [12], transportation[23,5]. *DEA* has also been applied in banking sector in conjunction with financial ratio. Halkos and Salamouris [19] used *DEA* in combination with key financial ratio to measure the performance of the Greek banking sector. They concluded that data envelopment analysis is superior to financial ratio as a performance measure. Therefore, they suggested that *DEA* should be used either an alternative or complement to ratio model for the evaluation of any business's performance. This conclusion is consistent to Oberholzer and Van der Westhuizen [26] who found a mixed result concerning the association between *DEA* and ratio model. Feroz *et al.,* [18] demonstrated that *DEA* can augment the conventional ratio analysis. It can provide a consistent and reliable measure of managerial or operational efficiency of a firm .They also argued that *DEA* can be a complement of ratio analysis specifically if the goal is to provide information about the operation and technical efficiency of the firm. Finally, one of the recent study conducted by Kuah *et al.,* [22] concluded that *DEA* is suitable to measure quality management efficiency and give improvement suggestions to the inefficient quality management. According to theses information, *DEA* is a considered as a powerful technique to estimate the efficiency and performance of any kind of organization. It's a mathematical liner programming method for assessing the comparative efficiency of DMU. It can handle multiple inputs and multiple outputs of the decision units as opposed to other technique such as ratio model and regression [20].

3. Data acquisition and methodology

3.1. *Data acquisition*

The data were obtained from financial statement available in Taiwan Stock Exchange database over the period 2006-2010. It consists of 24 firms from Taiwan's computer and its peripheral equipment industry. The firms are grouped in two according to the industry. In this study, only 12 companies form peripheral equipment are included due to the type of products they provide. They only produce computer's components not the main body of computer. They also are categorized as small sized firms owing to their size of average assets and revenue. To measure the efficiency among them we applied non-parametric linear programming technique named *DEA* Charnes *et al.*, [11]. Based on prior study, three inputs ($X1, X2, X3$) and two outputs ($Y1, Y2$) are employed. The inputs employed are measured by annual total fixed assets (FA), operating cost (OC) and number of labor (L) while the outputs are measured in term of annual revenue and non-operating income (NOI). Accordingly, the inputs and outputs used consist of:

$X1$: Fixed Assets (FA)

$X2$: Operating Cost (OC)

$X3$: Labor

$Y1$: Revenue

$Y2$: Non-operating income (NOI)

3.2. *Methodology*

In this study, we employed data envelopment analysis (DEA) as a non-parametric liner programing base technique to assess the comparative efficiencies of the several *DMUs* where the presence of multiple inputs and outputs makes comparison difficult [34, 20]. Assuming that we wish to evaluate the efficiency of n *DMUs*, let $N = \{1, 2...n\}$ denote the set of units being compared. If the units produce a single output using a single input only, the efficiency of the j decision-making unit $DMU\ j, j \in N$, is defined as:

$$\rho(j) = \frac{\beta_j}{\gamma_j} \tag{1}$$

In this model, β_j represent the output produced by DMU_j while the γ_j represent the value of inputs used. If the units produce multiple outputs using various input factors, the efficiency of DMU_j is defined as the ratio between a weighted sum of the outputs and a weighted sum of the inputs. Denote by $H = \{1, 2...s\}$ the set of production factors and by $K = \{1, 2...m\}$ the corresponding set of outputs. If $x_{ij}, i \in H$, denotes the quantity of input i used by DMU_j and $y_{rj}, r \in K$, the quantity of output r obtained, the efficiency of DMU_j is defined as:

$$\theta(j) = \frac{U_1 Y_{1j} + U_1 Y_{2j} \cdots\cdots U_m Y_{mj}}{V_1 Y_{1j} + V_2 X_{2j} + \cdots\cdots V_s X_{sj}} = \frac{\sum r \in k^{U_r Y_{rj}}}{\sum r \in H^{V_i X_{ij}}} \tag{2}$$

For weights $u_1, u_2 \ldots u_m$ associated with the outputs and $v_1, v_2 \ldots, v_s$, assigned to the input. It means that each *DMU* selects input and output weights that maximize its efficiency score. In general, a *DMU* is considered to be efficient if it obtains a score of 1 and a score of less than 1 implies that it is inefficient.

According to literature there are two *DEA* models. The first one was coined by Charnes *et al.,* [11] and hence named as *CCR* model, while the second developed by Banker *et al.,* [4] named as *BCC* models. These two models can be divided into two terms, one is the input oriented model, and another one is the output oriented model. The input orientation seeks to minimize the usage of inputs given a fixed level of output while the output orientation maximizes the level of output for a given level of inputs. The *CCR* model is built on the assumption of constant returns to the scale (CRS) while the *BCC* model is built on the assumption of variable returns to the scale (VRS) [24]. In order to solve the problem, we used output oriented version, each in the form of a pair of dual linear programs. The CCR-O dual model is given below [14, 15, and 17].

$$\max \theta + \Psi\left[\sum_{j=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right] \tag{3}$$

$$S.t \quad \sum_{j=1}^{r} X_{ij}\lambda_j + S_i^- = X_{io} \qquad i = 1, 2, 3 \ldots m$$

$$\sum_{j=1}^{r} Y_{rj}\lambda_j + S_r^- = \phi X_{ro} \qquad r = 1, 2, 3 \ldots s$$

$$\lambda_{j \geq o} \qquad j = 1, 2, 3 \ldots\ldots n$$

Where:

□ is efficiency of DMU.

S_j^- Is the slack variable represents the input excess value.

S_r^+ Represents surplus variable represents the output shortfall value.

ψ It is a so-called non-Archimedean element defined to be smaller than any positive real number.

λ_r Means the proportion of referencing *DMU* when measure the efficiency of DMU.

According to Banker *et al.*, [14] and Emmanuel [17] the BCC-O dual liner program has the same equation as applied in the CCR-O, but with convexity constraint adjoined:

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

The BCC-O model is shown in Eq. (4)

$$Max\, \theta + \Psi\left[\sum_{j=1}^{m} S_i^- + \sum_{r=1}^{S} S_i^+\right] \tag{4}$$

$$S.t \quad \sum_{j=1}^{r} X_{ij}\lambda_j + S_i^- = X_{io} \qquad i = 1,2,3\ldots m$$

$$\sum_{j=1}^{r} Y_{rj}\lambda_j + S_r^+ = \phi\gamma_{ro} \qquad r = 1,2,3\ldots S$$

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

$$\lambda_{j \geq o} \qquad j = 1,2,3\ldots\ldots n$$

For the measurement of efficiency, the *CCR* model measure overall efficiency (OE) of a *DMUs*, and *BCC* model can measure both the pure technical efficiency (PTE) and scale efficiency (SE) respectively.

In this paper we also applied some financial ratio as proposed by Avkiran [2] in order to validate our result. Financial ratios have been used to evaluate differences in financial management and efficiency among corporative enterprises [13]. The key financial ratios applied are as fallowed:

(I) Return on assets (ROA)

$$ROA = \left(\frac{NPAT}{S}\right) * \left[\frac{S}{(A_B + A_E)/2}\right] \tag{5}$$

Where:

NPAT Is the net profit after taxes; A_B total assets at beginning of period, A_E total asset at ending of the period, and S total sales. This ratio, measures how effectively the firm's assets are being used d to generate profits. In general, the larger of this ratio the better the firm is performing.

(II) Return on equity (ROE)

$$ROE = \left(\frac{NE}{S}\right) * \left[\frac{S}{A} * \left(1 + \frac{D}{E}\right)\right] \tag{6}$$

Where:

NE- net earnings after taxes; *A* total assets; *S* total sales; *D* total debt and *E* total equity.

It's a bottom line measure for the shareholders, measuring the profits earned for each dollar invested in the firm's stock. Thus, the higher of this ratio the higher is the efficiency.

(III) Profit margin

$$PM = \frac{NI}{S} \tag{7}$$

Where: *NI* is the net income, *S* total sales.

Is the ratio of profitability, the higher of this ratio the better is the company's profitability.

(IV) Earning per shares (EPS)

$$EPS = \frac{PAT}{\sum\left(S^* \frac{n}{12}\right)} \tag{8}$$

Where *PAT* stands for net profit after tax, *s* is the number of shares issued, and $\frac{n}{12}$ represents the fraction of the year outstanding. It is one of the important metric to determine firm's profitability and performance. The higher of this ratio with all else equal, the higher each shares should be worth, and the more money the company is making.

Revenue per labor (R/L)

$$R/L = \frac{TR}{L} \tag{9}$$

Where *TR* is the total revenue, and *L* is the total labor hired by company. This ratio indicates how productive each employee is in generating revenue for the firm. Thus an increasing in the index number revel high productivity.

Efficiency ratio (ER)

$$ER = \frac{OC}{TR} \tag{10}$$

Where, OC is operating cost, TR total, revenue during the period. This ratio shows how well the firms are doing by comparing the cost of running the business with its revenue. It expresses the percentage of revenue absorbed by operational cost. The lower the percentage the better is the efficiency.

4. Empirical results and analysis

The purpose of this study is to estimate the efficiency of the selected firms by using *DEA* model. The software DEA-solver was applied to generate the scores of overall efficiency (OE), pure technical efficiency (PTE) and scale effect (SE). Table 1 represent the result of *DEA* efficiency estimated. According to model, only two *DMUs* are relatively efficient throughout the period under investigation. The average overall efficiency score was 0.94 in 2006 and decrease to 0.82 in 2007, but it got back to 0.94 from 2008 to 2010.The average pure technical efficiency also experienced the same trend, it was 0.95 in 2006 but dropped to 0.88 in 2007, and recovered slightly to 0.96 from 2008 to 2010. It means that most of the companies under investigation did not reach yet their efficiency frontier. They need some improvement to be more technically efficient, by producing more outputs, using smallest possible amount of inputs [27]. Table 2, reports Pearson correlation matrix between inputs and outputs. For each pair of variables, the Pearson correlation coefficient and related p-value are provided. The coefficient measures the strength and direction of a linear relationship between variables. Results indicate that some variables are correlated at a significant level. For instance, the revenue and operating cost are positively correlated with efficiency at 0.01 levels (two-tailed test), and at 0.05 levels (Two-tailed test), respectively. Table 3, show the descriptive statistic of the variable employed in the study. In general, there is a large variation in the distribution of each inputs and output across the period of investigation.

We also investigated the situation of returns to scale in order to illustrate the change of the company's production scale. The returns to scale analysis are shown in Table 4. The constant returns to scale indicate that the company has reached the best scale. The increasing returns to scale indicates that an increase in inputs leads to a more than proportionate increase in output while decreasing returns to scale indicates that an increase in inputs leads to a less proportionate increase in outputs. In 2010 only two companies showed increasing returns to scale. It indicated that managers' capabilities to utilize companies' resources still need to be

Table 1

Efficiency scores from *DEA* model, 2006-2010

DMU	2006			2007			2008			2009			2010		
	OE	PTE	SE	OE	PTE	SE	OE	PTE	SE	OE	PTE	SE	OE	PTE	SE
DMU 1	1	1	1	1	1	1	0.91	0.91	1	1	1	1	1	1	1
DMU 2	1	1	1	0.94	0.94	1	0.97	0.98	0.98	0.95	0.96	0.99	0.96	0.98	0.98
DMU 3	0.99	1	0.99	0.94	0.95	0.99	0.95	0.96	0.99	1	1	1	0.97	1	0.97
DMU 4	0.91	0.91	1	0.66	0.68	0.97	0.89	0.89	1	0.94	0.94	1	0.93	0.94	0.99
DMU 5	0.79	0.85	0.93	0.61	0.77	0.79	0.85	0.87	0.98	0.71	0.72	0.99	0.83	0.83	1
DMU 6	1	1	1	0.83	0.94	0.88	1	1	1	1	1	1	1	1	1
DMU 7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
DMU 8	0.82	0.83	0.99	0.65	0.67	0.97	0.82	0.84	0.98	0.81	0.83	0.98	0.85	0.85	1
DMU 9	1	1	1	0.89	1	0.89	1	1	1	1	1	1	0.98	0.98	1
DMU 10	0.78	0.83	0.94	0.55	0.59	0.93	0.89	0.95	0.94	0.95	1	0.95	0.92	0.95	0.97
DMU 11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
DMU 12	1	1	1	0.79	1	0.78	0.78	1	0.78	0.75	1	0.75	0.82	1	0.82
Mean	0.94	0.95	0.98	0.82	0.88	0.93	0.92	0.95	0.97	0.93	0.95	0.97	0.94	0.96	0.98

Table 2

Correlation between inputs and outputs, 2006-2010

		FA	OC	Labor
Revenue	Correlation	.630(*)	.989(**)	.654(*)
	P-Value	0.028	.000	0.021
NOI	Correlation	.780(**)	0.527	.662(*)
	P- Value	0.003	0.078	0.019

Note: **Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

Table 3

Descriptive statistic for inputs and outputs, 2006-2010

	FA	OC	Labor	Revenue	NOI
Max	936670.8	11893987	654.4	12901155	1221379
Min	472	412883.8	20.4	484018.8	22292.4
Average	358203.5333	3541666.233	325.8166667	4161991.317	314111.95
SD	249213.8031	3354519.054	189.8704024	3657745.341	380482.6253

Table 4

Returns to scale results

DMU	2006	2007	2008	2009	2010
DMU1	Constant	Constant	Constant	Constant	Constant
DMU2	Constant	Constant	Constant	Decreasing	Decreasing
DMU3	Increasing	Constant	Constant	Constant	Decreasing
DMU4	Constant	Increasing	Constant	Constant	Decreasing
DMU5	Constant	Increasing	Increasing	Increasing	Constant
DMU6	Constant	Increasing	Constant	Constant	Constant
DMU7	Constant	Constant	Constant	Constant	Constant
DMU8	Constant	Increasing	Constant	Increasing	Decreasing
DMU9	Constant	Increasing	Constant	Constant	Decreasing
DMU10	Constant	Increasing	Constant	Increasing	Increasing
DMU11	Constant	Constant	Constant	Constant	Constant
DMU12	Constant	Increasing	Increasing	Increasing	Increasing

enhanced. They must reduce non-essential expenses in order to perform efficiently.

4.1. *Comparison between DEA efficiency scores and ratio model*

To compare *DEA* efficiency scores with standard financial ratio, we first ran the test of Pearson correlation coefficients to establish a significant link between them. The results associated with rank correlation are reported in table 5. The result shows that there is a significant correlation between profitability ratios and efficiency scores. This result is consistent to Casu and Molyneux [10] who found positive relation between profitability and efficiency. Concerning to efficiency ratio, there is a lower correlation between revenue per labor (R/L) and efficiency scores and a negative association between efficiency scores and operating expense per revenue (OC/R). Table 6, summarizes the descriptive statistic of ratio model applied in the study. The profitability ratio summarized in the table 6 carries important items that define the dimensions of the efficiency of revenue-producing organizations, while the efficiency ratios show the efficiency of the organizations in term of employee productivity and the cost of production. Therefore, they don't provide an overall estimation on total efficiency and performance of the firms, they also don't consider the cost of capital firms employ to produce and sell products. Based on above analyzes, we can conclude that *DEA* method seems to be superior in term of performance measuring. It can handle multiple inputs and outputs simultaneously and gives the ranking according to efficiency scores and improvement suggestion to the non-efficient. However the drawback of *DEA* is that it measures the efficiency but not effectivity.

5. Conclusions and summary

This research seeks to investigate the level of efficiency among twelve companies from the computer's peripheral industry over the period 2006-2010, using non-parametric approach of data envelopment analysis (DEA), in conjunction with a number of suggested financial efficiency ratio. The present paper extends empirical work in two ways. First, we applied *DEA* approach with all inputs and outputs selected. The evidence provided suggest that only two companies are relatively efficient with constant return to scale (CRS) throughout the period under investigation. Second, we ran the test of Person correlation coefficient in order to determine whether there is any association between efficiency scores derived by multiple-inputs and multiple outputs technologies and conventional

Table 5

Correlation coefficient between efficiency scores and ratio model, 2006-2010

		ROA	ROE	PM	RL	EPS	OC/R	OE	PTE	SE
ROA	Correlation	1	.993(**)	.863(**)	0.145	.959(**)	-0.45	.787(**)	.772(**)	.645(*)
	P-Value		.000	.000	0.654	.000	0.142	0.002	0.003	0.024
ROE	Correlation	.993(**)	1	.816(**)	0.187	.943(**)	-0.403	.777(**)	.765(**)	.626(*)
	P-Value	.000		0.001	0.56	.000	0.194	0.003	0.004	0.029
PM	Correlation	.863(**)	.816(**)	1	0.06	.829(**)	-0.421	.706(*)	.675(*)	.668(*)
	P-Value	.000	0.001		0.853	0.001	0.173	0.01	0.016	0.018
EPS	Correlation	.959(**)	.943(**)	.829(**)	0.023	1	-.592(*)	.773(**)	.785(**)	0.515
	P-Value	.000	.000	0.001	0.943		0.042	0.003	0.003	0.087
RL	Correlation	0.145	0.187	0.06	1	0.023	0.533	0.518	0.474	0.533
	P-Value	0.654	0.56	0.853		0.943	0.075	0.084	0.12	0.074
OC/R	Correlation	-0.45	-0.403	-0.421	0.533	-.592(*)	1	-0.134	-0.213	0.161
	P-Value	0.142	0.194	0.173	0.075	0.042		0.678	0.507	0.617

Note: ** Correlation is statistically significant at the 0.01 and 0.05 level (2-tailed): associated p-value

Table 6

Descriptive statistic for ratio model, 2006-2010

	ROA	ROE	PM	EPS	R/L	OC/R
Mean	3.716333333	4.2863333	2.9855	0.8261491	1.15766667	18948.15845
St. Deviation	11.28441402	16.331562	24.8508261	0.0962675	2.05903081	21576.667
Minimum	-21.968	-34.192	-40.452	0.6069813	-2.578	3793.928879
Maximum	16.636	21.196	52.728	0.9281171	3.882	75834.48614

ratio model. The result shows that there is a positive correlation between profitability measures and efficiency scores

This empirical work highlights that only two firms had an excellent result during the testing period. It means that in this industry they are better off in term of business-level strategies and they are in position to compete with big firms to win market shares. Differentiation, uniqueness, and technological innovation have been one of the key factors to achieve competitive advantage over their peers in the industry. Gradually, they are becoming a complementary industry inside the overall computer industry, creating a comprehensive industrial cluster from subsidiaries in that field.

DEA and financial ratio alone, do not measure the effectiveness. Thus we purpose the following linear combination:

$$B_{eff} = f(VA, OE, Fr)$$

Where:

B_{eff} - Enterprise effectiveness

VA - Value-added creation

OE - Overall efficiency derived by DEA

Fr - Stand for key financial indicator

The above liner combination states that the effectiveness of any business also depends on value added creation by the firms. The value added can be created through technological innovation, uniqueness and differentiations of product and services provided by organization.

This paper is not without its limitation. However, it could help the managers of the inefficient companies to restructure their organizational and business styles and review the resources to increase the performance and efficiency.

References

[1] Altman, Edward I. Financial Ratios, Discriminant Analysis and the Prediction of Corporate Bankruptcy. *The Journal of Finance*, Vol. 23(4), (Sep., 1968), pp. 589–609

[2] Avkiran, N. K., Stability and integrity tests in data envelopment analysis. *Socio-economic Planning Sciences,* Vol. 41, 2007, pp. 224–234.

[3] Badunenko, Oleg. Fritschb, Michael., Stephanc, Andreas. hat determines the Technical Efficiency of a Firm? The Importance of Industry, Location, and Size, Friedrich-Schiller-Universität Jena Carl-Zeiß-Str. 3, 07743 Jena, 2006.

[4] Banker, R. D., Charnes, A. and Cooper, W. W., "Some models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis", *Management Science*, Vol. 30, 1984, pp. 1078–1092.

[5] Barnum, David T., McNeil, Sue., Hart, Jonathan. "Comparing the Efficiency of Public Transportation Subunits using Data Envelopment Analysis" *Journal of Public Transportation*, 2007, Vol. 10(2).

[6] Barrosa, Carlos Pestana., Diekeb, Peter U.C. Performance evaluation of Italian airports: A data envelopment analysis. *Journal of Air Transport Management*, Vol. 13(4), 2007, pp. 184–19.

[7] Berger, A. N., and Humphrey, D. B., Measurement and efficiency issue in commercial banking. In: Griliches, Z. (Ed.), Output Measurement in the Service Sectors. University of Chicago Press, Chicago, 1992, pp. 245–279.

[8] Berger, A. N. and Humphrey, D.B. 'Efficiency of financial institutions: International survey and directions for further research'. *European Journal of Operational Research*, 98, 1997, pp. 175–212.

[9] Brockett, Patrick L.; Chang Ray E.; Rousseaun John J.; semple John H. and Yang, Chuanhou. "A Comparison of HMO efficiencies as a function of Provider autonomy" *Journal of risk and Insurance*, Vol. 71(1), 2004, pp. 1–19.

[10] Casu, B., and Molyneux, Ph., A comparative study of efficiency in European banking. *Appl. Econ*. Vol. 35, 2003, pp. 1865–1876.

[11] Charnes, A., W. W. Cooper, and E, Rhodes. Measuring the efficiency of decision making units. *European Journal of operation research*, 1978, pp. 429–44.

[12] Cheong, Yunjae and Leckenby, John D. An Evaluation of Advertising Media spending. Efficiency Using Data Envelopment Analysis, Paper

presented at the 2006 Conference of American Academy of Advertising, 2006.

[13] Chesnick, David S. (2000). Financial Management and Ratio Analysis for Cooperative Enterprises, US Department of Agriculture, Rural Business Cooperative Service, RBS Research Report 175.

[14] Cooper, W.W., *et al.,* In: Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References, and DEA-Solver Software .Kluwer, Academic Publishers, Norwell, Massachusetts, 2000.

[15] Cooper, W.W., *et al.,* In: Introduction to Data Envelopment Analysis and its uses: With *DEA* solver software and Reference. Springer, New York, 2006.

[16] Cummins, J. David., Weiss, Mary A. Analyzing Firm Performance in the Insurance Industry using Frontier Efficiency Method. In Dionne, G. (ed.), Handbook of Insurance. Boston, Kluwer, 2000.

[17] Emmanuel, T. Introduction to the Theory and Application of Data Envelopment Analysis: A foundation Text with Integrated software. Kluwer Academic publisher, Norwell, Massachusetts, 2001.

[18] Feroz, E. H., Kim, S. and Raab, RL. Financial Statement Analysis: A Data Envelopment Analysis approach. *Journal of the Operational Research Society*, Vol. 54, 2003, pp. 48–58.

[19] Halkos, George E. and Salamouris, Dimitrios S. Efficiency measurement of the Greek commercial banks with the use of financial ratios: a data envelopment analysis approach. *Management Accounting Research*, Vol. 15, 2004, pp. 201–224.

[20] K. M. Jibendu., Research Methodology on Data Envelopment Analysis (DEA), Universal Publisher, Boca Raton, Florida, USA. ISBN-10:1-59942-590-0 (paper), 2008.

[21] Kohers, T., Huang, M., and Kohers, N. Market perception of efficiency in bank holding company mergers: the roles of the *DEA* and SFA models in capturing merger potential. *Rev. Financial Econ*. Vol. 9, 2000, pp. 101–120.

[22] Kuah, Chuen T., Wong, Kuan Y., Behrouzi, Farzad. Application of Data Envelopment Analysis to Assess Quality Management Efficiency, World Academy of Science, *Engineering and Technology*, Vol. 70, 2010.

[23] Lin, Wen-Chen., Liu Chin –Feng. (2005). Performance efficiency valuation of the Taiwan's shipping industry: An application of Data Envelopment Analysis. Proceedings of the Eastern Asia Society for

Transportation Studies, Vol. 5, pp. 467–476, Research, Vol. 12(1), pp. 165–178.

[24] Liu, C.H., Lin, Sue J., Lewis, Charles. Evaluation of thermal power plant operational performance in Taiwan by data envelopment analysis. *Energy Policy*, Vol. 38, 2010, 1049–1058.

[25] McNamara, Ray., Duncan, Keit. Firm performance and macro-economic variables. School of business DISCUSSION PAPERS NO 59, 1995.

[26] Oberholzer, M., G. van derWesthuizen. “An empirical study on measuring efficiency and profitability of bank regions”, Meditari Accountancy, 2004.

[27] Oberholzer, M., Van der Westhuizen, G., and Van Rooyen, S. The influence of banks’ internal performance on market performance: A non-parametric approach. *Southern African Business Review*, Vol. 14, 2010.

[28] Penman, S. H. Financial Statement Analysis and Security Valuation, 3rd edition. Boston, MA: McGraw-Hill, 2007.

[29] Ray, Subhash C. Resource Use Efficiency in Public Schools: A Study of Connecticut Data, *Management Science*, Vol. 37(12), 1991, pp. 1620–1628.

[30] Sarıca, Kemal., Or, Ilhan. Efficiency assessment of Turkish power plants using data envelopment analysis. Science Direct, Energy, Vol. 32, 2007, pp. 1484–1499.

[31] Seroussy, D., Applying *DEA* to the I.D.F. Air-Force maintenance units, MSc Thesis, the Technion, Israel Institute of Technology, 1987.

[32] Steinman, Lukas., Gunnar Dittrich, Alexander Karman and Peter Zwifel. Measuring and Comparing the (In) Efficiency of German and Swiss Hospitals. *The European Journal of Health Economics*, Vol. 5 (3), 2004, pp. 216-226.

[33] Sunderland, D. and R. Price, “Linkages between Performance and Institutions in the Primary and Secondary Education Sector” OECD Economics Department Working Paper no. 558, OECD Publishing, 2007.

[34] Talluri, Srinivas. Data Envelopment Analysis: Models and Extensions. Holly S. Lewis, Feature Editor, Pennsylvania State University, 2000.

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