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PERFORMANCE EFFICIENCY EVALUATION OF THE TAIWAN'S SHIPPING INDUSTRY: AN APPLICATION OF DATA ENVELOPMENT ANALYSIS

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Abstract: This paper attempts to construct an efficient evaluation for a shipping industry with financial indicators, because sometimes non-financial indicators are difficult to obtain and are doubtful or untrustworthy. So financial indicators are an important method to evaluate performance. A financial statement is audited by CPA and it is easy to gather, so we do not doubt its trustworthiness. The main purpose of this paper is to measure the operating efficiency of a shipping industry and to highlight the status of operation performance so that managers or regulators can improve their performance. We use data envelopment analysis (DEA) to calculate the operating efficiency of 14 shipping firms in this paper. The empirical results show that performance evaluation for a shipping industry can be more comprehensive if financial ratios are considered.

Key Words: performance evaluation, data envelopment analysis (DEA), financial ratios, BCG matrix

1. INTRODUCTION

Because of the dramatic change in information technology and the business operation environment, firms face serious competition. This situation has also happened in the shipping industry. A good operating performance is critical for successful business. Accordingly, performance evaluation is a main concern of this study.
In the business management, financial ratios are usually one of the indicators used to evaluate a

firm's performance. Generally, the financial information of a company's business operations will be reported in the yearly financial statements, and a financial ratio simply constitutes one item divided by another in the financial statement. Financial ratios can be viewed as a preliminary reference for the analysis of the business performance.

This paper attempts to provide an acceptable evaluation of a firm's performance for managers. Traditionally, the evaluation of a firm's performance usually employs the financial ratio method, because it provides a simple description about the firm's financial performance in comparison with previous periods and helps to improve its performance of management. However, if we use the related financial indicators to measure technical efficiency in a shipping industry, it will lead to a problem of the weight assignment to each indicator. "The financial ratio method can be an appropriate method when firms use a single input or generate a single output. However, as in many firms, they employ various inputs to provide various services (outputs). Which ratio be selected becomes an issue of evaluators when a great number of related financial indicators are involved. One of the solving methods is to aggregate the average among all indicators in order to integrate a single measurement."

The DEA approach can be used to solve the above mentioned weight assignment problem. It uses a mathematical programming method to generate a set of weights for each indicator. It considers how much efficiency could be improved, and ranks the efficiency scores of individual firms. Charnes *et al.* (1978) were the first to describe the DEA model (the CCR model), using a mathematical programming model to determine the efficiency frontier when more than one measure is used. Thus, the DEA model developed in this paper is able to maintain fairness in performance assessment, generating objective weights.

This paper is divided into five sections. The first section is the background of the research problem including the importance of the evaluation performance for a shipping industry. The second section reviews literature relevant to the evaluation performance. We discuss the proposed DEA model and input/output items, respectively in third section. The fourth section compares DEA results to the financial ratios analysis. Lastly, we conclude the empirical findings and suggest areas for further research.

2. LITERATURE REVIEW

Having been employed in literature for many decades, financial ratios are the simplest tools for evaluating the financial performance of firms.

We can employ financial ratios to determine a firm's solvency, capital structure, profitability, liquidity and asset turnover. Beaver (1966) used financial ratios to develop an indicator that best differentiated between failed and non-failed firms using univariate analysis techniques. Altman (1968) used financial ratios to predict corporate bankruptcy. He found that the bankruptcy model has an accuracy rate of 93%, and is very successful in predicting failed and non-failed firms. Ohlson (1980) employed financial ratios to predict a firm's crisis. He found that there are four factors affecting a firm's vulnerability. These factors are firm's scale, financial structure, performance, and liquidity. Bernstein (1988) found financial ratios could divide into four kinds:

solvency, capital structure, profitability, and turnover. According to this information, financial ratios actually have the function to evaluate firm performance. Feng (2000) tried to construct a performance evaluation process for airlines taking financial ratios into consideration. He used grey relation analysis and the TOPSIS method to overcome the problem of small sample and outranking of airlines.

Since its introduction by Charnes *et al.* (1978), there have been many applications of DEA. Some applications have involved efficiency evaluation of organizations with characteristics similar to ports, such as hospitals (Banker *et al.*, 1986), schools (Ray, 1991), courts (Lewin *et al.*, 1982), and air force maintenance units (Charnes *et al.*, 1985). DEA has also been applied in the transportation sector to airlines (Banker and Johnston, 1994; Charnes *et al.*, 1996), and railways (Oum and Yu, 1994). Yeh (1996) was one of the first researchers to combine DEA with financial ratio analysis. She utilized DEA to evaluate bank performance. Her study empirically demonstrated that DEA, in conjunction with financial ratio analysis, can effectively aggregate and reclassify the perplexing ratios into meaningful financial dimensions, which enable analyze to gain insight into the financial operating strategies of banks. Data envelopment analysis (DEA) is an operations research-based method for measuring the performance efficiency of decision units that are characterized by multiple inputs and outputs. DEA converts multiple inputs and outputs of a decision unit into a single measure of performance, generally referred to as relative efficiency. (Donthu and Yoo, 1998, p. 91) Donthu and Yoo (1998) assessed retail productivity by DEA. So DEA approach can be used to solve the weight assignment problem and its relative efficiency to measure firm performance. Chen (2002) combined DEA measurements and manager prior opinion measurements to generate a posterior measurement for an overall measurement of the technical efficiency of banks in Taiwan. Emel *et al.* (2003) applied DEA to 82 industrial firms comprising the credit portfolio of one of Turkey's largest commercial banks. He used financial ratios to measure overall performance in a single financial efficiency score—"the credibility score".

These studies attest that the DEA approach is a good method to evaluate firm performance. Because DEA can solve weight problems, we use it to measure the operating efficiencies of 14 shipping firms in this paper.

3. METHODOLOGY

Charnes, Cooper, and Rhodes (1978) were the first to propose the DEA methodology as an evaluation tool for decision units. DEA has been applied successfully as a performance evaluation tool in many fields including manufacturing, school, banks, pharmacies, small business development centers, and nursing home chains. Seiford (1990) provides an excellent bibliography of DEA applications.

We employed a mathematical planning model (CCR model) to measure the efficiency frontier based on the concept of Pareto optimum. The basic idea of DEA is to identify the most efficient decision-making unit (DMU) among all DMUs. The most efficient DMU is called a Pareto-optimal unit and is considered the standard for comparison for all other DMUs. That is to say, a single firm is considered DEA Pareto efficient if it cannot increase any output or reduce any input without reducing other output or increasing other input. An efficient firm can enjoy efficiency scores of unity, while an inefficiency firm receives DEA scores of less than unity.

Efficiency is the ratio of the weighted sum of a firm to the weighted sum of inputs. The efficiency of any firm is computed as the maximum of a ratio of weighted firms to weighted inputs, subject to the condition that similar ratios, using the same weights, for all other firms under consideration, are less than or equal to one. Here, we denote the maximum efficiency as E_k, Y_{kj} as the *j*th output of the *k*th DMU and X_{ki} as the *i*th input of the *k*th DMU. If a DMU employs *p* input to produce *q* output, the score of *k*th DMU, E_k, is a solution from the fractional linear programming problem):

$$Max \quad E_k = \frac{\sum_{j=1}^{q} U_j Y_{kj}}{\sum_{i=1}^{p} V_i X_{ri}} \qquad \text{i=1,2,…,p} \quad \text{j=1,2,…,q}$$

$$s.t. \qquad \frac{\sum_{j=1}^{q} U_j Y_{rj}}{\sum_{i=1}^{p} V_i X_{ri}} \leq 1 \qquad \text{r=1,2,….,k,……,R}$$

$$U_j, V_i \geq \varepsilon > 0 \qquad \forall \ \text{i, j}$$

Where U_j and V_i are the variable weights in the *j*th output and the *i*th input, respectively. The former model can be reformulated by adding $\sum_{r=1}^{r} \lambda_r = 1$ to the problem, which provides valuable information about the cost benefits:

$$Min \quad TE = \theta - \varepsilon\left(\sum_{i=1}^{p} S_{ki}^{-} + \sum_{j=1}^{q} S_{kj}^{+}\right)$$

$$s.t. \quad \sum_{r=1}^{r} \lambda_r X_{ri} - \theta X_{ki} + S_{ki}^{-} = 0$$

$$\sum_{r=1}^{r} \lambda_r Y_{rj} - S_{kj}^{+} = Y_{rj}$$

$$\sum_{r=1}^{r} \lambda_r = 1$$

$$\lambda_r \geq 0, \quad S_{ki}^{-} \geq 0, \quad S_{kj}^{+} \geq 0, \quad \forall \ \text{i, j, k, r}$$

Where θ is the efficiency score and ε is a non-archimedean quantity which is very minute. We can calculate the relative efficiency score from the above model and further estimate the targeted value for each output/input of each shipping companies.

Feng (2000) studied airlines performance evaluation considering the financial factors. He pointed out that the input of an airline is characterized by sunk cost, while its output by intangible products, and its consumption by not-stored services. In view of characteristics of sunk cost, in addition to the fundamental items of the classified financial statements, flight equipment and interest expense are included in the financial factors to evaluate performance. Inventory is not included among the financial factors because of its intangible products and not-stored service characteristics. The characteristics of the shipping industry are similar with the characteristics of the air industry. Ross and Droge (2002) explored the performance of distribution center. They found that the capital and vehicles are important input variables. With the goal of maxmiuming shareholders' wealth, we choose stockholders' equity as a proxy for shareholders' wealth. Based on the above literature and considering the financial variables, we selected two input factors: total assets and stockholders' equity. In order to consider the direct relationship between input factors and output factors, we choose operating revenue and net income as output items.

4. EMPRICAL RESULTS

Unlike regression, DEA does not impose any particular functional from on the data, creating a more flexible piecewise linear function. So DEA is a good tool to evaluate enterprises' performance. In this study, there will be a DMU in one company. The empirical results serve as a valuable diagnostic tool as it can be observed first, with reference to the efficiency score of each individual unit, and second, the slack analysis provides direction for managerial auditing.

We choose 14 open market shipping companies as DMUs and collected the data of two input variables and two output variables from TEJ (Taiwan Economics Journal) database in 2003. This paper applies DEA to fourteen Taiwanese open- market shipping companies: First Steamship, EVEGREEN, Sincere Navigation, U-Ming, Evegreen Internation, TaJung, YML, TZE SHIN, Chinese Maritime Transport (CMT), China Container Terminal (CCT), ETITC, WAN HAI, Shanloong Transportation, and Taiwan Line for evaluation. Table 1 shows that 14 companies and input/output variables.

In the first analysis, four variables (2 outputs and 2 inputs) were used in DEA. The estimated efficiencies for the 14 shipping companies in Taiwan, along with their rank orders, are shown in Table 2. As explained before, these efficiencies were computed for each firm after taking into consideration the inputs and outputs of all 14 firms in the set. Hence these efficiencies are relative efficiencies. Moreover, the efficient firms (whose efficiency =1) were used as the benchmark. Therefore these efficiencies represent relative-to-best efficiencies.

U-Ming, YML, WAN HAI and Shanloong lay on the efficient frontier and hence had efficiency of 1. All other firms lay inside the frontier and hence were inefficient (had efficiency less than 1). Given that we used 2 outputs and 2 inputs, a pictorial representation of the efficient frontier (which requires more than 3 dimensions) was not possible. In order to appreciate these concepts a hypothetical 2-dimensional efficient frontier is shown in Figure 1. This analysis could be from DEA application using just 1 input and 1 output. The efficient firms are on the frontier, while other firms lie inside the frontier. The frontier basically connects the best performance under different input levels.

Table 1. Input/Output Variables of Taiwan's Fourteen Open-market Shipping Companies (unit one thousand NT dollars)

Corp.	Input		Output	
	Assets	Stockholders' equity	Operating Revenue	Net Income
First Steamship	3,323,320	2,575,354	140,754	40,490
EVEGREEN	74,377,629	38,864,522	35,207,238	3,604,776
Sincere Navigation	7,334,351	6,307,206	721,248	1,160,165
U-Ming	13,549,538	9,720,290	3,058,830	2,299,232
Evegreen Internation	24,630,312	18,180,236	4,614,527	560,696
TaJung	10,539,678	5,836,749	4,506,664	55,177
YML	53,643,651	28,823,464	62,913,555	6,649,097
TZE SHIN	2,973,602	2,179,529	2,076,286	106,925
CMT	2,947,123	2,428,391	1,187,215	280,195
CCT	3,882,266	884,134	1,248,514	33,294
ETITC	14,919,000	5,580,172	10,120,830	843,361
WAN HAI	32,570,631	20,319,773	37,660,493	4,430,006
Shanloong	2,184,338	1,118,764	4,920,851	129,908
Taiwan Line	5,991,346	4,525,048	2,357,181	771,641

Table 2 Efficiency of Firms (DEA Versus Regression)

Corp.	DEA Efficiency	DEA Ranking	Regression 1 Ranking[a]	Regression 2 Ranking[b]
First Steamship	0.0771	14	12	3
EVEGREEN	0.4063	9	9	8
Sincere Navigation	0.9322	5	2	9
U-Ming	1.0000	1	1	13
Evegreen Internation	0.1661	13	11	6
TaJung	0.1898	12	14	5
YML	1.0000	1	5	12
TZE SHIN	0.3908	10	10	11
CMT	0.6165	8	6	14
CCT	0.3221	11	13	7
ETITC	0.7129	7	8	10
WAN HAI	1.0000	1	3	4
Shanloong	1.0000	1	7	2
Taiwan Line	0.8042	6	4	1

Note: a. using Return on Assets (ROA) as the dependent variable.
b. using Return on Equity (ROE) as the dependent variable.

If we had relied on traditional financial statement analysis, for example, net income divided by average assets (Return on Assets; ROA), then U-Ming would have the highest productivity. The situation is the same with the DEA analysis. If the firm focused on net income divided by average equity (Return on Equity; ROE), then Taiwan Line would be ranked number 1. However, in the DEA analysis its efficiency was only 0.8042.

Regression has often been used to evaluate firm productivity. The main drawback of such analysis is that we can only use one output variable at a time as the dependent variable. Table 2 also exhibits the firm rankings by linear regression analysis using the 2 output variables as the dependent variables in 2 separate regression analysis. The last 2 columns of this table represent firm rankings using the 2 input variables as the independent variables and operating revenue and net income as the dependent variables, respectively. From this table it is clear that each of these regression-based rankings is different from the DEA-based rankings. Moreover, DEA analysis uses the best performance as the bases for efficiency computation, whereas regression uses the average performance as the bases for computations. Also, regression optimizes across all 14 firms and computes one model and the same coefficients for all firms. DEA optimizes over each firm separately, and computes unique weights for each firm.

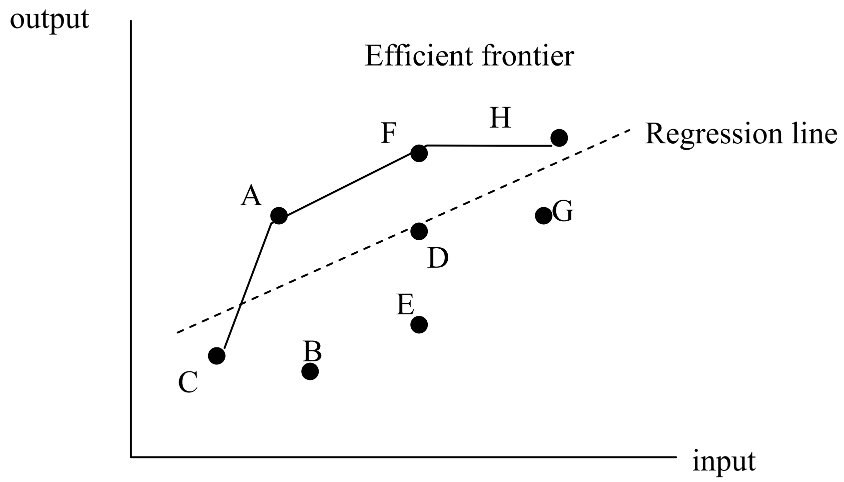

Figure 1. DEA Versus Regression (Hypothetical Illustration)

A closer look at each of the inefficient firms can be taken by sensitivity analysis at each firm level. For example, Table 3 displays the sensitivity analysis results for Taiwan line. This table shows the amount of slack in each of the controllable input and output observations for this firm. This slack is computed by comparing the input and output of Taiwan line with inputs and outputs of its efficient reference firms. Taiwan line can become efficient (increase efficiency from 0.8042 to 1.00) by decreasing an inputs by corresponding slack. The Table 3 shows Taiwan line can decrease stockholder's equity \$310,074 (increase liability relatively). Taiwan could utilize financial leverage to attain more operating effect. Moreover, interest expense could generate tax deduction. It is an advantage of financing.

Table 3 Sensitivity Analysis of Taiwan line

Variable Name	Estimated Weight	Value Measured	Value if Efficient	Slack
Operating Revenue	0.5598987	2,357,181	2,357,181	0
Net income	0.178606	771,641	771,641	0
Assets	0.00000001	5,991,346	5,991,346	0
Equity	0.4242356	4,525,048	4,214,974	310,074

Taiwan Line's estimated weights for the four variables are also shown in Table 3. DEA estimates these weights such that the estimated efficiency of 0.8042 for Taiwan Line is the maximum attainable. No other combination of weights would have produced a higher efficiency estimate for Taiwan Line and yet satisfy all of the constraints. No one variable dominates the productivity estimation of this firm. In the case of regression these weights are the same for all firms. In DEA these weights are uniquely estimated for each firm, hence, allowing for each firm to determine how they will become efficient. In other words, each firm is given its best shot because the unique weights are estimated for each firm so that the highest possible efficiency is estimated for that firm.

Examining the relationship between efficiency and profitability, we use the correlation coefficient between DEA efficiency scores and firm profit to show their correlation extent. Two measures of the firm profit, i.e. Return on Assets (ROA) and Returns on Equity (ROE), are selected and two corresponding correlation coefficients, 0.863 (ROA) and 0.93(ROE), are computed, respectively. We choose the higher correlation coefficient in the measures of return on equity to proceed with the following analysis. The business strategy matrix derived by Boston Consulting Group (BCG matrix) employed to illustrate the individual evidence in the relationship between shipping firms operating efficiency and profitability (see Table 4). It has been observed that 3 firms are in the "super stars" group which is characterized by high efficiency and high profitability. Conversely, 8 of 14 firms are characterized by low efficiency and low profit and are placed in the "problem child" group. We can argue that the 8 problem child firms should rearrange input to improve their performance.

Table 4. The Efficiency-Profit Matrix of 14 Shipping Firms

Efficiency	$E_k=1$	Shanloong (0.4909) **(Question Marks)**	U-Ming (1) YML (0.9752) WAN HAI (0.9217) **(Super Stars)**
	$E_k \neq 1$	ETITC (0.6389), CMT (0.4878); Evergreen (0.3921), TZE SHIN (0.2074), CCT (0.1592), Evegreen Internation (0.1304), First Steamship (0.0665), TaJung (0) **(Problem Child)**	Sincere Navigation (0.7776) Taiwan line (0.7209) **(Cash Cow)**
	0	0.5	1
		Profit (Return on Equity)*	

* The return on equity has been standardized.

5. CONCLUSIONS

This paper employs data envelopment analysis to evaluate the relative efficiency of 14 shipping companies in Taiwan. The estimated results show that 4 firms are relatively efficient, and that there is a rather high level of overall efficiency. It is U-Ming, YML, WAN HAI and Shanloong, respectively. The inefficient firms can effectively promote resource utilization efficiency by better handling labor and capital operating efficiency. We also compare the data envelopment analysis results to the financial ratios of traditional financial statement analysis and show that there is an inconsistent result. Thus we can not conclude which firm has a higher performance based on financial ratios only.

We encountered some key limitations in our research. First, output variables do not include quality-type indicators, e.g. service quality and equipment quality, because the data were unavailable. Second, foreign shipping companies are not included in our study due to limited data. It may lead to be unable to fully describe the whole picture in Taiwan's competitive situation. Finally, DEA does not guarantee the cause or remedy for the identified inefficiency. Internal audits or peer review are needed to define the types of operating changes that can affect efficiency improvements. It would be a meaningful task to finish them in the future research.

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