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Evaluating the Efficiency of Two-stage Networks using Ratio Analysis

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Abstract

Financial firms and institutes are evaluated based on comparisons between financial ratios. There are various techniques for evaluating the performance of firms based on ratios such as the liquidity ratio, current ratio, quick ratio, and so forth. In this study, firms with a two-stage network structure are evaluated using the Ratio Analysis technique. One advantage to the models proposed within a network structure herein is that they provide a comparison between the nonparametric method data envelopment analysis and ratio analysis in the analysis of financial ratios.

Keywords: Data Envelopment Analysis, Ratio Analysis, Performance Evaluation, Financial Ratio, Financial Evaluation

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1. Introduction

Evaluating financial firms and institutes based on financial ratios provides the firms with the opportunity to identify their strengths and weaknesses during financial years, and thereby overcome the barriers and move toward profitability. Thereby, financial ratios are important criteria for the evaluation of firms, and hence, the analysis of financial ratios is of great significance. There are various methods for analyzing these ratios, such as data envelopment analysis (DEA) and Ratio Analysis, the relationship between which is extremely important. Generally, financial ratios fall into five main categories, including liquidity ratios, profitability ratios, leverage ratios, market value ratios, and activity ratios. These financial ratios are defined based on assets, debts, market ratios, cost of goods sold (COGS), average accounts receivable, and sales invoices. Many financial firms and institutes have a two-stage network structure, and the two stages are divided based on a financial year. The first stage is related to the first half of the year, while the second stage pertains to the second half of the year. Although, the two-stage nature of networks varies in different firms, as the structure of financial firms and institutes may be dependent on specific seasons, customer supply terms and conditions, and so forth, which cannot be discussed in general. Therefore, defining this two-stage structure would allow the managers to be alert and vigilant, and this way the profitability and progress of the firm becomes the main criteria for their decision makings.

1.1 Data envelopment analysis

Data envelopment analysis is a mathematical programming model for evaluating the efficiency of decision-making units (DMUs) with multiple inputs and outputs. Due to its significance in the performance evaluation of firms and organizations, efficiency measurement has always been a topic of interest to researchers. Technically, DEA is based on a series of optimizations using linear programming, which is also called a nonparametric method [1].

DEA models can be classified into two categories: radial and non-radial. Radial models include traditional CCR and BCC models. These models can be regarded as either input or output oriented [1,2]. Non-radial models encompass alternative modelling specifications, such as the additive model, the multiplication model, the range-adjusted measure and the slacks-based measure [3].

In this method, an efficient frontier curve is formed by a series of points that are determined using mathematical programming. For determining these points, two assumptions can be made, namely constant and variable returns to scale (CRS; VRS). This nonparametric method, after a series of optimizations, determines whether a DMU is located on the efficiency frontier or not. This way, the efficient and inefficient units are separated [3].

As mentioned earlier, in evaluating DMUs with traditional DEA models such as BCC, CCR, efficiency scores may not have calculated correctly and we face problems such as efficiency underestimation and pseudo-inefficiency. It indicates that many DEA mathematical models include redundant restraints on weight. The CCR model has the above problems due to an inherent weight restriction, and to obtain the correct amount of efficiency, we must use these models with a weight restriction. To address the above problems, Despic, (2007) proposed the DEA-ratio based (DEA-R) model to solve the problem of intrinsic weight restrictions. The model was presented in the output orientation [4].

Wei et al. (2011, a, b, c) presented the DEA-R model in the input orientation, they showed that the efficiency scores obtained from the DEA-R model in the input orientation are greater than or equal to their corresponding efficiency scores obtained from the CCR model in the input orientation. Among the articles that modified DEA models to deal with ratio data [5-9].

1.2 Financial Ratios

Financial ratios are numerical values extracted from the financial statements of a firm with the aim of acquiring meaningful information. The numbers extracted from these financial statements, such as the balance sheet, profit and loss statements, and cash flow statements, are used in cases such as quantitative analyses and evaluations of liquidity, growth, profit margin, profitability, return rate, valuation, and so on. One of the most common methods of financial analysis is to calculate and evaluate financial ratios. These ratios are defined in multiple categories, and each focuses on one aspect of the financial condition of firms. Financial ratios are classified into the following main categories:

- Liquidity ratios
- Leverage ratios
- Activity ratios
- Profitability ratios
- Market value ratios

The present study aims to present ratio analysis models in two-stage network structures, and investigate their relationship with DEA models. This study addresses the research gap relating the relationship between ratio analysis and DEA, and technically, tries to determine which method is preferable for the evaluation of firms based on financial ratios. The rest of the current article is structured as follows. Section two reviews the basic concepts related to DEA and ratio analysis. In section three, corresponding models in ratio analysis and DEA are presented based on a network structure, and their relationship is assessed. And finally, section five presents an applied study, and the conclusion is provided at the end.

2. Ratio Analysis and DEA

2.1. Basic Concepts in DEA

The data envelopment analysis model is used to evaluate the performance of decision-making units, or better put, the system under evaluation. In the majority of organizations, input and output data are not easily accessible due to information confidentiality, desires to save time and money on data collection, or other reasons, and thereby only ratio data are provided. In such cases, obviously, the DEA technique based on ratio analysis can be compared with data envelopment analysis.

Technically, Farrell was the first to obtain an estimation of the desired function using a nonparametric method, and he won the Nobel Prize for that research. Based on five axioms, Farrell created a set called the production possibility set (PPS), and considered a part of that set as an estimation of the production function.

In 1978, Charnes, Cooper and Rhodes extended Farrell's model to multiple inputs and outputs, and presented the CCR model. After that, Banker, Charnes and Cooper proposed the BCC model in 1984, and these two models became the basis for efficiency analysis studies. In data envelopment analysis, by assigning weights to the inputs and outputs, they are transformed into a single virtual input and a single virtual output, and efficiency is defined as the ratio of the virtual output to the virtual input [1,2].

Definition 1. In performance evaluation, a decision-making unit refers to a unit that receives an input vector such as $X=(x_1,\dots,x_m)$ to produce an output vector such as $Y=(y_1,\dots,y_s)$. The assumption always is that all inputs and outputs are in homogenous units, and each DMU is considered as follows.

$$(X_o,Y_o)^T=(x_{1o},\dots,x_{mo},y_{1o},\dots,y_{so})$$

By determining the production function, the efficiency of a DMU can be easily evaluated. Now, the objective is to determine the efficient frontier or the production function, but due to various reasons, the production function is not easily calculated and it is usually not available. Using observations and the undeniable axioms governing DEA, Farrell (1957) for the first time formed a set called the production possibility set. Consider a set of n decision-making units in which $X_j=(x_{1j},\dots,x_{mj})$ and $Y_j=(y_{1j},\dots,y_{sj})$ are the input and output vectors of DMUj, respectively, where $Y_j \geq 0$, $Y_j \neq 0$ and $X_j \geq 0$, $X_j \neq 0$. Since the production function is not available, the PPS will not be available either. Now, the frontier of the PPS is considered to be an approximation of the production function, which is defined as follows.

$$T_c = \left\{ (X,Y) \middle| X \geq \sum_{j=1}^{n} \lambda_j X_j,\ Y \leq \sum_{j=1}^{n} \lambda_j Y_j,\ \lambda_j \geq 0,\ j=1,\ldots,n \right\}.$$

The set above is the only set that holds true in the following five axioms.

The first axiom is inclusion of observations, the second free disposability, the third unbounded ray or constant returns to scale (CRS), the fourth convexity, and the fifth minimal extrapolation.

If the unbounded ray axiom is ignored, the remaining axioms will define the unique set T_v as follows.

$$T_v = \left\{ (X,Y) \middle| X \geq \sum_{j=1}^{n} \lambda_j X_j,\ Y \leq \sum_{j=1}^{n} \lambda_j Y_j,\ \sum_{j=1}^{n} \lambda_j = 1,\ \lambda_j \geq 0,\ j=1,\ldots,n \right\}.$$

The set T_v is the smallest set holding true in the axioms of inclusion of observations, convexity, and feasibility. The symbols T_v and T_{BCC} are used synonymously, and both refer to a production technology formed by accepting these three axioms, or a set that holds true in all four axioms. Assuming T_v is the PPS, and assuming that the inputs are reduced and while the outputs are kept constant, the input-oriented BCC model under VRS assumption used to measure the relative efficiency of a DMU under evaluation would be as follow.

$$\begin{aligned} &\max \quad \theta \\ &s.t. \quad (\theta X_o, Y_o) \in T_v. \end{aligned}$$

The component-based form of the model (1) for evaluating a DMU under evaluation under VRS technology is as follows.

$$\begin{aligned} \min \quad & \theta \\ \text{s.t.} \quad & \sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{io} \qquad \text{i=1,...,m} \qquad (1) \\ & \sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{ro} \qquad \text{r=1,...,s} \\ & \sum_{j=1}^{n} \lambda_j = 1 \qquad\qquad (a1) \\ & \lambda_j \geq 0 \qquad\qquad \text{j=1,...,n.} \end{aligned}$$

The goal is to find a convex combination of DMUs that, using the least possible amount of inputs, would produce an amount of outputs equal to or greater than those of the DMU under evaluation. This goal can be achieved by using the model (a1). The model (a1) is always feasible, has an optimal finite solution, and $0 \leq \theta^* \leq 1$. It can be observed that this model is the envelopment form of the CCR model, to which the constraint $\sum_{j=1}^{n} \lambda_j = 1$ is added.

Definition 2. If the optimal value in the model (a1) equals one $(\theta^* = 1)$, then the DMU under evaluation is BCC-efficient.

Definition 3. If $\theta^* = 1$ and all slack variables are equal to zero in all optimal solutions, then the DMU under evaluation is Pareto-efficient in the BCC model.

2.2. Ratio Analysis Model

For the financial evaluation of firms, a series of financial information must be available, such as financial ratios. By assessing the financial ratios, investors can gain information regarding the stability of firms, the condition of their repayments, and their financial trends. One of these financial ratios is the liquidity ratio, which is divided into the two categories of the quick ratio and the current ratio.

First, it would better to provide a brief explanation about the liquidity ratio. The liquidity ratio is a financial ratio defined as the ratio of liquid assets to current debts, which of course falls into the two categories of the quick ratio and the current ratio.

By analyzing the liquidity ratios, one can become aware of the capability of a given firm in repaying its debts and fulfilling its short-term obligations.

Current ratio: the current ratio is a financial ratio in the category of liquidity ratios that is obtained by dividing the current assets by the current debts. This ratio will inform you of the capability of a given firm in repaying its short-term debts. The value obtained for the current ratio must be close to the number 1. If the ratio is less than 1 by a large degree, it is indicative that the firm may face issues in repaying its debts, and that if the firm was to repay its debts at the present time, it would not be able to do so. Although, this does not mean that the firm is bankrupt, but these ratios can merely inform the shareholders of the firm's current condition. A high current ratio indicates the firm's high capability of repaying the debts. However, an overly high current ratio shows that the liquidity of the firm is not being controlled properly, and indicates that the liquidity of the firm is not properly used toward profitability.

Quick ratio: the quick ratio in another type of liquidity ratio. This ratio is obtained by dividing the current assets (ignoring the inventory and prepayments) by the current debts. The quick ratio has a stricter and conservative view of the firm's capability in fulfilling the short-term obligations, and only considers the assets that can be liquidated quickly in its evaluation of firms. A quick ratio close to 1 shows the firm's desirable conditions in repaying its short-term debts, and a quick ratio less than one indicates a concerning situation and the lack of capability to quickly repay the debts.

However, a high quick ratio has two indications:

1) high liquidity in the firm or overly high demands;

2) attempts to ensure the creditors of the capability of repaying the debts.

These two cases also show the weakness of the firm's management in using liquid resources.

On the other hand, we show it is natural and possible to apply the DEA principle to handle indexes directly. For $j = 1, \dots, n$, let $(x_1^j, x_2^j, \dots, x_m^j)$ be inputs and $(y_1^j, y_2^j, \dots, y_s^j)$ be outputs of DMU_j. DEA models for index data are to directly use some of the indexes: $e_{ir}^j = y_r^j / x_i^j$ (as perhaps not all these i indexes are relevant) to evaluate performance of the DMUs. Here we assume that all the inputs and outputs are desirable so that one wishes to maximize the weighted sum. Consequently, one would like to estimate the performance score by solving the following DEA model:

$$\begin{aligned} \text{Max} \quad & h = \sum w_{ir} e_{ir}^0 && (2) \\ \text{s.t} \quad & \sum w_{ir} e_{ir}^0 \leq 1, && j = 1, \dots, n, \\ & w_{ir} \geq 0, \quad i = 1, \dots, m, && r = 1, \dots, s \end{aligned}$$

Thus the weights w_{ir} are decided to give the maximum score for the DMU_0. This model was firstly discussed by Fernandez-Castro and Smith [21] and has been used in [14]. Model (2) also looks like a DEA model without inputs; see [2,3].

3. Two-stage Network Ratio Analysis

In this section, we first propose a ratio analysis model for the first and second network stages, and then present the model for the overall network structure. Next, the relationship between the proposed models and data envelopment analysis is clarified.

3.1. Two-stage Network Structure in Ratio Analysis

Let $X_j = (x_{1j}, \dots, x_{mj})$ be the inputs of the firs network stage and $Z_j = (z_{j1}, \dots, z_{mj})$ the output vector of the first stage, which is also the input vector of the second stage (although, by considering a free and constant relationship). Furthermore, assume that $Y_j = (y_{1j}, \dots, y_{sj})$ is the output vector of the second network stage. Also, the vectors X_j, Y_j, and Z_j are always positive, and the ratios $\frac{Z_j}{Y_j}$ and $\frac{Y_j}{X_j}$ are defined and are the criteria for evaluation.

If X_j^t, Y_j^t, and Z_j^t for t=1,2 are the vectors of the first and second network stages relating to the first and second financial half-year of financial firms and institutes, an output-oriented efficiency measurement model is proposed in ratio analysis as follows (first network stage).

$$\text{Max} \quad \sum_{i=1}^{m} \sum_{p=1}^{f} wip \left(\frac{z_{po}}{x_{io}}\right) \qquad (3)$$

s.t $\sum_{i=1}^{m}\sum_{p=1}^{f} wip(\frac{Z_{pj}}{X_{ij}}) \leq 1$, j=1,…,n

$wip \geq 0$, i=1, …, m , p=1,…,f

Similarly, in the second network stage:

$$\text{Max} \quad \sum_{r=1}^{s}\sum_{p=1}^{f} Vrp(\frac{y_{ro}}{z_{po}}) \qquad (4)$$

s.t $\sum_{r=1}^{s}\sum_{p=1}^{f} Vrp\left(\frac{y_{rj}}{z_{pj}}\right) \leq 1$, j=1,…,n

$Vrp \geq 0$, r=1,…,s , p=1,…,f

The model for calculating the overall efficiency in the two-stage network, i.e. in the first financial year (t=1) and the second financial year (t=2), with the input vector X_j^t, output vector Y_j^t, and intermediate vector Z_j^t is proposed as follows:

$$\text{Max} \ \sum_{t=1}^{2}\sum_{i=1}^{m}\sum_{p=1}^{f} w_{ip}^{t}\left(\frac{z_{po}}{x_{io}}\right)^{t} + \sum_{t=1}^{2}\sum_{r=1}^{s}\sum_{p=1}^{f} V_{rp}^{t}(\frac{y_{ro}}{z_{po}})^{t} \qquad (5)$$

s.t $\sum_{i=1}^{m}\sum_{p=1}^{f} w_{ip}^{t}(\frac{z_{pj}}{x_{ij}})^{t} \leq 1$, j=1,…,n , t=1, 2

$\sum_{r=1}^{s}\sum_{p=1}^{f} V_{rp}^{t}(\frac{y_{rj}}{z_{pj}})^{t} \leq 1$, j=1, …, n, t=1, 2

$w_{ip}^{t} \geq 0 \ . V_{rp}^{t} \geq 0$, i=1, …, m,

r=1, …, s, p=1,…,f , t=1,2

It should be noted that in this model, in addition to the two-stage network, the financial firm or institute is also evaluated in the periods t and $t+1$. The reason is that in addition to the network structure, in which the firms are evaluated based on financial half-years, the firms are also analyzed in two consecutive years in order to provide managers with a detailed view of the firms' conditions based on financial ratios. And in reality, if a firm is found inefficient in this process, it would certainly face losses, and hence it requires a serious revision by the managers.

4. Relationship between Ratio Analysis and DEA Models

If we consider the ratio analysis model proposed for the first network stage with the inputs x_j and outputs z_j, while considering the dual variables λ_j corresponding with the model's restrictions, we have:

$$\text{Min} \quad \sum_{j=1}^{n} \lambda_j \qquad (6)$$

s.t $\sum_{j=1}^{n} \lambda_j(\frac{Z_{pj}}{X_{ij}}) \geq \frac{Z_{po}}{X_{io}}$ p=1,…,f , i=1,…,m

$\lambda_j \geq 0$, j=1,…,n.

Now, in the model above, we consider $\sum_{j=1}^{n} \lambda_j = \frac{1}{\theta}$, given that $\lambda_j = \frac{\mu_j}{\theta}$ and $\sum_{j=1}^{n} \mu_j = 1$. Then, we have:

$$\text{Max} \quad \theta \qquad (7)$$

s.t $\sum_{j=1}^{n} \mu_j(\frac{Z_{pj}}{X_{ij}}) \geq \theta \frac{Z_{po}}{X_{io}}$ p=1,…,f, i=1,…,m,

$\sum_{j=1}^{n} \mu_j = 1, \ \mu_j \geq 0$, j=1,…,n.

Therefore, in the model above, by considering $R_j = \frac{Z_{pj}}{X_{ij}}$, which is a financial ratio, we have:

$$\text{Max} \quad \theta \qquad (8)$$

s.t. $\sum_{j=1}^{n} \mu_j(R_j) \geq R_o \, \theta$

$\sum_{j=1}^{n} \mu_j = 1 \quad \mu_j \geq 0$, j=1,…,n.

The model above is the output-oriented DEA model in VRS technology without any inputs. Therefore, output-oriented ratio analysis models correspond with DEA models without inputs under VRS technology, and they analyze financial firms based on $R_j = \frac{Z_j}{X_j}$ ratios. What is important in the evaluation of firms based on financial ratios is that the returns to scale technology needs to be considered as variable in order to reach an accurate analysis of financial ratios.

Table 1. Ratio Analysis and DEA Models.

Output-oriented ratio analysis model	DEA model in VRS
Max $\frac{1}{2}(\theta^1+\theta^2)$ t=1,2 s.t $\sum_{j=1}^{n} \mu_j^t(\frac{z_j^t}{x_j^t}) \geq \theta^t \frac{z_o^t}{x_o^t}$, , j=1,..n t=1,2 $\sum_{j=1}^{n} \mu_j^t = 1$, $\mu_j^t \geq 0$	Max $\frac{1}{2}(\varphi^1+\varphi^2)$ t=1,2 s.t $\sum_{j=1}^{n} \lambda_j^t(R_j)^t \geq R_o^t\varphi^t$, j=1,..n t=1,2 $\sum_{j=1}^{n} \lambda_j^t = 1$, $\lambda_j^t \geq 0$

Now, if we want to present the models for the evaluation of firms in the periods t=1,2, the two models would be proposed as follows.
Table 1 shows the corresponding models in DEA and Ratio Analysis in two time periods t=1 and t=2.
Obviously, for $\lambda_j^t = e_o^t$, $\varphi^t = 1$, and $\theta^t = 1$, the feasibility of the models above is apparent, and the optimal solutions of these models determine the efficiency of the firm under evaluation.

Definition: If DMU_0 is efficient, then $\theta^t = 1$ for t=1,2.

In the first network stage, the ratio analysis model is considered and then, in the first stage of the network, the ratio analysis model is considered by considering the output to the input of assets to debts.

5. Applied Study

In this section, by considering 21 decision-making units, ratio analysis models with four inputs and four outputs are used in a two-stage network. The data provided in Table 2 indicate the four inputs related to current debts and overall debts in the DMUs.

Table 2. Current debts and overall debts for the 21 decision-making units under study

	I1	I2	I3	I4
DMU1	96	86	4000	14730450
DMU2	75	88	2565	41144517
DMU3	77	85	1343	28792550
DMU4	91	93	1500	24277018
DMU5	89	83	1680	43355800
DMU6	102	97	3750	45571800
DMU7	96	90	3313	78011675
DMU8	85	92	1500	14969393
DMU9	106	84	1600	61024310
DMU10	107	95	1725	21625962
DMU11	94	78	1920	39664990
DMU12	78	89	4433	23106000
DMU13	102	107	2500	17756770
DMU14	82	92	2800	30082208
DMU15	77	92	1630	48034155
DMU16	89	85	1127	35631132
DMU17	84	104	3400	33983780
DMU18	94	91	1304	37568447
DMU19	97	95	4206	5504769
DMU20	79	81	3372	33088649
DMU21	50	18	100	4587655

Table 3. Current assets and overall assets for the 21 decision-making units under study

	O1	O2	O3	O4
DMU1	55830	4530	1307	145
DMU2	36740	320	8385	175
DMU3	38004	7111	6588	113
DMU4	35469	5910	10820	128
DMU5	52927	8599	9493	101
DMU6	70254	3457	7536	182
DMU7	32585	25847	14118	154
DMU8	42900	74111	1634	154
DMU9	85399	32543	10206	179
DMU10	46924	9859	6608	117
DMU11	36652	23581	11996	137
DMU12	39582	78411	7422	124
DMU13	56144	25830	7380	185
DMU14	87716	1425	630	251
DMU15	50210	9686	10247	128
DMU16	47727	73515	7302	185
DMU17	52923	32515	4740	109
DMU18	78550	98413	4745	172
DMU19	46154	45613	1611	129
DMU20	42887	74611	3560	218
DMU21	54698	96312	4712	110

Table 4. Efficiency scores of DMUs in the first network stage with ratio analysis

Unit	Efficiency score of first network stage	First ratio	Second ratio	Third ratio	Fourth ratio	Reference unit
DMU1	0.5316	1094.0	1926.2	3038.8	5350.7	DMU21
DMU2	0.4478	1094.0	1926.2	3038.8	5350.7	DMU21
DMU3	0.4512	1094.0	1926.2	3038.8	5350.7	DMU21
DMU4	0.3563	1094.0	1926.2	3038.8	5350.7	DMU21
DMU5	0.5436	1094.0	1926.2	3038.8	5350.7	DMU21
DMU6	0.6296	1094.0	1926.2	3038.8	5350.7	DMU21
DMU7	.3103	1094.0	1926.2	3038.8	5350.7	DMU21
DMU8	0.4614	1094.0	1926.2	3038.8	5350.7	DMU21
DMU9	0.7365	1094.0	1926.2	3038.8	5350.7	DMU21
DMU10	0.4009	1094.0	1926.2	3038.8	5350.7	DMU21
DMU11	.03564	1094.0	1926.2	3038.8	5350.7	DMU21
DMU12	0.5219	1094.0	1926.2	3038.8	5350.7	DMU21
DMU13	0.5032	1094.0	1926.2	3038.8	5350.7	DMU21
DMU14	0.9778	1094.0	1926.2	3038.8	5350.7	DMU21
DMU15	0.5916	1094.0	1926.2	3038.8	5350.7	DMU21
DMU16	0.4902	1094.0	1926.2	3038.8	5350.7	DMU21
DMU17	0.5759	1094.0	1926.2	3038.8	5350.7	DMU21
DMU18	0.7639	1094.0	1926.2	3038.8	5350.7	DMU21
DMU19	0.4349	1094.0	1926.2	3038.8	5350.7	DMU21
DMU20	0.4962	1094.0	1926.2	3038.8	5350.7	DMU21
DMU21	1.0000	1094.0	1926.2	3038.8	5350.7	DMU21

Table 5. Efficiency scores of DMUs in the second network stage with ratio analysis

Unit	Efficiency score of second network stage	First ratio	Secon d ratio	Third ratio	Fourth ratio	Reference unit
DMU1	0.4105	4.5	0.1	0.0	0.0	DMU21
DMU2	0.5142	6.4	0.1	0.0	0.0	DMU4 DMU16 DMU21
DMU3	0.7136	6.9	0.1	0.0	0.0	DMU4 DMU16 DMU21
DMU4	1.0000	7.2	0.1	0.0	0.0	DMU4
DMU5	0.7834	7.2	0.1	0.0	0.0	DMU4
DMU6	0.3447	5.8	0.1	0.0	0.0	DMU4 DMU16 DMU21
DMU7	0.5908	7.2	0.1	0.0	0.0	DMU4
DMU8	0.7487	5.6	0.1	0.0	0.0	DMU16 DMU21
DMU9	0.9267	6.9	0.1	0.0	0.0	DMU4 DMU21
DMU10	0.6010	6.4	0.1	0.0	0.0	DMU4 DMU16 DMU21
DMU11	0.8662	7.2	0.1	0.0	0.0	DMU4
DMU12	0.3418	4.9	0.1	0.0	0.0	DMU4 DMU21
DMU13	0.5922	5.2	0.1	0.0	0.0	DMU16 DMU21
DMU14	0.6425	5.7	0.1	0.0	0.0	DMU16 DMU21
DMU15	0.8763	7.2	0.1	0.0	0.0	DMU4 DMU16
DMU16	1.0000	6.5	0.2	0.0	0.0	DMU16
DMU17	0.2442	5.7	0.1	0.0	0.0	DMU4 DMU16 DMU21
DMU18	0.8106	6.4	0.2	0.0	0.0	DMU16 DMU21
DMU19	0.9773	4.5	0.1	0.0	0.0	DMU21
DMU20	0.4713	5.6	0.1	0.0	0.0	DMU16 DMU21
DMU21	1.0000	4.5	0.1	0.0	0.0	DMU21

In Table 4, the second column presents the efficiency scores in the first network stage, and columns two, three, and four present the quick ratios, which are defined as ratios of assets to debts, all calculated based on the ratio analysis model. The last column of Table 4 shows the reference units for the 21 DMUs, which as can be seen, unit 21 is selected as the reference for all DMUs. Moreover, only unit 21 is efficient in the first network stage, and the optimal ratio is hence determined based on this unit.

It can be observed in Table 5 that units 4,16, and 21 are efficient, and that in the second network stage, the reference units are combinations of these three units.

In Table 5, the second, third, and fourth ratios can be ignored. Therefore, based on the fact that units 4,16, and 21 are efficient, we can calculate the quick ratios.

In Table 6, units 2,7,15,14,20, and 21 are efficient in the overall network, and all ratios except the final four can be considered as defined and optimal indicators for the overall network. In the last column of Table 6, the reference units 2,4,7,20, and 21 are used as criteria for benchmarking.

Table 6. Efficiency scores of DMUs in the overall **network with** ratio analysis

Unit	Ratios calculated for the overall network using the ratio analysis model																	**Reference unit**
DMU1	0.5830	1083.0	1060.1	55.0	2.6	2096.6	2929.9	146.1	4.6	313.0	526.3	25.8	0.6	0.0	0.0	0.0	0.0	DMU4 DMU21
DMU2	1.0000	489.9	4.3	111.8	2.3	417.5	3.6	95.3	2.0	14.3	0.1	3.3	0.1	0.0	0.0	0.0	0.0	DMU2
DMU3	0.7277	678.3	432.8	117.6	2.0	985.8	1093.6	134.8	2.5	125.7	191.0	13.2	0.3	0.0	0.0	0.0	0.0	DMU2 DMU15 DMU21
DMU4	09265	607.0	856.9	128.3	1.8	1311.3	2082.8	194.1	3.3	200.3	346.6	19.5	0.4	0.0	0.0	0.0	.0.0	DMU7 DMU21
DMU5	0.8369	710.6	414.4	127.5	1.7	931.8	937.7	136.7	2.1	111.3	156.7	12.6	0.2	0.0	0.0	0.0	0.0	DMU7 DMU15DMU21
DMU6	0.7770	886.5	1157.5	95.1	2.3	2021.1	3210.5	189.9	4.5	334.7	577.6	29.4	0.7	0.0	0.0	0.0	0.0	DMU2 DMU14 DMU21
DMU7	1.0000	339.4	269.2	147.1	1.6	362.1	287.2	156.9	1.7	9.8	7.8	4.3	0.0	0.0	0.0	0.0	0.0	DMU7
DMU8	0.7077	868.8	1232.0	60.9	2.6	1703.2	2733.2	134.2	4.2	251.4	433.9	21.2	0.5	0.0	0.0	0.0	0.0	DMU14 DMU20 DMU21
DMU9	0.8776	918.0	1209.2	109.7	2.0	2045.9	3261.7	201.9	4.2	341.4	581.9	30.9	0.7	0.0	0.0	0.0	0.0	DMU15 DMU21
DMU10	0.5453	804.2	883.6	113.2	2.0	1589.2	2347.9	174.8	3.5	249.1	416.3	23.3	0.5	0.0	0.	0.0	0.0	DMU2,DMU7, DMU15DMU21
DMU11	0.9251	469.6	55.1	138.0	1.7	823.8	1160.6	175.0	2.5	102.5	172.6	11.7	0.2	0.0	0.0	0.0	0.0	DMU7 DMU21
DMU12	0.8172	777.0	1230.1	116.4	1.9	1914.2	3223.3	217.7	4.3	321.3	561.8	29.1	0.7	0.0	0.0	.00	0.0	DMU7 DMU21
DMU13	0.7731	817.6	864.7	93.6	2.3	1642.5	2394.9	160.9	3.9	254.1	430.6	22.6	0.5	0.0	.0.0	0.0	0.0	DMU2 DMU14 DMU21
DMU14	1.0000	1069.7	17.4	7.7	3.1	953.4	15.5	6.8	2.7	31.3	0.5	0.2	0.1	0.0	0.0	0.0	0.0	DMU14
DMU15	1.0000	625.1	125.8	133.1	1.7	545.8	105.3	11.4	1.4	30.8	5.9	6.3	0.1	0.0	0.0	0.0	0.0	DMU15
DMU16	0.8824	739.8	936.1	93.0	2.4	1481.0	2295.2	152.5	3.8	226.1	387.5	2.3	0.5	0.0	0.0	0.0	0.0	DMU2 DMU20 DMU21
DMU17	0.5910	1066.1	1831.0	95.5	2.2	2908.2	5081.7	253.6	5.9	520.3	914.5	45.2	1.0	0.0	0.0	0.0	0.0	DMU2 DMU15 DMU21
DMU18	0.7675	1088.8	1518.1	75.7	2.4	2592.9	4210.0	207.3	5.4	436.7	757.	37.1	0.9	0.0	0.0	0.0	0.0	DMU14 DMU21
DMU19	0.9773	1094.0	1926.2	94.2	2.2	3038.8	5350.7	261.8	3.1	547.5	963.1	47.1	1.1	0.0	0.0	0.0	0.0	DMU21
DMU20	1.0000	542.9	944.4	45.1	2.8	529.5	921.1	44.0	2.7	12.7	22.1	1.1	0.1	0.0	0.0	0.0	0.0	DMU20
DMU21	1.0000	1094.0	1926.2	94.2	2.2	3038.8	5350.7	261.8	6.1	547.0	963.1							

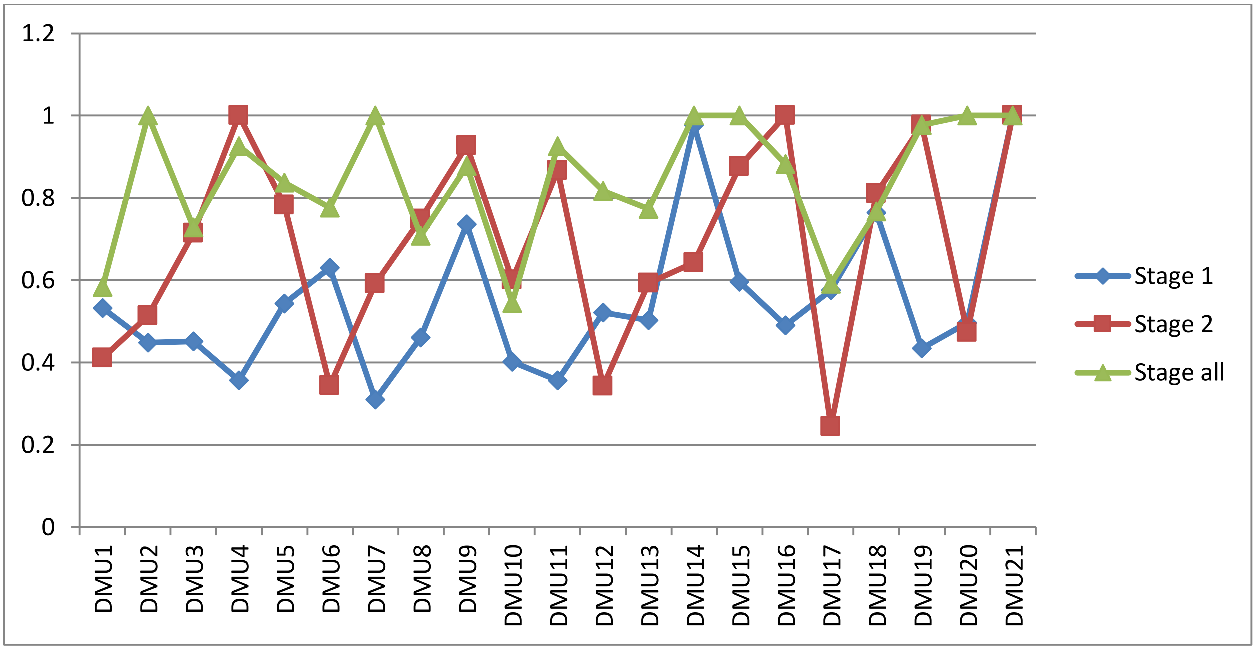

Fig 1: Efficiency scores of the 21 DMUs in the first, second network stages, and the overall network

Figure 1 shows the efficiency scores of the 21 DMUs under study in the first and second network stages and the overall network. Generally, the efficiency score is a number between zero and one, and it can be observed that efficiency scores in the overall network are greater than or equal to efficiency scores in the first stage. However, in the second stage, the overall efficiency score is not greater than the stage-wise score in some units. Thereby, based on the overall efficiency, these 21 DMUs are good criteria for quick ratios.

6. Conclusion

At the end of financial years, managers are always worried about the performance of their firms based on financial ratios. However, if they can make an initial evaluation based on financial ratios in the financial half-years of the firm, they may receive the necessary warnings sooner and prevent the firm from facing possible losses. Ratio analysis and data envelopment analysis are different techniques, but in returns to scale technology, they provide a similar process to firm analysts. In the current study, in addition to proposing models for two-stage network structures, the dynamicity of firms in two different years would also provide the possibility of evaluation. Therefore, in addition to efficiency calculation in each separate network stage, suitable benchmarks are also presented for financial ratios in both first and second network stages.

For future research, it is recommended to use non-radial network ratio analysis models for evaluating financial ratios and investigating the weaknesses of firms based on ratios such as the liquidity ratio, quick ratio, and leverage ratio.

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