APPLICABILITY OF DEA-DA APPROACH IN ASSESSING FINANCIAL DISTRESS OF PUBLIC LISTED COMPANIES IN MALAYSIA

Mazura Mokhtar[1*], Saharani Abdul Rashid[2]

[1, 2]College of Computing, Informatics and Mathematics
Universiti Teknologi MARA Cawangan Pahang Kampus Raub, 27600 Raub, Pahang, Malaysia

[*]Corresponding author: mazura_mokhtar@uitm.edu.my

Abstract

Financial distress has long been a crucial topic in corporate finance due to its negative impact on a country's economy. Numerous methods have been developed and proposed as early warning tools to assess financial distress. Therefore, this study aims to examine the applicability of Data Envelopment Analysis-Discriminant Analysis (DEA-DA) method in assessing financial distress of public listed companies in Malaysia. An equally balanced and matched sample of 100 companies listed in the Main Market of Bursa Malaysia was used in this study covering the period from 2014 to 2023. Three financial ratios, namely, working capital to total assets, retained earnings to total assets, and current asset turnover were used as the independent factors. The DEA-DA approach was carried out in two stages. The first stage classifies the companies into financially distressed and non-financially distressed groups and identifies companies that overlap between these two classifications. Then, the second stage was performed to segregate the overlap companies into one of the two groups. The results of this study show that, the DEA-DA approach could accurately classify 91% of the companies into the groups. The findings can assist managers, shareholders, financial institutions, auditors and investors in Malaysia to assess financial distress.

Keyword: data envelopment analysis, discriminant analysis, financial distress

Introduction

Corporate financial distress is one of the critical issues which has been extensively studied in accounting and finance literature. Financial distress refers to a condition where a company's operating cash flows are not sufficient to satisfy the company's financial obligations (Ali & Nasir, 2018). Among the common causes of financial distress are poor financial planning, poor management, high levels of debts and difficulties in operating successfully in the market. Corporate financial distress has an adverse effect on the economy, as it may cause substantial financial losses not only to the business community, but also to society as a whole.

In Malaysia, a public listed company that falls under the financial distress condition is classified as PN17 company (Practice Note 17/2005). This company does not have a core business or its shareholders' fund is less than 25% of the total issued and total paid up capital. In order to maintain its listing status, a PN17 company is required to submit a proposal to the Approving Authority to restructure the company. As of 1st January 2023, there are a total of 27 companies fall under PN17 which represent 2.85% from the total of 946 companies listed on Bursa Malaysia. The growing number of financially distressed companies in Malaysia

demonstrates the importance of accurate and reliable financial distress prediction models, as they can provide stakeholders with early signals of potential bankruptcy or financial distress.

Financial distress prediction has been studied by many researchers using different approaches. Beaver (1966) employed univariate statistical approach based on some selected ratios. Later on, Altman (1968) used Discriminant Analysis (DA) and financial ratios to develop a model for assessing corporate financial failures. This model, known as Z-score model, has been employed by many studies to measure financial health of the companies in different markets. For example, Fai et al. (2022) and Kim-Soon et al. (2022) used the Altman's model to predict financial distress among public listed companies in Malaysia. Nurasik et al. (2023) predicted financial distress in packaging and plastic companies in Indonesia, while Sareen and Sharma (2022) assessed financial distress in automotive sector in India.

Another method used for assessing financial distress of companies is Data Envelopment Analysis (DEA). DEA is a non-parametric method used to measure the relative efficiency of a group decision-making units based on their respective inputs and outputs. Li et al. (2014), utilized DEA to assess corporate distress among Chinese companies. Recently, Štefko et al. (2020) employed additive DEA model to predict bankruptcy of a business in Slovakia. One of the limitations of DEA model is that it cannot handle negative value which usually found in financial data (Sueyoshi & Goto, 2009). To overcome this limitation, Sueyoshi (2004) introduced a new version of DEA by combining DEA and discriminant analysis (DA). The new approach, named DEA-DA, incorporates unique features of DEA into the framework of DA. The DEA-DA approach has been applied to assess corporate bankruptcy by Sueyoshi and Goto (2009) and Torabi et al. (2022). However, research on the application of DEA-DA for investigating corporate financial distress is still very limited. To fill the gap, this study examines the applicability of DEA-DA approach in determining financial distress among publicly listed companies in Malaysia.

Methodology

Sample Selection

The sample of this study consists of 100 companies listed on Main Market of Bursa Malaysia out of which 50 were classified as financially distressed (PN17) and 50 financially healthy companies during the period of 2014-2023. This study adopted convenience-balanced sampling technique as in Beaver (1966) and Altman (1968) to select and pair financially distressed and financially healthy companies. Each financially distressed company was matched with a financially healthy company in the same industry that has approximately the same asset size and same financial reporting year. This sample-match technique ensures that the financial distress model produces the lowest number of bias results (Karbhari & Zulkarnain 2004).

Independent Variables

In this study, three financial ratios were used as the independent factors for the DEA-DA model. The ratios are working capital to total assets (WCTA), retained earnings to total assets (RETA) and current asset turnover (CAT). WCTA ratio serves as an indicator to evaluate a company's ability to meet its short-term obligations. A low WCTA may indicate that the company is experiencing difficulty in meeting its immediate financial obligations, which could be the early sign of financial distress. RETA ratio is used to measure the proportion of a company's asset that are funded by retained profits. A low RETA indicates that the company finances its assets by external financing sources such as debt or new equity. CAT ratio measures the ability of a company to generate sales from its current assets such as cash and inventory. A low CAT ratio

may suggest underutilization of current assets in generating revenue or inefficiency in operations. The selection of these three financial ratios was based on the empirical findings from Abdullah (2020), which found that these ratios have the highest ability to distinguish between financially distressed and non-financially distressed companies.

Data Collection

Financial ratios for the financially distressed companies and their matched counterparts were computed at the end of the fiscal year immediately preceding the year of being listed under the PN17 category by Bursa Malaysia. All the financial data for the companies were obtained from *Refinitiv Eikon* platform.

DEA-DA Model for Assessing Financial Distress

The DEA-DA approach consists of two stages (Sueyoshi & Goto, 2009). The first stage classifies companies into two groups and identifies the existence of overlaps between the groups. The second stage reclassifies companies in the overlap. Suppose that there are two groups G_1 and G_2, each with n_1 and n_2 companies, respectively. In this study, G_1 $(j = 1, \ldots, n_1)$ is a group of financially distressed companies and G_2 $(j = 1, \ldots, n_2)$ is a group of non-financially distressed companies. It is also assumed that $n_1 + n_2 = n$ and $G_1 \cup G_2 = G$. Each company j is characterized by m independent factors $(i = 1, \ldots, m)$ denoted by z_{ij}. The group membership of each company is required to be determined before the computation. The first stage of the DEA-DA approach is formulated as follows:

$$
\begin{aligned}
&\text{Min } s \\
&\text{s.t.} \quad \sum_{i=1}^{m} \left(\lambda_i^+ - \lambda_i^-\right) z_{ij} - d + s \geq 0, \quad j \in G_1 \\
&\qquad \sum_{i=1}^{m} \left(\lambda_i^+ - \lambda_i^-\right) z_{ij} - d - s \leq -\varepsilon, \quad j \in G_2 \\
&\qquad \sum_{i=1}^{m} \left(\lambda_i^+ + \lambda_i^-\right) = 1 \\
&\qquad \zeta_i^+ \geq \lambda_i^+ \geq \varepsilon \zeta_i^+ \qquad i = 1, \ldots, m \\
&\qquad \zeta_i^- \geq \lambda_i^- \geq \varepsilon \zeta_i^- \qquad i = 1, \ldots, m \\
&\qquad \zeta_i^+ + \zeta_i^- \leq 1 \qquad i = 1, \ldots, m \\
&\qquad \lambda_i^+ + \lambda_i^- \geq \varepsilon \qquad i = 1, \ldots, m \\
&\qquad \zeta_i^+, \zeta_i^- : 0 \text{ or } 1 \\
&\qquad \lambda_i^+, \lambda_i^- \geq 0 \\
&\qquad d, s : \text{ unrestricted in sign}
\end{aligned}
\tag{1}
$$

Here, λ_i^+ and λ_i^- are the weights estimated for the i-th independent factor, ζ_i^+ and ζ_i^- are binary variables that represent lower limits for λ_i^+ and λ_i^-, respectively. The objective function minimizes an unknown variable s that represents the size of an overlap between G_1 and G_2. The overlap is bounded by $d - s$ and $d + s$ where d represents the discriminant score. A predetermined small number ε is used to separate the two groups clearly. The optimal solutions

of model (1) are λ_i^{+*}, λ_i^{-*} d^* and s^*. These values were then used to separate all the companies into the following subsets: $G = G_1 \cup G_2 = C_1 \cup D_1 \cup C_2 \cup D_2$ where

$$C_1 = \left\{ j \in G_1 \middle| \sum_{i=1}^{m} \left(\lambda_i^{+*} - \lambda_i^{-*}\right) z_{ij} > d^* + s^* \right\} \text{ and} \tag{2}$$

$$C_2 = \left\{ j \in G_2 \middle| \sum_{i=1}^{m} \left(\lambda_i^{+*} - \lambda_i^{-*}\right) z_{ij} < d^* - s^* \right\} \tag{3}$$

Here, $D_1 = G_1 - C_1$ and $D_2 = G_2 - C_2$. From the classification, it can be determined that companies in C_1 belong to G_1 and those in C_2 belong to G_2. The set $D_1 \cup D_2$ consists of companies that are not yet classified due to the existence of overlapping. The existence of an overlap is recognized by the value of s^*. If $s^* \geq 0$, then it indicates that there is overlap, if $s^* \leq 0$ it indicates no overlap. The classification of these companies was determined in the second stage using the following model.

$$\begin{aligned}
&\text{Min} \sum_{j \in D_1} y_j + \sum_{j \in D_2} y_j \\
&\text{s.t:} \quad \sum_{i=1}^{m} \left(\lambda_i^{+} - \lambda_i^{-}\right) z_{ij} - C + My_j \geq 0, \qquad j \in D_1 \\
&\qquad \sum_{i=1}^{m} \left(\lambda_i^{+} - \lambda_i^{-}\right) z_{ij} - C - My_j \leq -\varepsilon, \qquad j \in D_2 \\
&\qquad \sum_{i=1}^{m} \left(\lambda_i^{+} + \lambda_i^{-}\right) = 1 \\
&\qquad \zeta_i^{+} \geq \lambda_i^{+} \geq \varepsilon\zeta_i^{+} \qquad i = 1, \ldots, m \\
&\qquad \zeta_i^{-} \geq \lambda_i^{-} \geq \varepsilon\zeta_i^{-} \qquad i = 1, \ldots, m \\
&\qquad \zeta_i^{+} + \zeta_i^{-} \leq 1 \qquad i = 1, \ldots, m \\
&\qquad \lambda_i^{+} + \lambda_i^{-} \geq \varepsilon \qquad i = 1, \ldots, m \\
&\qquad \zeta_i^{+}, \zeta_i^{-}, y_j : 0 \text{ or } 1 \\
&\qquad \lambda_i^{+}, \lambda_i^{-} \geq 0 \\
&\qquad C : \text{unrestricted in sign}
\end{aligned} \tag{4}$$

where M is a predetermined large number and ε is a given small number. The objective function minimizes the total number of incorrectly classified companies by counting a binary variable y_j. Optimal values for C^*, λ_i^{+*} and λ_i^{-*} obtained after solving model (2) were then used to achieve the final classification for companies in the overlap group based on rules (5) and (6). In this study, both Model (1) and Model (4) were solved using MATLAB R2017b software.

$$\text{If } \sum_{i=1}^{m} \left(\lambda_i^{+*} - \lambda_i^{-*}\right) z_{ij} \leq C^* - \varepsilon \text{ then } j \in G_2 \tag{5}$$

$$\text{If } \sum_{i=1}^{m} \left(\lambda_i^{+*} - \lambda_i^{-*}\right) z_{ij} \leq C^* - \varepsilon \text{ then } j \in G_2 \tag{6}$$

Results and Discussion

The optimal values obtained from model (1) in the first stage are presented in **Table 1**. As shown in the table, the value of s^* is greater than 0 which indicates that there is overlap between groups G_1 and G_2. Based on the optimal values in **Table 1**, the companies were then classified using rules (2) and (3).

The result of the classification is shown in **Table 2**. According to this table, 39 out of 50 companies in group G_1 were correctly classified as financially distressed companies and 33 companies in group G_2 were correctly classified as non-financially distressed companies. Meanwhile, the total number of overlaps in group G_1 and G_2 are 11 and 17 companies, respectively. Thus, the correct classification rate in the first stage is 72%.

Table 1 Optimal Solutions of the First Stage

Variable	Optimal Value
s^*	0.2461
d^*	-0.2376
λ_1^{+*}	0
λ_1^{-*}	0.6248
λ_2^{+*}	0
λ_2^{-*}	0.2362
λ_3^{+*}	0
λ_3^{-*}	0.1390

Table 2 Results of Classification in the First Stage

Group	Correct Classification	Overlap
G_1	39	11
‹ G_2	33	17
Total	**72**	**28**

To further classify companies in the overlap group, model (4) in the second stage was used. **Table 3** displays the results of solving model (4). Based on the optimal values in Table 3, the final classification of 28 companies in the overlap group was determined using rules (5) and (6), and the result of the classification is shown in **Table 4**. According to the third and sixth columns of Table 4, from the 28 companies, there are still nine companies that were incorrectly classified. Companies 8, 10, 39 and 43, which are originally in financially distressed group were incorrectly classified as non-financially distressed companies, while companies 62, 64, 66, 74 and 84 that are in non-financially distressed group were incorrectly classified as financially distressed companies. Thus, the percentage of correct classification in the second stage is 67.86%. Overall, the integrated DEA-DA approach could correctly classify 91% of the 100 companies. These results affirm the efficacy of the approach in distinguishing between financially distressed and non-distressed companies.

Table 3 Optimal solutions in the second stage

Variable	Optimal Value
C^*	-0.03416
λ_1^{+*}	0
λ_1^{-*}	0.8999
λ_2^{+*}	0
λ_2^{-*}	0.0001
λ_3^{+*}	0
λ_3^{-*}	0.1000

Table 4 Results of classification in the second stage

Companies	Value	Classification	Companies	Value	Classification
4	1.8921	G1	64	-0.0302	G1*
6	-0.0342	G1	66	0.4457	G1*
8	-0.0511	G2*	69	-0.1266	G2
10	-0.0538	G2*	71	-0.4087	G2
21	0.2450	G1	73	-0.2825	G2
23	-0.0051	G1	74	-0.0257	G1*
37	0.2223	G1	76	-0.1031	G2
39	-0.8500	G2*	77	-0.1931	G2
40	0.2823	G1	79	-0.2253	G2
41	0.2139	G1	81	-0.2785	G2
43	-0.1368	G2*	82	-0.2291	G2
60	-0.0891	G2	84	-0.0090	G1*
61	-0.5674	G2	91	-0.3574	G2
62	-0.3716	G1*	95	-0.0905	G2

* Misclassification

Conclusion

This study examines the applicability of DEA-DA approach in assessing financial distress for publicly listed companies in Malaysia. The assessment was performed in two stages. The first stage classifies the companies into two groups, financially distressed group and non-financially distressed group. This stage also identifies the existence of overlap between the groups. Then, the second stage reclassifies companies in the overlap group. The results of this study show that, the classification accuracy rate of the DEA-DA approach is above 65% (72% in the first stage, 67.86% in the second stage), and overall, the method can yield a correct classification accuracy of 91%. This study concludes that the DEA-DA approach has the ability to correctly classify financially distressed and non-financially distressed companies in Malaysia. For future research, it is recommended to include more financial ratios as the independent factors and compare the performance of DEA-DA with other classification methods, such as logistic regression and discriminant analysis.

Ethics Statement

The research does not require research ethics approval.

Authors Contribution

All authors contributed to all aspects of this work. All authors have read and agreed to the published version of the manuscript.

Conflict of interests

The authors declare no conflict of interest.

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