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Research Paper

Determining the Credit Score and Credit Rating of Firms using the Combination of KMV-Merton Model and Financial Ratios

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Abstract
Credit risk management has become a must in this era due to the increase in the number of businesses defaulting. Building upon the legacy of Kealhofer, McQuown, and Vasicek (KMV), a mathematical model is introduced based on Merton model called KMV-Merton model to predict the credit risk of firms. The KMV-Merton model is commonly used in previous default studies but is said to be lacking in necessary detail. Hence, this study aims to combine the KMV-Merton model with the financial ratios to determine the firms' credit scores and ratings. Based on the sample data of four firms, the KMV-Merton model is used to estimate the default probabilities. The data is also used to estimate the firms' liquidity, solvency, indebtedness, return on asset (ROA), and interest coverage. According to the weightages established in this analysis, scores were assigned based on those estimates to calculate the total credit score. The firms were then given a rating based on their respective credit score. The credit ratings are compared to the real credit ratings rated by Malaysian Rating Corporation Berhad (MARC). According to the comparison, three of the four companies have credit scores that are comparable to MARC's. Two A-rated firms and one D-rated firm have the same ratings. The other receives a C instead of a B. This shows that the credit scoring technique used can grade the low and the high credit risk firms, but not strictly for a firm with a medium level of credit risk. Although research on credit scoring have been done previously, the combination of KMV-Merton model and financial ratios in one credit scoring model based on the calculated weightages gives new branch to the current studies. In practice, this study aids risk managers, bankers, and investors in making wise decisions through a smooth and persuasive process of monitoring firms' credit risk.

Keywords
Credit Score, KMV-Merton Model, Financial Ratios, Credit Rating, Default, Credit Risk

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1. INTRODUCTION

Recent statistics by Kraemer (2020) revealed that 2019 is the most challenging year compared to the previous years as the number of firms bankruptcies rose. A rare default case occurred after the investment-grade (high) rated firms were reported to default. The firms' failure to pay debts will affect the organization in the firms themselves and lenders and the economy. Therefore, practical credit risk assessment is a must to curb the risk transmission. Credit scoring is a perfect example of one of the methods to grade firms' credit risk. The literature of credit scoring is very limited and only starts to be widely used from the 21st century especially for consumer lending (Abdou and Pointon, 2011). Credit scoring contains elements that are quantitative and qualitative (Haralambie et al., 2016). The qualitative part can be done based on judgemental, but the essential factor is the quantitative part where empirical criterion can be obtained statistically or mathematically (Chijoriga, 2011). In this research, credit scoring is done quantitatively based on the KMV-Merton model and financial ratios.

Commonly, KMV-Merton Model is used to predict the probability of default of firms. This includes studies from (Crosbie and Bohn, 2019; Vassalou and Xing, 2004; Zhang et al., 2010; Bharath and Shumway, 2004; Kollár and Gondžárová, 2015). Meanwhile, the financial ratios are needed to evaluate firms' liquidity, solvency, leverage, and profitability as done by (Altman, 1967; Beaver, 1966; Zorn et al., 2018). However, (Bharath and Shumway, 2004) demonstrated that the use of the KMV-Merton model is inadequate as a default forecaster. Thus, some financial ratios were recommended to improve the KMV-Merton model's performance (Liang, 2012).

A few researchers such as Benos and Papanastasopoulos, 2007; Liang, 2012; Andrikopoulos and Khorasgani, 2018 focused on incorporating the financial ratios with the KMV-Merton model to improve the accuracy of their default prediction. Most

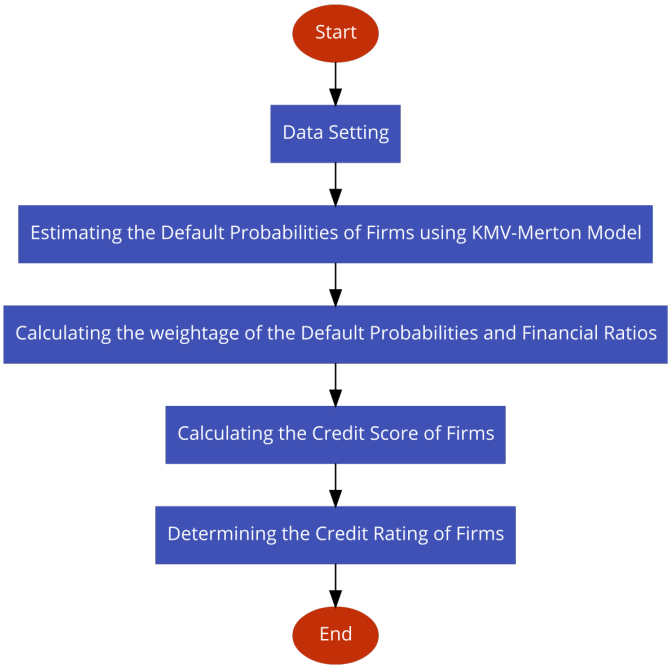

Figure 1. The Research Process of the Study

of the researchers used both the KMV-Merton model and financial ratios to produce a hybrid default model. Contradicted to this research where the KMV-Merton model is combined with the financial ratios into one credit scoring formula to determine the credit ratings of firms. In this credit scoring model, the weightage of each financial ratio and KMV-Merton model are calculated based on certain criteria. Therefore, this research aims to determine the credit score and credit ratings of the selected firms using the combination of the KMV-Merton model and financial ratios. This research presents the other view to credit scoring that employs the KMV-Merton model and financial ratios to assess a firm's credit risk. In addition, comparisons are made between the credit ratings measured in this research and the MARC credit ratings.

The following is how the rest of the paper is organized: The second section explains the research methods, including data setting, default probability estimations, calculating weightages and credit scores, and assessing firm credit ratings. The findings of this study were discussed in the third part. Lastly is the conclusion.

2. METHODOLOGY

The process of this study is presented in term of flowchart as in Figure 1. All the process are explained in detail in the following sub-sections.

2.1 Data Setting

Samples of four firms' financial data: Sime Darby Plantation, Tenaga Nasional Berhad (TNB), Alam Maritim Resources Berhad, and Press Metal Berhad are used in this study. Based on MARC's credit ratings, these four firms were chosen to represent the strong, medium, and bad rated firms. All data was gathered according to the year in which the credit rating was published from 2014 to 2019.

The data is obtained from the firms' annual report, including current assets, current liabilities, total equity, total liabilities, total assets, net profit, earning before net interest, and interest expenses. Table 1 describes the descriptive statistics of data obtained from the firms' annual report. These data are used to calculate the financial ratios of the firms, as presented in Table 3. Table 3 shows the selected financial ratios and their formula based on (Caracota et al., 2010). Liquidity refers to a firm's ability to repay its short-term debt (Yameen et al., 2019). Next, when dealing with the banking sector, solvency is used to assess a firm's viability (Zorn et al., 2018). The term "indebtedness" refers to a firm's willingness to carry debt and fulfil its obligations (Gibson, 1987). Meanwhile, return on asset (ROA) is a metric that calculates how profitable a firm is as a result of its assets (Rosikah et al., 2018). Finally, interest coverage is used to assess a firm's ability to pay interest (Nwanna and Ivie, 2017). There are five ratios involved, and they are liquidity, solvency, indebtedness, return on assets (ROA), and interest coverage (time interest earned).

The data from the firms' quarter report that includes the short-term and long-term borrowings are used to define the book value of liabilities. This study also utilized the outstanding shares obtained from the quarterly report and the historical daily price obtained from Finance, 2020; Investing, 2020. The short-term borrowings, long-term borrowings and the outstanding share are assumed fixed according to the quarter reports. Table 2 describes the descriptive statistics of data obtained from the firms' quarterly report. This data was set up as a process to estimate firms' default probabilities.

2.2 Estimating the Default Probabilities of Firms using the KMV-Merton Model

KMV-Merton model is the extended model of the Merton (1974) model where a new parameter called distance to default (DD) is introduced in this model. Default occurs when the firm's market value of the asset falls below the default point, defined as the firms' book value of liabilities (Crosbie and Bohn, 2019).

There are five steps involved to estimate the probability of default of firms using the KMV-Merton model. The first step is to calculate the daily market value of firms' equity by multiplying each of the daily prices with the outstanding shares. The second step is to calculate the daily book value of liabilities, D by defining it as a total borrowing of the short term plus half of the long-term borrowings. One-half of the liabilities are used, as the default point usually lies between total liabilities and current liabilities (Crosbie and Bohn, 2019). The third step is to add together the firms' market value of equity and the book value of liabilities to get the daily asset's market value, V_t. The fourth step is to generate the daily natural log of the assets' market values returns, $\ln(V_t/V_{t-1})$. Here, the average return, μ and the standard deviation, σ are calculated as the firms' expected

Table 1. The Descriptive Statistics of Data Obtained from the Firms' Annual Report

Item (RM)	N	Descriptive Statistics			
		Minimum	Maximum	Mean	Std. Deviation
Current Asset	4	1,669,956,000	278,540,906,000	77,601,969,750	134,390,656,391
Current Liabilities	4	2,072,044,000	252,381,385,000	70,628,376,750	121,561,848,422
Equity	4	597,127,000	59,282,100,000	19,480,180,500	27,405,184,942
Total Liabilities	4	151,297,000	45,411,700,000	13,914,587,250	21,239,042,871
Total Assets	4	870,890,000	178,847,200,000	53,420,926,250	84,487,428,574
Net Profit	4	-145,380,000	4,529,200,000	1,192,855,000	2,230,747,917
Earning Before Net	4	-138,897,441	8,206,800,000	2,226,447,64	3,995,582,703
Interest Expenses	4	6,654,090	1,487,700,000	389,511,523	732,403,723

Table 2. The Descriptive Statistics of Data Obtained from the Firms' Quarterly Report

Item (RM)	N	Descriptive Statistics			
		Minimum	Maximum	Mean	Std. Deviation
Outstanding Share	16	257,869,000	6,885,000,000	3,458,423,438	2,961,295,203
Short Term Borrowing (RM)	16	89,363,000	6,061,000,000	2,209,695,813	1,891,270,258
Long Term Borrowing (RM)	16	15,016,000	43,737,900,000	11,921,773,688	18,723,901,636

returns and daily volatility, respectively. Since asset returns follows the random walk properties and probability of default is estimated annually, thus the daily volatility is annualized by multiplying it by the square root of trading days, which is 252 days in a typical year (Glenn, 2018). The fifth step is calculating the distance to default, d using the following equation:

$$d = \frac{ln(\frac{V_t}{D}) + (\mu - \frac{\sigma^2}{2})t}{t\sqrt{\sigma}} \quad (1)$$

The parameter d is defined as the number of standard deviations away from default (Crosbie and Bohn, 2019) where V_t is the market value of the asset at any time t, D is the book value of liabilities, μ is the expected asset returns, σ is the asset volatility and t =1 year.

Finally is to estimate the annual default probability of the firms. Merton, 1974 assumed that the asset returns' random component is normally distributed. Thus, the probability of default, P_t, is written in term of standard cumulative normal distribution function and it is defined as the inverse of d expressed as follows:

$$\begin{aligned} P_t &= 1 - P(Z < d) \\ &= P(Z < -d) \\ &= \int_{-\infty}^{-d} e^{-\frac{1}{2}z^2} dz \end{aligned} \quad (2)$$

A firm is said to have a higher default probability as the value approaching one, and a lower default probability as the value is approaching 0. The larger the distance to default, the lesser the firm's probability to default.

2.3 Calculating the Weightage of Default Probability and Financial Ratios

Calculating weightage is essential to determine the weightage of each financial ratio and default probability according to specific criteria in credit scoring. All the five financial rat ios (X_1, X_2, X_3, X_4, X_5) used in Table 3 and the default probability (P_t) are denoted as the credit risk indicators $i = P_t, X_1, X_2, X_3, X_4, X_5$. The formula used to calculate the weightage of each credit risk indicators i, W_i, is presented as:

$$W_i = \frac{S_i}{\sum_{i=1}^{6} S_i} \quad (3)$$

Given S_i is the score of each credit risk indicator i, and it is calculated based on the approach of O'Loughlin (2009) as expressed below:

$$S_i = \sum_{j=1}^{8} W_j S_j \quad (4)$$

where j is the eight criteria shown in Table 4. Hence, W_j is the weight to criteria and S_j is the criteria score that is determined in this study.

There are eight criteria defined by O'Loughlin (2009) in the weighted scoring model, which are value, risk, urgency, stakeholder, success, difficulty, relationship, and compliance. Each criterion has been given its own percentage, W_j, as shown in Table 4. The value and risk represent the accuracy of the credit risk indicators and the ability to measure risk, respectively. Urgency shows the ability to alert the firms on taking immediate action in any case of a default event. A stakeholder is where there is any

Table 3. The Financial Ratios (Caracota et al., 2010)

No.	Financial ratios	Formula
1	Liquidity, X_1	$\frac{\text{current assets}}{\text{current liabilities}}$
2	Solvency, X_2	$\frac{\text{equity}}{\text{total liabilities}}$
3	Indebtedness, X_3	$\frac{\text{total liabilities}}{\text{equity}}$
4	Return on asset (ROA), X_4	$\frac{\text{net profit}}{\text{total assets}}$
5	Interest coverage (Time interest earned), X_4	$\frac{\text{earning before net interest, costs, and tax}}{\text{interest expense}}$

Table 4. The Score Weightage

Criteria, j	Weight to criteria W_j	Criteria Score, S_j					
		P_t	X_1	X_2	X_3	X_4	X_5
Value	20%	9	4	7	9	6	6
Risk	20%	9	5	8	8	7	8
Urgency	15%	9	7	8	8	7	7
Success	10%	6	6	7	6	8	8
Compliance	5%	7	2	6	6	2	2
Relationships	5%	9	4	9	9	4	8
Stakeholder	15%	4	5	4	8	9	7
Difficulty	10%	7	4	4	4	4	4
Score, S_i		7.65	4.90	6.65	7.55	6.50	6.60
Weightage, W_i (%)	100	19	12	17	19	16	17

Table 5. The Scoring of Probability of Default (Credit, 2014)

Default Probability, P_t (%)	Score, k
0.00-0.12	10
0.12 – 0.27	9
0.27-0.34	8
0.34 – 0.55	7
0.55 – 0.87	6
0.87 – 1.40	5
1.40 – 2.10	4
2.10 – 4.00	3
4.00 – 9.99	2
9.99 – 50.00	1
50.00 – 100	0

involvement between the credit risk indicators and stakeholders. Success describes the success of credit risk indicators to measure the firm's financial performance. Difficulty relates to how the model acquires its needed parameters. The relationship criterion shows how the models have any relation to credit risk. Lastly, the compliance measures the level of the credit risk indicators in conforming to any related law.

The criteria scores, S_j is set up in this study based on the importance and relevancy of the credit risk indicators i in fulfilling the criteria. Its score can be in the ranges extremely important (9 to 10), averagely important (6 to 8), and least important (0 to

Table 6. The Scoring of Financial Ratios (Caracota et al., 2010)

Financial ratios	Ratio	Score, k
Liquidity	$X_1 \geq 1.3$	7
	$1.1 \leq X_1 < 1.3$	5
	$1 \leq X_1 < 1.1$	3
	$0 \leq X_1 < 1$	1
Solvency	$X_2 \geq 0.1$	9
	$0.07 \leq X_2 < 0.1$	6
	$0.05 \leq X_2 < 0.07$	3
	$X_2 < 0.05$	0
Indebtedness	$0 \leq X_3 < 2$	6
	$2 \leq X_3 < 4$	5
	$4 \leq X_3 < 6$	3
	$X_3 > 6$	0
ROA	$X_4 \geq 0.05$	2
	$0 < X_4 < 0.05$	0
Interest coverage	$X_5 \geq 0.03$	10
	$0.02 \leq X_5 < 0.03$	8
	$0.01 \leq X_5 < 0.02$	5
	$X_5 < 0.01$	0

5). For example, as shown in Table 4, the probability of default is scored as 9 for the value criterion. It is scored as extremely important because the probability of default value is considered a significant value that could predict firms' default (Liang, 2012). The probability of default is shown to score the highest in almost all the criteria, corresponding to its importance for this research. There is an exception in the stakeholder criterion. Usually, stakeholders are concerned about the firm's profit and its consistency with the revenue stream. The ROA is the most preferred by the stakeholders as they measure the firm's profitability. Thus ROA scored the highest. The results of implementing the equations (3) and (4) are given in Table 4. Table 4 presents the score weightage of the credit risk indicators *i*.

2.4 Calculating the Credit Score of Firms

This part is where the combination of the KMV-Merton model and financial ratios took place, as all the scores were added into one formula to determine the credit score of the selected firms. The credit score of the firms, f is determined based on the following equation expressed as (Chikomba et al., 2013):

$$f = \sum_{i=1}^{6} W_i\left(\frac{k_i}{max\ k_i}\right) \tag{5}$$

where W_i is the weightage of the credit risk indicators i calculated using equation (3). Meanwhile k_i is the score assigned as the default probability and financial ratios were estimated and then mapped into Tables 5 and 6. Tables 5 and 6 show the score given for the default probability and financial ratios. The max k_i is the maximum score that can be obtained for the default probability and financial ratios as given in Tables 5 and 6. The scores given in Tables 5 and 6 were assigned by (Credit, 2014; Caracota et al., 2010) to indicate the strength of firms based on a certain level of credit risk. In this case, the worst score given is zero, while the excellent score can be varied from two to ten.

Table 7. The Credit Rating Maps to the Credit Score (Chikomba et al., 2013)

Credit Score, f (%)	Credit rating	Level of credit risk
75 – 100	A	Low
60 – 74	B	Medium
50 – 59	C	High
25 – 0	D	Default

2.5 Determining the Credit Rating of the Firms

The firms' credit rating can be determined by comparing the calculated firms' credit scores with Table 7. Table 7 presents the credit rating maps to the credit score. The last step is comparing the credit ratings determined with the ratings given by the MARC. Beforehand, some adjustment is made to standardize MARC's credit rating as presented in Table 8.

Table 8. Credit Ratings Equivalent to MARC Ratings

Credit Rating	MARC Rating
A	AAA,AA,A
B	BBB,BB,B
C	C
D	D

3. RESULTS AND DISCUSSION

3.1 The Default Probabilities and Financial Ratios

In this study, the default probabilities of the four firms are calculated using equation (2) of the KMV-Merton model, as described in section 2.2. In the meantime, the financial ratios are determined using the formula in Table 3. Tables 9 and 10 show the results of implementing the equation and the formula.

Table 9 presents the results of estimating the firms' default probabilities using the KMV-Merton model. Based on the asset and liabilities values given in Table 9, the leverage ratio (book value of liabilities / market value of asset) is calculated to measure firm's financial leverage. Sime Darby Plantation has the lowest leverage ratio of 0.12, which is followed by TNB (0.24), Alam Maritim (0.45), and Press Metal (0.77). Leverage ratio indicates how much of a firm's capital is funded by debt. The Press Metal borrowed 77 percent of its money, while Alam Maritim borrowed nearly half. Sime Darby Plantation and TNB, on the other hand, only used 12 percent and 24 percent of their resources in the form of debt, respectively. The amount of permissible leverage, on the other hand, is determined by the sector in which the firm work. Some businesses are prone to taking on a lot of debt. As a result, other factors such as the anticipated return must be considered. Based on Table 9 only the Sime Darby Plantation is expected to have a positive return while others have negative returns. In terms of volatility, the asset of Press Metal is the most volatilized, and next is the Alam Maritim, Sime Darby Plantation, and TNB. These are parallel where firms with higher asset volatility tend to have a lesser amount of leverage ratio (Patel and Pereira, 2007). Considering all these, Sime Darby Plantation is predicted to have the highest DD, while the Press Metal is expected to have the lowest DD. Therefore, the PD of the Sime Darby is the lowest, followed by TNB. Still, both have approximately 0% of PD. Then, the value of PD goes higher to 4% for Alam Maritim and even higher than 42% for Press Metal.

Table 10 shows the financial ratios estimated for the selected firms. Alam Maritim is found to have the highest liquidity and solvency among all the firms and the lowest indebtedness, ROA, and interest coverage. This contradicted the Press Metal, where it has the lowest liquidity and solvency but the highest indebtedness, ROA, and interest coverage. Instability in these financial ratios of both firms showing a sign of poor financial performance. Although Alam Maritim has the highest liquidity and solvency, it has problems paying debt and gaining profit. Meanwhile, Press Metal has problems countering its assets over its liability and has the lowest viability even if it can pay its debt. Unlike the

Table 9. The Result of Estimating the firms' default probabilities using the KMV-Merton Model

	Sime Darby Plantation	Tenaga Nasional Berhad (TNB)	Alam Maritim Resources Berhad	Press Metal Berhad
Market value of asset (RM'000)	42640750	99853648	304671	2214991
Book Value of Liabilities (RM'000)	5117500	24445500	138268	1703075
Expected return	0.0006711	-0.0000698	-0.000712	-0.000034
Asset volatility	0.2016	0.1493	0.4041475	0.5659
Distance to default (DD)	10.4169	9.3502	1.751	0.1814
Probability of default (PD)	1.04E-25	4.37E-21	4.00E-02	4.28E-01

Table 10. The Financial Ratios of Firms

	Sime Darby Plantation	Tenaga Nasional Berhad (TNB)	Alam Maritim Resources Berhad	Press Metal Berhad
Liquidity	1.0435	1.0820	1.1037	0.8059
Solvency	2.0479	1.3054	3.9467	0.9278
Indebtedness	0.4883	0.7660	0.2534	1.0778
Return on asset	0.0043	0.0253	-0.1669	0.0487
Interest coverage	7.7993	5.5164	-20.8740	36.5553

Table 11. The Credit Score of the Firms

Credit Risk	Weightage, W_i (%)	Max k_i	Score, k_i			
			Sime Darby Plantation	Tenaga Nasional Berhad	Alam Maritim Resources Berhad	Press Metal Berhad
Pt	19	10	10	10	2	1
X1	12	7	3	3	5	1
X2	17	9	9	9	9	9
X3	19	6	6	6	6	6
X4	16	2	0	0	0	0
X5	17	10	10	10	0	10
Credit score, f (%)	100	-	77	77	48	57

Table 12. The Comparison of the Credit rating and MARC Rating

Firm	Credit Score, f (%)	Credit rating	MARC Rating
Sime Darby Plantation	77	A	A
Tenaga Nasional Berhad	77	A	A
Press Metal Berhad	57	C	B
Alam Maritim Resources Berhad	48	D	D

Sime Darby Plantation and TNB, where their financial ratios are more stable.

3.2 Credit Score and Credit Rating

The credit score of the firms is calculated using equation (5), where the weightage of the default probability and financial ratios are determined beforehand using equations (3) and (4). Then, the credit ratings of the firms are determined according to the score obtained using Table 7. Tables 11 and 12 presents the results of calculating the credit score and the determining the credit ratings, respectively.

Table 11 shows the credit score of firms. A larger score means the firms have better financial performances. Based on Tables 9 and 10, we found that Sime Darby and TNB can be categorized as firms with low default risk and stable firms, and thus, both firms were given maximum scores in PD and three out of five financial ratios. This is contradicted to the Alam Maritim, where it only scored maximum in solvency and indebtedness. The same goes for Press Metal with the addition of maximum score in interest coverage. None of the firms obtained the maximum score in liquidity and ROA. As a result, the final credit score for Sime Darby Plantation and TNB (77%) are the highest, followed by Press Metal (57%) and lastly Alam Maritim (48%). This can also be seen clearly in Table 12. Table 12 presents the comparison of the credit rating and MARC Rating. Sime Darby Plantation and TNB were rated A, while Alam Maritim was rated D. Only Press Metal rating does not match with the MARC ratings as Press Metal was rated C instead of B.

4. CONCLUSIONS

In this research, a method for determining a firm's credit score is presented to grade the credit risk of the firms, which uses a combination of the KMV-Merton model and financial ratios corresponding to the certain weightage. Four firms have been selected: Sime Darby Plantation, Tenaga Nasional Berhad, Alam Maritim Resources Berhad, and Press metal Berhad. These firms' financial data was utilized to estimate the firms' PD, liquidity, solvency, indebtedness, profitability, and interest coverage. We found that higher asset to debt ratio, higher returns, and lower volatility estimates higher DD and, thus, lower PD. Meanwhile, higher liquidity, solvency, profitability, interest coverage, and lower indebtedness estimate better financial performance. Based on these results, Sime Darby Plantation and TNB are found to have a low default risk and secure financial account compared to the Alam Maritim and Press Metal. This is seen as the credit score determined for both Sime Darby Plantation and TNB is 77%, followed by Press Metal 57% and Alam Maritim 48%. Those scores bring Sime Darby Plantation and TNB as A-rated firms and Alam Maritim as a D-rated firm, while ratings for Press Metal are between B-rated and C-rated firms. Overall, a combination of both financial ratios and the KMV-Merton model in credit scoring is one of the valuable way of measuring credit risk, especially in grading the low and high credit risk firms. However, further research is needed in the future. More data is needed to restrict the study's scope according to the firms' sectors and other macroeconomic factors. An adjustment can be made to the weighted scoring model's criteria and scores to follow specific business requirements. The way scores were assigned to each level of credit risk also can be improved according to countries' economic environment.

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