Available online at https://journal.rescollacomm.com/index.php/ijqrm/index

International Journal of Quantitative Research and Modeling

e-ISSN 2721-477X
p-ISSN 2722-5046

Vol. 4, No. 4, pp. 200-206, 2023

Determination of Insurance Premiums to Mitigate the Risk of Company Losses Due to Supplier Failure Using Black-Scholes-Merton Model

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Abstract

The Micro and Small Enterprises (MSMEs) sector in Indonesia has made a significant contribution to the Indonesian economy. However, MSMEs in Indonesia face various challenges that may occur in the future, for example, supplier failure. Therefore, it is essential to determine the right form of risk mitigation to reduce the impact of supplier failure for MSMEs, and one such approach is to have insurance. This study aims to calculate the premium price using the Black-Scholes-Merton model approach. The data used is the aggregate losses experienced by MSMEs fostered partners of PT Wijaya Karya (Persero) Tbk. Data simulation was generated on lognormal distribution to determine the premium price. The application of the Black-Scholes-Merton model on the calculations showed that MSMEs have to pay a premium of IDR 4,165,061 for one year.

Keywords: Supplier Failure; Loss Insurance; Supply Chain; Data Simulation; Black-Scholes-Merton Model.

1. Introduction

According to The Coordinating Ministry for Economic Affairs, Micro, Small, and Medium Enterprises (MMSMEs) in Indonesia have a significant contribution to the Gross Domestic Product (GDP), namely 60.5% of the total GDP in 2022. In practice, MMSMEs use a supply chain system through close partnerships with suppliers (Hwihanus et al., 2022). If and when the supplier experiences a failure, the business risks being unable to meet all customer requirements in the short term and will not meet customer requirements if it eventually goes out of business (Zsidisin & Wagner, 2010). Therefore, it is essential to have strategic financial risk management. One approach, among others, is by working with insurance companies.

In previous research conducted by Valverde (2014), they discussed how to reduce the risk of bankruptcy for a company by using the Black-Scholes-Merton model. It said that detecting problems and protecting against supplier failure should be a top priority for companies. Tsipouri et al. (2010) discussed various cases in the production or procurement process of an innovation, one of which is the risk that the supplier stops operating. It was stated that one way that can be used as a solution to solve this problem is to insure it. Insurance is the most effective way of mitigating risk and can be used continuously.

Based on previous research, this study intends to apply the Black-Scholes-Merton model to calculate insurance premiums based on losses due to supplier failure. The difference between this research and previous studies is the object of research. In this study, namely, the MSME partners fostered by PT Wijaya Karya (Persero) Tbk. MMSMEs can use this research to find out the insurance premium to avoid the risks that can occur due to supplier failure.

2. Literature Review

2.1. Risk Pooling and Insurance

Risk pooling, known as a centralized system, is a form of risk management practiced by insurance. This centralized system does not change a company's loss estimates but reduces the uncertainty of losses (Valverde, 2014). According to the provisions of Article 246 of the Indonesian Commercial Code, insurance or coverage is an agreement whereby

the insurer binds himself to the insured by receiving a premium to provide compensation to him due to loss, damage, or loss of expected profits that he may suffer as a result of an event (uncertain event).

Risk pooling is a fundamental thing in the concept of insurance. An insurance risk pool is a group of individuals whose loss costs are combined to calculate the premium. Thus, the contributions or insurance premiums that each insurer has paid are not savings; therefore, each member is not entitled to ask for the funds that have been paid or contributed back, even though he has never used the funds.

2.2. Goodness-of-Fit Test

Goodness of fit using the Chi-Square test is used to determine whether the data distribution fits the theoretical distribution model hypothesis. According to the Chi-Square table, the Chi-Square significance value is determined based on the degree of freedom and the critical value. Decision-making in the Chi-Square test uses the parameter χ^2_{count} which can be calculated using the following equation (Tang et al., 2012):

$$\chi^2_{count} = \sum_{i=1}^{g}\left[\frac{(O_i - E_i)^2}{E_i}\right] \tag{1}$$

The hypothesis to be tested is

H_0 : the data follows a certain distribution

H_1 : the data follows other distributions

with the decision criteria if $\chi^2_{count} < \chi^2_{table}$ so H_0 is accepted, meaning that the observed sample distribution has the sama distribution as the theoretical distributions. Where g is number of subgroups; O_i is frequency of observations in sub group i; E_i is the frequency of expectations in the sub group i.

2.3. Data Uniformity and Sufficiency Test

A data uniformity test needs to be carried out to know whether there is a discrepancy in the data that has been collected. Testing is carried out by determining the Upper Control Limit (BKA) and Lower Control Limit (BKB). Determination of BKA and BKB is carried out using equations (2) and (3)

$$BKA = \bar{X} + Q\sigma \tag{2}$$

$$BKB = \bar{X} - Q\sigma \tag{3}$$

The data sufficiency test was carried out to find out whether the data that had been collected through distributing questionnaires was sufficient to be used in solving existing problems (Rahma et al., 2018). The data sufficiency test is carried out through equation (4)

$$N' = \frac{Q/S\sqrt{N\sum X^2 - (\sum X)^2}}{\sum X} \tag{4}$$

where X: the data, $\bar{X}$: average of the data, Q: level of confidence, σ: standard deviation, N: the amount of data obtained, N': amount of data required for research, and S: degree of accuracy.

2.4. Black-Scholes-Merton Model

The Black-Scholes-Merton model was first developed by Fisher Black, Myron Scholes, and Robert Merton. The European type Black-Scholes-Merton equation has two options: a buy option and a put option with the following equation:

$$C = S_t N(d_1) - Ke^{-rT}N(d_2) \tag{5}$$

and

$$P = Ke^{-rT}N(-d_2) - S_t N(-d_1) \tag{6}$$

where

$$d_1 = \frac{ln\left(\frac{S_0}{K}\right) + \left(r + \frac{\sigma_T^2}{2}\right)T}{\sigma_T\sqrt{T}} \tag{7}$$

$$d_2 = \frac{\ln\left(\frac{S_0}{K}\right) + \left(r - \frac{\sigma_T^2}{2}\right)T}{\sigma_T\sqrt{T}} \quad = d_1 - \sigma_T\sqrt{T} \tag{8}$$

With C: call option, P: put option, S_t: lose value, K: strike price, T: time, r: risk free interest rate, $N(d_1)$: the cumulative density of the normal distribution of d_1, $N(d_2)$: the cumulative density of the normal distribution of d_2.

Insurance for loss due to supplier failure depends on the realizable value of the loss. The BSM model is used for calculating is as follows:

$$Premium = Ke^{-rT}N(-d_2) \tag{9}$$

3. Materials and Methods

3.1. Materials

The object of this study are MSMEs fostered partners of PT Wijaya Karya (Persero) Tbk. The data was obtained by collecting information from MSMEs owners regarding the losses due to supplier failure. The purpose is to determine the cost of insurance premiums of the MSMEs using the Black-Scholes-Merton model. Easyfit and Microsoft Excel software are utilized to help simplify the calculation process.

3.2. Methods

The steps executed in this study are as follows:

1) Collect data on MSME losses due to supplier failures,
2) Determine and test the distribution of loss data using equation (1),
3) Transform the data using natural logarithms, then test the uniformity and adequacy of the data,
4) Data simulation generated for fulfilling data adequacy test,
5) Performing a chi-squared test to prove the data is lognormal distributed for fulfilling the Black Scholes Merton model uses equation (1),
6) Determining the amount of insurance premium due to supplier failure is carried out using the Black-Scholes-Merton model, which refers to equations (7), (8), and (9).

4. Results and Discussion

The data used in this study were obtained by distributing questionnaires to MSMEs fostered partners of PT Wijaya Karya (Persero) Tbk. The questionnaire received 67 respondents, whereas the MSMEs that have experienced losses due to supplier failure are 44 respondents. The following are data on the amount of MSME losses due to supplier failure grouped by the category presented in Table 1.

Table 1: Data on the amount of MSME losses due to supplier failure

Initial	Amount of Losses	Initial	Amount of Losses
Bg	IDR10,000,000	VV	IDR25,000,000
AG	IDR35,000,000	SMB	IDR15,000,000
EG	IDR100,000,000	RW	IDR30,000,000
AR	IDR4,000,000	MN	IDR900,000
FMA	IDR3,500,000	H	IDR2,500,000
Dm	IDR5,500,000	GN	IDR4,500,000
AMD	IDR5,000,000	MM	IDR6,000,000
AN	IDR10,000,000	VL	IDR15,000,000
ChA	IDR2,500,000	SY	IDR6,000,000
MD	IDR35,000,000	BS	IDR1,500,000
DR	IDR5,500,000	Sk	IDR3,000,000
FF	IDR800,000	BR	IDR5,000,000
RR	IDR25,000,000	DN	IDR1,500,000
UD	IDR2,500,000	MS	IDR15,000,000
MU	IDR700,000	Lv	IDR700,000

Initial	Amount of Losses	Initial	Amount of Losses
Egi	IDR8,500,000	ER	IDR45,000,000
LA	IDR3,000,000	RI	IDR13,000,000
DP	IDR8,500,000	Gn	IDR2,500,000
hs	IDR3,000,000	Mo	IDR47,000,000
AFA	IDR16,000,000	LWP	IDR1,000,000
YR	IDR2,700,000	Dm	IDR700,000
RZ	IDR4,500,000	BS	IDR300,000

Table 1 shows that 44 MSMEs have experienced losses, with the largest loss of IDR 100,000,000.00 and the slightest loss of IDR 300,000.00.

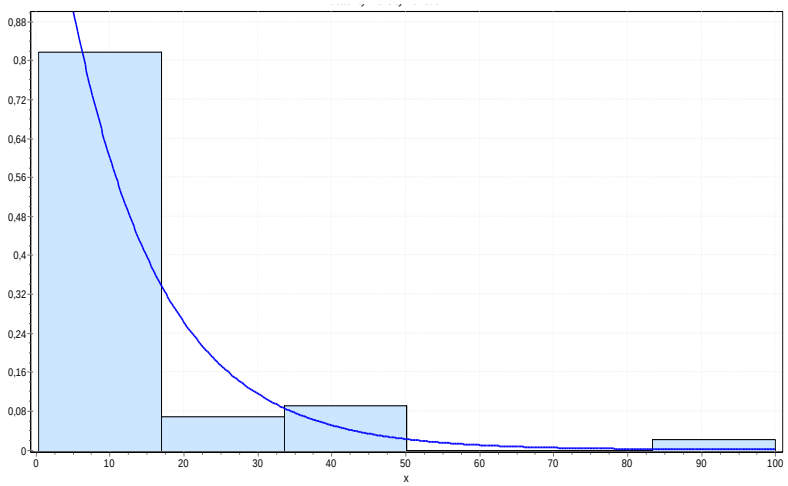

Figure 1: Polygon Histogram MSMEs Amount of Losses

Based on Figure 1, it can be assumed that the data on losses experienced by MSMEs in one year shows the exponential distribution of data. A statistical test analysis was carried out using the Chi-Square test to determine whether the data was Exponentially-distributed. With the help of EasyFit Software, the chi-square goodness of fit test results are presented in Table 2.

Table 2: Exponential Chi-Square Goodness of Fit Test Result

Exponential Chi-Square Goodness of Fit Test

Amount of Losses	Statistics (χ^2)	7.9122
	χ^2_{cr}	9.4877
	Result	$\chi^2 < \chi^2_{cr}$ or $7.9122 < 9.4877$
	Conclusion	H_0 is accepted, data is exponentially distributed

The data then get transformed by natural logarithms and is carried out using Microsoft Excel software. Then data uniformity and sufficiency tests were carried out on the transformed data. In the data uniformity test, the Upper Uniformity Limit (BKA) and Uniformity Limit (BKB) are calculated using Equation (2) and Equation (3) with the value of the average $\bar{X} = 1.71117$; quartile $Q = 2$; standard deviation $\sigma = 1.32585$ that is:

$$BKA = \bar{X} + Q\sigma$$
$$= 2.05900 + 2 \cdot 1.06702$$
$$= 4.193043$$

and

$$BKB = \bar{X} - Q\sigma$$
$$= 2.05900 + 2 \cdot 1.06702$$
$$= -0.07505$$

Based on the calculation results above, the data displayed in graphical form in Figure 2.

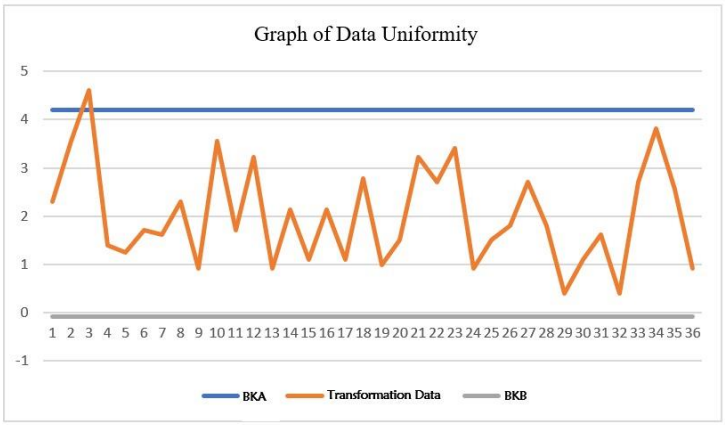

Figure 2: Graph of Data Uniformity

From Figure 2 can be seen that there is more excellent data than the BKA value, so the data is excluded from the research data. Furthermore, the data sufficiency test was carried out using Equation (4) with description $N = 36$, $K = 2$, and $S = 0.05$

$$N' = \frac{K/S\sqrt{N\sum X^2 - (\sum X)^2}}{\sum X}$$
$$= \frac{2/0.05\sqrt{36(176.6402) - (71.5777)^2}}{71.5777}$$
$$= 386$$

This shows that the value is N<N', meaning that the data obtained through the questionnaire is not sufficient. Therefore, it is necessary to simulate by generating random numbers to meet the sufficient data. With the help of EasyFit software, the random numbers generated through the simulation are 400, so the total amount of data used in the study is 436. Then the simulation data is displayed in the form of a polygon histogram in Figure 3.

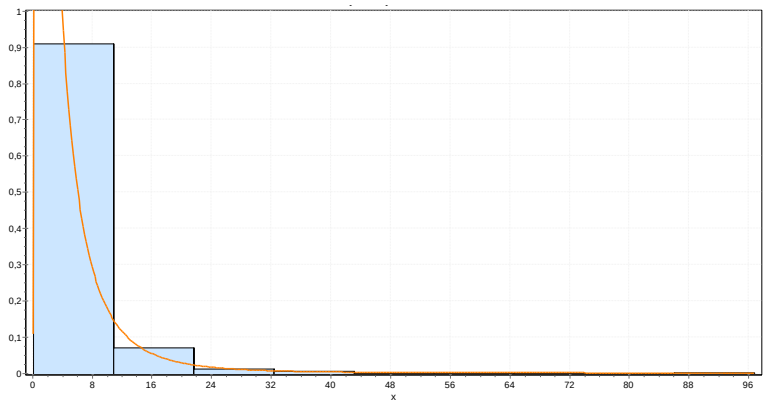

Figure 3: Polygon Histogram Data Simulation

As presented in Figure 3, it shows that the simulated data has a lognormal distribution. The Chi-Square test was carried out with the help of EasyFit software using a significance level of 0.05.

Table 3: Lognormal Chi-Square Goodness of Fit Test Result

Lognormal Chi-Square Goodness of Fit Test		
Data Simulation	Statistics (χ^2)	3.2061
	χ^2_{cr}	15.507
	Result	$\chi^2 < \chi^2_{cr}$ or $3.2061 < 15.507$
	Conclusion	H_0 is accepted, data is lognormally distributed

Figure 3 and Table 3 show that the data is Lognormally distributed, which signifies it meets the assumptions of the Black Scholes Merton Model. The determination of insurance premiums for MSME losses due to supplier failure is carried out based on the time of premium payment, referring to the equation (7), (8), and (9), it calculated as follows:

$S_t = 126.2671$ (Based on the largest value of the simulation data)
$K = 20$ (Based on the smallest capital of MSMEs)
$\sigma = 1.3259$ (Based on the variance of the transformed data)
$\sigma^2 = 1.7579$ (Based on the variance of the transformed data)
$r = 5.75\%$ per year
For $T = 1$ the premium value can be calculated as follows:

$$r = \frac{0.0575}{12} = 0.004792$$

$$d_1 = \frac{\ln(S_t/K)+(r+0.5\sigma^2)T}{\sigma\sqrt{T}}$$
$$= \frac{\ln(126.2671/20)+(0.00479+(0.5\cdot 1.7579))1}{1.3259\sqrt{1}}$$
$$= 5.006816$$

$$d_2 = d_1 - \sigma\sqrt{T}$$
$$= 5.006816 - 1.3259\sqrt{1}$$
$$= 4.624076$$

$$N(-d_2) = 0.0000002$$

Premium $= Ke^{-rT}N(-d_2)$
$= 20(e^{-0.00479})0.0000002$
$= 0.0000376$ (in million)
=IDR 37.62

Calculations are then carried out until the value of $T = 12$ shown in Tabel 3

Table 3: Lognormal Chi-Square Goodness of Fit Test Result

T	r	d_1	d_2	$N(-d_2)$	P	$Premium$(IDR)	%
1	0.004792	5.006816	4.624076	$1.88E-06$	$3.76E-05$	37,612,176.83	0.00019%
2	0.009583	3.69264	3.151364	0.000813	0.016225	16,225,069.89	0.08113%
3	0.014375	3.132744	2.469818	0.006759	0.134697	134,696,883.2	0.67%
4	0.019167	2.814981	2.0495	0.020207	0.401559	401,559,094.2	2.01%
5	0.023958	2.608978	1.753144	0.039789	0.787869	787,869,121.7	3.94%
6	0.02875	2.464897	1.527378	0.063333	1.248592	1,248,591,575	6.24%
7	0.033542	2.359115	1.346478	0.089074	1.746966	1,746,965,684	8.73%
8	0.038333	2.278835	1.196282	0.115793	2.257433	2,257,433,007	11.29%
9	0.043125	2.21647	1.068248	0.142704	2.763251	2,763,250,546	13.82%
10	0.047917	2.167204	0.956872	0.169316	3.253767	3,253,766,886	16.27%
11	0.052708	2.127823	0.858416	0.195331	3.722364	3,722,364.15	18.61%
12	0.0575	2.096093	0.770241	0.220579	4.165061	4,165,061.09	20.83%

Table 3 shows the premiums that must be paid as a result of losses incurred by MSME-fostered partners of PT Wijaya Karya (Persero) Tbk. caused by the failure of the supplier.

5. Conclusion

Losses experienced by 44 SMEs caused by supplier failures show that the extensive data of losses has an exponential distribution. This shows that the longer the time elapses, the smaller the probability of MSME losses due to supplier failure. Based on calculations using the black scholes merton model, the price of insurance premiums for MSMEs fostered partners of PT Wijaya Karya (Persero) Tbk. due to supplier failure for insurance for one year amounting to IDR 4,165,061.09.

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