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

International Journal of Business, Economics and Social Development

e-ISSN 2722-1156
p-ISSN 27722-1164

Vol. 5, No. 1, pp. 38-44, 2024

Determination of Mount Eruption Insurance Premiums in Indonesia Based on Collective Risk and Level of Risk Spread

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Abstract

Volcano eruption insurance is an insurance product that provides financial protection to policy holders who experience losses due to volcanic eruptions. This insurance product is still rarely developed in Indonesia, even though this country is very vulnerable to natural disasters. Therefore, this research aims to carry out a simulation of determining volcanic eruption disaster insurance premiums based on collective risk and the level of risk distribution. The data used in this research is the frequency of events and economic losses due to volcanic eruptions. Event frequency and loss data are analyzed using a collective risk model. Apart from that, determining insurance premiums also takes into account loading factors and the level of risk distribution from volcanic eruption disaster data. From the results of the analysis, it was found that natural disaster insurance premiums had increased, along with an increase in the loading factor provided. In addition, insurance premium expenses are influenced by the collective risks faced by customers. The greater the collective risk faced, the greater the insurance premium that customers must bear. Based on the results of the estimates carried out, it is hoped that this research can provide an overview to the Indonesian government in estimating the Mount Meletus insurance scheme. Meanwhile, insurance companies can get an idea of determining insurance premiums according to conditions in the field.

Keywords: Natural disasters, volcanic eruptions, insurance, premiums

1. Introduction

Indonesia is a country located in the Pacific Ring of Fire which has high seismic and volcanic activity (Pambudi, 2018; Kalfin et al., 2020; Sukono et al., 2022; Cahyandari et al., 2023). This causes Indonesia to frequently experience volcanic eruptions, which can cause major damage and loss to property and community interests. Volcanic eruption disasters can also have an impact on the national economy, such as reducing economic growth, increasing inflation, disrupting production and distribution activities, and increasing the burden on the state budget (Hidayat et al., 2021; Chester et al., 2000). Volcano eruption insurance is an insurance product that can provide financial protection for property owners affected by the volcanic eruption disaster (Smolka and Käser 2015). Volcano eruption insurance can provide benefits in the form of reimbursement for the costs of repairing or replacing property damaged by a volcanic eruption, such as agricultural crops, livestock, residential areas and infrastructure (Blong et al., 2017).

One of the challenges in Mount Meletus disaster insurance is determining premium rates that are appropriate to the level of disaster risk. Mount Meletus insurance premiums are the amount of money that customers must pay to the insurance company in return for the guaranteed protection provided (Brata et al., 2021; Oramas-Dorta et al., 2021). Insurance premiums must reflect the probability and magnitude of losses that may occur as a result of a disaster. If the premium is too low, the insurance company will experience losses because it cannot cover customer claims. If premiums are too high, customers will be reluctant to buy insurance because they feel it is not commensurate with the benefits they obtain (Franke, 2017; Nurse et al., 2020). Therefore, in determining volcanic eruption disaster insurance

premium rates, it is necessary to carry out a disaster risk analysis using historical data, mathematical models and computer simulations. The Mount Meletus disaster risk analysis aims to estimate the frequency, intensity and impact of disasters in an area. From disaster risk analysis, the expected loss value can be obtained, namely the average loss that is expected to occur in a certain time period. This expected loss value can be used as a basis for calculating pure disaster insurance premiums (Kalfin et al., 2022a; Kalfin et al., 2022b; Kalfin et al., 2023).

Pure disaster insurance premiums include the expected value of losses, without taking into account administrative costs, commissions, profits and other factors. The pure premium for disaster insurance can be considered the minimum price that customers must pay to obtain insurance protection (Deng et al., 2021; Wang et al., 2023). The amount of coverage is determined based on the maximum value that will be paid by the insurance company in the event of a total loss due to a disaster. The amount of coverage can be determined based on market value, replacement value, or agreement value between the customer and the insurance company. There has been quite a lot of previous research discussing disaster insurance premiums. Research by Kafin et al., (2020) created a mathematical model to determine the amount of premium that must be paid by local governments. Determining the aggregate claims model uses data on the number of claims taken from the number of events and the number of claims taken from the number of losses due to natural disasters in Indonesia. In this research, the insurance premiums that must be paid by local governments in Indonesia are determined using the Black Scholes Method approach. In research by Sukono et al., (2022), a collective risk model was used to determine natural disaster insurance premiums. In determining natural disaster insurance premiums, use the pure premium principle. From the results of the analysis, provide appropriate insurance premiums for the Indonesian government, based on the frequency of events and economic losses due to disasters that occur.

Based on the main problem above, the research carried out will focus on determining insurance premiums for the volcanic eruption disaster that occurred in Indonesia. In determining the insurance premium, the pure premium principle is used to obtain the standard premium for volcano insurance. When determining volcanic eruption insurance premiums, consider economic losses and the frequency of incidents based on previous year's incident data. Later, based on this data, it can be used as a reference in determining appropriate insurance premiums for the Indonesian government. The implications of the results of this research can certainly provide an overview of the standard insurance premiums that must be paid by the Indonesian government in dealing with Mount Eruption. In addition, the results of this research can provide a reference for model insurance companies in determining volcanic eruption insurance premiums.

2. Data and Statistical Analysis

2.1. Research data

In this research, the data used is the frequency of volcanic eruption disaster events and losses from 2000-2020. Data on the frequency of natural disasters used in this research were obtained through Databoks (https://databoks.katadata.co.id/) and the National Disaster Management Agency (https://dibi.bnpb.go.id/). Meanwhile, data on losses from volcanic eruptions is not available and comprehensively captures the number of losses due to volcanic eruptions each year. Therefore, in collecting data on losses from volcanic eruptions, it is obtained from collecting news information on losses from natural disasters that occur every year (from 2000-2020). In collecting data on losses due to Mount Eruption, it is based on data on the frequency of Mount Eruption events that occur every year. So, the loss data used in this research is an estimate of the losses that occur each year due to volcanic eruptions. The estimated losses used in this research are in the form of damage to agricultural land, dead livestock, infrastructure and houses damaged by volcanic ash from the erupting volcano. Thus, the volcanic eruption insurance premium obtained from the analysis results is an approximate estimate.

2.2. Statistical analysis

To calculate the frequency of events that occur within a certain time span, we can use the Poisson process. The Poisson process is also often used as a model for various phenomena, for example a model for the number of natural disasters occurring in one unit of time. If there is $N(t)$ which is the number of volcanic eruption disaster events that occurred up to time t, with $t \geq 0$, then it is called a counting stochastic process. An example of a counting process is the number of volcanic eruptions in Indonesia in the time span t. In determining the mean and variance of the Poisson process on the frequency of volcanic eruptions, it can be formulated as follows (Kalfin et al., 2021b):

$$E\big(N(t)\big) = \lambda t \tag{1}$$

and

$$Var\big(N(t)\big) = \lambda t \tag{2}$$

The Weibull distribution has high flexibility, that is, it can change into other distributions such as the exponential distribution depending on the value of the scale and shape parameters. The Weibull distribution can handle asymmetric data, which often occurs in disaster loss data. The Weibull distribution can describe the failure rate of an object that increases or decreases with increasing time, which corresponds to the unpredictable characteristics of natural disasters. The Weibull distribution can be used to create control charts that can monitor the quality of the production process, which is useful for reducing the risk of losses due to natural disasters. By using the Weibull distribution, insurance companies can estimate the amount of premium that must be paid by customers who take out volcanic eruption insurance. This premium can be determined by calculating the expected value and standard deviation of losses that may occur due to a volcanic eruption. Apart from that, Weibull distribution can also help insurance companies to manage risk. In this Weibull distribution, it is used to determine the value of expectation and variance for losses due to volcanic eruptions which are formulated in equations (3) and (4) (Akgül et al., 2016; Wais, 2017):

$$E(X) = \lambda\Gamma\left(1 + \frac{1}{k}\right) \tag{3}$$

and

$$Var(X) = \lambda^2\left[\Gamma\left(1 + \frac{2}{k}\right) - \Gamma^2\left(1 + \frac{1}{k}\right)\right] \tag{4}$$

Collective risk models take into account the variability of insurance claims, so they can provide better protection for insurance companies. Collective risk models calculate insurance premiums by adding the expected value and standard deviation of insurance claims, which is a measure of the dispersion or diversity of insurance claims. In addition, collective risk models can anticipate fluctuations or uncertainties in insurance claims that may occur in the future. Collective risk models are determined based on large data of economic losses and the number of events, which can be used to measure the risk of an insurance company as a whole. Determination of collective risk values is based on expectations and variance from volcanic eruption data which are formulated in equations (5) and (6) (Kalfin et al., 2020; Sukono et al., 2022; Kalfin et al., 2022b).

$$E(S) = E(N)E(X) \tag{5}$$

and

$$Var(S) = E(N)Var(X) + \big(E(X)\big)^2 Var(N) \tag{6}$$

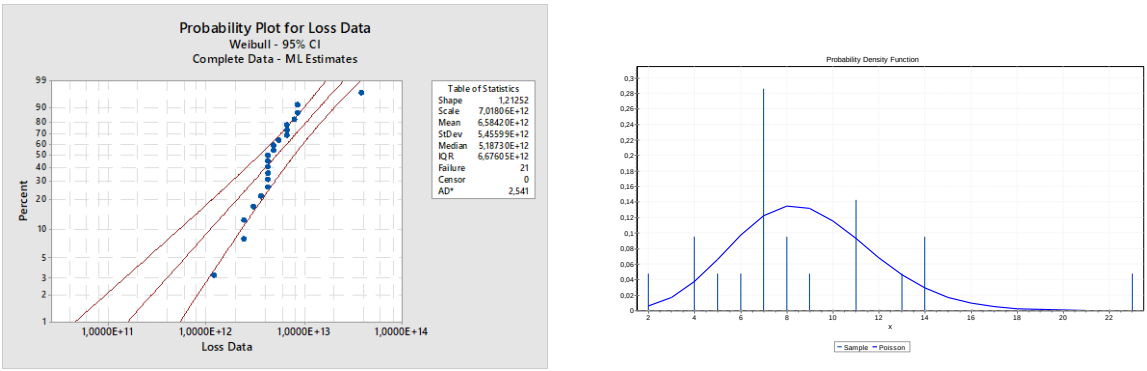
Determining insurance premiums using the standard deviation principle certainly takes into account the variability of the collective risk of volcanic eruptions, so that it can provide better protection for insurance companies and customers. The standard deviation principle calculates insurance premiums by adding the expected value of insurance claims with the standard deviation of the insurance collective risk, which is a measure of the spread or diversity of the collective risk of a volcanic eruption disaster. Thus, this principle can anticipate fluctuations or uncertainty in insurance claims (collective risk) that may occur in the future (Denuit and Robert, 2021; Fujii et al, 2017).

$$p(t) = E(S) + \tau\sqrt{Var(S)}\,, \tag{7}$$

with $\tau > 0$.

3. Results

The variables that are of concern in determining the collective risk of disasters are the frequency of events and losses due to volcanic eruptions. The frequency of events is determined by the number of volcanic eruptions that occur each year from 2000-2020. Meanwhile, disaster losses are determined based on the total losses that occur each year. Furthermore, data on the frequency of occurrence and losses of natural disasters that occur each year are analyzed as a reference in determining the collective risk of volcanic eruptions. The data used needs to be analyzed first to test whether the data on the frequency of volcanic eruptions follows the Poisson distribution model, and the data on losses from volcanic eruptions follows the Weibull distribution model. Analysis of data on the frequency of events and losses due to volcanic eruptions was assisted by Easyfit software Version 5.5. Analysis of the distribution model for the goodness of fit parameter estimation results for frequency of events and loss data due to volcanic eruptions is given in Figure 1.



(a) (b)

Figure 1: Probability plot distribution of data; (a) frequency of events, (b) disaster losses

Poisson [#5]					
Kolmogorov-Smirnov					
Sample Size	21				
Statistic	0,17714				
P-Value	0,47198				
Rank	2				
α	0,2	0,1	0,05	0,02	0,01
Critical Value	0,22617	0,25858	0,28724	0,32104	0,34427
Reject?	No	No	No	No	No

(a)

Weibull [#60]					
Kolmogorov-Smirnov					
Sample Size	21				
Statistic	0,17276				
P-Value	0,50344				
Rank	3				
α	0,2	0,1	0,05	0,02	0,01
Critical Value	0,22617	0,25858	0,28724	0,32104	0,34427
Reject?	No	No	No	No	No

(b)

Figure 2: Goodness of Fit results for erupting volcano data using the Kolmogorov–Smirnov test; (a) frequency of events, (b) disaster losses

Based on the goodness of fit data on the frequency of events and loss data due to volcanic eruptions in Figures 1 and 2, both data follow a predetermined distribution model. Data on the frequency of volcanic eruptions follows a Poisson distribution model, and data on losses from volcanic eruptions follows a Weibull distribution model.

Based on Figure 2a, data on the frequency of volcanic eruptions follows a Poisson distribution model. Next, the event frequency data needs to be estimated using a Poisson process to determine the mean and variance. Based on data on the frequency of volcanic eruptions, the average (λ) was obtained as 10.71, with time $t = 1$.

$$E\big(N(t)\big) = \lambda t = 10.71 \times 1 = 10.71$$

$$Var\big(N(t)\big) = \lambda t = 10.71 \times 1 = 10.71$$

Furthermore, descriptive statistics on the frequency of events and economic losses due to volcanic eruptions are presented in Table 1 as follows:

Table 1: Descriptive Statistics of Mount Erupting Disaster Data

	Amount of data	Mean	Variance
Frequency of occurrence	21	10.71	10.71
Economic loss	21	6.5842×10^{12}	2.97678×10^{25}

Based on Table 1, the collective risk can be determined from the frequency of volcanic eruptions and losses. In determining the expectations and variance of collective disaster risk using equations (5) and (6).

$$E(S) = E(N)E(X) = (10.71) \times (6.5842 \times 10^{12}) = 7.05 \times 10^{13}$$

and

$$\begin{aligned} Var(S) &= E(N)Var(X) + \big(E(X)\big)^2 Var(N) \\ &= [(10.71) \times (2.97678 \times 10^{25})] + [(6.5842 \times 10^{12})^2 \times (10.71)] \\ &= 7.8342 \times 10^{26} \end{aligned}$$

Based on the results of the analysis, the collective risk expectations and variances for volcanic eruptions were respectively 7.05×10^13 and 7.8342×10^26. Based on the expected value and collective risk variance, the volcano eruption insurance premium can then be determined using equation (7). In determining the insurance premium, a

simulation is also carried out to see the disaster insurance premium if the loading factor is in the range of 1%-10%. The results of calculating insurance premiums for the Mount Eruption disaster are given in Table 2.

Table 2: Mount Eruption Insurance Premiums

Loading Factor	Insurance Premium
1%	7.08249×10^{13}
2%	7.11048×10^{13}
3%	7.13847×10^{13}
4%	7.16646×10^{13}
5%	7.19445×10^{13}
6%	7.22244×10^{13}
7%	7.25043×10^{13}
8%	7.27842×10^{13}
9%	7.30641×10^{13}
10%	7.3344×10^{13}

Based on the results of the Mount Eruption insurance premium calculation in Table 2, a bar diagram of disaster insurance premiums is then created which is given in Figure 3.

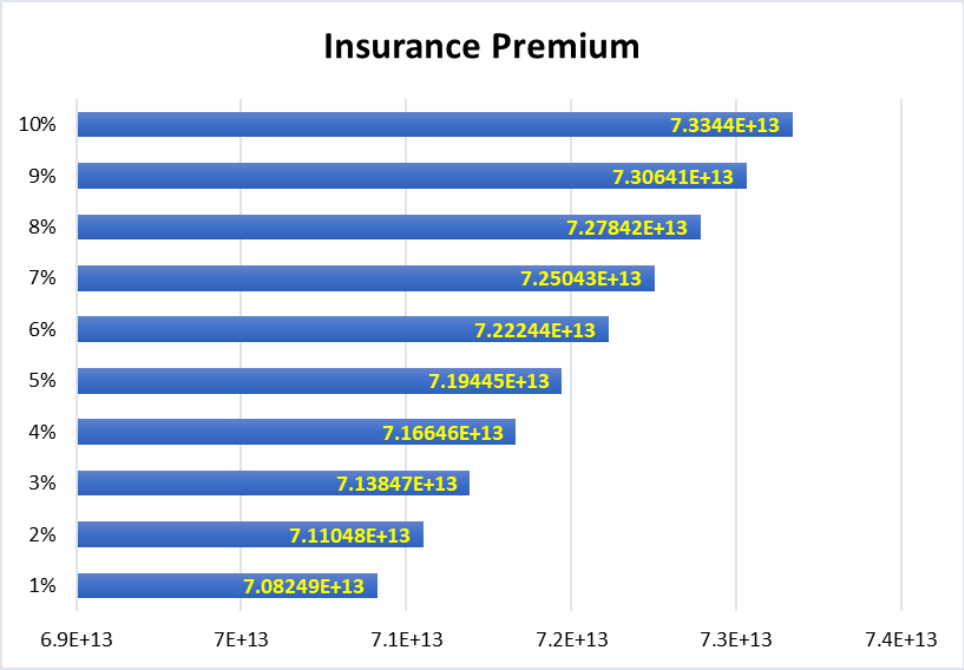


Figure 3: Mount Eruption Insurance Premium Bar Chart

Based on the Mount Eruption insurance premium in Figure 3, the insurance premium increases along with the loading factor provided. If a large loading factor is given, the insurance premium will also increase. Loading factor is an additional fee charged by insurance companies to customers to cover higher risks or greater office operational costs. On the other hand, if the loading factor given is small, then the insurance premium that must be paid will also be small. This is because it shows that the risks faced by the Company or those insured are lower or require lower insurance costs. In addition, the model for determining insurance premiums considers standard deviation which can be used to measure the uncertainty or variability of the risks faced, which influences the size of disaster insurance premiums. By using standard deviation in determining insurance premiums, the level of collective risk distribution can be taken into account. The greater the risk spread of the volcanic eruption disaster, the greater the insurance premium that customers must pay.

4. Discussion

Indonesia, which is a country prone to volcanic eruptions, of course needs to buy volcanic eruption insurance. This insurance has a very important role in helping the community and local governments in providing disaster management funds. The existence of Mount Eruption insurance can help in post-disaster economic recovery due to

volcanic eruptions. However, the development of volcanic eruption disaster insurance products and research in Indonesia is still very minimal. Especially for the government and insurance companies in providing insurance policies and products related to volcanic eruption disasters in Indonesia is still very lacking. One of the reasons why the development of this insurance product is that it is influenced by the large risk of loss from an eruption disaster means that insurance companies are not brave enough to bear this risk. Therefore, a more in-depth study is needed to develop volcano disaster insurance products in Indonesia. Funds for disaster management of volcanic eruptions in Indonesia still come from various sources including APBN/APBD, Corporate Social Responsibility, and donations from the community. These funding sources are used for various volcanic eruption disaster management activities, such as monitoring volcanic activity, evacuating residents, providing logistics, and post-disaster recovery.

Funds for dealing with volcanic eruptions in Indonesia do not yet provide guarantees for the risk of losses in the form of damage to agricultural crops, death of livestock, damage to residential areas and damage to infrastructure caused by volcanic eruptions. Therefore, volcano eruption insurance is very important for people who live in areas prone to volcanic eruptions. With insurance, people have certainty in dealing with losses caused by volcanic eruptions. Apart from causing fatalities and injuries, volcanic eruptions can also damage agricultural crops, the death of livestock, damage to residential areas and damage to infrastructure. If this risk of loss is not resolved quickly, of course the economic recovery of communities affected by volcanic eruptions will be hampered. Thus, the economic growth of the area is also hampered. In this research, we provide a general overview regarding determining Mount Meletus insurance premiums. Where, the determination of premiums is generally based on losses from volcanic eruptions. Research related to volcanic eruption disasters will continue to develop if data is generally available. This data is very important to help the government, researchers and society prepare for volcanic eruption disasters.

Besides preparing funds in the effort to mitigate volcanic eruptions, disaster mitigation efforts need to be carried out before the disaster occurs. Efforts that are crucial in maintaining the safety and welfare of the community living around the volcano. Although eruptions cannot be completely avoided, effective prevention and mitigation measures can reduce the impact. Efforts that can be made include providing understanding and knowledge in disaster mitigation. Efforts carried out include providing the community with an understanding of the local area that can be used as a place of refuge. Communities living around volcanoes need to know safe areas to evacuate to when a volcanic eruption occurs. Communities need to monitor and listen to information about the status of the volcano from reliable sources, such as PVMBG or BNPB. Communities need to follow guidance and counselling from responsible parties, such as BPBD or BNPB, on how to deal with volcanic eruptions. Communities must have basic needs supplies, such as adequate medicines and food, to deal with volcanic eruptions.

Besides mitigation efforts that need to be prepared by the community, the government also needs to take policies related to handling volcanic eruptions. Some steps that can be taken by the Indonesian government in efforts to mitigate volcanic disasters include monitoring and observing activities on active volcanoes. The Indonesian government can monitor and observe the activities of active volcanoes to estimate the possibility of a volcanic eruption. The Indonesian government can also create and provide maps of disaster-prone areas of volcanic eruptions, maps of volcanic danger zones, and other supporting maps, such as geological maps of volcanoes, to help the community recognize local areas that can be used as a place of refuge. The Indonesian government can create standard operating procedures for handling volcanic eruption disasters to minimize the impact caused by volcanic eruptions. The Indonesian government can also provide guidance and dissemination of volcano information to the community to increase awareness and knowledge in disaster mitigation. The Indonesian government needs to prepare evacuation scenarios to help the community evacuate when a volcanic eruption occurs. The Indonesian government can ensure that the community has basic needs supplies, such as adequate medicines and food, to deal with volcanic eruptions.

5. Conclussion

Indonesia is a country that has many active volcanoes which can cause detrimental natural disasters. Volcanic eruptions can cause damage to agricultural crops, livestock, residential areas and infrastructure. Therefore, it is necessary to have volcanic eruption disaster insurance which can provide financial protection to affected communities. Volcano disaster insurance is an insurance product that provides coverage for the risk of loss caused by a volcanic eruption. Volcano eruption disaster insurance premiums are the amount of money that insurance participants must pay to the insurance company to obtain insurance protection. Volcano eruption disaster insurance premiums are determined based on a collective risk model, namely a mathematical model that combines two components, namely claim frequency and economic losses. Claim frequency is the number of claims submitted by insurance participants in a certain period. Economic losses are the total amount of damage experienced by customers due to the volcanic eruption. Collective risk models can use historical data about the frequency of volcanic eruptions and losses in Indonesia to estimate the risks faced by insurance participants. Collective risk models can help insurance companies to set fair and competitive volcanic eruption disaster insurance premium rates, as well as help insurance participants to choose insurance products that suit their needs and abilities. Apart from that, in determining insurance premiums, the level of risk distribution for volcanic eruptions is also taken into account, which is based on the

standard deviation of the data. Loading factors also influence the amount of insurance premiums that customers need to pay.

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