Available online at http://iorajournal.org/indx.php/orics /index

Operations Research: International Conference Series

e-ISSN: 2722-0974
p-ISSN: 2723-1739

Vol. 4, No. 1, pp. 13-16, 2023

Determination of Earthquake Insurance Premium Based on Great Physical and Economic Loss Using the Bayesian Method

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Abstract

Indonesia is an area prone to earthquakes because it is traversed by the meeting point of 3 tectonic plates, namely: the Indo-Australian plate, the Eurasian plate and the Pacific plate. An earthquake is an event where the earth vibrates due to a sudden restraint of energy in the earth which is characterized by the breaking of rock layers in the earth's crust. Almost all regions in Indonesia are at risk of being exposed to earthquakes. To anticipate the risk of natural disasters, earthquakes are advised to join the insurance program provided by the insurance company. This study aims to determine earthquake insurance premiums based on large physical and economic losses. The method used is the Bayesian method. This method produces each estimated loss value which is then used to calculate the combined estimated loss value. After that, the combined estimated loss value is used to calculate the premium value. The result of this research is the premium which is calculated based on the principle of expected value and standard deviation principle. The premium resulting from the expected value principle is lower than the premium resulting from the standard deviation principle.

Keywords: Insurance, earthquake, loss estimation, Bayesian method premium.

1. Introduction

Indonesia's geographical condition is at the meeting point of two tectonic faults and volcanic circles and is flanked by two large oceans which makes this country very vulnerable to natural disaster risks.

According to the World Bank, Indonesia is one of 35 countries in the world that have a high risk of loss of life and economic loss due to the impact of various types of natural disasters (Source: Fiskal.kemenkeu.go.id). Almost all regions in Indonesia are exposed to risks from nine major natural disasters, one of which is an earthquake. Earthquakes are natural disasters that are difficult to predict. Several earthquakes were recorded in Indonesia which caused enormous losses, including the earthquake in Aceh and northern Sumatra in 2004, the earthquake that occurred in Palu and Donggala in 2018 and the earthquake that occurred in Cianjur in 2022 The occurrence of this natural earthquake disaster provides a clear picture and fact of how vulnerable this country is to disasters and considering the large losses from earthquakes that must be borne by the government, a system should have been established to ease the government's burden. One solution is to transfer risk to the private sector through earthquake insurance.

According to Law No. 2 of 1992 article 1 paragraph 1, Insurance or coverage is an agreement between two or more parties, by which the insurer binds himself to the insured, by receiving payment of insurance premiums, to provide reimbursement to the insured due to loss, damage or loss of profits incurred expected or legal responsibility to a third party that may be suffered by the insured, arising from an uncertain event, or to provide a payment based on the death or life of an insured person (Source: ojk.go.id). There are several types of insurance companies, namely general insurance companies, life insurance companies, and reinsurance companies.

In this study, the calculation of earthquake insurance premiums will be carried out based on the amount of physical and economic losses using the Bayesian method. The Bayesian method was chosen because it can estimate parameters more informatively even though the data used is incomplete. Meanwhile, the premium calculation principle used is the expected value principle and the standard deviation principle.

2. Literature Review

2.1. Bayesian Method

The method used in this research is the Bayesian method. This method is used to estimate the parameters of the unknown Pareto distribution, namely the shape parameter θ. The Pareto distribution is an assumption of the distribution of the estimated loss model in this study.

2.2. Likelihood Function

The likelihood function of the earthquake loss model is assumed to have a Pareto distribution with the probability density function (PDF) as follows

$$p(x) = \begin{cases} \theta \frac{x_m^{\theta}}{x^{\theta+1}}, & x \geq x_m; \theta > 0 \\ 0, & another\ x. \end{cases} \quad (1)$$

The likelihood function is derived from the above equation and the following equation is obtained

$$L(\theta|X_1, X_2, X_3, \dots, X_n) = \theta^n x_m^{n\theta} \prod_{i=1}^{n} x_i^{-\theta-1}. \quad (2)$$

2.3. Prior Distribution

Because the loss data model is Pareto distributed, the conjugate prior $p(\theta)$ is proportional to the Gamma distribution (Fink, 1997). The PDF of the Gamma distribution with hyperparameters α and β is as follows

$$p(\theta) = \begin{cases} \frac{1}{\Gamma(a)b^a} \theta^{a-1} e^{-\frac{\theta}{b}}, & \theta \geq 0; a, b > 0 \\ 0, & another\ \theta. \end{cases} \quad (3)$$

2.4. Posterior Distribution

Since the prior distribution is a conjugation for likelihood, the posterior distribution is proportional to the multiplication of the likelihood function and the prior distribution (Paudel, et al., 2013; Kleindorfer & Kunreuther, 1999; Chen, et al., 2012), namely

$$p(\theta|x) = L(\theta|X)p(\theta). \quad (4)$$

To get the estimate from the loss model ($\hat{\theta}$), the following equation is used

$$p(\theta|x) \propto \frac{\theta^{\alpha-1} e^{-\left(\frac{\theta}{\beta}\right)}}{\beta^{\alpha}\Gamma(\alpha)} \quad (5)$$

With $\alpha = a + n$ and $\beta = \frac{1}{\frac{1}{b} + \ln\left(\prod_{i=1}^{n} x_i - n.\ln(x_m)\right)}$ (Arnold, et al., 1998; Moschopoulos & Sha, 2005). After the prior distribution parameter is obtained, the shape parameter θ is estimated using the following equation

$$\hat{\theta} = E[\theta|x] = \int_0^{\infty} \theta\ p(\theta|x)\ d\theta \quad (6)$$

2.5. Continuous Joint Distribution

The combined expected value of $E(Z)$ is obtained from the values of $E(X)$ and $E(Y)$, where the value of $E(X)$ is the expected value of physical losses and $E(Y)$ is the expected value of economic losses, so the following equation is obtained:

$$E(Z) = E(X) + E(Y). \quad (7)$$

if X and Y are variable values that each have a $Var(X)$ and $Var(Y)$ value then the $Var(Z)$ value is defined as follows

$$Var(Z) = Var(X) + Var(Y) - 2cov(X, Y). \quad (8)$$

2.6. Principles of Premium Insurance

The principle of calculating the premium used in this study is the principle of the expectation value and the principle of standard deviation (Kaas, et al., 2008; Bulinskaya, 2017). The following is the equation of the expectation value principle

$$P = (1 + w)E(Z) \quad (9)$$

where P is the premium value, $E(Z)$ represents the estimated loss of data, and $w > 0$ which states the load factor or risk avoidance coefficient of insurance companies such as administration, taxes, etc. which is assumed to be 0.02 or 2%.

For the standard deviation principle, the following equation is used

$$P = w\left(\sqrt{Var(Z)}\right) + E(Z) \tag{10}$$

where P is the premium value, $E(Z)$ represents the estimated loss of data, $w > 0$ represents the load factor, and $\sqrt{Var(Z)}$ represents the standard deviation of the estimated total loss.

3. Materials and Methods

3.1. Materials

The object of this research is earthquake insurance premiums. The data used in this research is secondary data obtained from BNPB. This data is data on potential physical and economic losses in Maluku in 2016-2020 caused by earthquakes. This study estimates the parameters of the earthquake loss model using the Bayesian method and then calculates the premium using the expected value principle and the standard deviation principle.

3.2. Methods

The method used in this study is the Bayesian method. This method was used because of the limited data obtained. The step for estimating the model parameters of the losses caused by the earthquake starts from modeling the loss data, the likelihood data function, determining the prior distribution, which then obtains the posterior distribution which is used to estimate the model parameters.

4. Results and Discussion

The data used in this study is data on potential physical and economic losses in 7 districts/cities of Maluku caused by the 2016-2020 earthquake. The regencies/cities used in this study were Central Maluku Regency, Buru Regency, West Seram Regency, East Seram Regency, Southwest Maluku Regency, South Buru Regency, Ambon City. data is divided into 2 information. on information data I on physical and economic losses obtained from BNPB data. As for information data II, physical and economic losses are assumed data obtained by the average loss per person from information data I multiplied by the number of people affected.

after each data is known, the prior distribution parameters on physical loss will be estimated and $a = 5.3115$ and $b = 245.54$ are obtained. The prior distribution parameters are used to estimate the posterior distribution parameters using equation (5) and the parameters, mean, and variance are obtained as presented in Table 1.

Table 1: Summary of statistics parameter θ on physical loss

$\hat{\theta}$	$\boldsymbol{\alpha}$	$\boldsymbol{\beta}$	**Average/mean (Billion IDR)**	**Variance (Billion IDR)**	**Standard Deviation (Billion IDR)**
2.2173	12.3115	0.1801	813.6851657	1374132.507	1172.233981

Based on the posterior distribution function in equation (6), the estimated value of θ which is the estimated on physical loss value is $\hat{\theta} = 2.2173$. The $\hat{\theta}$ value is an estimate of the shape parameters of the Pareto distribution.

After that, the prior distribution parameters on economic loss will be estimated and $a = 4.4572$ and $b = 29.139$ are obtained. The prior distribution parameters are used to estimate the posterior distribution parameters using equation (5) and the parameters, mean, and variance are obtained as presented in Table 2.

Table 2: Summary of statistics parameter θ on economic loss

$\hat{\theta}$	$\boldsymbol{\alpha}$	$\boldsymbol{\beta}$	**Average/mean (Billion IDR)**	**Variance (Billion IDR)**	**Standard Deviation (Billion IDR)**
2.1161	11.4572	0.1847	81.07008324	26751.78903	163.5597415

Based on the posterior distribution function in equation (6), the estimated value of θ which is the estimated on economic loss value is $\hat{\theta} = 2.1161$. The $\hat{\theta}$ value is an estimate of the shape parameters of the Pareto distribution.

For each loss data, the model parameters have been estimated using the Bayesian method, the average, variance and standard deviation values are obtained. Then the combined average value, combined variance and combined standard deviation are calculated as presented in Table 3.

Table 3: Statistical summary of Pareto distributed combined loss estimates.

Average/mean (Billion IDR)	Variance (Billion IDR)	Standard Deviation (Billion IDR)
894.7552489	1531025.834	1237.346287

Then the insurance premium value is calculated using the expected value principle and the standard deviation principle for each loss using equations 9 and 10. The following results of earthquake calculations based on 2 principles are presented in Table 4.

Table 4: Expected principle premium value and standard deviation

Expected Value (Billion IDR)	Standard Deviation Value (Billion IDR)
912.6503539	919.5021746

Based on Table 4, it can be seen that the insurance premium value based on the expectation principle is smaller than the premium value calculated using the standard deviation principle. This relieves the insured party but the insurer needs to review whether the premium value with the expectation principle is also beneficial for his own party or the standard deviation principle is more mutualism. Therefore, it is necessary to recalculate various factors so that neither party is harmed.

5. Conclusion

Based on the assumptions, the information II model of physical and economic losses caused by earthquakes is Pareto distributed with each scale parameter $x_m = 446.714$ and $x_m = 42.759$ and each unknown shape θ value. The value of the shape parameter θ for physical and economic losses was estimated using the Bayesian method and the respective values were obtained, namely $\hat{\theta} = 2.2173$ and $\hat{\theta} = 2.1161$. The amount of the premium value is generated using the expected premium principle of 912.6503539 Billion IDR and a standard deviation of 919.5021746 Billion IDR. From the results of the two premium principles it can be seen that the value of the insurance premium under the expectation principle is smaller than the premium value calculated by the standard deviation principle.

References

Arnold, B. C., Castillo, E., & Sarabia, J. M. (1998). Bayesian analysis for classical distributions using conditionally specified priors. *Sankhyā: The Indian Journal of Statistics, Series B*, 228-245.

Bulinskaya, E. (2017). New research directions in modern actuarial sciences. *Modern Problems of Stochastic Analysis and Statistics: Selected Contributions In Honor of Valentin Konakov*, 349-408.

Chen, C. W., Tseng, C. P., Hsu, W. K., & Chiang, W. L. (2012). A novel strategy to determine the insurance and risk control plan for natural disaster risk management. *Natural Hazards*, *64*, 1391-1403.Takeuchi, J., Sakagami, Y., & Perez, R. C. (2016). The mother and child health handbook in Japan as a health promotion tool: An overview of its history, contents, use, benefits, and global influence. *Global pediatric health*, *3*, 2333794X16649884.

Fink, D. (1997). A compendium of conjugate priors. *See http://www. people. cornell. edu/pages/df36/CONJINTRnew% 20TEX. pdf*, *46*.

Kaas, R., Goovaerts, M., Dhaene, J., & Denuit, M. (2008). *Modern actuarial risk theory: using R* (Vol. 128). Springer Science & Business Media.

Kleindorfer, P. R., & Kunreuther, H. (1999). The complementary roles of mitigation and insurance in managing catastrophic risks. *Risk analysis*, *19*(4), 727-738.

Moschopoulos, P., & Sha, N. (2005). Bayesian inference of scale parameters in exponential family using conditionally specified priors. *Communications in Statistics-Theory and Methods*, *34*(2), 303-318.

Paudel, Y., Botzen, W. J. W., & Aerts, J. C. J. H. (2013). Estimation of insurance premiums for coverage against natural disaster risk: an application of Bayesian Inference. *Natural Hazards and Earth System Sciences*, *13*(3), 737-754.