Insurance Premium Determination Model and Innovation for Economic Recovery Due to Natural Disasters in Indonesia

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Abstract: Climate change that occurs causes the risk of natural disasters to continue to increase throughout the world. Economic losses are unavoidable, leading to the need for continuous innovation in post-disaster economic recovery efforts. Insurance is one of the offers in providing funding for the economic recovery that occurs. This study aimed to develop innovations and models for determining natural disaster insurance premiums with a subsidy and tax system. In addition, the developed model considers the disaster risk index in the form of the level of risk distribution, the frequency of events, and economic losses. In this study, the data used were the frequency of events and economic losses obtained from the Indonesian National Disaster Management Agency. The data used were 20 database periods from 2000 to 2019. This study used the collective risk method from the index of natural disaster risk parameters. From the results of the analysis, it was found that the level of distribution of disaster risk affected the determination of insurance premiums. The amount of insurance premiums is increasing along with the increase in the magnitude of the spread of disaster risk. In addition, if taxes and subsidies are reduced, then for high-risk areas, there will be a decrease in the burden of insurance premiums, and for low-risk areas, there will be an increase in the premium burden that must be paid. On the basis of the results of the analysis on the insurance model, it was found that the insurance premiums in each province varied. The results of this study are expected to be a reference for the government and private companies in implementing disaster insurance in Indonesia. In addition, the results of this study can be a means of developing innovations for disaster risk management that occurs.

Keywords: natural disasters; risk; insurance; subsidy; economic recovery innovation

1. Introduction

Natural disasters that occur in each area, of course, have a risk impact on the area [1,2]. Disasters that occur can cause damage to infrastructure [3], environmental damage [4], damage to settlements [5], and loss of livelihoods [6–8]. The impact of risks that occur due to natural disasters causes economic losses for the government and local communities. The economic losses that occur are caused by the damage and inhibition of facilities and infrastructure in economic activities. Various efforts were made by the local government in overcoming the economic losses that occurred [9–11]. In addition, efforts are being made to provide funds in an effort to accelerate the economic recovery of areas affected by natural disasters. Economic recovery due to natural disasters needs to be carried out by the local government. This is so that the community’s economy can quickly recover from adversity [12–15]. Some of the efforts that can be done are building infrastructure, buildings, and providing business capital for the community. In Indonesia, in dealing with the risk of loss due to natural disasters, regional disaster management funds are allocated by the local government [16–18]. However, if the natural disaster that occurs
is categorized on a national scale, the disaster-affected area will receive assistance from the central government. The funds obtained are budgeted from the national disaster management fund. However, in practice, the available funds have not been sufficient in an effort to recover the economy of the disaster-affected area. Therefore, innovation is needed that can minimize the impact of natural disaster risk and look for alternatives in providing funds for economic recovery efforts.

Many researchers have developed innovations in efforts to reduce the impact of risks, including the introduction of disaster mitigation in schools and in the community [19,20], the preparedness of medical personnel in dealing with disasters [21,22], digital technology in disaster risk reduction [21–25], disaster management infrastructure development [26,27], and purchasing disaster risk insurance [28,29]. Natural disasters that occur, of course, have a socio-economic impact on the community. Natural disasters and economic losses are interrelated. If natural disasters occur and continue to increase in frequency, then economic losses cannot be avoided and also increase. Therefore, innovations in various aspects of the risk of losses due to disasters need to be developed and sustainable in minimizing the risks that occur. Research that discusses economic losses and natural disasters has been carried out by previous researchers. Several studies have been conducted in the form of the impact of damage due to natural disasters [30], losses caused by natural disasters to an area [31], and post-disaster economic recovery [32]. Cases of natural disasters continue to increase every year, causing economic losses due to natural disasters to also continue to increase. This is because of global warming, which triggers climate change [33,34]. One of the innovations that can be done in overcoming economic losses is buying disaster insurance.

Disaster insurance is a marketing innovation in the form of risk transfer. The risk of loss due to disasters experienced by the community (customers) can be transferred to insurance companies [35]. Here, if the customer experiences a natural disaster and suffers an economic loss, the insurance company will provide an agreed amount of funds to the customer. The purpose of providing funds is so that customers can recover their economy after the disaster that occurred. However, customers also have an obligation to purchase insurance in the form of paying premiums within the agreed timeframe. There have been many studies that discuss insurance in post-disaster economic recovery efforts. Several research topics that discuss disaster insurance are the analysis of the level of public trust in purchasing disaster insurance [36–38], the effectiveness of disaster insurance in funding recovery economics [39–41], and determination of disaster insurance premiums [41–44]. In determining insurance premiums, it is necessary to consider several indicators related to the economic condition of the community, the geography of an area, the type of disaster, and the level of potential disaster. On the basis of these indicators, it can be considered in determining disaster insurance premiums. In addition, in determining premiums, it is necessary to determine the level of community ability so that the disaster insurance offered is of interest [45].

On the basis of previous research, disaster insurance as an innovation in reducing the risk of economic loss is quite interesting to do. However, on the basis of previous research, there is a gap in that previous studies in determining insurance premiums have not combined collective risk, the level of risk spread, nor subsidies and taxes. Moreover, the model developed by [44] in determining the premium did not consider collective risk and the level of risk spread but did consider subsidies and taxes. Furthermore, in the model developed by [28], in determining the premium, subsidies and taxes were not considered. However, the model does take into account the collective risk and the level of risk spread. In the research of [46], the determination of insurance premiums is mapped on the basis of the potential for disasters in each region. However, the determination of the premium does not take into account the collective risk and the level of distribution of disaster risk. In addition, in the research of [42,47] in determining the premium for each region, they are assumed to be the same, but in reality, the potential for disasters in each region in Indonesia is different. On the basis of this gap, the task in this research is to combine the three variables, namely, collective risk, the level of risk distribution, and subsidies and
taxes in the development of the model. Therefore, this study aims to develop a model for determining insurance premiums and to develop disaster insurance innovations in post-disaster economic recovery with a subsidy and tax system in Indonesia.

The difference between this research and previous research lies in the model developed, which considers collective risk and the application of the subsidy and tax system. In addition, this research is a new innovation in Indonesia, in the form of natural disaster insurance with a subsidy and tax system, where the innovation is in accordance with the geographical conditions of the regions in Indonesia, which are mapped to each province in disaster management. The cross-subsidy system is applied to the insurance model, in which areas with low disaster potential will provide subsidies (taxable) to areas with high natural disaster potential. The development of a model for determining premiums and innovation for disaster insurance with cross subsidies is carried out because the regions in Indonesia are divided into 34 regions (provinces). The 34 provinces have different disaster potentials, so there will be areas with high disaster insurance premiums. The model for determining disaster insurance premiums pays attention to the proportion of incident frequency, collective risk, and the level of distribution of natural disaster risk data. Thus, from the analysis results, insurance premiums were obtained from each province in Indonesia, so that with the development of disaster insurance innovation with a cross-subsidy system, provinces with high natural disaster risk are not burdened with high insurance premiums. Therefore, the hypotheses in this study are (1) the innovation of natural disaster insurance with a cross-subsidy system will be very appropriate to the geographical conditions in Indonesia, and (2) the development of a model for determining natural disaster insurance premiums will provide insurance premiums based on the level of potential natural disasters in each area.

This paper specifically discusses innovations in dealing with the risk of economic loss with disaster insurance. This paper presents models and analysis results related to insurance as a means of post-disaster economic recovery. This paper also pays attention to impact and disaster-based accountability, where the premium calculation uses economic loss data that can be nominalized in currency. The innovations developed in this research are very useful for the government (regulator) in efforts to recover an economy that has been hit by natural disasters. If the government generates a policy in innovating the risk of economic loss on the basis of insurance, it is relatively more effective. Thus, the government has a supply of funds to build the economy so that it can recover quickly after the disaster.

2. Materials and Methods

2.1. Research Methods and Data

This study used a quantitative method, wherein this method was used to test theories related to natural disaster insurance by examining the relationship between variables. In this study, the variables that were considered are collective risk, the level of risk distribution, and subsidies and taxes. In this study, secondary data were used in the process of determining natural disaster insurance premiums from the developed model. The data used were the frequency of events and economic losses in the analysis process of determining disaster insurance premiums, in the time span from 2000 to 2019. The data used in this study were obtained from the National Disaster Management Agency in Indonesia [48,49]. The data on the frequency of events and economic losses used in this study only focused on each province in Indonesia. The data on the frequency of events used were all cases of natural disasters that occurred during 2000–2019, while data on economic losses in the form of damage caused by natural disasters were calculated in the rupiah currency throughout 2000–2019. In this study, we limited the year of use of analytical data to 2019, due to the COVID-19 pandemic causing data in 2020 to not be recorded properly, while in 2021, the data were still not maximally recorded. Thus, this study used data before the COVID-19 pandemic hit in Indonesia and the rest of the world. The data obtained were then used to carry out statistical analysis to be applied to the determination of insurance premiums with the subsidy system that has been developed.
2.2. Statistical Analysis

The statistical analysis used is a basic concept method that is needed in defining or determining statistical measures in the form of expectations and variances from natural disaster data. The variables in this study are data on the frequency of natural disasters (discrete) and economic losses due to natural disasters (continuous). Determination of expectations and variances from the predicted data is needed as a basis for determining disaster insurance premiums based on previous event data. Statistical analysis in determining the expectation $E(N)$ and variance $Var(N)$ of the frequency of disaster events is formulated as follows:

$$E(N) = \sum_x xf(x)$$  \hspace{1cm} (1)

and

$$Var(N) = E[X^2] - \mu^2$$  \hspace{1cm} (2)

Furthermore, in determining the expectation of $E(X)$ and the variance of $Var(X)$ of the economic losses of natural disasters using the Weibull distribution analysis, which is formulated as follows:

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

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

The insurance premium determination model uses collective risk based on cases of economic events and losses due to natural disasters. In the case of insurance for economic losses due to natural disasters, various aspects of risk need to be considered in determining insurance premiums. If the aspects related to the causes of economic losses are not analyzed properly, the company can suffer losses if there are claims submitted by customers. In this study, the aspects that cause disaster risk are the frequency of events and economic losses. If a natural disaster occurs, then economic losses are also unavoidable. Thus, in this study, these two aspects were considered in determining disaster insurance. The determination of the expected value of $E(S)$ and the variance of the collective risk $Var(S)$ is formulated as follows:

$$E(S) = E(N)E(X)$$  \hspace{1cm} (5)

and

$$Var(S) = E(N)Var(X) + (E(X))^2Var(N)$$  \hspace{1cm} (6)

2.3. Basic Model of Disaster Insurance with Subsidies

The model for determining insurance premiums with subsidies is the result of the development of [44]. In the model developed by [44], the process of determining insurance premiums is divided into two, namely, on the basis of the level of potential disaster in an area and individual risk (economic loss). In this model, the distribution process is seen on the basis of the potential for natural disasters, namely, in high-risk and low-risk areas. High-risk areas are where the proportion of natural disasters are denoted by $\pi_H$, and low-risk areas for the proportion of disasters are denoted by $\pi_L$ with $0 < \pi_L < \pi_H < 1$. Furthermore, for risk measurement, the model developed by [44] uses individual risk in the form of economic losses due to natural disasters. In this model, for areas that have the proportion of natural disasters in the range $[0:0.4]$, they are categorized as a low-risk area. Meanwhile, for areas that have a proportion of natural disasters in the range $(0.4:1]$, they are categorized as high-risk areas. The calculation of insurance premiums that must be paid for each area is notated as follows:

$$P_L = \pi_L E(X) + \xi_L; \ \pi_L = 0.4 \text{ for; } 0 \leq \pi_L \leq 0.4$$  \hspace{1cm} (7)

$$P_H = \pi_H E(X) - \xi_H; \ \pi_H = 0.6 \text{ for; } 0.4 < \pi_H \leq 1$$  \hspace{1cm} (8)
where $P_L$ represents the premium to be paid by low-risk regions, $P_H$ represents the premium to be paid by high-risk regions, $\xi_L$ represents the tax paid by low-risk regions, and $\xi_H$ represents subsidies received by high-risk regions. The calculation process of the amount of tax that must be issued by low-risk areas and subsidies received for high-risk areas in the calculation of insurance premiums is as follows:

$$\xi_L = \lambda (\pi_H - \pi_L) E(X) \quad (9)$$
$$\xi_H = (1 - \lambda) (\pi_H - \pi_L) E(X) \quad (10)$$

where $\lambda$ is the specified incentive (in the form of %) for areas with low risk and high frequency of natural disaster cases. If each risk in each region is considered the same, namely, $P_L = P_H$, then the insurance premium calculation process (for all regions, it is assumed to have the same risk) is calculated as follows:

$$P^* = [\lambda \pi_H + (1 - \lambda) \pi_L] E(X) \quad (11)$$

Thus, from Equation (11), in determining natural disaster insurance premiums for each area that has a high and low potential for natural disasters, it is considered the same. The disaster insurance model in Equation (11) is used if the disaster cases that occur in each region are the same. In addition, the model in Equation (11) can be used if the insurance premium does not consider subsidies or taxes in its calculation.

3. Results and Discussion

This section describes the development of a natural disaster insurance model by considering the number of subsidies and taxes in each region in Indonesia. Taxes will be imposed on areas with low risk, while subsidies will be given to areas with a high proportion of occurrences. In determining an area with small and high potential for natural disasters, it is determined on the basis of the proportion of natural disasters. The subsidy and tax system is used in the developed model because it is very suitable for regional conditions in Indonesia, which is divided into 34 provinces. The model development also considers the level of risk spread from the disaster that occurs. From the model that has been developed, further analysis was carried out on the data on the frequency of events and economic losses that occur in Indonesia. The analysis was conducted to obtain the amount of insurance premiums from each province in Indonesia. From the results of the analysis, we also obtained the amount of the highest premium to the lowest insurance premium from 34 provinces in Indonesia.

3.1. Development of a Disaster Insurance Model with Subsidies

In this section, from the model that was made by [44], it is redeveloped by considering the collective risk and the level of distribution of natural disaster risk data. In the model from [44], in determining disaster insurance premiums, individual risk is still used. In addition, the model does not consider the level of distribution of natural disaster risk. On the basis of Equations (7) and (8), the model formulation developed is as follows:

$$P^*_{\text{SD}}(i) = \begin{cases} 
\pi_i E(S) + \tau \sqrt{\text{Var}(S)} + \xi; & 0 \leq \pi_i \leq 0.5 \\
\pi_i E(S) + \tau \sqrt{\text{Var}(S)} - \xi; & 0.5 < \pi_i \leq 1 
\end{cases} \quad (12)$$

where from Equation (12), for collective risk expectations $E(S) = E(N)E(X)$ and collective risk variance $\text{Var}(S) = E(N)\text{Var}(X) + (E(X))^2 \text{Var}(N)$, so that it can be reformulated to

$$P^*_{\text{SD}}(i) = \begin{cases} 
\pi_i E(N)E(X) + \tau \sqrt{E(N)\text{Var}(X) + (E(X))^2\text{Var}(N)} + \xi; & 0 \leq \pi_i \leq 0.5 \\
\pi_i E(N)E(X) + \tau \sqrt{E(N)\text{Var}(X) + (E(X))^2\text{Var}(N)} - \xi; & 0.5 < \pi_i \leq 1 
\end{cases} \quad (13)$$

for $\pi_i = \frac{n_i}{\sum_{i=1}^{N} n_i}$ and $\xi = \pi_i E(X)$. 


The model for determining insurance premiums with subsidies in Equation (13) was developed using the standard deviation principle. The development of a model for determining insurance premiums by considering the standard deviation was done so on the basis of the results of research by [50]. In [50], it is stated that the determination of non-life insurance premiums needs to consider the standard deviation of the risk data used to see the level of distribution. The level of spread of the risk of natural disasters can affect the results of the calculation of the amount of insurance premiums. The greater the level of distribution of natural disaster risk, of course, the greater the insurance premium. In the insurance premium model that has been developed, \( P_{\text{SD}}^* \) represents the insurance premium in area \( i \) with the principle of expected value, \( \pi_i \) represents the proportion of natural disasters in area \( i \), \( E(S) \) represents the collective risk expectation, \( Var(S) \) represents the collective risk variance, \( +\varsigma \) represents the disaster insurance tax, \( -\varsigma \) represents the disaster insurance subsidy, and \( n_i \) represents the frequency of disaster events in area \( i \).

**Proposition 1.** Insurance premium function \( P_{\text{SD}}^*(\pi_i) \) is a discontinuous function at \( \pi_i = 0.5 \).

**Proof.** Notice that the function \( P_{\text{SD}}^*(\pi_i) \) is a model for determining insurance premiums with a subsidy system as follows:

\[
P_{\text{SD}}^* = \begin{cases} 
\pi_i E(S) + \tau \sqrt{Var(S)} + \varsigma; & 0 \leq \pi_i \leq 0.5 \\
\pi_i E(S) + \tau \sqrt{Var(S)} - \varsigma; & 0.5 < \pi_i \leq 1 
\end{cases}
\]

It is known that a function \( P_{\text{SD}}^*(\pi_i) \) is said to be continuous at \( \pi_i = 0.5 \) if it fulfills all three conditions:

(a) \( P_{\text{SD}}^*(0.5) \) countable

Thus, for \( \pi_i = 0.5 \) obtained \( P_{\text{SD}}^*(0.5) = 0.5 E(S) + \tau \sqrt{Var(S)} + \varsigma \).

(b) \( \lim_{\pi_i \to 0.5} P_{\text{SD}}^*(\pi_i) \) can be calculated by \( \lim_{\pi_i \to 0.5} P_{\text{SD}}^*(\pi_i) = \lim_{\pi_i \to 0.5} P_{\text{SD}}^*(\pi_i) \)

It can be calculated for the left limit, i.e.,

\[
\lim_{\pi_i \to 0.5^-} P_{\text{SD}}^*(\pi_i) = \lim_{\pi_i \to 0.5^-} \pi_i E(S) + \tau \sqrt{Var(S)} + \varsigma = 0.5 E(S) + \tau \sqrt{Var(S)} + \varsigma
\]

Meanwhile, the right limit is

\[
\lim_{\pi_i \to 0.5^+} P_{\text{SD}}^*(\pi_i) = \lim_{\pi_i \to 0.5^+} \pi_i E(S) + \tau \sqrt{Var(S)} - \varsigma = 0.5 E(S) + \tau \sqrt{Var(S)} - \varsigma
\]

(c) \( \lim_{\pi_i \to 0.5} P_{\text{SD}}^*(\pi_i) = P_{\text{SD}}^*(0.5) \)

On the basis of the results obtained in terms (a) and (b), it can be seen that

\[
\lim_{\pi_i \to 0.5^-} P_{\text{SD}}^*(\pi_i) = P_{\text{SD}}^*(0.5) \neq \lim_{\pi_i \to 0.5^+} P_{\text{SD}}^*(\pi_i)
\]

Since the function \( P_{\text{SD}}^*(\pi_i) \) does not satisfy all three conditions, the function \( P_{\text{SD}}^*(\pi_i) \) is discontinuous at \( \pi_i = 0.5 \). □

Furthermore, for the function \( P_{\text{SD}}^*(\pi_i) \) in Proposition 1, a simulation is carried out using Maple 13 software. In the simulation, it can be seen the point or surface line of the natural disaster insurance premium, with the proportion of natural disasters in the range \([0; 1]\). On the basis of the simulation results, it can be seen in Figure 1 as follows:
Since the function \( P^*_{\pi\beta}(\pi) \) does not satisfy all three conditions, the function \( P^*_{\pi\beta}(\pi) \) is a discontinuous function at \( \pi = 0 \).

**Proposition 2.** Insurance premium function \( P^*_{SD}(\zeta) \) is a discontinuous function at \( \zeta = 0 \).

**Proof.** Notice that the function \( P^*_{SD}(\zeta) \) is a model for determining insurance premiums with a subsidy system as follows:

\[
P^*_{SD}(\zeta) = \begin{cases} 
\pi_i E(S) + \tau \sqrt{Var(S)} + \zeta; & 0 \leq \pi_i \leq 0.5 \\
\pi_i E(S) + \tau \sqrt{Var(S)} - \zeta; & 0.5 < \pi_i \leq 1 
\end{cases}
\]

It is known that a function \( P^*_{SD}(\zeta) \) is said to be continuous at \( \zeta = 0 \) if it fulfills all three conditions:
(a) \( P_{SD}^*(0) \) countable

Thus, for \( \zeta = 0 \) obtained \( P_{SD}^*(0) = \pi_i E(S) + \tau \sqrt{\text{Var}(S)} \).

(b) \( \lim_{\zeta \to 0^-} P_{SD}^*(\zeta) \) can be calculated by \( \lim_{\zeta \to 0^-} P_{SD}^*(\zeta) = \lim_{\zeta \to 0^+} P_{SD}^*(\zeta) \).

It can be calculated for the left limit, i.e.,

\[
\lim_{\zeta \to 0^-} P_{SD}^*(\zeta) = \lim_{\zeta \to 0^-} \pi_i E(S) + \tau \sqrt{\text{Var}(S)} + \zeta = \pi_i E(S) + \tau \sqrt{\text{Var}(S)}
\]

Meanwhile, the right limit is

\[
\lim_{\zeta \to 0^+} P_{SD}^*(\zeta) = \lim_{\zeta \to 0^+} \pi_i E(S) + \tau \sqrt{\text{Var}(S)} - \zeta = \pi_i E(S) + \tau \sqrt{\text{Var}(S)}
\]

(c) \( \lim_{\zeta \to 0} P_{SD}^*(\zeta) = P_{SD}^*(0) \).

On the basis of the results obtained in terms (a) and (b), it can be seen that

\[
\lim_{\zeta \to 0^-} P_{SD}^*(\zeta) = P_{SD}^*(0) = \lim_{\zeta \to 0^+} P_{SD}^*(\zeta)
\]

Since the function \( P_{SD}^*(\zeta) \) satisfies all three conditions of a continuous function, the function \( P_{SD}^*(\zeta) \) is continuous a \( \zeta = 0 \). □

On the basis of Proposition 2, a simulation was carried out to see the surface line of natural disaster insurance premiums. The simulation was carried out by making the value of the \( \zeta \) subsidy towards zero. This was done to determine how much influence the value of subsidies and taxes have on the determination of insurance premiums. In this simulation, it was also intended to determine the surface line of disaster insurance premiums in the range of event proportions \([0; 1]\) when taxes and subsidies became zero. For this simulation, we used Maple 13 software, where the simulation results are given in Figure 2 as follows:

![Figure 2. Graph of determining insurance premiums with a subsidy system.](image-url)

In Figure 2, it can be seen that in low-risk areas with a range of proportions \([0; 0.5]\), they experienced a decrease in natural disaster insurance premiums. The decline in premiums occurred in line with the reduction in taxes issued by customers in low-risk areas. On the
other hand, for high-risk areas with a range of proportions (0.5; 1], the value of natural disaster insurance premiums that must be borne by customers continued to increase. The increase in insurance premiums was influenced by a reduction in subsidies obtained in high-risk areas. The subsidy received by the customer will reduce the premium to be borne. The greater the subsidy obtained, of course there will be a reduction in the premium borne by the customer [51,52]. Insurance premiums form a linear line if the amount of the subsidy already reached zero, which means that low-risk areas no longer provide subsidies (taxed) and high-risk areas do not receive subsidies.

3.2. Disaster Insurance Data Analysis with Subsidies

On the basis of data from the Indonesian Disaster Risk Index [49], regional mapping based on the index of the level of disaster risk that occurs in each province in Indonesia was divided into two, namely, high and low. The determination of the disaster risk index was carried out on the basis of the result of the multiplication of the disaster with the value of the risk class. The weight value was obtained from the type of hazard on the basis of the frequency of occurrence and the risk posed. Conversely, the class value was determined on the basis of each index of the type of natural disaster that occurs in each province. The mapping of the natural disaster risk index in each province on the basis of the results of the calculation of the score is provided in Figure 3.

![Figure 3. Mapping of the disaster risk index in Indonesia.](image-url)

In Figure 3, it can be seen that for areas whose score index is green, it is shown that the province is included in the category of small disaster risk. As for the blue area, it indicates that the province is in a high-risk area. As shown in the bar chart in Figure 3, West Sulawesi had the highest score index compared to other provinces. This shows that the western province has the highest level of disaster risk when compared to other provinces in Indonesia. In addition, DKI Jakarta had the lowest disaster score index when compared to provinces in Indonesia. In the process of calculating the score index, it is not only seen how much disaster occurred in the province, but also the frequency of disasters and the level of loss or damage caused to areas hit by natural disasters. The number of natural disasters that occur in each region does not guarantee that it has a great risk. This is influenced by the
types of disasters, which have different impacts of damage and losses. For example, when compared to the types of floods and tsunamis, the level of risk posed is definitely different. The tsunami disaster has a greater risk of loss and damage when compared to floods.

As seen in the risk index in Figure 3, the proportion of the risk index in each province in Indonesia was determined. Determination of the proportion was divided into two parts, namely, high and low, which was carried out by mapping based on the level of potential disaster risk. The proportion of disaster risk in each province is provided in Table 1.

Table 1. Proportion of disaster risk index in each province in Indonesia.

| High-Risk Area | Province           | Proportion | Low-Risk Area | Province           | Proportion |
|----------------|--------------------|------------|---------------|--------------------|------------|
| West Sulawesi  | 0.58670645         | DI Yogyakarta | 0.496598432  |
| Bengkulu      | 0.570883806        | East Southeast Nusa | 0.496492713  |
| Bangka Belitung Islands | 0.569262778 | North Sulawesi | 0.49148867  |
| Maluku        | 0.56738804         | South Sumatra | 0.490678156  |
| South Sulawesi| 0.562038631        | Jambi       | 0.488563771  |
| Southeast Sulawesi | 0.555801197 | West Kalimantan | 0.488035175  |
| Banten        | 0.545757871        | East Java   | 0.473586881  |
| East Kalimantan| 0.542762493     | Central Java | 0.468653317  |
| North Kalimantan| 0.541352903   | Central Kalimantan | 0.467631365  |
| Aceh          | 0.541211944        | Bali        | 0.45610797   |
| West Sumatra  | 0.526939849        | West Southeast Nusa | 0.451244885  |
| Riau          | 0.518975668        | Gorontalo   | 0.446276082  |
| Lampung       | 0.51724892         | Papua       | 0.433096419  |
| West Java     | 0.513830666        | Riau Islands | 0.410190587  |
| North Maluku  | 0.51319635         | DKI Jakarta | 0.225604823  |
| North Sumatra | 0.511610562        |              |               |
| Central Sulawesi | 0.510835288   |              |               |
| South Kalimantan| 0.510800048   |              |               |
| West Papua    | 0.510796524        |              |               |

According to the proportion of natural disaster risk index in each province in Indonesia, West Sulawesi Province had the largest proportion of 0.58670645 when compared to other provinces. Meanwhile, the area with the lowest proportion of disaster risk index was found to be DKI Jakarta province, with a proportion value of 0.225604823 when compared to other provinces. The proportion of the disaster loss index can determine how much premium will be received. The results in Table 1 will be used as a reference in determining disaster insurance premiums, as well as regions to be taxed and regions receiving subsidies.

In the next stage, descriptive statistics were carried out on data on the frequency of events and economic losses due to natural disasters in Indonesia. Descriptive statistical analysis is needed in determining the expectation and variance of the disaster risk index data used in determining the premium. The risk index that is considered in determining disaster insurance premiums is the frequency of events and economic losses that occur in Indonesia. On the basis of the results of the analysis, descriptive statistics were obtained from the disaster risk index data given in Table 2.

Table 2. Descriptive statistics disaster risk data.

| Disaster Risk Index | Occurrence Frequency (N) | Economic Loss (X) | Std. Deviation | Variance |
|---------------------|--------------------------|-------------------|----------------|----------|
| Expectation         | 2562.0000                | 42,066,867,692 | 1587.41120    | 2562.0000|
| Std. Deviation      | 47,804,880,752.85        | 2.28531 × 10^{21}|

In terms the results in Table 2, they will be used at the stage of determining natural disaster insurance premiums. The model used in determining natural disaster insurance premiums is using Equation (13). The model that was developed also uses the risk tolerance
threshold level determined by an insurance company. In the analysis of determining the insurance premium, the risk tolerance used is 1%. The determined premium can be a reference for the government and insurance companies in implementing a risk management system in Indonesia. According to the results of the analysis, insurance premiums in each province in Indonesia are provided in Table 3.

As shown in the results in Table 3, insurance premiums in each province in Indonesia are varied. The large proportion of disaster risk also affects the amount of natural disaster insurance premiums. It can be seen that the highest natural disaster insurance premiums are in the province of West Sulawesi. This is because the province of West Sulawesi has the largest proportion of disaster risk among other provinces. Vice versa, for DKI Jakarta, with the smallest proportion of disaster risk, the premium to be paid is the smallest among the provinces.

### 4. Discussion

Indonesia is one of the largest countries in the world, ranking as the 15th largest worldwide. In addition, the Indonesian state consists of large and small islands. Therefore, appropriate innovations are needed in an effort to mitigate the risk of economic losses due to disasters. Several studies have been conducted by previous researchers in terms of dealing with natural disasters, one of them regarding buying insurance. In the research of [53], the innovative scheme for reducing the risk of loss developed in each country is certainly different. In contrast, the innovations offered by [38], in the developed model, disaster insurance premiums are charged to the public. Where for this model, it is not necessarily applicable and accepted by the people in Indonesia. This is because the application of natural disaster insurance in Indonesia has not yet experienced significant development and is a new thing. This is influenced by the lack of public understanding in mitigating the risk of loss by buying natural disaster insurance. Thus far, people in Indonesia, in dealing with the risk of loss, still expect assistance in the form of budgets from local and state governments. However, on the basis of the results of research by [47], it is stated that the budget provided by the government is not sufficient in efforts to mitigate the risk of losses due to disasters. Thus, what occurred in disaster-affected areas was a slowdown in economic recovery.

### Table 3. Disaster insurance premiums in each province in Indonesia.

| Province                | Premium (IDR) | Province                | Premium (IDR) |
|-------------------------|---------------|-------------------------|---------------|
| West Sulawesi           | 63,240,023,161,914 | DI Yogyakarta           | 53,574,174,368,079 |
| Bengkulu                | 61,353,398,353,842  | East Southeast Nusa     | 53,662,775,998,193  |
| Bangka Belitung Islands | 61,360,759,732,080  | North Sulawesi          | 53,023,253,156,946  |
| Maluku                  | 60,981,110,554,336  | South Sumatra           | 52,935,865,654,491  |
| South Sulawesi          | 60,582,478,917,705  | Jambi                   | 52,707,898,256,781  |
| Southeast Sulawesi      | 59,910,499,873,097  | West Kalimantan         | 52,650,906,407,235  |
| Banten                  | 58,828,499,716,526  | East Java               | 51,093,129,189,669  |
| East Kalimantan         | 58,505,797,915,444  | Central Java            | 50,561,205,261,679  |
| North Kalimantan        | 58,353,938,244,346  | Central Kalimantan      | 50,451,021,019,453  |
| Aceh                    | 58,338,752,277,236  | Bali                    | 49,208,598,701,934  |
| West Sumatra            | 56,801,173,107,372  | West Southeast Nusa     | 48,684,273,687,201  |
| Riau                    | 55,943,165,965,670  | Gorontalo               | 48,148,550,302,583  |
| Lampung                 | 55,757,137,868,576  | Papua                   | 46,727,553,523,525  |
| West Java               | 55,388,878,166,164  | Riau Islands            | 44,257,906,715,001  |
| North Maluku            | 55,320,541,314,170  | DKI Jakarta             | 24,356,352,894,928  |
| North Sumatra           | 55,149,699,184,185  |                         |               |
| Central Sulawesi        | 55,066,176,365,081  |                         |               |
| South Kalimantan        | 55,062,379,873,304  |                         |               |
| West Papua              | 55,062,000,224,126  |                         |               |
When viewed on the basis of the geographical conditions of the willyah in Indonesia, as given in Figure 4, Indonesia consists of large and small islands and is mapped on the basis of each province. Each province is led by a governor, and each governor takes care of their respective areas in disaster management. Therefore, in disaster management, it is necessary to map the potential disaster risk index on the basis of each province in Indonesia. This is in line with the research conducted by [46], where in the process of determining insurance, it is necessary to consider the proportion of the disaster risk index from each region, so that the premium borne in each region can be in accordance with the risk index. On the basis of the mapping of the potential disaster risk index, it is then mapped into two on the basis of the natural disaster risk index in each province, namely, areas with high and low natural disaster potential. The mapping of potential natural disaster risk index in each province is provided in Figure 4.

![Figure 4. Map of disaster risk index in each province in Indonesia.](image_url)

As shown Figure 4, for regions with a high natural disaster risk index, there are 19 provinces, while the remaining 15 provinces have a low natural disaster risk index. Based on the risk index data, it is used as a reference in the process of determining disaster insurance premiums. In practice, from the innovations offered, high-risk areas will receive subsidies from low-risk areas, while for low-risk areas, they will provide subsidies (taxable) to reduce the premium burden for high-risk areas, where the innovations offered are in accordance with regional conditions in Indonesia, which in disaster management are mapped into 34 provinces. In addition, each province has its own regional disaster management fund. This proves the first hypothesis that the innovation of natural disaster insurance with a cross-subsidy system is very suitable for the geographical conditions in Indonesia, where, according to [54], the subsidies provided can reduce the premium burden borne by policyholders.

Mathematical models in determining natural disaster insurance premiums need to be developed to support the designed innovation ideas. The premium determination model that has been developed by previous researchers may not necessarily be used and applicable in Indonesia because geographical conditions and area size can affect the developed model. In the model developed by [55], the cross-subsidy system was not considered because the potential for disasters in each region is considered the same. However, this model cannot be applied because disaster risk mapping in Indonesia is mapped to each province. On the basis of the mathematical model developed by previous researchers, [44] research is quite interesting in terms of its development in Indonesia in the form of determining insurance premiums with a cross-subsidy system. However, the mathematical model...
developed was modified by adding collective risk and the level of distribution of disaster risk. Conversely, in [50], it is stated that the level of distribution of disaster risk needs to be a concern in determining non-life insurance premiums. In addition, in the research of [56] in determining insurance premiums, it is necessary to consider collective risk, where in disaster insurance, the frequency of events and economic losses is the dominant factor in the mathematical modeling of natural disaster insurance. On the basis of these considerations, a model was developed by combining collective risk, the level of potential disaster risk index, the level of risk distribution, subsidies, and taxes. Thus, the obtained model was divided into two parts, namely, natural disaster insurance premiums for areas with a high and low natural disaster risk index.

In the insurance premium determination model, the proportion of disaster events can determine how much premium the customer has to pay. The higher the level of potential natural disasters in an area, the higher the insurance premium that must be borne. This is because the level of potential natural disasters that occur is directly proportional to the level of risk of economic losses caused [57,58]. This is because the developed model considers the proportion of the disaster risk index, causing the insurance premiums in each province in Indonesia to vary. This can be seen in Table 3, where the variations that occur can also be influenced by the level of subsidies and taxes in each region. The existence of a cross-subsidy system certainly reduces the premium burden that must be borne by high-risk areas. The cross-subsidy system, of course, can also build mutual cooperation in accelerating regional economic recovery in Indonesia with various levels of disaster potential. This proves the second hypothesis, which states that from the developed insurance premium determination model, it provides insurance premiums that vary on the basis of the level of potential disaster in each region.

5. Conclusions

Research that discusses insurance in an effort to innovate the impact of disaster risk is quite interesting to continue to be developed, as disasters that occur cause economic losses. Therefore, continuous innovation is needed in post-disaster economic recovery efforts. In this study, the development of the model was carried out by considering the level of distribution of natural disaster risk. The level of spread of natural disaster risk needs to be considered in the model for determining insurance premiums. This is necessary in anticipating the occurrence of claims beyond capacity, so that there can be failure to pay claims and insurance company losses. In the insurance premium calculation model, the magnitude of the spread of disaster risk can affect the calculation of premiums. Insurance premiums will be greater if the spread of risk is greater. Various aspects of the insurance premium calculation model need to be considered on an ongoing basis.

In the insurance premium model, it is necessary to pay attention to aspects of collective risk, not only to individual risks. The aspect of selective risk used in this study is an index of the frequency of events and economic losses. The use of a subsidy and tax system in the insurance model is a form of mutual cooperation in reducing the burden of insurance premiums that must be paid by high-risk areas. In addition, the application of the developed insurance model is very suitable for regional conditions in Indonesia. Regional mapping in Indonesia is divided into 34 provinces, with a regional disaster management budget for each province. On the basis of the results of the analysis, it was found that the insurance premiums in each province vary. DKI Jakarta province is the area with the smallest disaster insurance premium, and West Sulawesi province is the area with the largest disaster insurance premium.

The limitation of this research is that the developed model did not consider the level of income or economic growth in each region, as the level of economic growth can be a consideration in disaster insurance innovation with a cross-subsidized system. On the basis of the limitations of this study, it can be further developed by further researchers in developing a model for determining insurance premiums by considering the level of economic growth in each region. Thus, a model for determining insurance premiums with
a high potential for natural disasters is obtained with a certain level of economic growth and vice versa.

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