Determining Sustainable Rice Farming through Supply Chain Risk Management: A Case Study in Central Java, Indonesia

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Abstract- The government through the Department of Agriculture has been cooperating with Indonesian Insurance Services or PT. AsuransiJasa Indonesia (PT. Jasindo), to implement an insurance program for farmers throughout the country known as rice farming insurance (RFI). The supply chain efficiency and risk management may be two causal factors to uplift the economic conditions of the agricultural communities. The premium rate for 1 hectare of land designated at 3% of the maximum benefit value of IDR 6,000,000. Consequently, the premium received by PT. Jasindo for each hectare is IDR 180,000 of which the Government subsidy pays IDR 144,000, and farmers will pay the remaining IDR 36,000 of the premium. This research will determine the actuarily fair premium rate, both theoretically and using the data of rice harvest yield in Central Java Province from 1990-2017. The calculation, employing the rice harvest yield data, results in the premium rate. The farmers must pay for each hectare from IDR 56,000 (minimum) to IDR 161,600 (maximum) with an average value of IDR 110,750. Meanwhile, the standard deviation principle used, the premium results between IDR 78,151 and IDR 143,349. The rate of IDR 208,458 per hectare has theoretically generated if there are 100 participants per regency (city) or in size of 3,500 hectares throughout Central Java Province and IDR 182,846 per hectare if there are 10,000 participants or about 350,000 hectares. These values are not much different from RFI premium currently applied to farmers throughout Indonesia.

Keywords- Agricultural, supply chain management, Risk management, Benefit, Farmer, Insurance, Premium.

1. Introduction

Supply chain management has become a major part of companies/firms management systems due the numerous benefit associated to supply chains in todays’ business environment. However, although such supply chain design changes and supply chain management initiatives have great potential to make operations leaner and more efficient in a stable environment, they simultaneously increase the fragility and vulnerability of supply chains to disruptions. Most of the rice farmers in Java and Bali Islands are smallholders with averagely 0.3 hectares of land [1] so that any slightest harvest failure will significantly impact on them. Such a loss significantly influences some farmers’ survivability. One of the solutions to overcome loss for harvest failure is to implement agricultural insurance. Before this agricultural insurance is applied, trials need to be performed first. These trials aim at preparing appropriate agricultural insurance concept. An examination of agricultural insurance implementation has been conducted in the planting season from October 2012 to March 2013 in West Java, East Java and South Sumatera provinces. The trial is held on respectively 1000 hectares of the farm by involving PT. Jasindo to be the insurer. PT can only perform the prosecution. Jasindo on 623.12 hectares of rice farm, which is still far from the expected 3000 hectares for the three provinces. The premium rate applied in the trial is IDR 180,000 per hectare (farmers pay only IDR 36,000, and the Government pays the remaining) with a total maximum benefit of IDR 6,000,000. With the total size of land on which trial has conducted of 623.12 hectares, the total premium received by PT. Jasindo is IDR 112,161,600. The premium received can only cover 18 claims for compensation, each of which is 1 hectare in size and receives maximum compensation (benefit) of IDR 6,000,000. Thus, with the premium it has received, it is certain that PT. Jasindo will suffer a loss since it is quite
impossible that harvest failure will occur only on 18 hectares out of 623.12 hectares. Harvest failure occurs on 87.28 hectares of land. Consequently, PT. Jasindo must pay the claims for 87.28 x IDR 6,000,000 = IDR 523,680,000 or 467% of the premium value it has received. In this trial, PT. Jasindo suffers loss for IDR 523,680,000 – IDR 112,161,000 = IDR 411,519,000.

Even if it suffers loss, the percentage of harvest failure is only (87.28/623.12) x 100% = 14%. [1], estimates that from 1989-1991, the rate of rice harvest failure caused by flood, dry and pest is respectively 0.21%, 0.50% and 0.06% of total planting area. The percentage of harvest failure in this trial is deemed as within reasonable limit; thus the agricultural insurance may be implemented. With a premium of IDR 180,000 and benefit (coverage) of IDR 6,000,000, then 34 farmers are needed to be participants. From the 34 participants, the collected premium will be 34 x IDR 180,000 = IDR 6,120,000, and there will be a difference of IDR 120,000 from the coverage value of IDR 6,000,000. It means that from 34 participants, only one farmer may suffer harvest failure; thus the harvest failure probability is 1/34 = 0.02941 = 0.03.

An analogue calculation gives a number that from 100 participants, only three farmers may suffer harvest failure. Thus the harvest failure probability is 3 hectares out of 100 hectares. Thesae are a break-even, in which the company neither gain profit nor suffer loss. The number of 34 participants has surpassed the number 30 as required in the law of large numbers. Thus the premium calculation may be based on a normally distributed harvest yield data.

[2] have discussed normal curve method. This method assumes that harvest yield distribution is normal [3,4,5]. Furthermore, some authors [4], [6,7,8] studied the empirical natured method that based on the relationship between the average of observed loss and the coverage value. Meanwhile, there are several authors, namely [9,10,11,7] used the parametric and non-parametric method in calculating agricultural insurance premium. In the parametric approach, a farming harvest yield assumption follows specific distribution such as usual, beta or gamma, while non-parametric method used histogram and kernel estimator to estimate the distribution of the farming harvest yield. The rice farming insurance (RFI) premium rate for Central Java province will be determined in this research. The RFI premium rate is theoretically calculated using the short-term individual risk theory and the trial yield data. Also, the premium rate will be calculated using the data of rice harvest yield in Central Java from 1990-2017 (Central Bureau of Statistics), which fulfill normal distribution hypothesis. The RFI premium calculation result may be taken as supporting calculation standard or baseline that the currently designated premium rate of RFI is reasonable. However, if the premium calculation result is much different from current premium calculation, then the results of this research may become material for review or revision in determining actuarially and practically fairer RFI premium rate.

2. Material and Methods

The premium rate is normally determined in two ways, theoretically and application on harvest yield data. This study employs secondary data and its analysis through a quantitative approach. Here, the data are annual rice harvest yield from 1990-2017 in 35 regencies/cities in Central Java Province, and 6 of which are central cities. The premium rate is theoretically calculated using short-term individual risk theory [12] to obtain an actuarially fair premium rate. The practically fair premium rate is computed using normally distributed harvest yield data. For example, δ it represents the total aggregate claims the company must pay to participants with harvest failure. Following [12,13], the RFI premium rate is calculated using an expectation value principle,

\[ P = (1 + \theta) \cdot E[S] \]  (1)

Whereas, \( \theta \) represented as relative security loading. The \( \theta \) is then determined using the equation (1).

\[ P_r(S \leq (1 + \theta) \cdot E[S]) = 0.95 \]

And then it is solved using the law of large numbers approach [12]:

\[ P_r \left( S - E[S] \leq \frac{\theta \cdot E[S]}{\sqrt{\text{Var}(S)}} \right) = 0.95 = P_r(Z \leq 1.645) \]

(2)

From (equation 2), we then obtained

\[ \theta = 1.645 \cdot \frac{\sqrt{\text{Var}(S)}}{E[S]} \]  (3)

Expectation and variance of total aggregate claim \( S \) are calculated using the equations (4) and (5):
The rice harvest yield data has given in quintal unit per hectare, taken from Central Java in number from 1991-2017. The normality test of the harvest yield data tested for data normality using Kolmogorov-Smirnov test [14,15]. When the harvest yield data follows the normality assumption, then the RFI premium rate for all regencies/cities in Central Java could be calculated using three formulas established above. After that, a single and equal RFI premium rate for Central Java can be determined using the mean method. The normality test of rice harvest yield data in 35 regencies and cities in Central Java is tested using the Kolmogorov-Smirnov test. In this test, the null hypothesis is the rice harvest yield of each regency/city in Central Java Province are normally distributed. Note that the hypothesis test is a two-sided test. Here, the null hypothesis is accepted when the Kolmogorov-Smirnov value higher than Kolmogorov-Smirnov table D_e. Following [2], it assumed that agricultural harvest yield normally distributed with parameter \( \mu \) and \( \sigma^2 \). If the variation coefficient is equal to 0.25 or \( \sigma = 0.25 \mu \), then the insurance premium rate for the scope of \( \alpha \times 100\% \) is

\[
P_i = \Phi\left(\frac{\alpha\mu - \mu}{0.25\mu}\right)(\alpha\mu - \mu) + \phi\left(\frac{\alpha\mu - \mu}{0.25\mu}\right) \cdot 0.25\mu
\]

Since \( \sigma = 0.25\mu \) equation (6) shall become

\[
P_i = (\mu(\alpha - 1)) \cdot \Phi\left(\frac{\mu(\alpha - 1)}{\sigma}\right) + \sigma \cdot \phi\left(\frac{\mu(\alpha - 1)}{\sigma}\right)
\]

With \( \Phi(z) \) is the cumulative distribution function of which values viewed in Standard Normal Table, and \( \phi(z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{z^2}{2}} \) is the standard normal distribution probability density function. The estimated premium is calculated using the average and standard deviation of a sample. Thus equation (7) shall become

\[
P_i = (\bar{x}(\alpha - 1)) \cdot \Phi\left(\frac{\bar{x}(\alpha - 1)}{s}\right) + s \cdot \phi\left(\frac{\bar{x}(\alpha - 1)}{s}\right)
\]

Note that one of the authors [16] have proposed a formula of actuarially fair AUTP premium rate as follows

\[
P_2 = 6 \cdot \Phi\left(-\frac{0.75\mu}{\sigma}\right) - 8 \frac{\sigma}{\mu} \left[ \phi\left(-\frac{0.75\mu}{\sigma}\right) - \frac{1}{\sqrt{2\pi}} \right]
\]

It is reasonable that all regencies/cities in Central Java uses single premium price with an equal rate. The simplest way to calculate the single premium is to take the average of all premium values [13]:

\[
\bar{P} = \frac{1}{n} \sum_{i=1}^{n} P_i
\]

With \( P_i \) is the premium price for each regency/city. The other single premium rate is computed using the standard deviation principle. The variance of premium rate is

\[
\sigma^2_p = \frac{1}{n-1} \sum_{i=1}^{n} (P_i - \bar{P})^2
\]

For a 95% level of significance, the confidence interval of the premium rate is

\[
(\bar{P} - 1.645 \cdot \sigma_p ; \bar{P} + 1.645 \cdot \sigma_p)
\]

3. Result and Discussion

3.1. The Determination of Rice Farming Insurance Premium Analysision Trial

With RFI premium rate of IDR 180,000 and the coverage of IDR 6,000,000, the trial needs 34 farmers to be participants. Maximum 1 out of 34 participants may suffer harvest failure, or the harvest failure probability is \( 1/34 = 0.03 \). For example, for each regency/city in Central Java, the
condition is assumed to be homogenous. Therefore, there will be \( k = 1, 2, \ldots, 35 \) samples of regency/city and the harvest failure probability for each regency/city is \( q_k = 0.03 \) with a maximum benefit of \( b_k = 6 \) (IDR 6,000,000). For example, \( n_k = 100 \) participants taken for each regency/city, which \( k \) is some regency/city. Using the equations (4) and (5) for \( n = 3,500 \) farmers:

\[
E[S] = \sum_{j=1}^{3500} E[X_j] = \sum_{k=1}^{35} n_k \cdot b_k \cdot q_k = 35 \cdot 100 \cdot 0.03 \cdot 6 = 630,
\]

And,

\[
Var(S) = \sum_{j=1}^{3500} Var(X_j) = \sum_{k=1}^{35} n_k \cdot b_k^2 \cdot q_k \cdot (1 - q_k)
\]

\[
= 35 \cdot 100 \cdot 1.0476 = 3,666.60
\]

From equation (3), the \( \theta \) is 0.1581 and actuarially fair RFI premium rate is then calculated using the equation (1):

\[
P = (1 + \theta) \cdot E[S] = 1.1581 \cdot 630 \cdot IDR 1,000,000
\]

\[
= IDR 729,603,000.
\]

The RFI premium for each participant is IDR 729,603,000 / 3,500 = IDR 208,458. The calculation results are not much different from the RFI premium rate designated by the Government. Adding more participants may be made to achieve a premium close to the premium. For example, the number of participants for each regency/city is 10,000 farmers or totally \( n = 350,000 \) throughout Central Java, the expectation and variance of total aggregate claim \( S \) calculated using equations (4) and (5) are \( E[S] = 63,000 \), and \( Var(S) = 366,660 \) the relative security loading is \( \theta = 0.01581 \) calculated using equation (3). The RFI premium rate calculated using the equation (1) is given as

\[
P = 1.01581 \cdot 63,000 \cdot IDR 1,000,000 = IDR 63,996,030,000
\]

The RFI premium for each participant is IDR 63,996,030,000 / 350,000 = IDR 182,846. This number is quite close to the premium of IDR 180,000.

### 3.2. The Rice Farming Insurance Scheme

The program of RFI is a mandate from the law the Government must implement and is also a form of Government’s concern and alignments to the economically weak community. RFI program is mandated by article 37-39, Law No. 19 of 2013 concerning The Farmer Protection and Empowerment [17]. The RFI has been implemented by the Government (Department of Agriculture) in cooperation with PT. Jasindo. The premium rate and benefit do not vary with the premium rate and benefit during the trial. One of the reasons why RFI is necessary is the results of Agricultural Census 2013 [15]. This Agricultural Census, conducted by [18], generates data that about 79.8% of households who work on food crops are those who work on a rice farm. [19,14] illustrates that RFI is limitedly designed to replace planting expenses incurred during a planting season, thus in case of 100% harvest failure, the farmers will neither gain profit nor suffer loss. The illustration also clarifies that the maximum RFI benefit of IDR 6,000,000 is a fair benefit value. There are essential matters related to the scheme of RFI, i.e. (i) Every RFI participant may receive only a maximum of 2 hectares of land insured. (ii) The maximum coverage value and benefit participant may receive IDR 6,000,000 per hectare. (iii) The RFI insurance premium is established to be 3% of coverage value or IDR 180,000 per hectare, with 80% is subsidised/paid by the Government (IDR 144,000 per hectare), and the remaining 20% shall be paid by the farmer (IDR 36,000 per hectare). Thus, the farmer shall pay the premium only 0.6% of the coverage value. (iv) The insurable risks include drought, flood, and Plant Invading Organism (OPT) attack. (v) The insurance coverage period shall apply to one planting season. (vi) The farmer who harvests maximum only 25% of the planted area will receive full compensation (IDR 6,000,000). Other cases shall depend on the damage level and farming life [1].

### 3.3. The Rice Farming Insurance Premium Calculations

One of the principles used in determining the premium rate is the fairness principle, which is fair for both farmers and the insurer [14]. The designated premium should neither be too high (which will overburden farmers) nor too low (which will cause the insurer’s loss). Premium rate appropriate designation requires an actuarial method to calculate the premium rate. The parametric method assumes that harvest yield follows certain distribution such as normal, beta or gamma [21]. Harvest yield loss probability is the area below probability density function curve when harvest yield is lower than the insured return. From
in Table 1 column 7, 8 and nine, the two districts were excluded.

Analysis of the harvest yield data used in this research results in variation coefficient value \( \frac{s}{\bar{x}} \) which is relatively low or close to 0 (Table 1 column 5). Consequently, the data of harvest yield in all regencies/cities in Central Java may be declared as quite normal. Relatively low coefficient of variation causes \( \frac{s}{\bar{x}} \) high, and the value \(-0.75 \cdot \frac{s}{\bar{x}} \) is unavailable in Standard Normal Table. Consequently \( \Phi\left(-0.75 \cdot \frac{s}{\bar{x}}\right) = 0 \) and \( \phi\left(-0.75 \cdot \frac{s}{\bar{x}}\right) = 0 \) thus equation (11) becomes

\[
P_1 = \frac{4}{\sqrt{2\pi}} \cdot \frac{s}{\bar{x}} = 1.60 \cdot \frac{s}{\bar{x}}
\]

Equation (15) explains that the higher the coefficient of variation, the higher the premium rate is. Premium calculation using equations (14) or (15) is given in Table 1 column 8. Equation (15) also explains that in case harvest yield is normally distributed with variation coefficient close to 0, then the premium price determining model shall depend only on the variation coefficient and may be determined without a standardnormal table. In equation (14), the cumulative value is calculated in assistance of Standard Normal Table \( Z \sim N(0,1) \).

Almost all Standard Normal Tables only attach value up to \( z = 3.99 \). The complete table puts value \( z \) up to \( z = 4.99 \). Meanwhile, the calculation using the data results in value \( z > 5 \), thus the use of Standard Normal Table results in \( \Phi(z)=0 \) and \( \phi(z)=0 \).

Following [20] and the equation (13) for \( z \geq 5.5 \), we then get

\[
\Phi(z)=1-\frac{1}{\sqrt{2\pi}} \exp\left(-\frac{1}{2} z^2 - \frac{94}{100} z^{-2}\right) ; \quad z \geq 5.5
\]

(16)

Following the equation (16), we get the results as

\[
\Phi(-z) = 1 - \Phi(z) = \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{1}{2} z^2 - \frac{94}{100} z^{-2}\right)
\]

(17)

Furthermore, the equation (17) is used to approach the value \( \Phi\left(-0.75 \cdot \frac{s}{\bar{x}}\right) = \Phi(-0.75 \cdot z) \) on the equation
Moreover, the premium rate is then computed using the equation (18) as given in Table 1 column 9. Here, the column (9) of Table 1 is the same as the column (8). It is due to the value \(-0.75 \cdot \frac{x}{s}\) is quite low, thus \(\Phi\left(-0.75 \cdot \frac{x}{s}\right) = 0\).

\[
P_s = 6 \cdot \Phi\left(-0.75 \cdot \frac{x}{s}\right) + 1.60 \cdot \frac{s}{x}
\]

(18)

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<th>Regency(es)</th>
<th>(\bar{X})</th>
<th>(s)</th>
<th>(\frac{s}{\chi^2})</th>
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<th>P1</th>
<th>P2</th>
<th>P3</th>
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<td>Eq. 13</td>
<td>Eq. 15</td>
<td>Eq. 18</td>
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<td>0.211</td>
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<td>Semarang</td>
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<td>4.227</td>
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<td>0.123</td>
<td>1,686,573</td>
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<tr>
<td>30</td>
<td>Sragen</td>
<td>55.204</td>
<td>3.69</td>
<td>0.067</td>
<td>0.152</td>
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<td>31</td>
<td>Sukoharjo</td>
<td>58.765</td>
<td>5.038</td>
<td>0.086</td>
<td>0.236</td>
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<td>137,600</td>
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<td>Tegal</td>
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</table>
### 3.4. The RFI Premium Calculation for Central Java Province

The results in the premium rate of the farmers in Central Java Province must pay for each hectare from IDR 111,650 (minimum) to IDR 322,190 (maximum). It is reasonable that all regencies/cities in Central Java uses single premium price with an equal rate. Therefore, a single premium will be calculated for Central Java Province. The simplest way is to take the average of all premium values using equation (10). This method is called a pure premium principle. Using equation (10), the single premium rate generated for Central Java Province is $P = \frac{\text{ IDR } 3,544,000}{32} = \text{ IDR } 110,750$.

The other single premium rate calculation uses standard deviation principle. The variance of premium rate is calculated from equation (11)

$$\sigma^2_P = \frac{1}{31} \times 32,943,554,816 = 1,062,695,317.$$  

With the level of significance 95%, the premium rate calculates with equation (12) is at the interval (IDR 78,151; IDR 143,349).

### 4. Conclusions

In this paper sustainable rice farming through supply chain risk management was determined. The use of the equation (9) which requires the coefficient of variation of 0.25 produces a very high premium price. In Central Java case, equation (9) cannot be implemented since the coefficient of variation of harvest yield is close to 0 (even if the results presented). The RFI premium rate for 1 hectare of land designated at 3% of the maximum benefit value of IDR 6,000,000, i.e. IDR 180,000. According to the calculation results, the lowest RFI premium is IDR 56,000 in Wonosobo Regency, and the highest premium is IDR 161,600 in Salatiga City. The fair RFI premium rate for Central Java Province, when the pure premium principle is used to calculate, is IDR 110,750. Meanwhile, when the standard deviation principle is used, the premium has resulted between IDR 78,151 and IDR 143,349.

The theoretical calculation showed the premium value of IDR 208,458 per hectare when there are only 100 participants per regency (city) and IDR 182,846 per hectare if there are 10,000 participants per regency (city). These numbers are not much different from the currently implemented premium rate.

### References


### Table: Premium Calculation for Central Java Province

<table>
<thead>
<tr>
<th>Regency</th>
<th>Area</th>
<th>Premium Rate</th>
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<tbody>
<tr>
<td>Temanggung</td>
<td>55.8</td>
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<td>Wonogiri</td>
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<td>Wonosobo</td>
<td>51.276</td>
<td>0.202</td>
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</table>

<table>
<thead>
<tr>
<th>Total premium (IDR)</th>
<th>3,544,000</th>
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</thead>
<tbody>
<tr>
<td>Pure premium principle (IDR)</td>
<td>3,544,000/32 = 110,750</td>
</tr>
<tr>
<td>Deviation standard principle (IDR)</td>
<td>(78,151 ; 143,349)</td>
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</tbody>
</table>


