A Bootstrap Simulation for comparison of Group Risk Plan and Multi-Peril Crop Insurance Policy

Valantino Agus Sutomo
Lecture of Prasetiya Mulya University, Jl BSD Raya Utama, BSD City-Tangerang, Prasetiya Mulya University
E-mail: valantino.sutomo@pmbs.ac.id

Dian Kusumaningrum
Lecture of Prasetiya Mulya University, Jl BSD Raya Utama, BSD City-Tangerang, Prasetiya Mulya University

Rahma Anisa
Lecture of Institut Pertanian Bogor, IPB Campus, Jalan Meranti Wing 22 Level 4, Dramaga, Babakan, Dramaga, Bogor, Institut Pertanian Bogor

Aryana Paramita
Student of Prasetiya Mulya University, Jl BSD Raya Utama, BSD City-Tangerang, Prasetiya Mulya University

Abstract. Agricultural insurance is one of the solutions for farmers to avoid risks such as climate change, pest, disease and price fall which increase the risk of crop failure. Indonesian Ministry of Agriculture (MoA) and Jasindo have been using subsidized Multi-Perils Crop Insurance (MPCI) and faced some disadvantages that mainly due to high risk moral hazard, adverse selection, and high administrative costs. Our research provides an alternative policy area yield index insurance known as Group Risk Plan (GRP) to handle this problem. To find homogeneous basis risk in GRP, the data was classified into two categories: up to and above two hectares. Bootstrapping approach was used to find MPCI and GRP indemnity amount for each term of harvesting period. In addition, both parametric estimation and goodness of fit test indicated appropriate distribution used by MPCI and GRP in each term of harvesting period as well. To compare the aggregate loss distribution, the conditional value at risk \( CVaR(X) \) measures the mean of excess loss exceeding \( VaR(X) \). It reflects how risky and measures the amount of money insurance company should retain. Simulations indicated that MPCI has greater \( CVaR(X) \) than GRP, which implies the higher likelihood of loss. The insurance company should have enough reserve for MPCI to cover that loss. On the other hand, the GRP policy that minimizes moral hazard and adverse selection thereby reduces administrative costs and offers potential to market at lower costs, may encourage farmers to do good farming practices that will result in the lower likelihood of loss. Therefore, GRP could be considered as an alternative crop insurance policy in Indonesia.

Keywords: Multi-Peril Crop Insurance (MPCI), GRP (Group Research Plan), Bootstrapping, \( CVaR(X) \).
1. Introduction
Agriculture is still one of the main occupations for the rural poor in Indonesia. Farmers in Java have been struggling with challenges, e.g. climate change which causes significant impact in the agriculture sector in a form of higher crop failure risk. Our research points out that farmers are exposed to nature, human error, pest and disease, etc. More than 15% of the interviewed farmers had the pest, drought and commodity price fall as their main risk factors for the past three years. To protect farmers from either the loss of their crops due to natural disasters or even the loss of revenue due to declines in the prices of agricultural commodities, crop insurance has been established in Indonesia since the year 2012.

Crop insurance in Indonesia has been in progress since the pilot project was initiated by the Ministry of Agriculture (MoA). Indemnity-based-crop-policy or also known as Multi-Peril Crop Insurance (MPCI) was applied all this time. However, it is designed only for farmers with working land up to two hectares and is heavily subsidized by the government [14]. This policy carries out some disadvantages, e.g. high risk of moral hazard and adverse selection, high administrative cost, and low quality of human resources [1]. The MoA targeted a total of three million hectares of rice field per year to be covered by crop insurance though the realization was only one-third of it [14]. Enthusiasm emerged in looking into other policies such as Group Risk Plan (GRP) crop insurance which manages to mitigate previously mentioned risks. Moreover, GRP is considered more suitable for smallholder farmer [1].

This research focuses on analyzing the potentials of applying GRP as an alternative policy based on the comparison of its indemnity that was calculated from two-hundred-farmers loss data gathered through a field survey in Karawang and Bogor, West Java as two of the most productive granaries in Indonesia. The results will be used as the main indicators of promoting GRP as an alternative crop insurance policy in Indonesia.

2. Crop Insurance policy and Survey Data
MPCI is type of insurance in which an insured yield is established as a percentage of historical average yield of the insured farmer. MPCI is suitable for many perils or multiple damage cause of loss which makes it a bit difficult to predict the loss. In MPCI, if the realized yield is less than the insured yield, an indemnity is paid equal to the difference of actual and insured yield, multiplied by a pre-agreed value of sum insured per unit of yield. There are so many disadvantages to perform the MPCI contract, e.g. high risk of moral hazard and adverse selection, high administrative cost, fluctuation of price fall and low quality of human resources [1]. Particularly in Indonesia, the government will subsidize 80% of the premium to increase the affordability of small farmers to pay the premium [14].

In a specific area yield index insurance, known as GRP, the indemnity is calculated on the realized average yield of an area such as county or district. The insured yield is established as a percentage of the average yield for the area [3]. Policyholder will receive an indemnity whenever the realized county yield is less than specified critical yield (or strike), regardless of the realized yield on farm level [4]. The disadvantage of MPCI becomes the advantage of GRP, which then minimizes moral hazard and adverse selection as well as reducing the administrative costs [1].

2.1. Survey Design
Based on discussion held with MoA and Jasindo, lots of Indonesian farmers in Indramayu and Cirebon put interest on crop insurance. However, there was another potential area mentioned, Karawang, where the pilot survey was conducted. Karawang is a modern, structured and feasible area for agriculture especially paddy in West Java. As large as 30,000 hectares of Karawang land...
have been insured. Bogor was also concerned due to its different characteristics. The survey involved a total of 200 respondents representing Bogor (37.5%) and Karawang (62.5%). The sampling method was based on systematic random sampling and the districts were chosen based on paddy harvest potentials selection. It would be interesting to see whether these characteristics will result in different policy choices between MPCI and GRP.

2.2. Multi-Perils Crop Insurance (MPCI) and Area Yield Index I Insurance (GRP)
In MPCI (multi perils crop insurance), we also use yield loss from damaged area to determine indemnity function [5] as :

\[ \text{Indemnity} = \hat{y} \cdot \text{sum insured per hectare} \]  

In GRP (group risk plan), we are using yield loss to determine indemnity function following Miranda’s model [13] as :

\[ \text{Indemnity} = \max(y_c - \hat{y}, 0) \cdot \text{sum insured per hectare} \]  

\( \hat{y} \) is the realization of damaged area of farmer’s land, while \( y_c \) is critical yield index for GRP, if farmer suffers loss below or less than critical yield loss, then the indemnity will be paid-off [4]. Meanwhile, if farmer suffers loss greater than critical yield loss, then no indemnity will be paid.

2.3. Loss Modeling
Parametric estimation is applied to determine the parameter of loss distribution. MLE is prominent method to estimate the parameter distribution according to the data. Moreover, the goodness of fit test selects the appropriate distribution which is suitable and well fit to the data.

In order to compare the loss distribution between MPCI and GRP, Value at Risk at \( p \) and TVaR at probability \( p \) are used to describe the upper tail of certain distribution. Generally, we denote the mean excess loss \( (e_X(d)) \) as the expected of excess loss value that is greater at certain amount \( (d) \) [11], written as :

\[ e_X(d) = \mathbb{E}[X - d|X > d] = \frac{\int_{d}^{\infty} S(x)dx}{S(d)} = \frac{\mathbb{E}[(X - d)^+]}{S(d)} \]  

Value at Risk at \( p \) can be interpreted as \( p \)-percentile of certain distribution of random variable \( X \) [11], which written as :

\[ \text{VaR}_p(X) = x_p = F_X^{-1}(p) \]  

Tail Value at Risk at probability \( p \) is the expected value of the upper tail distribution [11], which written as :

\[ \text{TVaR}_p(X) = E[X|X > \text{VaR}_p(X)] = E[X - \text{VaR}_p(X)|X > \text{VaR}_p(X)] + \text{VaR}_p(X) = CVaR_p(X) + \text{VaR}_p(X) \]  

3. Bootstrapp Simulation and Loss Modeling
Generally, farmers used 2-3 times planting season per annum since the harvesting period approximately 3-4 months [1]. Thereby we divided it into 3 terms or planting season: First term starts on November and ends in February, second term starts from March to June and the third term starts from July to October.
Expected area yield loss is average of historical loss data, and calculated using linear spline or moving average [4]. Coverage is a choice variable that allows a policyholder to increase or decrease the amount of protection per unit area. Critical yield index is the multiplication of expected area yield loss and coverage [4]. The Tables 1 and 2 summarize the critical yield index for land area less than equal to 2 Ha and greater 2 Ha.

### Table 1. Land area less than equal to 2 hectares on term 1

| Land Area less 2 Ha | Expected Area Yield Loss | Coverage | Critical Yield Index |
|---------------------|--------------------------|----------|----------------------|
| 0 to 5,000 m²       | 343.81 m²                | 90%      | 309.43 m²            |
| 5,000 to 10,000 m²  | 2,332.61 m²              | 80%      | 1,866.1 m²           |
| 10,000 to 16,000 m² | 3524.32 m²               | 80%      | 2819.46 m²           |

### Table 2. Land area greater than 2 hectares on term 1

| Land Area less 2 Ha | Expected Area Yield Loss | Coverage | Critical Yield Index |
|---------------------|--------------------------|----------|----------------------|
| 20,000 to 25,000 m² | 5471.43 m²               | 90%      | 4924.29 m²           |
| 25,000 to 140,000 m²| 7996.59 m²               | 80%      | 6397.27 m²           |

Based information on Tables 1 and 2, there is one disadvantage of GRP that is basis risk due to land area. We cannot obtain the precise critical yield index per group if we have heterogeneous land area. Farmers who have land area less than critical yield index will always have opportunity to obtain indemnity, on the contrary is unfair. Hence, the critical yield index will be bias and unfair.

In this paper, we only consider the land area less than equal to 2 Ha. The sum insured of 6 million IDR per hectare for each farmer is implemented to compensate the farmer’s cost due to crop failure on both MPCI and GRP policy. Furthermore, the critical yield index ($y_c$) of GRP policy ≤ 2 Ha for the term 1 and 2 are $2864.6 \text{ m}^2$ and $3067.6 \text{ m}^2$ respectively.

Bootstrapping method is applied to the data for each land area and damaged area in 2 different groups of land (less than 2 Ha and greater than 2 Ha). It is used to obtain more sample data and a smooth graph. Moreover, we have drawn and calculated the mean and standard deviation for the land area and damage area in each step of bootstrapping method. Running 10,000 times of bootstrapping and calculating average and standard deviation in each running step produce the graph on figure 1 & 2.

After bootstrapping process, the histograms look smoother. Furthermore, MPCI indemnity on figure 1 has tendency to be a normal distribution, but GRP Indemnity on figure 2 has tendency to be skewed to the right. Figure 3 shows that GRP claim amount (GRP indemnity amount) between area less than equal to 2 Ha and greater than 2 Ha is different by characteristic on the number of claims against the claim amount. Hence, we only take consideration for land area less than equal to 2 Ha.
Figure 1. Histogram of MPCI Indemnity ≤ 2 Ha term 1 after bootstrap

Figure 2. Histogram of GRP Indemnity ≤ 2 Ha term 1 after bootstrap

Figure 3. Number of Claims of GRP policy with land area ≤ 2 Ha and > 2 Ha.

Parametric estimation and goodness of fit test were used to determine the parameter distribution of GRP and MPCI term 1 and 2 for land area less than two hectares. Maximum likelihood estimator (MLE) is best estimator to obtain the parameter of certain distribution from the data, while the Anderson Darling and Cramer von-mises are used to fit the model through the data as well [11]. Since our data is skewed to the right, Cramer von-mises is good to fit and capture the tail distribution. The results are summarized in Tables 3 & 4:

Comparison between GRP term 1 and 2 show that the distribution changes from Gamma to Weibull, followed by the increasing of expected value, standard deviation and 75% value at
Table 3. Characteristic of each policy where areas $\leq 2$ Ha in IDR

| Policy        | Distribution | $E[X]$       | $\sigma$      | $VaR_{0.75}(X)$ |
|---------------|--------------|--------------|---------------|-----------------|
| GRP Term 1    | Gamma        | 107,961.77   | 101,253.17    | 149,388.55      |
| MPCI Term 1   | Normal       | 1,983,989.03 | 240,105.56    | 2,145,937.78    |
| GRP Term 2    | Weibull      | 139,300.61   | 117,260.73    | 194,432.75      |
| MPCI Term 2   | Normal       | 2,099,260.15 | 285,078.32    | 2,291,542.55    |

Table 4. TVaR of each policy where areas $\leq 2$ Ha in IDR

| Policy        | Distribution | $VaR_{0.75}(X)$ | $TVaR_{0.75}(X)$ |
|---------------|--------------|-----------------|-----------------|
| GRP Term 1    | Gamma        | 149,388.55      | 248,610.16      |
| MPCI Term 1   | Normal       | 2,145,937.78    | 2,289,188.72    |
| GRP Term 2    | Weibull      | 194,432.75      | 313,179.62      |
| MPCI Term 2   | Normal       | 2,291,542.55    | 2,461,625       |

risk. However, the MPCI distribution remains normally distributed with slightly different at the expected value ($\mu$), and increases 40,000 rupiah in standard deviation ($\sigma$). It means that if the GRP policy wants to be implemented then we should adjust the pure premium over the term (harvesting period).

GRP indemnity on equation 2 allows the insurance company to pay-off at maximum $y_c$, while MPCI indemnity on equation 1 pays off at the maximum coverage of loss. The GRP policy could be a solution to hedge crop failure risks due to moral hazard that is unsolved in the MPCI policy [1]. GRP policy can be considered as ”option on the stock market” which gives the upper bound of damage land ($y_c$) due to crop failure.

4. Conclusion and Discussion

GRP or area yield index insurances mitigates moral hazard and adverse selection and therefore endorse farmers to do good farming practices to reduce crop failure [3, 4]. It is important to notice the $TVaR_{\gamma_p}(X)$, where the value of $TVaR_{\gamma_p}(X)$ from MPCI is almost nine times higher than GRP. It thereby results in the higher likelihood of loss, especially on the large claim amount (extreme value). Hence, insurance company should retain greater amount of money as a claim reserving for MPCI rather than GRP policy.

Currently, the premium policy of MPCI (area $\leq$ two hectares), which is $3\% \cdot 6$ million rupiah = 180,000 IDR [14], is still not enough to cover existing risks of MPCI policy in Karawang and Bogor. Simulation shows that the premium should be increased up to around 2 million rupiah per term due to the basis risk. Moreover, based on the survey data, paddy farmer’s willingness to pay for GRP policy is approximately equal to the expected loss of the policy, which is around 100,000 rupiah. It is a good sign to encourage paddy farmer to buy GRP policy, since the benefit comes both side insurance company and paddy farmer. Therefore, GRP could be considered as an alternative crop insurance policy in Indonesia.

5. References

[1] Aryanti, Brigitta, 2014, *Designing Crop Insurance to Help Farmers Transfer Risk of Crop Loss in Rural Indonesia* (Harvard University).
[2] Austin M P and Van Niel K P, 2011, Improving Species Distribution Models for Climate Change Studies: Variable Selection and Scale, *Journal of Biogeography* pages 1-8 Vol 38, Wiley.

[3] Baquet, A.E. and J.Skees, 1994, *Group Risk Plan Insurance: An alternative Management Tool for farmers* (Choices 1st Quarter) pp.25-28.

[4] Barnett, Barry J, Hu, Y, Black, J.Roy, Skees, Jerry.R. *Is Area Yield Insurance Competitive with Farm Yield Insurance* (Georgia University).

[5] Betts R A, 2005, Integrated Approaches to Climate-Crop Modelling: Needs and Challenges, *Phil. Trans. R. Soc. B* pages 2049-2065 Vol 360, Royal Society.

[6] Bokusheva R and Breustedt G, 2012, The Effectiveness of Weather-Based Index Insurance and Area-Yield Crop Insurance: How Reliable are ex post Predictions for Yield Risk Reduction?, *Quarterly Journal of International Agriculture* pages 135-156 Vol 51.

[7] Chang L Y and Chen W C, 2005, Data mining of tree-based models to analyze freeway accident frequency, *Journal of Safety Research* pages 365-375 Vol 36.

[8] Chen J, Brissette F P, Picher P L and Caya D, 2017, Impacts of Weighting Climate Models for Hydro-Meteorological Climate Change Studies, *Journal of Hydrology* pages 534-546 Vol 549, Elsevier B. V.

[9] Doncaster C P, Tavoni A and Dyke J G, 2017, Using Adaptation Insurance to Incentivize Climate-change Mitigation, *Ecological Economics* pages 246-258 Vol 135, Elsevier B. V.

[10] Kelly D L and Tan Z, 2015, Learning and climate feedbacks: Optimal climate insurance and fat tails, *Journal of Environmental Economics and Management* pages 98-122 Vol 72, Elsevier B. V.

[11] Khulman, S A, Panjer, H, and Willmot, G, 2012, *Loss Models* 4th ed (New Jersey : Wiley).

[12] Lemott M J, Lyskawa K and Rozumek P, 2015, Farm Income Insurance as An Alternative for Traditional Crop Insurance, *Procedia Economics and Finance* pages 439-449 Vol 33, Elsevier B. V.

[13] Miranda, M.J, 1991, *Area Yield Insurance Reconsidered* (Amer.J.Agr.Econ) vol 73.

[14] Pasaribu SM, Sudiyanto A, 2016, *Agricultural Risk Management: Lesson Learned from the Application of Rice Crop Insurance in Indonesia*, In: Kaneko S, Kawanishi M, editors, Climate Change Policies and Challenges in Indonesia, Tokyo (JP): Springer, p 305-322, doi: 10.1007/978-4-31-55994-8-14.

[15] Rao K N, 2010, Index Based Crop Insurance, *Agriculture and Agricultural Science Procedia* pages 193-203 Vol 1, Elsevier B. V.

[16] Turvey C G, Gao X, Nie R, Wang L and Kong R, 2013, *Subjective Risks, Objective Risks and the Crop Insurance Problem in Rural China* (The Geneva Papers : The International Association for the Study of Insurance Economics) vol 38 pages 612-633.