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PREMIUM-PRICING OF CROP REVENUE INSURANCE IN LAGUNA

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ABSTRACT – Traditional crop insurance provides protection against loss in crop yield. This insurance pays the benefit, which is the farmer's capital or cost of production, whenever the expected yield is not met. However, this insurance does not cover losses in expected revenue whenever the palay price drops. Thus, this study developed a pricing model for a revenue insurance product for rice. This insurance provides protection against losses in both yield and revenue. This was done by combining a traditional crop insurance and a European put option. This new insurance gives the benefit whenever the yield is below 4, 000 kg/ha, or a price lower than a chosen strike price from PhP 14 to PhP 20. The traditional crop insurance was priced using the Expected Value Principle, while the European put option was priced using the Black Scholes model. Results showed that traditional insurance has a premium price of PhP 1, 051.15 per hectare for a PhP 25, 000 benefit, while the European put option has a price of PhP 1.08 to PhP 4.09 per kg of palay depending on the strike price. The results of this study could be used by the government and the insurance providers in offering crop insurance.

Keywords: crop insurance, European option, put option, revenue insurance

INTRODUCTION

The Philippines is one of the most disaster-prone country (FAO, 2003), ranking third as the most vulnerable country to climate change (United Nations University, 2011). Annually, natural disasters such as storms, torrential rains and flooding bring damage to properties, agriculture, and sometimes result to loss of lives. The government has set up disaster risk reduction and management offices to lessen the impact of such natural calamities. However, despite these efforts, properties amounting to millions of pesos are still lost to typhoons and flooding. Perhaps, what is problematic here is that the people has no control on where and when mother nature will unleash the rains: that is, there is no way to control the arrival, path and severity of the typhoons.

The financial impact of these disasters could be reduced by using insurance. Insurance is a financial contract that provides full or partial compensation for loss that is beyond the control of the insured (Bowers et al., 1997). Insurance works by giving out a benefit (or reimbursement to the loss) whenever disaster strikes, and can be purchased by paying a premium. To receive the benefit of the insurance, loss assessment is first done: if this is a life insurance, then the insurer must ascertain that the insured person is dead, if this is an auto-mobile insurance, then it must be established that the car is damaged or broken.

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One sector that is greatly affected by natural disasters is agriculture. Agriculture plays an important role in the Philippine economy. According to Philippine Statistic Authority (PSA), about 32% of the country's land area is agricultural lands. According to United Nation Food and Agricultural Organization (FAO), agriculture contributes to the gross domestic product at about 20%, and it involves about 40% of Filipino workers (FAO, 2003).

It can be helpful for the farmers to have an agricultural insurance. The traditional crop insurance offered in the Philippines provides protection against yield losses caused by natural calamities, pests and diseases, and other unforeseen events. This pays the benefit, which is the farmer's cost of production, whenever the yield is below the covered or secured yield. With the benefit of the insurance, the farmer will regain his capital, which he could use to plant in the next cropping season. This offers great help to most farmers, who are amongst the poorest citizen in the country (Reyes and Domingo, 2009).

However, the problem with this type of insurance is that it only covers loss in yield. At the start of the cropping, farmers expect certain revenue from selling their harvest. Due to different market forces and other causes, the price of palay (unhusked rice) during the time of the farmer's harvest may drop. For example, in 2015, the price of palay in January is PhP 17.16 per kg while the it is at PhP 13.89 per kg in April. If the farmer expected he can sell his harvest in April at the same rate as in January, then he will be short of around PhP 3 per kg. This can also be considered as loss in the farmer's point of view.

The model for pricing the traditional insurance could not be directly used in pricing an insurance which also covers the farmer's expected revenue. Yield is usually determined by weather, soil type, quality of seed and other factors, and generally increases year by year due to advances in technology and good agricultural practices. Palay price, on the other hand, is determined by the yield, and other market factors, such as the supply and demand of palay, inflation and other economic factors.

This study aims to develop a model for revenue insurance, which is a combination of a traditional insurance and another insurance securing the price of the palay, in the Philippines specifically in the province of Laguna. This new insurance product will be composed of the traditional crop insurance and a European put option. A put option is a financial contract that offers the buyer the right, but not the obligation, to sell a financial asset at an agreed-upon price (strike price) during a certain period (Hull, 2012). A European option is a type of option that can only be exercised, in this case sold, at the end of the period (Hayes, 2017). Since the farmer would only be able to know the price of palay at the end of the cropping season, hence the choice of using the European put option.

In other countries, there are several studies on crop revenue insurance reporting the success or other improvements that can be done in the designing a revenue insurance. According to Munich Re (2011), the only two countries that has successfully managed crop revenue insurance are the United States of America and Canada. However, at the start of the implementation of this type of insurance in Canada, the result is not as ideal as the result in United States. The reason is that they used historical prices instead of recent prices which resulted to the discontinuation of the policy (Coble and Dismukes, 2006). Improvements are made before they managed to continue this type of insurance in their country. A study in the United States by Coble et. al. (2007) argued that when the revenue trigger is weakly correlated with farm revenue it provides less effective risk reduction.

Another study in United States focuses on time varying yield distributions. Zhu et al. (2011) used the accurate modelling of the yield. They argued that yield distribution changes over time and hence, a model that captures this change is needed so that insurance providers would be able to design the insurance better.

However, though the design of the insurance is an integral part in this study, according to Munich Re (2011), one of the most important factors for the success of any crop insurance is the extensive support from the government, both for regulation and finances. It will be difficult for the farmers to pay for the whole premium for this policy because it is expensive compared to yield insurance. This is because of the higher risk of the revenue insurance, coming from both the price and yield, compared to only yield in the tradition insurance. The government can also reduce the transaction cost for the processing of revenue insurance (Goodwin, 2011).

The next section of the paper will discuss the main steps followed in this study. This will aid those who will want to replicate this study for other locations. The following section will show the results of this study including significant observations in the collected data, and the model of the premium and a computation for premium for a chosen benefit level.

The goal of this study is to price a crop revenue insurance for the province of Laguna. Specifically, this study aims to characterize the yield and palay price collected; to develop a pricing model specific for Laguna for the traditional insurance; and finally, to price the European put option.

METHODOLOGY

This study is conducted in the University of the Philippines Los Baños from August to December 2017. Data and information collected are from the agricultural offices in Laguna. Hence, the results of this study may only be valid for this province as the yield and price of palay in other locations may differ from that of Laguna. Nevertheless, this study can be reproduced for other locations using the same methodology.

Figure 1 shows the map and the different towns of Laguna. There are around 29 municipalities and cities in Laguna, with about 15 to 19 ha of land for rice cultivation as of 2015, according to the Regional Office of the Department of Agriculture in Calauan, Laguna. The municipalities of Victoria, Mabitac and Pila are the highest contributor in rice cultivation.

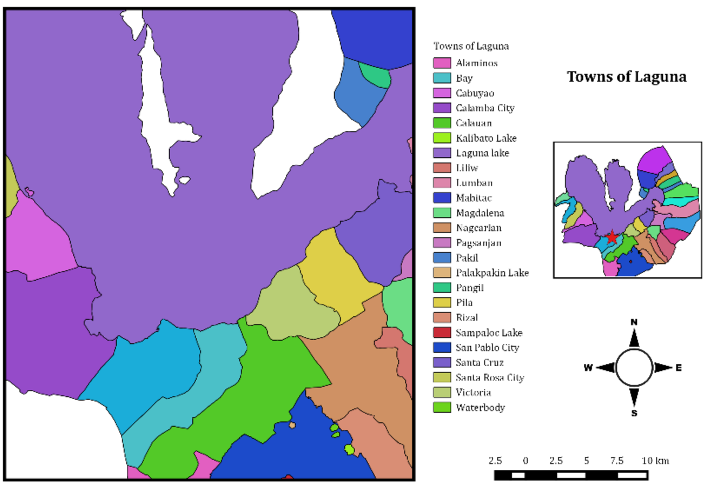

Figure 1. Map of Laguna.

The province of Laguna experiences Type I climate. In this climate type, the area experiences dry season during the months of November to April, and rainy season for the rest of the year. Farmers can squeeze in two planting seasons: wet season starts in April and ends in September, while dry season starts in December and ends in April (International Rice Research Institute, 2016).

Historical weather data from year 1985 to 2015 is gathered from the UPLB Agrometeorological Station, which is summarized in Figure 2. According to the data, the maximum temperature (tmax) and minimum temperature (tmin), and solar radiation (srad) deviates from one month to another insignificantly, which is to be expected for a tropical country. The average tmax is 31.58^{O}C while the average tmin is 22.98^{O}C: the hottest months are from April to June, while the coldest months are from December to February. Fortunately, this range falls within the optimal range of temperature for rice cultivation (Yoshida, 1981). Rainfall is the weather factor that deviates greatly. The driest months are from January to May, while the rainiest months are from June to December. This agrees with Laguna experiencing a Type I climate, albeit a slight adjustment on the arrival of rainy season. On the average, Laguna receives around 2, 183 mm of rainfall per year, exceeding the 1, 000 mm mark recommended that the area should receive for it to be suitable for the cultivation of rice (Yoshida, 1981).

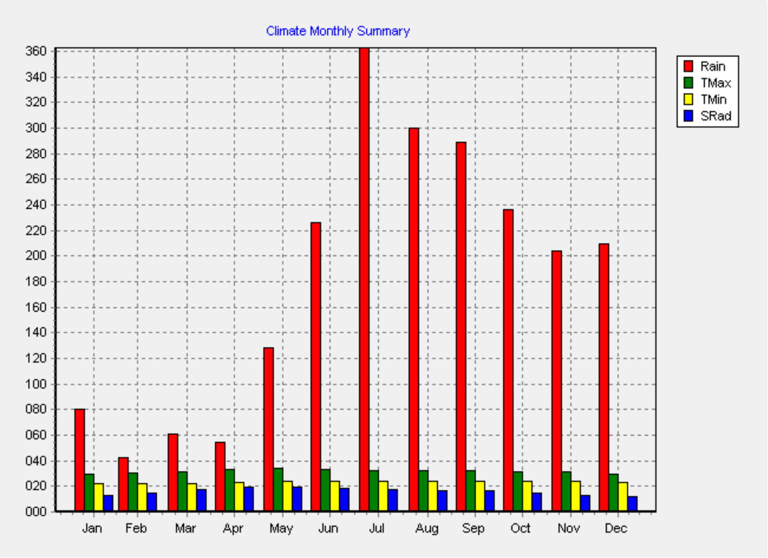

Figure 2. 30-year average rainfall, temperature and solar radiation distribution.

The data used in this paper are collected from the Philippine Statistical Authority in San Pablo, Laguna and the website CountrySTAT Philippines. Palay yield and palay price from the year 1987 to 2017 are gathered. This study uses semi-annual actual palay yield in kilograms per hectare (kg/ha) and farmgate palay prices in pesos (PhP) per kg in cities and municipalities of Laguna. After collecting the data, the mean, and other statistical measure of the data are obtained. For the data on yield, these values would be used in the next steps (such as setting the baseline for insurance to start benefit payout) and x The data used in this paper are collected from the Philippine Statistical Authority in San Pablo, Laguna and the website CountrySTAT Philippines. Palay yield and palay price from the year 1987 to 2017 are gathered. This study uses semi-annual actual palay yield in kilograms per hectare (kg/ha) and farmgate palay prices in pesos (PhP) per kg in cities and municipalities of Laguna. After collecting the data, the mean, and other statistical measure of the data are obtained. For the data on yield, these values would be used in the next steps (such as setting the baseline for insurance to start benefit payout) and would give an idea on the efficiency of rice production in Laguna. Another procedure performed on the yield data is to find the distribution. This is done because known pricing model for insurance utilizes the expected value of the data, which can easily be derived using the distribution. Model fitting is performed to find the best-fit distribution from known and existing distributions using XLSTAT, which is an add-in in excel. The distribution with a *p-value* > 0.05 is selected.

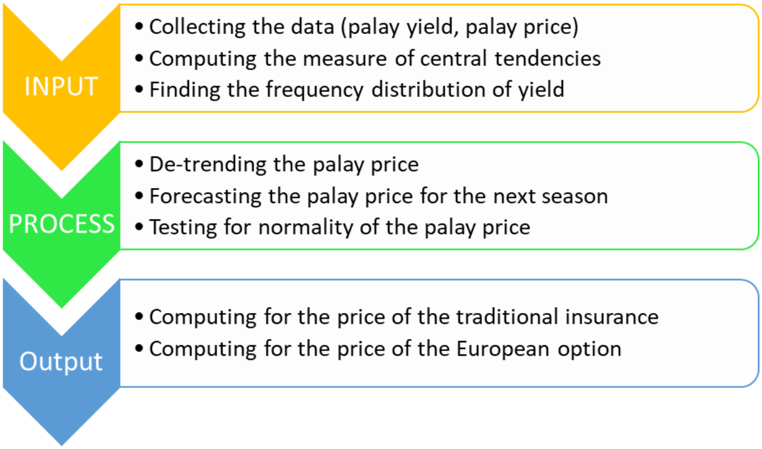

Figure 3. Conceptual framework of the study.

Now, the data on palay price is expected to present an increasing trend, which is brought by inflation, and seasonality, due to the different plating season (wet and dry season). To have an unbiased computation, de-trending the palay price is necessary. To detrend the price, R Software is used to separate the three time-series components of the price, namely seasonality, trend and irregularity cycle. Palay price for the next season is forecasted (this will be also used as baseline for insurance to start benefit payout): double exponential smoothing is performed using the statistical software EViews. After getting the detrended price values, Wilk-Shapiro Test is used to test the normality of palay price. This is performed since some pricing models are only applicable for data that presents Normal distribution.

After the data are cleaned and prepared, the price of the traditional insurance and the European option can now be computed. For the traditional insurance, the expected value of the yield using the formula from the chosen distribution is obtained. This expected value is multiplied to the desired benefit of the insurance.

To price the European put option, Black-Scholes model is used (Shreve, 2004). The Black-Scholes formula, which requires the price to have a Normal distribution, for the put option with r as the risk-free rate is

$$P = Ke^{-rt}\phi(-d_2) - S_T\phi(-d_1) \quad [1]$$

K, the strike price, is set to different values ranging from 14 to 20 (in pesos).
S_T, the stock price, is the forecasted value of price.

The formula for d_1 and d_2 are as follows:

$$d_1 = \frac{\ln\left(\frac{S_T}{K}\right) + t\left(r + \frac{\sigma^2}{2}\right)}{\sigma\sqrt{(t)}} \quad \text{and} \quad d_2 = d_1 - \sigma\sqrt{t}.$$

RESULTS AND DISCUSSION

Results of Data Collection

Figure 4 shows the semi-annual palay yield (in kg/ha) from year 1987 to 2017. Visually, the graph shows a gradual general increase in yield. Variability in yield can be observed from year 2011 to 2017. This could be due to the highly variable weather and more intense rainfalls brought by climate change. To see more information on the data, Figure 5 shows the bar graph of palay yield from year 1987 to 2017, as well as the mean yield, and other statistical measures of the data. Data shows that the mean yield in Laguna is at 4, 055 kg/ha, with a deviation of 485 kg/ha. This shows that the rice production in Laguna expects around 4, 000 kg/ha every season, and with this value near the national yield average, this shows that rice production in Laguna is efficient. The minimum yield is 2, 328 kg/ha, which was experienced on the second half of year 1995. This can be attributed as an impact of the Super Typhoon Rosing. Typhoon Rosing hit Southern Tagalog in November 1995 with 290 kph maximum sustained winds. Many lives and about PhP 10.829 are lost to Typhoon Rosing (DOST, 2010).

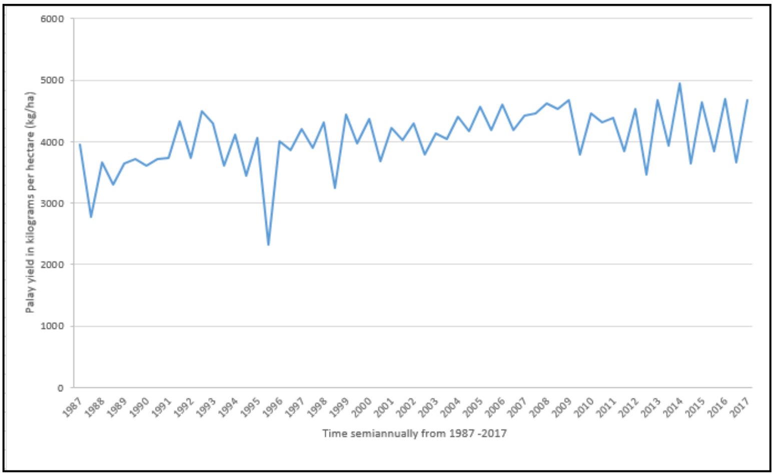

Figure 4. Palay yield (in kg/ha) semi-annually from year 1987 to 2017.

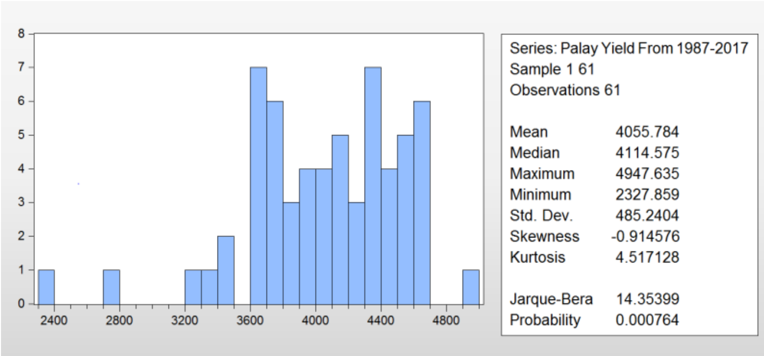

Figure 5. Palay yield (in kg/ha) and some statistical data.

Figure 6 shows the line graph for price per kg of palay from year 1990 to 2017. It can be seen that there is an increasing trend in the price of the palay. Price of palay started at around PhP 5 per kg and increased to around PhP 18 per kg. This increase can be attributed mainly to price inflation every year as well as other market factors such as demand and supply of palay.

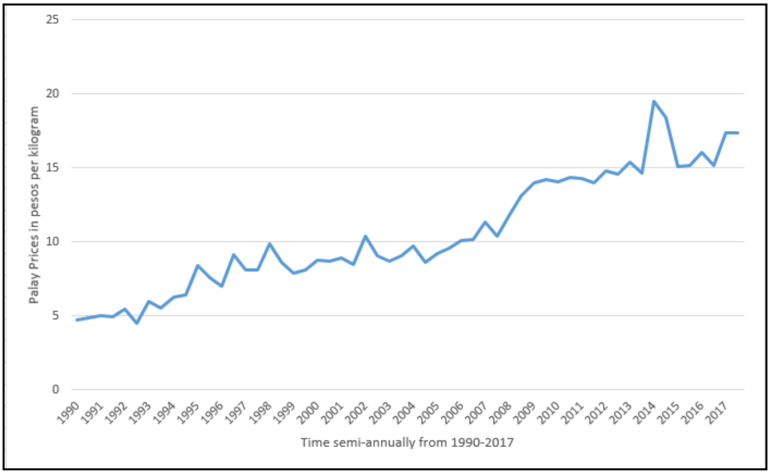

Figure 6. Price per kg of palay from year 1990 to 2017.

Results of finding the distribution of loss in yield

To find the percentage loss in yield, the palay yield per season is subtracted from a 4, 000 kg/ha, then divided by this same amount. If the resulting value is negative, it is set as zero. Note that the 4, 000 kg/ha, which is around the mean yield of the province, is used as the baseline yield, and insurance starts paying out the benefit if the yield (in kg/ha) falls below this amount.

Figure 7 shows the histogram of percentage of loss per season. It should be noted that while most seasons show positive losses, there are some seasons where the percentage of loss is zero. This could mean two things. First, for the insurer, it means that offering insurance in Laguna could be profitable. This is because if there is no loss in yield, then the insurance will not have to give benefit to the farmers and can take the premium as profit. Second, for the farmer, it means that getting an insurance policy would be beneficial to them. Since losses are likely in Laguna, then having an insurance give the farmers a peace of mind that whenever losses happen they can at least recover their capital which they can use for the next planting season.

Visibly from Figure 7, the distribution does not follow the Normal distribution. It is important to know if the distribution is Normal since most popular insurance pricing methods require Normal distribution. Distribution analysis and data fitting is then used to find a suitable distribution of the data. Using XLSTAT, an MS Excel add-in, Beta distribution with parameters $\alpha = 0.243$ and $\beta = 5.547$ is chosen, having a *p-value* > 0.05.

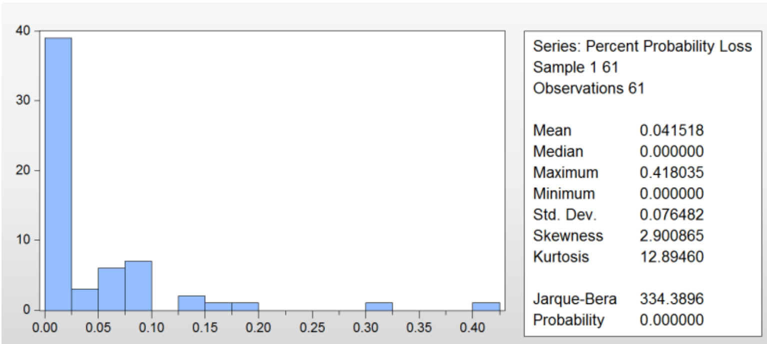

Figure 7. Histogram of percentage loss in yield and statistics.

Before proceeding, note that the probability distribution function of the Beta distribution with parameters α and β is given by

$$f(X) = Beta(\alpha, \beta) = \frac{x^{\alpha-1}(1-x)^{\beta-1}}{B(\alpha, \beta)}$$

, where *B* is the Beta function. [2]

The Beta distribution has expected value and variance of

$$E[X] = \frac{\alpha}{\alpha+\beta} \text{ ,} \quad [3]$$

$$Var[X] = \frac{\alpha\beta}{(\alpha+\beta)^2(\alpha+\beta+1)} \text{ ,} \quad [4]$$

(Ross, 2010).

Now, the probability density function of the fitted beta distribution is given by,

$$Beta(0.243,5.547) = \frac{x^{0.243-1}(1-x)^{5.547-1}}{B(0.243,5.547)}, \quad [5]$$

with B as

$$B(0.243,5.547) = \int_0^1 t^{0.243-1}(1-t)^{5.547-1}dt. \quad [6]$$

Analysis of price of palay

From Figure 6, the increasing trend in the price of palay per kg is notable. To do analysis in the price of palay, de-trending of price is done. The study uses R software to separate the three time-series components of the price. Figures 7 and 8 show the trend and seasonality component of the data. From Figure 7, the trend component, shows that because of inflation the increase in the price, which is around 67% from year 1990 to 2017, is very fast and high. The seasonality trend (Figure 8) shows the price difference between the dry and wet season. The seasonality shows that the yield is higher in the wet season than during the dry season.

Due to the trend and seasonality of the data, direct application of the values may not viable as it may give biased results. To remedy this, values are de-trended (Figure 9). Once more, these de-trended values are tested for Normal distribution, again because of existing pricing methods are anchored on Normal distribution. Fortunately, according the Wilk-Shapiro test done, the data is Normally distributed (Figure 10). The price of palay per kg for 2017 is also computed. This will be used as a baseline price in the pricing the European put option. The resulting price using the one-parameter exponential smoothing was PhP 16.75.

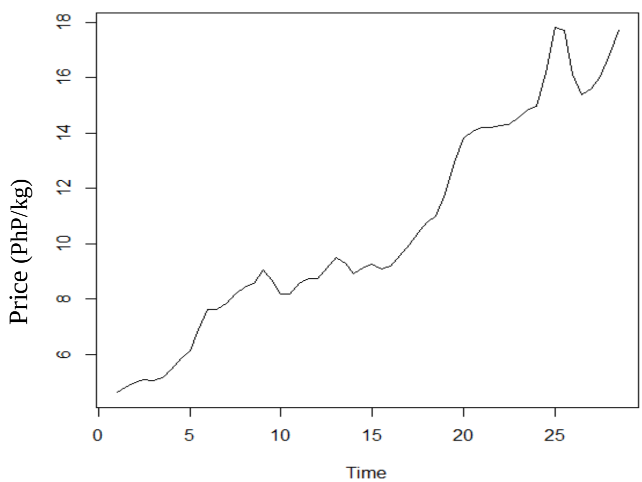

Figure 7. Trend-cycle component.

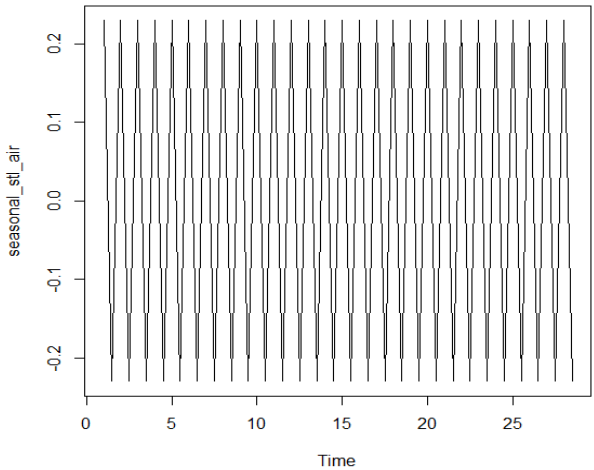

Figure 8. Seasonality component.

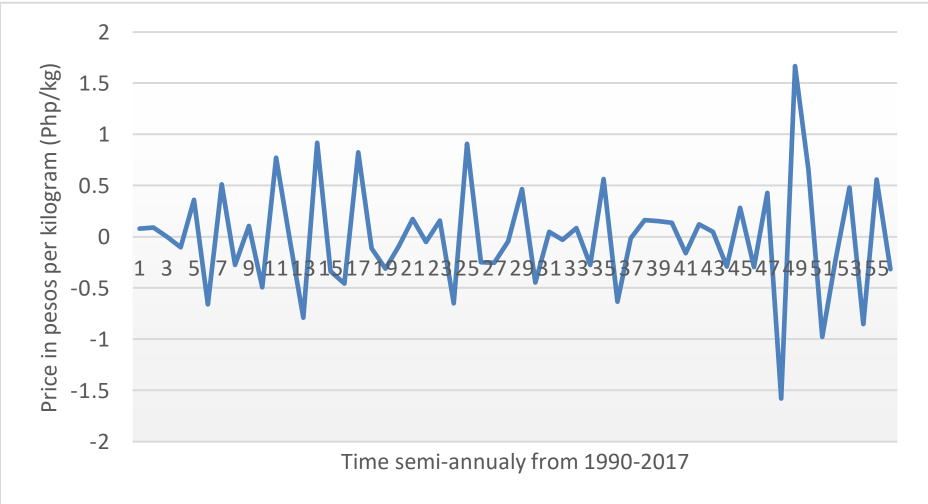

Figure 9. De-trended values of palay price.

Design of the insurance policy

Pricing the traditional insurance. In computing the premium of an insurance policy, one must assure that the premiums collected should be enough to cover the benefit payouts and provide a reasonable profit to the company (American Academy of Actuaries, 2010). The premium should be as low as possible, and hence be as competitive and as attractive as possible (Kaas, et. al., 2008). In this study, the expected value principle is used. This principle works by assuring the equivalence between the premiums received and the benefits paid out (Bowers, et. al., 1997).

Denote by

- B — the chosen benefit of the insurance (in PhP),
- $PV\,B$ — the present value of a unit of insurance, this is the time value of benefit when the insurance policy is issued, note that $PV\,B$ is at most B because of inflation or other interest considerations
- a — the value of regular payments to fully purchase a unit of insurance
- $PV\,a$ — the present value of the regular payments.

Now, by the equivalence principle, the premium to be charged to an insurance policy is

$$Premium = \frac{E[PV\ B]}{E[PV\ a]} \times B. \qquad [7]$$

In this study, it is assumed that:

a. the premium is a single payment done when the policy is purchased,
b. a single benefit payment is made, if ever loss is experienced,
c. the end of the contract coincides with the end of the planting season, and
d. the total benefit is the capital or the cost of production of the farmer. For this study, it is assumed to be PhP 25, 000.

With these assumptions:

a. $E[PV\ a]$ = 1since a single payment is to be made, and this value should be equal to the benefit that will be paid at the end of the contract if ever loss happens.
b. $E[PV\ B]$ is Beta-distributed (equation [5]) with expected value following equation [3].
c. B = 25, 000.

Thus, the premium formula is given by

$$Premium = \frac{\alpha}{\alpha+\beta} \times 25{,}000 = 1{,}051.15. \qquad [8]$$

Therefore, the premium of the insurance is PhP 1, 051.15 per hectare of land insured.

Pricing European Put Option. After de-trending the price, testing for the normality of the price must be done. Figure 6 shows the Shapiro-Wilk normality test with the *p-value* of 0.291>0.05. Thus, the detrended price is normally distributed.

Now, to price the European put option, the parameters for the formula in equation [1] must be determined. These parameters are K, the strike price, S_T, the stock price, r, the risk-free rate, and σ, the volatility. Now, K is set from PhP 14 to PhP 20, which is a range of insured price of palay per kg that the farmer can choose from. This means that if the farmer chooses a strike value of PhP 14, then the farmer would receive the insurance benefit if the price of palay falls below this strike value for that particular season. Choosing a higher strike value would mean a higher chance that the farmer would receive the insurance benefit, but this also means that the farmer would pay a higher premium. Thus, the farmer must be careful in choosing the strike value. S_T is set as the forecasted palay price of PhP 16.75. r is taken as 3.75%. σ is computed as the standard deviation of the de-trended price of palay which is 0.533. Now, the time in year is taken as 0.5 as planting either happen at the first half of the year or at the next half of the year. In summary, the parameters are:

K = 14, 14.5, 15, 15.5, …, 20 (PhP)
S_T = 16.758 (PhP)
r = 3.75%
σ = 0.533458 (PhP)
t = 0.5 (years)

Table 1 gives the computed price in PhP with different strike values. These values are only for one unit of European option. A unit of European option covers only one kg of palay.

```
> price
Time Series:
Start = c(1, 1)
End = c(28, 2)
Frequency = 2
 [1]  0.079142170  0.090202900  0.002412949 -0.104053009  0.363163798
 [6] -0.659494954  0.512044807 -0.275838401  0.108346518 -0.490570829
[11]  0.774018012 -0.041062857 -0.789237874  0.920940942 -0.334004610
[16] -0.457643741  0.825552526 -0.112639108 -0.309669136 -0.092596912
[21]  0.174195179 -0.051081427  0.158447641 -0.646606844  0.908580738
[26] -0.247203212 -0.252408871 -0.043922285  0.463366964 -0.444756550
[31]  0.051079359 -0.028174288  0.086867714 -0.271537768  0.566437371
[36] -0.633720113 -0.013341886  0.162223585  0.154149307  0.137887651
[41] -0.157929617  0.122141032  0.049645049 -0.291577206  0.285850766
[46] -0.293008299  0.431868670 -1.578542063  1.667298094  0.657543538
[51] -0.976779995 -0.219997738  0.483403185 -0.854175099  0.557939777
[56] -0.313445439
> shapiro.test(price)

        Shapiro-Wilk normality test

data:  price
W = 0.97488, p-value = 0.291
```

Figure 10. Detrended price value and Shapiro-Wilk normality test using R software.

Table 1. Computed European option price.

Strike Prices (PhP)	Put market price (PhP)
14.00	1.08
14.50	1.27
15.00	1.47
15.50	1.70
16.00	1.94
16.50	2.19
17.00	2.46
17.50	2.75
18.00	3.05
18.50	3.37
19.00	3.70
19.50	4.04
20.00	4.39

Summary of crop revenue insurance. The final price of the revenue insurance is derived by adding the price of the European put option and the premium of the insurance. As an illustration, Table 2 shows the price of the revenue insurance given different strike values and different number of units (one kg of palay) of option. If a farmer chooses to buy a revenue insurance with 1, 000 unit of option (meaning he is securing a 1,000 kg yield) with a strike value of PhP 17.00, then the farmer would need to pay PhP 3, 511.15. Note that the strike value should be the value that the farmer is expecting he could sale his palay for. Now, if the farmer experiences yield loss that season, meaning his yield falls below 4, 000 kg/ha, then the insurance company would pay the farmer PhP 25, 000. Furthermore, if the farmer sells the remainder of his yield but sells the palay at less PhP 17.00 per kg say around PhP 15.00 per kg, then the insurer would also make payments to the farmer equivalent to the difference of the strike price and the actual price multiplied to the number of units, that is (17-15) × 1, 000 = PhP 2, 000. All in all, the farmer receives PhP 27, 000 from the insurance company by paying PhP 3, 511.15.

Table 2. Computed price revenue insurance.

	Number of units (per kg)			
Strike Prices (PhP)	**1**	**10**	**100**	**1000**
14.00	1052.23	1061.95	1159.15	2131.15
14.50	1052.42	1063.85	1178.15	2321.15
15.00	1052.62	1065.85	1198.15	2521.15
15.50	1052.85	1068.15	1221.15	2751.15
16.00	1053.09	1070.55	1245.15	2991.15
16.50	1053.34	1073.05	1270.15	3241.15
17.00	1053.61	1075.75	1297.15	3511.15
17.50	1053.9	1078.65	1326.15	3801.15
18.00	1054.2	1081.65	1356.15	4101.15
18.50	1054.52	1084.85	1388.15	4421.15
19.00	1054.85	1088.15	1421.15	4751.15
19.50	1055.19	1091.55	1455.15	5091.15
20.00	1055.54	1095.05	1490.15	5441.15

CONCLUSION AND RECOMMENDATIONS

This study presents a way to guard against the damages brought by natural calamities: insurance. In particular, this study presents method in pricing a revenue insurance for the province of Laguna. The study finds that offering a revenue insurance is feasible. The next step in pricing this insurance is looking at the acceptability of the computed price to the farmer. This can be done through interviews and conducting a willingness to pay study. It will be good if the results of such study agree with the prices presented in this study. However, in case it is found that prices here are higher than what farmers can pay, then this study can be revised by using a utility-based pricing model to incorporate the willingness of the farmers to pay for this type of insurance. Another study that can be done is to look at the long run profitability of this insurance.

Nevertheless, natural disasters strike the country every now and then. People are getting more and more resilient and are preparing better now to the effects of such disasters. However, sometimes still, damages are inevitable and one way to financial protect one's self is through insurance.

STATEMENT OF AUTHORSHIP

The first, second and third authors collected the data and did the analysis, as well as prepared the draft of the report. The fourth author made recommendations to improve the study and finalized the manuscript.

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