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# NET REVENUE INSURANCE FOR BEEF IN REGION IV-A (CALABARZON)

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**ABSTRACT** – The cattle industry was identified as one of the least developed industry in the country due to numerous risks that greatly affect the cattle farmers' income, including market risks such as sudden movements in livestock and feed prices. In this study, we priced an insurance policy designed for cattle farmers in Region IV-A (CALABARZON) to insure their average net revenue. We model the behavior of the gate price of cattle for slaughter and the price of feeds consumed by the livestock and consider the revenue as the primary factor in designing an insurance using the Principle of Net Revenue Insurance. We consider a Net Revenue Insurance in the form of a path dependent option in which the payoff depends, not on the values of livestock and feed prices on a given day, but on the path that prices take over the life of the option or insurance product. An Asian Option is used to insure the expected average revenue of cattle farmers. Monte Carlo simulation is used to price the option. Prices of the resulting Asian Option are calculated using different time intervals, risk-neutral interest rates and initial prices.

*Keywords: Asian Option, Livestock Insurance, Revenue Insurance*

## INTRODUCTION

Agriculture sector has been one of the major contributors in the economy of the Philippines. About 9% of the Gross Domestic Product of the country comes from this sector where it employs around 28% of the total labor forces of the Philippines as of 2018. (Plecher, 2020; Teves, 2018).

The food consumption nowadays was still dominated by crops but the shift of diets of humans has been visibly directing towards meat consumption. As a result, meat production has been growing at a significant pace. It was determined that cattle has been one of the dominant livestock not just in the country but also in the world (Urech et al., 2017).

According to Philippine Statistics Authority or PSA (2018), as of July 1, 2018, the total cattle industry was estimated at 2.55 million heads. However, the Philippines has negative growth rate in the cattle industry. Ilocos Region, Central Visayas, CALABARZON, Western Visayas and Northern Mindanao were the regions dominating the cattle population which establish 52.25 percent of the cattle in the country. CALABARZON alone contributes 10.48 percent of the national production of cattle meats (Philippine Statistics Authority, 2018).



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A typical Filipino consumes about 28.8 kilograms of meat annually, 3 kilograms of which are beef. With the increasing demand for beef, at the same time, with the declining trend in local cattle production, DOST-PCAARRD expects that importation of both beef and live cattle in large volumes will continue, and thus, possibility of killing the local cattle industry. Nevertheless, this scenario shows that the beef cattle sector has a big room for growth and productivity (Philippine Statistics Authority, 2018).

The economic potential, in terms of national income and jobs it can offer, of the cattle industry is inevitable. However, a lot of risks were present in the industry itself which are possible reasons for the continuous decline in the trend of the cattle production. According to Urech et. al (2017), risk being faced by the cattle industry can be categorized into four: mortality risks, which includes accidents, epidemic and non-epidemic diseases, natural mortality and loss of productivity; weather risks; market risks, which include sudden movements in livestock and input prices; and local regulatory frameworks, such as disease control, animal welfare, transport, and environmental protection. At the same time, there is continuous increase in the demand in cattle production in the Philippines. To maintain and further enhance the industry, it is significant to take necessary actions to protect the cattle farmers' interest. A possible step is to ensure the profit of cattle farm owners by compensating with the possible loss they might encounter due to several market risks.

The Philippine Crop Insurance Corporation (PCIC) has been the provider of livestock insurance in the country covering agricultural livestock, such as cattle, horse, swine, goat, sheep, poultry and game fowls and animals. The PCIC offers the Livestock Mortality Insurance Program. Under this program, the type of insurance is divided into four types of insurance cover, namely: Non-Commercial Mortality Insurance Cover, Commercial Mortality Insurance Cover, Special Cover for livestock dispersal, and Special Cover for game fowls and animals. The said policies only cover death due to accidents, diseases, and other covered risks directly affecting the livestock (Philippine Crop Insurance Corporation, 2015).

Due to several market risks that might cause substantial losses to cattle farmers, which is difficult for them to recover given their financial resources. A tool for managing the risk is necessary. A type of insurance that can protect the farmers from market risk is a revenue insurance. This type of insurance is already offered in other countries such as the United States. In the United States, they are offering two types of livestock revenue insurance for feeder cattle. The first one is the livestock gross margin that protects loss of gross margin, that is, the return over feed costs. Payment will be made if the actual gross margin is lower than the expected gross margin (gross margin guarantee). The second type is the livestock risk protection which protects against low livestock price. Payment will be made if at the end of the insurance coverage, the price of the livestock is lower than the expected price (coverage price). (Edwards, 2009).

In a paper entitled “Conceptual Issues in Livestock Insurance”, Calum Turvey defined the Principles of Net Revenue Insurance as a path dependent option in which the payoff depends, not on the values of livestock and feed prices on a given day, but on the path that prices take over the life of the option or insurance product (Turvey, 2003). Options are financial contracts defined to be a right, not an obligation, to buy or sell the underlying asset in some specified time interval. Chad et al (2001) also studied the livestock revenue insurance in the form of an option, specifically an Asian basket option.

In this study, we price an insurance, in the form an option, that will protect the income of the cattle farmers due to several market risks. The specific type of option that will be used is an Asian option. Asian option is path dependent and is based to the average price of the underlying asset over a time interval (Mcdonald, 2006). We will consider the net revenue of the cattle farmers in Region IV-A (CALABARZON) as the underlying asset and use the Principles of Net Revenue for pricing the option.

Thus, the main goal of the study is to price an insurance policy designed for cattle farmers in Region IV-A (CALABARZON) to insure their average net revenue. Specifically, the study aims to observe the behavior of the gate price of cattle for slaughter and the price of feeds consumed by the livestock; apply the Principles of Net Revenue Insurance in designing a net revenue insurance in the form of an Asian Option; and price the net revenue insurance considering different assumptions.

## METHODOLOGY

To design the net revenue insurance, we first consider data sets for the price of the livestock and the feeds. We model the behavior of the prices and determine the parameters for the models. Lastly, since the insurance is in the form of an option, we use an existing method in pricing options.

### *Net Revenue Insurance*

We suppose that the net revenue R per cattle is given by

(1) $R = \alpha P - \beta F$

where $P$ and $F$ are the price of livestock and feeds, respectively. The parameter $\alpha$ corresponds to the monthly growth of the cattle in kilograms, $\beta$ is the kilograms of feed required for $\alpha$ kilogram gain on the cattle's weight (Turvey, 2003). The price of livestock $P$ to be considered would be the farmgate price of cattle meat, while the price of feeds F to be used will be the market price of the feed to be considered.

The value of $\alpha$ will be obtained using linear regression where the weight of the cow will be dependent variable and the age is the independent variable. Meanwhile, the value of $\beta$ will be determined depending on the constant amount of feeds in kilograms being given to the cows.

The path that prices take over the life of the option or insurance product is where this path dependent option's payoff depends on, not on the path of livestock and feed prices on a given day. If parameters $\alpha$ and $\beta$ are set to be fixed coefficients and Pt and Ft are assumed to follow geometric Brownian motions, then

(2) $dF_t = \gamma_F F_t\, dt + \delta_F F_t\, dw_F$

(3) $dP_t = \gamma_P P_t\, dt + \delta_P P_t\, dw_P$

where $\gamma_F$ and $\gamma_P$ are the drift rates and $\delta_F$ and $\delta_P$ are the volatilities of feed and cattle prices. $dw_F$ and $dw_P$ represents the Wiener processes.

The dataset of $P$ and $F$ will be validated if it follows a geometric Brownian motion (GBM). The GBM process is mostly assumed as a model for various quantities such as stock prices, natural resource prices, and the demand growth of some products or services (Marathe & Ryan, 2005). The GBM process is also used as a model for pricing options.

A variable $Y_k$, $0 \leq k \leq \infty$, follows GBM process with drift parameter $\mu$ and volatility parameter $\sigma$, if, for all nonnegative values of $k$ and $t$, the random variable $Y_{k+t} / Y_k$ is independent of all values of the variable up to time $k$ and if in addition, $ln\,(Y_{k+t} / Y_k)$ has a normal distribution with mean $\mu t$ and variance $\sigma^2 t$, independent of $k$, where $\mu$ and $\sigma$ are constants. To check if a stochastic process follows GBM, there are two assumptions to be satisfied: (1) normality of the log ratios ($w(k)$) with constant mean and variance, where $w(k)=ln\,(Y_{k+t}) - ln\,(Y_k)$, and (2) independence from previous data or log ratios are independent of their past values (Marathe & Ryan, 2005). For the assumption of normality, a statistical test of normality

will be conducted for log ratios of both datasets. For the assumption of independence, Student's t-test will be used.

***Asian Option***

The path dependent option to be considered for the net revenue insurance is an Asian option. Options are contracts defined to be the right, but not an obligation, to buy or sell the underlying asset in some specified time interval. Specifically, Asian option is an option whose payoff is dependent on the average of the underlying asset, in this study, the net revenue. The average net revenue is given by

$$J = \frac{1}{t_2 - t_1} \int_{t_1}^{t_2} R(t)dt \quad (4)$$

where $t_1$ is the beginning of the averaging period to be considered and $t_2$ is the end of the averaging period and $R(t)$ is the realization of the net revenue at time $t$. Hence, the payoff of the option is given by $Max\ [0, K - J]$ where $J$ is defined in equation 4. Since the average realization is represented by $J$ then if the strike price, say $K$, is greater than the average realization $J$, its implication would be the obligation of the insurance to pay the difference between $K$ and $J$, otherwise no payment by the insurer would be done (Turvey, 2003). The goal of the Asian option is to ensure that the average revenue of the cattle farmer is within their expected average income, represented by $K$, on the duration of the contract.

For the pricing of the Asian option, different risk-neutral rates are considered in the calculation of premiums. For the time interval, we consider 3 months, 6 months and 12 months.

***Simulation for Pricing Asian Option***

Assuming it was shown that the cattle meat and feed prices follows GBM, then, at expiration ($T$ = 3, 6, 12 months) the net revenue per kilogram at time t is calculated using

$$R(t) = P_t - (\beta / \alpha)F_t \quad (5)$$

where evolution of prices of feed and cattle meat are given by:

$$F_t = F_{t-\Delta t} e^{\left(r - 0.5\sigma_F^2\right)\Delta t + \sigma_F \sqrt{\Delta t} Z(0,1)} \quad (6)$$

$$P_t = P_{t-\Delta t} e^{\left(r - 0.5\sigma_P^2\right)\Delta t + \sigma_P \sqrt{\Delta t} Z(0,1)} \quad (7)$$

where $r$ is the risk-neutral growth rate to be consider, $\sigma_F$ and $\sigma_P$ represents the volatility rate of the feed and cattle meat prices, respectively. $Z(0,1)$ represents a standard normal deviation with mean 0 and standard deviation 1. Substituting the random prices on each day into a time $t$ version of equation 5 generates the time path for the net revenues based on changes in prices.

As shown in equation 4, calculation of the average net revenue requires integration. Since closed form of the integral is not available, it is necessary to discretize equation 4. A tool that is commonly used in approximating the integral is Riemann Sum. This tool will be used in simulating the average net revenue of the cattle farmers. Using Riemann sum, equation 13 can be approximated using

$$J = \frac{1}{t_2 - t_1} \sum_{t_1 \le t \le t_2} R(t). \quad (8)$$

The study will use the monthly farmgate price of cattle for slaughter in Region IV-A CALABARZON from January 1993 to September 2018 from the Philippine Statistics Authority (PSA). Another data set is the market price of cattle feeds in Cavite obtained from the record of sales of Degz

Poultry Supply and General Merchandise, an establishment offering farm animal feeds including cattle feeds, which has homogeneous pricing system in all six branches across the province. Data obtained were from February 2015 to October 2018 market prices. Average prices throughout the month were used as the market price on that specific month to match the data from PSA. Lastly, the target weights of calves based on Kennedy (2010) will also be used.

The study focuses on the net revenue of each kilogram of cattle meat with an assumption that only one input and one output is being considered. With this assumption, the study limits the cattle being considered to cattle for slaughter or cattle killed for their meat so that the only output being considered is its meat, and a specific diet recommended and being used by some farmers who uses Pullet Developer Pellet Economical (PDP Eco) so that only one feed will be the input by the farmers with assumption that the forage they eat will be the abundant grass so that it will not contribute to the cost of feed and thus, the only input being considered is the amount of feed being consumed by the cattle.

## RESULTS AND DISCUSSION

We determine the parameters for the net revenue R per cattle, and the prices of the cattle meat and cattle feed were tested to follow a GBM process. With that, we price the insurance, in the form of an Asian Option, with different combinations of time interval, risk free rates and initial prices.

### *Cattle and Feed Price Model*

Pearson's product moment correlation test was used to determine if multicollinearity exists between the cattle's age and weight. The test shows that the correlation between the cattle's age and change in cattle's weight is 0.9999977. This implies that there is a very strong and direct correlation between the two variables and thus, the two variables can be a predictor of one another. Other assumptions of a linear regression model were also satisfied. With the weight of the cow as dependent variable and the age as the independent variable, we now formulate the linear regression model. Based on the results of linear fitting through the aid of R software, the linear regression model was given by $y = 19.335968x + 57.964427$ this implies that $\alpha = 19.335968$. Also, as shown in Figure 1, the linear regression model captures the behavior of the actual data for the cattle weight.

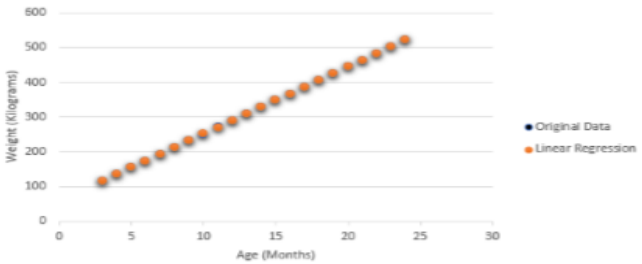


**Figure 1**. Scatter plot of original dataset vs linear regression model for age and weight of cattle.

Also, the amount of PDP Eco being consumed by the cows is 0.72 kilograms each day or 21.6 kilograms for a month. This diet was suggested by the seller of the feeds and is also practiced by most of the buyer of this feed in Degz Poultry Supply and General Merchandise. Hence, we have $\beta = 21.6$.

Now, the two prices must satisfy the assumptions of a GBM process. Recall that the assumptions of Geometric Brownian motion are: (1) normality of the log normal ratios and (2) independence of each log normal ratio from the past log normal ratios. Using the Jarque-Bera tests, results shows that the log normal ratios of the feed prices and the cattle meat prices are both normally distributed. For the log normal ratios of the market prices of feed and of cattle meat at time $t$ and $t+1$, using Student's t-tests show that the log normal ratios of the market prices of feeds and cattle meat are independent from their previous data. Therefore, the two prices satisfy all the assumptions of a GBM process.

Since the assumptions of GBM were satisfied by both datasets, drift and volatility rates can now be calculated using the means and variances of the log normal ratios. With the aid of Microsoft Excel, the calculated values are shown in Table 1.

**Table 1**. Drift rates and volatility rates of the cattle prices and feed prices.

| | **Cattle Prices** | **Feed Prices** |
|---|---|---|
| Drift Rates | 0.002948 | 0.008852 |
| Volatility Rates | 0.011769 | 0.013721 |

***Net Revenue Insurance Pricing***

We first consider the strike price, $K = 87.24$, which is a result of computation of the average net revenue form the data gathered from Philippine Statistics Authority and Degz Poultry Supply and General Merchandise. This will be used to calculate the Asian option payoff on different cases. Cases to be considered are combination of risk-free rates, 0.2948%, 0.8852% and 0.5900%, and time intervals, 3 months, 6 months, and 12 months. A computer program using SciLab was used to implement Monte Carlo simulations with 10,000 runs.

Based on Table 2, with $F_0 = 23$ and $P_0 = 100$, the price of the Asian Option is decreasing as we increase the time to be considered from 3 months to 6 months and to 12 months. This shows that as time goes by, the possibility of achieving the target average revenue gets higher, thus, the less the premium price is. Also, as we increase the risk-free rate r the price of the Asian Option also decreases. This is due to the time value of money.

**Table 2**. Price of the Asian Option, $K = 87.24$, $F_0 = 23$, and $P_0 = 100$.

| **Risk-free rate ($r$)** | **Time of Expiration ($T$) (in months)** | **Price of the Asian Option** |
|---|---|---|
| 0.002948 | 3 | 7.4270958 |
| 0.002948 | 6 | 7.0027168 |
| 0.002948 | 12 | 6.2147896 |
| 0.005900 | 3 | 7.025052 |
| 0.005900 | 6 | 6.1885427 |
| 0.005900 | 12 | 4.6423406 |
| 0.008852 | 3 | 6.6581479 |
| 0.008852 | 6 | 5.4133251 |
| 0.008852 | 12 | 3.2076662 |

**Table 3**. Price of the Asian Option, $r = 0.0059$ and $T = 6$ months.

| Strike Price ($K$) | Initial Feed Price ($F_0$) | Initial Cattle Price ($P_0$) | Price of the Asian Option |
|---|---|---|---|
| 87.24 | 20 | 100 | 3.5812314 |
| 87.24 | 23 | 100 | 6.1885427 |
| 87.24 | 25 | 100 | 7.9621882 |
| 87.24 | 23 | 95 | 11.089452 |
| 87.24 | 23 | 105 | 1.5306518 |
| 80 | 23 | 100 | 0.3540736 |
| 87 | 23 | 100 | 5.9495179 |
| 90 | 23 | 100 | 8.840046 |

Suppose that the risk-free rate, $r$, is 0.0059 and the term of the insurance is $T = 6$ months. The price of the Asian Option on different cases of initial feed price, initial cattle price, and strike price are given in Table 3. It is observed that increasing the initial market price of the feed results to an increase in the price of the Asian Option. Note that an increase in the feed price leads to a decrease in revenue. Hence, if at the start of the insurance contract, the initial feed price is high, the average net revenue may not be as high, leading to a higher premium price for the insurance.

An increase in the initial market farmgate price of the cattle results to a decrease in the price of the Asian Option. Note that an increase in the cattle price leads to an increase in revenue. Hence, if at the start of the insurance contract, the initial cattle price is high, the expected average net revenue is also high, leading to a cheaper premium price for the insurance.

Lastly, it is also shown that an increase in the value of the strike price will also increase the price of the Asian Option. Note that the strike price represents the target average net revenue. Hence, if the strike price is high, the possibility that this target average net revenue may not be attained in the duration of the insurance. Thus, leading to a high premium price.

## CONCLUSION AND RECOMMENDATIONS

In this study, we are able to design an Asian Option, with the net revenue of the cattle farmers as the underlying asset, using the Principle of Net Revenue, as defined by Calum Turvey. Also, the study shows that the market price of Pullet Developer Pellet Economical and the farmgate price of cattle in Region IV-A (CALABARZON) follow a Geometric Brownian motion process. Using the feed as input, the model for the net revenue per cattle is formulated and used to design a net revenue insurance in the form of an Asian option. This insurance gives protection to cattle farmers against market risks that can lessen their average net revenue. It is observed that the price of the insurance has inverse relationship with the risk-free rates, and the initial farmgate price of cattle meat, at the same time, a direct relationship with the initial market price of the feed considered and the strike price.

For further study, it is recommended to use models for the Net Revenue with multiple inputs to consider other expenses of cattle farmers such as supplements, labor, if any, and utilities. For the feeding method to be considered, it is suggested to consider other emerging beef cattle diets to cope up with the trend in the cattle industry, they might consider feeding method like "supak" method, a force feeding scheme, that is famous in Batangas and is highly adopted by other provinces in the country (Agrimag, 2019). A more general data set (e.g., data set for the whole country, price of feeds in other parts of the country) can also be studied for better inclusivity of the insurance that will be designed.

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**STATEMENT OF AUTHORSHIP**

Both authors conceptualized and designed the study. The first author gathered the data, conducted the simulations, analyzed the data, and prepared the manuscript. The second author made recommendations in the conduct of simulations and analysis of data, and reviewed and edited the final paper.

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