

# *Study on the Pricing of Crop Income Insurance*

## —A Case Study of Maize in Guizhou Province

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**Abstract**—Agricultural income insurance can simultaneously disperse the natural and market risks faced by farmers in the production process and stabilize farmers' expected income. However, the research on agricultural income insurance in Guizhou Province is still in the preliminary exploration stage, and the research on the formulation and implementation of the core program of crop income insurance pricing is weak. This paper focuses on the pricing methods of crop income insurance in Guizhou Province, and provides a strong guarantee for the healthy and sustainable development of agricultural income insurance. In this paper, the corn in Guizhou Province is taken as an example. First, the linear sliding average method is used to eliminate the trend term, and kernel function is used to estimate the distribution. Then use the Copula function to connect the two edge distributions, and finally calculate the premium based on the Monte Carlo simulation 10, 000 times. There is a weak negative correlation between the price risk of corn in Guizhou Province and the risk of yield, which results the income risk less than the sum of production risk and price risk.

**Keywords**—Income insurance; Kernel function; Copula model; Monte Carlo; Linear sliding average method;

### I. INTRODUCTION

Agricultural insurance is an important tool to reduce agricultural disaster losses, stabilize food income, and diversify agricultural risks. The "No. 1 Document" promulgated by the Central Committee in 2004 clearly stated the clear requirements for the development of agricultural insurance. Different regions will carry out insurance pilot work on major food crops and cash crops according to local conditions. In the early days of reform and opening up in Guizhou Province, problems such as poor natural conditions, fragile ecology, low cultivated land resources, and shortage of food supply have affected the sustained and healthy development of the economy and society. Corn is the main food crop and feed crop in Guizhou. Its planting area is stable at around 100hm<sup>2</sup>, and the output has increased from 600,000 tons in 1949 to 3.191 million tons in 2015, which is 5.3 times that of 1949. The proportion of total grain output has been in 1949, 21% increased to 26.77% in 2015. Especially in the past 10 years, the rapid development of animal husbandry in Guizhou, Guizhou's independent innovation and the large-scale promotion and cultivation of high-quality protein corn have achieved remarkable results. Therefore, it is of great significance to carry out corn income insurance in Guizhou Province and reduce the income risk of farmers, which is a key

to the development of precision poverty alleviation work in Guizhou Province.

In response to the problem of determining the income insurance premium rate of crops, relevant scholars at home and abroad have conducted relevant research. First, research on the advantages of foreign crop income insurance: Goodwin(2004) and O 'donoghue (2010) showed that in areas with high incidence of natural disasters and accidents, farmers tend to reduce planting area to reduce losses. Income insurance can effectively transfer and spread agricultural risks, so large-scale promotion of income insurance can encourage farmers to increase the planting area. Secondly, in terms of crop income insurance pricing: Studies such as Tejada(2008) and Ghosh (2008) calculated the conclusion that production risk and price risk are negatively correlated through Copula method. In terms of the single production risk of production insurance, Copula method takes into account the negative correlation between the two and reduces the rate and compensation of income insurance.

The domestic exploration of crop income insurance is relatively late, and the research results are relatively thin. First of all, the research on the advantages of crop income insurance in China: According to the research results of xiao yugu and wang ke (2013), crop income insurance is more suitable for the needs of farmers than merely agricultural production insurance and price index insurance, and can guarantee farmers to obtain stable expected income. Meanwhile, the development of crop income insurance can effectively promote the innovation of agricultural insurance. Secondly, in the aspect of crop income insurance pricing: Zhang Qiao, Wang Ke, Li Yue (2015) and other research designed the Hebei wheat income insurance plan, determined the rate of wheat income insurance in Hebei Province, and supported crop income insurance. Compared with traditional production insurance, it has a higher level of safety, and the income insurance rate level is lower than the production insurance rate.

Agricultural insurance is divided into two categories: production insurance and income insurance [5]. Production insurance is more common in crop insurance. In the operation activities generated by farmers, the output caused by natural disasters or accidents is lower than the output in the insurance contract, and insurance company gives compensation, but the insurance company does not cover the fluctuation of crop prices risk. For income insured, as long as their income is lower than their insured income, the insurance company will

compensate, regardless of the single factor price, the risk caused by price changes, and the loss caused by the combination of the two, the insurance company will give Compensation. When an accident within the scope of liability specified in the insurance contract occurs, the insurance company will pay the difference in income when the actual income of the farmer is lower than the guaranteed level of income [2]. Crop income insurance is more powerful than production insurance to avoid risks, so insurance income insurance can make farmers' income more stable.

## II. DATA AND METHODS

### A. Data and detrending processing

The corn yield data of Guizhou Province from 1994 to 2016 is extracted from the China Statistical Yearbook. The situation of corn price data is more complicated, and there are two types of data: actual spot price data and futures price data. Due to the relatively late establishment of the futures market, the existence of data can not effectively reflect the price of the spot. Therefore, the actual price data is used in this paper. From 1994 to 2016, the price of corn in Guizhou Province was taken from the "Compilation of National Agricultural Costs and Revenues". This paper analyzes the average yield and annual price data of corn in Guizhou Province. In this paper, the time series data is detrended first, and the linear sliding average method is used to divide the output into two parts: the trend quantity of yield and the random quantity of yield. The price is divided into the trend amount of the price and the random amount of the price. The trend amount reflects the increasing expected output and price under the influence of external factors. The random quantity reflects the impact of agricultural risk. The larger the absolute value, the greater the degree of deviation of the data from the trend, indicating that the corn in the year the impact of various types of agricultural risks on the growth process is more severe.

### B. Corn income insurance pricing model

The kernel function is widely used in non-parametric estimation. In order to ensure the accuracy of the kernel function estimation, some limiting conditions are usually added to the kernel function  $K(\cdot)$ , such as continuity, symmetry, non-negativeness, boundedness and the like. The Gaussian nucleus (Gauss) satisfies the nature of the defined conditions. Therefore, the Gaussian nucleus is selected as the data for the price and yield risk of crops. The choice of the density of the core density has a significant effect on the accuracy of the estimator. The window width  $h_n$  is too small, the estimated tail random interference increases, and the variance of the curve fitting is increased, so that the fitted curve is not smooth enough. Too large will lead to an excessive averaging of the probability density, masking the volatility in the sequence and making the characteristics of the data lost. In this paper, we choose the continuous Gaussian kernel as the kernel function, Therefore, the optimal choice of minimization integral mean square deviation method was selected to evaluate the pros and cons of  $h_n$ .

The Copula function has a very rich family of functions. The copula family functions are usually divided into two broad

categories, the Elliptical Copula function and the Archimedean Copula function. Archimedean Copula has an advantage in assessing extreme tail correlations. The perspective of an insurance company, tail correlation is the key to risk management; insurers may be more interested in the correlation between production and price in extreme weather or market activity [1]. For this reason, Archimedean Copula is becoming more and more popular in the field of risk management. Common types are Clayton Copula function and Frank Copula function. This article takes corn in Guizhou Province as an example, taking into account the dual risks of production and price, the risk assessment and determination of corn. The linear sliding average method is used to analyze the time series and price time series of corn yield, and the kernel density is used to estimate the distribution. Then select the most suitable Copula model by calculating various correlation coefficients. The copula function can construct flexible multivariate distributions without the need to assume the form of multivariate joint distribution, so Copula functions are widely used in various fields. In the financial sector, investors typically choose low-relevant assets into products to reduce risk, and use simulation to generate random numbers to calculate risk values to measure risk. In the field of agricultural insurance, it is mainly used for insurance pricing, such as full farm income insurance, agricultural portfolio pricing, and crop income insurance pricing [6].

## III. CORN INCOME INSURANCE PRICING

According to the linear sliding average method, non-parametric method distribution fitting, Copula function and Monte Carlo simulation method introduced above, we process and analyze the time series data and price time series data of annual corn yield in Guizhou Province. Based on this, the insurance pricing problem of corn income is solved. Using software for data analysis and solving the model, the software used is MATLAB 2014a, Eviews8.0, and the empirical analysis process is as follows.

### A. Determination of the joint distribution

We first calculate the trend output based on corn production. The trend line is smoother than the original production line and the trend is more stable. Therefore, it can be reflected that the trend output is the result of better separated risk production. In order to investigate the characteristics of random fluctuation series of yield risk, we need to use Eviews8.0 software to test its stability, and the t-statistic and p-value obtained by ADF test on the risk yield sequence. The value of t-statistic is -4.87. Since the P value is 0.00, the null hypothesis that the unit root exists is rejected under the level of significance. The yield risk no longer contains the trend item, and the trend item is well separated from the risk production. According to the kernel function selection window width method, the risk data is substituted into the kernel function window width  $h_n = 55.48$ . Substituting it into the definition gives the cumulative distribution function of the sample. The kernel function can better fit the yield risk data.

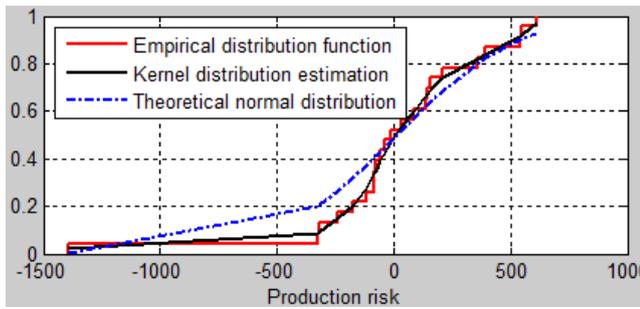


Fig. 1. Cumulative distribution function of yield risk

Similarly, we use the linear sliding average method to fit the original price to obtain the trend price. The processed data is more suitable for risk analysis than the original data.

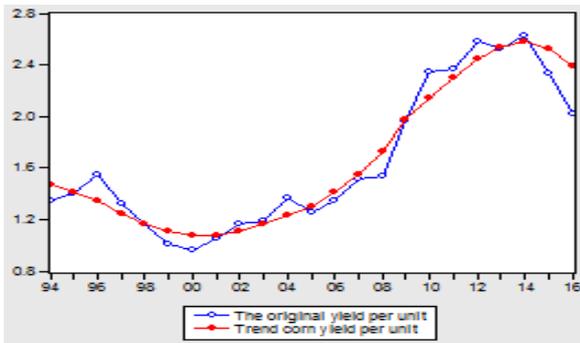


Fig. 2. Price series linear sliding average method fitting map

In order to investigate the characteristics of the price risk stochastic volatility sequence, we need to use Eviews software to test its stability, the t statistic obtained by ADF test on the risk price series and the p value, the value of t statistic is -2.1, The P value is 0.03, so the null hypothesis that the unit root is rejected under the 5% significance level, the price risk no longer contains the trend item, and the price trend item and the risk price are sufficiently separated. According to the kernel function selection window width method, the risk data is substituted into the kernel function window width for calculating the yield risk  $h_n = 0.0913$ . In the determination of the cumulative distribution function of the kernel function, the Copula method is used to analyze the relationship between the two. According to the cumulative distribution of the yield and price risk of the Gaussian kernel function, the Copula function is used to determine the joint distribution parameters and the Kendall rank correlation coefficient  $\tau$ , Spearman  $\rho_s$  rank correlation coefficient, and calculate the squared Euclidean distance of the fitted copula function and the empirical copula function[4]. In this paper, we choose Gaussian Copula function and t-Copula function, Frank Copula three copula functions to fit, choose the optimal copula function according to the minimum square Euclidean distance, and finally get the estimated result of copula function as follows:

TABLE I. COPULA ESTIMATION RESULTS OF JOINT DISTRIBUTION

Copula type	parameter	Kendall- $\tau$	Spearman- $\rho$	Euclidean distance
Gaussian	-0.2152	-0.1381	-0.1381	0.0401
t	-0.2913	-0.1882	-0.1882	0.0443
Frank	-1.8355	-0.1974	-0.1974	0.0485

From Table we can see that the squared Euclidean distances of the three copula functions are from small to large: Gaussian Copula, t-Copula function, Frank Copula. Therefore, Gaussian Copula is closer to the true distribution, so we choose the Gaussian Copula function as a model for the joint distribution of risk production and price. According to the calculated Kendall rank correlation coefficient  $\tau$  and Spearman  $\rho_s$  rank correlation coefficient of Gaussian Copula function, there is a negative correlation between corn yield risk and price risk.

### B. Rate determination of income insurance

Corn income risk is affected by both production risk and price risk. The joint distribution is fitted by the Gaussian-copula function. The Monte Carlo method is used to perform repeated sampling based on the Gaussian-copula function 10000 times, and the 10000 sets of random numbers obtained by sampling are substituted into the cumulative function of the Gaussian kernel function. Through the inverse function, the data of expected yield and price risk are obtained. With 2016 as the reference year, the expected risk is added to the 2016 trend item. The expected corn income is equal to the expected yield of corn multiplied by the expected price of corn. The net rate of income insurance is determined by the expected income into the income insurance pricing formula. Accurate measurement of premium rates is critical for insurers, and determines whether the insured is willing to insure and whether the insurer can continue to operate. The pricing of income insurance is to compensate the direct economic loss of the farmers when the actual yield and price changes cause the crop income to change less than the contracted expected insurance amount. At the same time, in order to reduce the frequent compensation for high frequency losses to farmers, and to alleviate the moral hazard of the insurance industry, the insurance level will be set. The general level of protection will be set in the interval [80%, 100%], the level of protection is too low, only in extreme cases, farmers will be compensated, farmers are not willing to participate in insurance, the level of protection is set too high, will increase the cost of agricultural insurance Therefore, you should choose the appropriate level of protection.

TABLE II. NET RATE OF CORN INCOME INSURANCE

Level of protection	Corn income insurance
100%	10.07%
95%	8.51%
90%	4.13%
85%	1.03%
80%	0.07%

This paper uses the price data of corn yield and corn in Guizhou Province to realize income insurance pricing. The conclusions are as follows: First, the nonparametric Gaussian kernel function can better fit the distribution of risk data. The straight line smoothing method is used to detrend the original

data, and the risk data of the trend item is removed from the time series data. The data is fitted to the Gaussian kernel function. By comparing with the empirical distribution, the kernel function can better handle the fat-tail distribution. Secondly, according to the Gaussian-copula function, the results of the joint distribution correlation between yield risk and price risk show that the Kendall rank correlation coefficient and the Spearman rank correlation coefficient are -0.1381 and -0.1381, respectively, indicating the negative correlation between yield risk and price risk, when corn yields increase, the price of corn will decrease and income insurance will have a natural hedging effect, which will ensure the stable income of farmers. Third, the effective agricultural data collection system is the core factor for the accurate pricing of crop income insurance. The data collection of corn price in this paper comes from the "National Agricultural Product Cost-benefit Data Compilation", which cannot effectively reflect the changes of different varieties of corn prices. The government has established an effective agricultural futures trading platform to better capture price fluctuations. When the guarantee level is 85%, the net rate of corn income insurance is 1.03%, which provides a theoretical reference for the development of corn income insurance in Guizhou Province [3].

#### IV. SUGGESTION

Based on the relevant conclusions of corn pricing in Guizhou Province, this paper summarizes the experience of foreign countries in successfully implementing income insurance, analyzes the development status of corn crops in Guizhou Province during recent years, and on this basis, this paper proposes three suggestions for the development of corn income insurance in Guizhou Province:

First, Guizhou Province should carry out income insurance in different regions. There are 9 prefecture-level cities in Guizhou Province. The two cities with the highest corn production are Bijie City and Zunyi City. Pilot corn income insurance will be given priority in these two major maize producing areas, first to the county as a unit, and then to the city. Income insurance should design different levels of protection, not only meet the needs of farmers with different risk preferences for risk management and enhance the willingness of farmers on purchasing insurance, but also reduce the operating costs of insurance companies to implement income insurance and improve the income of insurance companies.

Second, Guizhou Province should actively establish a large agricultural database. The insurance company's accurate pricing of income insurance rely on the output and price data of crop history in Guizhou Province. The prices of different types of agricultural products are different. Insurance companies need to consume a lot of manpower and resources to collect data, thus improving the operating costs of insurance companies. The Guizhou provincial government should actively establish an agricultural big data trading platform. Through convenient data sharing, it not only provides an effective channel for insurance companies to collect data, but also provides a guarantee for accurate pricing of income insurance.

Third, Guizhou Province should establish a scientific income insurance subsidy mechanism. The government's construction of a scientific income insurance subsidy mechanism and the rational allocation of central and local subsidy ratios are the keys to promoting the development of crop income insurance. The corn industry in Guizhou Province faces the dual risks of production and price. Because of the negative correlation between production and price, the two variables can be "naturally hedged", the risk of income insurance is less than the sum of production risk and price risk. Therefore, the Guizhou Provincial Government should actively promote the development of income insurance and provide strong support for the sustainable development of agricultural health in Guizhou Province.

#### V. CONCLUSION

In summary, Guizhou Province is located in the Yunnan-Guizhou Plateau, and the climate is relatively harsh. It is more likely to cause crop planting risks due to natural conditions, however, the successful implementation of crop income insurance can well solve the needs of China's farmers' income risk management. This paper takes Guizhou corn as an example, and combines the data of corn yield and price records in Guizhou Province to discuss the issue of corn crop income insurance pricing. The research on agricultural income insurance in Guizhou Province is still in the preliminary exploration stage, and the research on the formulation and implementation of the core program of insurance product income insurance pricing is weak. Guizhou Province should first be piloted and promoted in the main producing areas. The government should improve the large database system and the scientific subsidy mechanism to provide a strong guarantee for the healthy and sustainable development of income insurance.

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