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# OPTIMAL INSURANCE PRICING FOR A NOVEL FARMING CONTRACT MECHANISM

***Abstract.*** *This paper analyzes the optimal production and pricing decisions in a novel contract mechanism consisting of an insurance company, a farmer and a futures company. We call the novel farming contract mechanism as "insurance + futures" mechanism (IFM). The key feature of IFM is to fully guarantee the farmer's profits, motivate the insurance company to participate in the mechanism and control the risk of VaR (Value-at-Risk) faced by the futures company. We study the optimal production quantity for the farmer, the optimal premium rate for the insurance company and the optimal strike price for the futures company. The effects of parameters on the optimal decisions of the production quantity and strike price are analyzed. Our analyses provide managerial insights on the contract terms of IFM through the numerical illustrations including agricultural production of wheat, corn, soybean. We find that the farmer's profits in IFM are higher than the uninsured case. The expected return of the insurance company is positively correlated with the standard deviation of futures basis. We suggest the insurance company to purchase the futures options with a higher standard deviation of basis for hedging risk.*

***Keywords:*** *optimal insurance pricing; Value at risk (VaR); insurance agreement price.*

**JEL Classification: G22,G31,G32**



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## 1. Introduction

Agricultural insurance is an important part of IFM. Scholars have studied the effects of agricultural insurances on agricultural production through theoretical and empirical research, such as planting structure (Wu, 1999; Young et al.,2001) and environmental quality (Chang and Mishra, 2012), output (Xu and Liao, 2014), welfare (Chantarat et al. 2017). In the practical application of agricultural insurance, some scholars have studied price fluctuation risk hedging with insurance (Mahul,2003; Ranganathan and Ananthakumar, 2017), and optimal strategies of the supply chain in contract farming (Lu et al.,2017; Peng and Pang, 2019). Some scholars explored the impacts of agricultural index insurance on agricultural production, such as weather index(Salgueiro,2019; Tang et al., 2019) and index insurances for grasslands(Vroege et al. 2019), also the design of agricultural index insurance contracts(Brick and Visser,2015). As we know, when farmers sign an insurance contract with the insurance company, the risk is completely transferred to the insurance company. However, agricultural production has high price and demand uncertainties. Many insurance companies lack the enthusiasm to engage in agricultural insurance business.

In view of the defects in agricultural insurance, scholars advocate the use of futures options to transfer agricultural risk to financial markets (Meliyara and Javier , 2017; Radha and Balakrishnan, 2017). The futures and options market stabilizes and improves farmers' income, effectively transfers price risk and improves the functions of agricultural insurance and crop futures market (Broll et al., 2013; Sharma, 2016). Also, the futures and options market creates flexible and diverse hybrid cash contracts that can meet different needs for each subject of contract farming (Kemp,1996). The U.S. government has also explored the practical activities of using futures to improve the government's agricultural economic policies. In 1985, the U.S. food safety act proposed to expand the direct and indirect use of futures and options among farmers (Heifner and Wright, 1989). In the study of agricultural "insurance + futures" model, scholars mainly focus on the risk dispersion function of agricultural insurance and the price discovery function of agricultural product futures options (Anderson, 2010), believing that it can protect farmers' income (Darnhofer et al., 2010), resist the risk of price decline (Lotan et al., 2004) and carry out research on the pricing decision of an entity, such as using the improved BS model to calculate crop price insurance premium (Ye et al., 2017). Although the "insurance + futures" model has been greatly



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popularized and applied in recent years, few scholars have conducted research on how to build the interest connection mechanism under the "insurance + futures" model. In fact, subject to factors such as the correlation between futures market and spot market, the market capacity of agricultural futures trading and systemic risk, the “insurance+futures” pattern is not as perfect as it seems. The key issue is the risk management faced by futures companies, which is the "last mile" in the "insurance + futures" pattern. This paper takes insurance pricing and risk management of futures companies as a whole and further studies the risk management strategy of futures companies.

Different from the traditional agricultural insurance, the agricultural insurance under the "insurance + futures" mode does not exist independently. The agricultural insurance signed by insurance companies and farmers is linked to the agreements between insurance companies and futures companies. In addition, the "insurance + futures" model establishes a market interest compensation mechanism, which can compensate for farmers' losses by market means and avoid the distortion of crop price caused by administrative intervention. Thus, the applying trend of agricultural insurance lies in establishing a reasonable insurance price system. This paper studies the linkage effect between insurance and OTC option prices, and proposes the insurance pricing method in "insurance + futures" model based on the theories of fair pricing and participatory pricing.

In summary, the subjects in the "insurance + futures" pattern are in a chain relationship. In the existing research, scholars have almost independently applied insurance and futures to contract farming and agricultural risk management. Very few studies have considered both insurance and futures in agricultural risk management. This paper mainly includes agricultural insurance and reinsurance, and the risk management of over-the-counter options of futures companies, etc. The research results will provide reference for forming the interest connection mechanism of "insurance + futures" model, promoting benign development and the marketization process of "insurance + futures" pattern.

## 2. Problem description and basic assumptions

### 2.1 Problem description

The "insurance + futures" pattern involves farmers, insurance companies and futures companies, forming a closed cycle of risk diversification and benefits for all parties. Farmers or agriculture-related enterprises purchase insurance and transfer risks to insurance companies. The insurance companies then buy the



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over-the-counter options of futures from risk management subsidiary for "reinsurance". The risk management subsidiary finally enters the futures market to hedge the OTC options and transfer the risk to the futures market.

This paper studies the problems of the insurance agreement price, optimal production volume and premium rate between farmers and insurance companies under the "insurance + futures" model. In the agricultural production stage, farmers negotiate with the insurance companies to determine the insurance agreement price and insured production volume. If the market price is lower than the agreement price during the insurance period, farmers will receive insurance compensation. Considering that insurance companies are faced with random market price risk after the end of production, they sign European put options with futures companies to realize reinsurance. Futures companies achieve reasonable risk control by measures of risk management. When the market price is lower than the agreement price, the insurance companies will accept the farmers' claims. At the same time, if the futures price is lower than the strike price, the futures companies will compensate the insurance companies for the price difference. The agricultural insurance lapses when the market price is higher than the agreement price. This paper assumes that the futures company dominates the option strike price to minimize its VaR; Insurance companies can adjust the premium rate appropriately to ensure the maximization of farmers' income without loss; Farmers determine production volume to maximize their profits.

**2.2 Basic assumptions**

Before modeling, make following assumptions:

(1) To ensure farmers income $\Pi_f$ maximum as the prerequisite, assuming that the insured amount $q$ is determined by farmers. Once $q$ is determined, the farmer's production volume is also recorded as $q$. Assume that the production cost of farmers $C(q)$ satisfies $C(q)' > 0$,$C(q)'' > 0$. Based on the study in Ye et al. (2017), the cost function is assumed to be $C(q) = c_0 + c_1 q + c_2 q^2$, where $c_0$ is the fixed cost; $c_1 q > 0$ is the input cost of producing agricultural products; $c_2 > 0$ is the effort cost coefficient of farmers, $c_2 q$ is the effort cost of farmers to produce agricultural products.

(2) After signing the insurance contracts with the insurance companies, farmers transfer the risk to insurance companies. And then the insurance companies transfer the risk to the futures companies with mature professional technology. The insurance companies signed the OTC option contracts with the futures



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companies. This paper proposes that the strike price of OTC option $k$ is determined by futures companies.

(3) The strike price of over-the-counter options signed by insurance companies and futures companies (the cost of purchasing options$\varphi$) is determined by using B-S option pricing model. According to the Black-Scholes-Merton option pricing model $\varphi = ke^{-rT}N(-d_2) - f_0N(-d_1)$, $f_0$ is the underlying futures price at the beginning of the contract ; $d_1 = \frac{ln\left(\frac{f_0}{k}\right)+\frac{\sigma^2}{2}}{\sigma}$; $d_2 = \frac{ln\left(\frac{f_0}{k}\right)-\frac{\sigma^2}{2}}{\sigma}$. $\sigma$ is the annualized volatility of the underlying asset. Considering that the agricultural production cycle is usually one year, and in order to simplify the calculation, it is assumed that the option maturity $T = 1$and the risk-free interest rate $r = 0$.

(4) Bajo et al., (2014) pointed out the superiority of futures option equivalent to spot option. In this paper, the underlying asset of OTC option was assumed to be the futures corresponding to agricultural product spot, in which the spot price is recorded as $\tilde{p}$ and the futures price corresponding to the spot as $\tilde{f}$. The basis is the difference between the spot price and the futures price of a particular commodity at a particular time and place. Mark $\tilde{\varepsilon}$ as the basis and suppose $\tilde{\varepsilon} \sim N(0, \sigma_{\tilde{\varepsilon}}{}^2)$ with reference to the study by Sakong and Hallam (1993).

(5) In this paper, $\bar{f}$ is used to represent the average futures price. $\Pi_f^i, i = 1,2$ is used to represent the income of farmers in different situations, where $i = 1$ is used to represent the situation of farmers purchasing agricultural insurance and $i = 2$ is used to represent the situation of farmers not purchasing agricultural insurance; $\alpha(0 < \alpha \leq 1)$ is used to represent the premium rate determined by insurance companies.

## 3. Basic model construction

### 3.1 Optimal pricing model for futures company

According to the practical reality of "insurance + futures" model in China, this paper assumes that the agreement price signed by farmers and insurance companies and the strike price of OTC options signed by insurance companies.

**Proposition 1** Based on the principle of fair pricing, the option strike price signed by the futures companies is $k^* = \bar{f}$.



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An analysis of Proposition 1 is given below. In order to avoid the possible losses caused by the decline in the spot price of crops, insurance companies and futures companies sign futures put options corresponding to the spot. The position of the options is $q$ and the insurance companies need to pay the futures companies the option premium $q\varphi$. When the corresponding futures price drops below the strike price $k$, the insurance companies exercise the right so that the futures companies must pay the insurance companies $\left(k-\tilde{f}\right)^{+}q$. Otherwise, the insurance companies give up the right and loses the option premium.

Based on the above analysis, the return function of the futures company can be expressed as

$$\Pi_m = q\varphi - \left(k-\tilde{f}\right)^{+}q \tag{1}$$

As an option seller, futures companies can use professional risk management methods to further transfer price risk to the futures market. This paper chooses to minimize the value at risk (VaR) as the risk management goal of futures companies. That is to say, at the significance level $\eta$, $\mathrm{P}(\Pi_m \leq -VaR)=\eta$ is satisfied

$$P\left\{\left(k-\tilde{f}\right)^{+} \geq \frac{q\varphi+VaR}{q}\right\}=\eta \tag{2}$$

Suppose $Y=\left(k-\tilde{f}\right)^{+}$, the distribution function of $Y$

$$F_Y(y)=P(Y\leq y)=P(\left(k-\tilde{f}\right)^{+}\leq y)$$

Therefore, when $y<0$, $F_Y(y)=0$; when $y\geq 0$,

$$\begin{aligned} F_Y(y) &= P\left(\left(k-\tilde{f}\right)^{+}\leq y\right) \\ &= P\left(k>\tilde{f}\right)P\left(\tilde{f}\geq k-y\right)+P(k\leq\tilde{f})P(y\geq 0) \\ &= F_{\tilde{f}}(k)\left[1-F_{\tilde{f}}(k-y)\right]+1-F_{\tilde{f}}(k) \\ &= 1-F_{\tilde{f}}(k)F_{\tilde{f}}(k-y) \end{aligned} \tag{3}$$

By substituting equation (3) into equation (2), $1-F_{\tilde{f}}(k)F_{\tilde{f}}\left(k-\frac{q\varphi+VaR}{q}\right)=1-\eta$ can be obtained. Therefore, it can be concluded that

$$VaR = qk - q\varphi - qF_{\tilde{f}}^{-1}\left(\frac{\eta}{F_{\tilde{f}}(k)}\right)$$



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Therefore, it is obtained by the first-order condition of the minimum VaR of risk loss

$$\frac{\partial \mathrm{VaR}}{\partial \mathrm{k}} = q(1 - \frac{\partial \varphi}{\partial k} - \frac{\partial F^{-1}(\frac{\eta}{F(k)})}{\partial k}) \tag{4}$$

Suppose $\phi(\mathrm{x})$ represents the density function of the standard normal distribution, and partial derivative of φ on $k$ is

$$\frac{\partial \varphi}{\partial k} = N(-d_2) + \frac{1}{\sigma}\phi(-d_2) - \frac{f_0}{\sigma k}\phi(-d_1) \tag{5}$$

When the futures price follows the geometric Brownian motion $df_t = f_t(\mu dt + \sigma dB_t)$, $lnf_t \sim N(m, v^2)$ where $m = lnf_0 + (\mu - \frac{1}{2}\sigma^2)$, $v = \sigma$. In this case, $F_{\tilde{f}_t}(x) = \Phi(d_3(x))$ where $\Phi(x)$ is the standard normal distribution; $d_3(x) = \frac{1}{\sigma}(ln\frac{x}{f_0} - (\mu - \frac{1}{2}\sigma^2))$. And then

$$F_{\tilde{f}_t}^{-1}(x) = f_0 e^{\phi^{-1}(x)\sigma + \mu - \frac{1}{2}\sigma^2}$$

Substituting $\frac{\eta}{F(k)}$ , we can get

$$F_{\tilde{f}}^{-1}\left(\frac{\eta}{F_{\tilde{f}}(k)}\right) = f_0 e^{\Phi^{-1}(\frac{\eta}{F_{\tilde{f}}(k)})\sigma + \mu - \frac{1}{2}\sigma^2}$$

Further derivation, we get

$$\frac{\partial F_{\tilde{f}}^{-1}\left(\frac{\eta}{F_{\tilde{f}}(k)}\right)}{\partial k} = f_0 \sigma \frac{\partial \Phi^{-1}(\frac{\eta}{F_{\tilde{f}}(k)})}{\partial \mathrm{k}} e^{\Phi^{-1}(\frac{\eta}{F_{\tilde{f}}(k)})\sigma + \mu - \frac{1}{2}\sigma^2} \tag{6}$$

For the random variables $Z \sim \mathrm{N}(0,1)$ satisfy $\mathrm{P}\left(\mathrm{Z} \leq \Phi^{-1}\left(\frac{\eta}{F_{\tilde{f}}(k)}\right)\right) = \frac{\eta}{F_{\tilde{f}}(k)}$, the integral form is

$$\int_{-\infty}^{\Phi^{-1}\left(\frac{\eta}{F_{\tilde{f}}(k)}\right)} \frac{1}{\sqrt{2\pi}} e^{-\frac{y^2}{2}} dy = \frac{\eta}{F_{\tilde{f}}(k)}$$

By derivative again, we can get



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$$\frac{\partial \Phi^{-1}\left(\frac{\eta}{F_{\tilde{f}}(k)}\right)}{\partial k} = -\frac{\eta\sqrt{2\pi}}{F_{\tilde{f}}{}^{2}(k)}\frac{\partial F_{\tilde{f}}(k)}{\partial k}e^{\frac{[\Phi^{-1}\left(\frac{\eta}{F_{\tilde{f}}(k)}\right)]^2}{2}}$$

Substitute $\frac{\partial F_{\tilde{f}}(k)}{\partial k} = \frac{1}{\sigma k}\phi(d_3(k))$into the above equation

$$\frac{\partial F_{\tilde{f}}{}^{-1}(\frac{\eta}{F_{\tilde{f}}(k)})}{\partial k} = -\frac{\sqrt{2\pi}\eta\Phi(d_3)f_0}{k_{\Phi}{}^2(d_3)}e^{\frac{(\Phi^{-1}(\frac{\eta}{\Phi(d_3)}))^2}{2}+\Phi^{-1}\left(\frac{\eta}{\phi(d_3)}\right)+\mu-\frac{1}{2}\sigma^2} \tag{7}$$

Through the test in Figure 3.1, we can get

$$fk = \frac{\partial \varphi}{\partial k} + \frac{\partial F_{\tilde{f}}{}^{-1}\left(\frac{\eta}{F_{\tilde{f}}(k)}\right)}{\partial k} < 1 \tag{8}$$

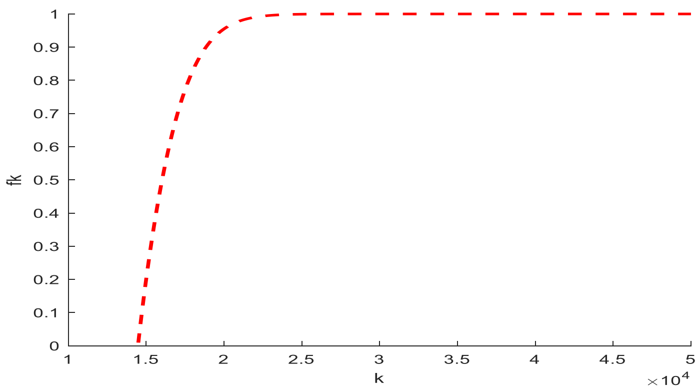


**Figure 3.1. Relation between k and *fk***

As can be seen from Figure 3.1, the first-order condition $\frac{\partial VaR}{\partial k}$ in equation (4) is always greater than 0, that is, *VaR* monotonically increases with respect to *k*. That is, futures companies face downside risks that increase with the strike price. Therefore, the futures companies expect that the strike price is lower. Also, when the futures companies and farms is docked, insurance companies expect the price is higher. Based on the two-party game and the principle of fair pricing, this paper proposes to use the average futures price as the strike price, that is, $k^*=\bar{f}$. In fact, in the practice of "insurance + futures" model in China, insurance companies often take the average price of the underlying futures in two months before the insurance term expires as the agreement price, and the strike price is the same. For example, in the corn project of Liaoning province in 2016, the option expiration settlement price and claim settlement price are the arithmetic average price of the price of



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corn futures C1701 from mid-October to mid-December.

**3.2 Optimal decision model of insurance companies**

After determining the insurance price and the over-the-counter option strike price, this section studies how premiums are fixed by insurance companies. In order to stimulate the enthusiasm of insurance companies, the premium rate $\alpha$ decided by insurance companies should meet the condition that the expected return of insurance companies is not negative. The premium rate corresponding to the expected return of the insurance companies is the fair premium rate.

After the insurance companies sign the insurance with the farmers, the spot price drops due to the sharp fluctuation of the market price of agricultural products, which may cause the insurance companies to pay a large amount of claims in excess of the premiums received. For the insurance contract signed with the farmers, the income of the insurance companies is $\Pi_{c1} = kq\alpha - (k - \tilde{p})^{+}q$. The agreement price is equal to the option strike price $k$. At the same time, the insurance companies sign the over-the-counter option to transfer the compensation risk, and the income is

$$\Pi_{c2} = \left(k - \tilde{f}\right)^{+} q - q\varphi \mathrm{u}$$

The expected return of the insurance companies is

$$\begin{aligned} E(\Pi_c) &= kq\alpha - qE(k - \tilde{p})^{+} \\ &= kq\alpha - qE\left(k - \tilde{f} - \tilde{\varepsilon}\right)^{+} \qquad (9) \\ &= kq\alpha - q\int_{0}^{+\infty}\int_{-\infty}^{k-\tilde{f}}\left(k - \tilde{f} - \tilde{\varepsilon}\right)\cdot f\left(\tilde{f}\right)\cdot f(\tilde{\varepsilon})d\tilde{f}d\tilde{\varepsilon} \end{aligned}$$

It can be seen from equation (9) that the expected earnings of insurance companies increase with the growth of premium rate $\alpha$. In order to improve the enthusiasm of insurance companies, this paper limits $\alpha$ to satisfy$E(\Pi_c) \geq 0$.

**3.3 The optimal production model of farmers**

After the futures companies determine the option strike price and the insurance companies determine the premium rate, the farmers determine the optimal production volume in order to maximize the income. In order to facilitate the comparison, this paper gives the optimal decision-making under the two situations of farmers' participation and non -participation.



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**Proposition 2** In the case of insurance, in order to maximize their expected earnings, the optimal production determined is

$$q_1^* = \frac{\bar{f} - c_1 + s - k\alpha}{2c_2}$$

where $s = \int_0^k (k - \tilde{f}) \cdot f(\tilde{f}) d\tilde{f}$

If farmers do not take insurance, the optimal decision is

$$q_2^* = \frac{\bar{p} - c_1}{2c_2}$$

**Proof:** When farmers choose to buy insurance, farmers need to pay premiums kqα and bear production costs $C(q) = c_0 + c_1 q + c_2 q^2$. When the spot price of crops declines due to market price fluctuations, farmers receive claims from insurance companies. Therefore, farmers' income is expressed as $\Pi_f^2 = \tilde{p}q - C(q) + (k - \tilde{p})^+ q - kq\alpha$.

According to $\tilde{p} = \tilde{f} + \tilde{\varepsilon}$, $E(\tilde{\varepsilon}) = 0$, we get $E(\tilde{p}) = \bar{f}$. Therefore, the expected income function of farmers is

$$E(\Pi_f^1) = \bar{f}q - c_0 - c_1 q - c_2 q^2 + E\left(k - \tilde{f}\right)^+ q - kq\alpha$$

$$= \bar{f}q - c_0 - c_1 q - c_2 q^2 + q\int_0^k \left(k - \tilde{f}\right) \cdot f\left(\tilde{f}\right) d\tilde{f} - kq\alpha$$

From the first partial derivative of $E(\Pi_f)$ with regard to q, we can get the optimal production of farmers

$$q_1^* = \frac{\bar{f} - c_1 + \int_0^k (k - \tilde{f}) \cdot f(\tilde{f}) d\tilde{f} - k\alpha}{2c_2} \quad (10)$$

Without insurance, farmers bear the risk of all market price fluctuations and the expected return is

$$E\left(\Pi_f^2\right) = \bar{p}q - c_0 - c_1 q - c_2 q^2$$

The optimal production volume of farmers without insurance is

$$q_2^* = \frac{\bar{p} - c_1}{2c_2}$$

**4. Study results**

In the study, wheat, corn, soybean and their corresponding futures are selected for numerical analysis. According to the correlation coefficient estimation, setting the



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production cost coefficients being respectively $c_0$=1500, $c_1$=0.5, $c_2$=0.015 [1]. According to the data of three crops in China *Wind* database, the parameters of three futures are calculated, and the results are shown in table 4.1:

**Table 4.1. Estimated parameters of different crops**

| | $\mu$ | σ | $\sigma_{\tilde{\varepsilon}}$ | $\bar{f}$ |
|---|---|---|---|---|
| wheat | 0.1891 | 7.7166 | 71.14 | 2354.9 |
| corn | 0.1239 | 7.4949 | 42.84 | 1832.1 |
| soybean | 0.1212 | 8.0915 | 83.97 | 3144.0 |

Set $y(k) = k - \varphi - F_{\tilde{f}}^{-1}\left(\frac{\eta}{F_{\tilde{f}}(k)}\right)$, so $VaR = q \cdot y(k)$. Based on table 4.1, the relationship between agreement price $k$ and $y(k)$ is shown in figure 4.1:

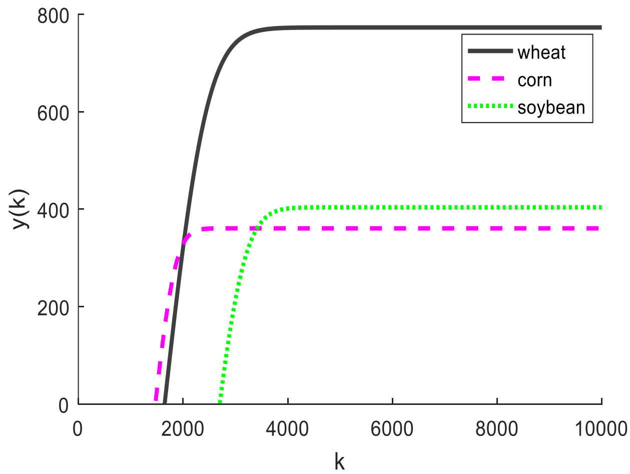


**Figure 4.1. The relationship between agreement price $k$ and $y(k)$**

From figure 4.1, $y(k)$ of the three crops all increase with the growth of k, and are stable at the maximum value when k reaches a certain point. At the same time, $k=\bar{f}$ can be observed near the meddle of the increasing interval, which further confirms the conclusion of proposition 1.

The parameters are substituted into proposition 2, and the relationship between optimal yield and premium rate is shown in figure 4.2:

[1] The three agricultural products selected in the numerical analysis are wheat, corn and soybean. According to the actual data, the production costs of these agricultural products are relatively close. In order to facilitate the comparison, this paper supposes the production cost parameters of the three crops to be the same.



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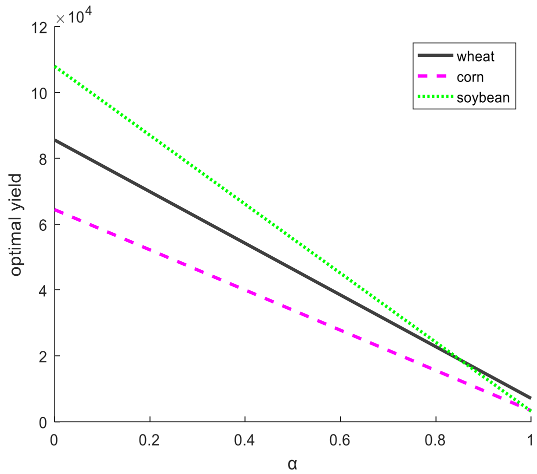


**Figure 4.2. Optimal yield under different crops**

It can be seen from figure 4.2 that the optimal yield q* is a linear decreasing function of premium rate, and the slope coefficient is agreement price. At a lower level of the same premium rate, the optimal yield of soybeans is the highest and that of corn is the lowest. It is not difficult to find that the optimal yield increases with the growth of average futures price. This figure also reflects that it is necessary to buy agricultural insurance for large-scale agricultural products.

Equation (10) is further substituted into the expected return function of the insurance companies, and the relationship between the expected maximum return of insurance companies and the premium rate is shown in figure 4.3:

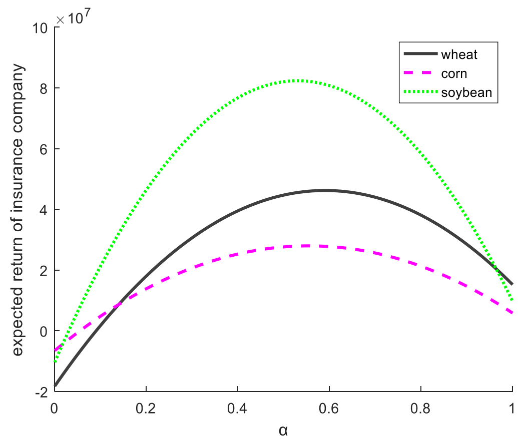


**Figure 4.3. Expected maximum return of insurance companies**



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From figure 4.3, the expected return of the insurance company increases with the growth of premium rate within a certain range, and then decreases after reaching the peak. The premium rates for three crops corresponding to the peak are within 0.5 to 0.6, which doesn't mean higher premium rates are better for insurance companies. This is because once the premium rate is high, it will frustrate the enthusiasm of farmers for production, which leads to the reduction of production capacity and ultimately affects the earnings of insurance companies. Secondly, the insurance companies corresponding to soybean are expected to benefit the most. The insurance premium rates for wheat, corn and soybean are around 9.14%, 5.83% and 3.64% respectively. This indicates that the premium rate reasonably formulated by the insurance companies should be the smallest at the same level of income. High premium will damage the interests of farmers and reduce their enthusiasm to participate in insurance programs. It also shows that the main role of insurance companies in the "order + insurance + futures" model is to protect farmers' returns and defuse the risk of crop price decline. Under this mechanism, insurance companies can cooperate with futures companies to expand insurance varieties and enhance their risk management ability.

The income of farmers is also affected by the premium rate, as shown in figure 4.4:

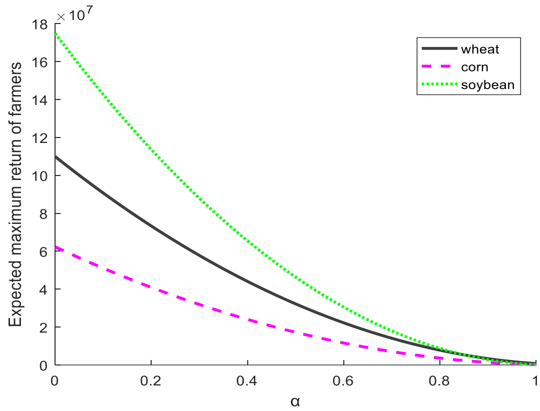


**Figure 4.4. Expected maximum return of farmers under different crops**

The income of farmers decreases with the increase of the premium rate. When the premium rate approaches 1, the expected return of farmers also approaches 0. This shows that high premium rate resulting in the farmers to bear more premium costs, is unfavorable to the farmers. Figure 4.5 indicates the effects of different



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premium rates on farmers' planting income:

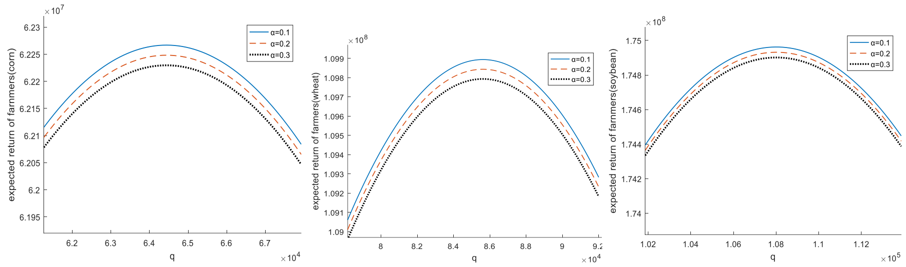


**Figure 4.5. Expected return of farmers under different premium rates**

It can be seen that farmers' income decreases when premium rate increases. This further confirms the conclusion in figure 4.3. Also, farmers do not produce as much as possible. When the production capacity is large, the higher premium expenditure and cost will lead to the reduction of farmers' income. Farmers should choose the best yield to maximize their own returns. In contrast, farmers get the highest expected return from soybean production, followed by wheat and corn.

Considering that the benefits of participating in agricultural insurance are greater than those of not participating in agricultural insurance, farmers generally take an active part in agricultural insurance. The following is an example to compare and analyze the income of farmers under two conditions of insurance and non-insurance.

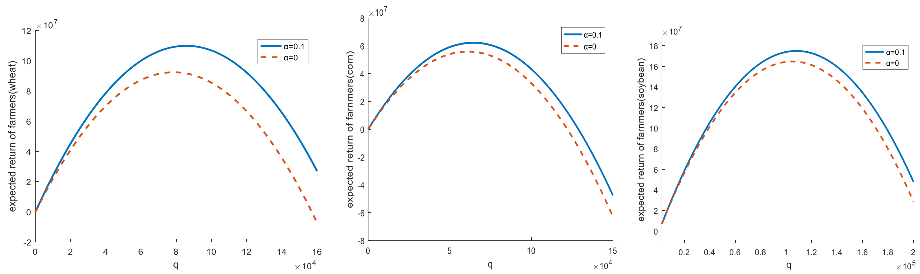


**Figure 4.6.Comparison of the expected return of farmers**

From figure 4.6, the expected benefit of farmers is greater when they cooperate with insurance companies in the three cases. It means that the implementation of "insurance + futures" model can increase farmers' planting income, disperse the risk of crop price fluctuation to futures market, and promote the development of agricultural modernization. Based on this, the government and relevant departments should actively guide farmers to participate in the "insurance + futures" model, enhance farmers' awareness and confidence in insurance, and



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provide financial support to expand the coverage of farmers.

In this paper, the underlying asset of OTC option signed by insurance companies and futures companies is not the agricultural product itself, but the corresponding future. Then, the spot price determines whether insurance companies need to compensate for farmers, and the future price determines whether the over-the-counter options need to exercise. In this way, agricultural insurance and OTC option are not completely consistent because of the basis difference. In order to analyze the effect of different futures varieties under the same agricultural products (with different basis difference distribution) on the yield, the standard deviation of basis is changed while other parameters stay unchanged. Since the volatility of basis not affect the VaR risk of futures companies and farmers' return, the following is the analysis about the impact of different futures varieties on the expected return of insurance companies.

**Table 4.2. Expected return of insurance companies under various basis**

| $\sigma_{\tilde{\varepsilon}\,soybean}$ | $\pi_{c\ soybean}$ $(\times 10^7)$ | $\sigma_{\tilde{\varepsilon}\ wheat}$ | $\pi_{c\ wheat}$ $(\times 10^6)$ | $\sigma_{\tilde{\varepsilon}\ corn}$ | $\pi_{c\ corn}$ $(\times 10^6)$ |
|---|---|---|---|---|---|
| 77.93 | 2.2782 | 66.90 | 3.9131 | 36.84 | 5.3807 |
| 80.69 | 2.2823 | 69.66 | 4.0166 | 38.95 | 5.4313 |
| 83.45 | 2.2892 | 72.41 | 4.0720 | 41.05 | 5.4379 |
| 86.21 | 2.2887 | 75.17 | 4.1947 | 43.16 | 5.4825 |
| 88.97 | 2.2962 | 77.93 | 4.2404 | 45.26 | 5.5044 |
| 91.72 | 2.2969 | 80.69 | 4.3233 | 47.37 | 5.5418 |

As can be seen from table 4.2, the expected returns of insurance companies are positively correlated with the standard deviation of basis. Therefore, insurance companies prefer the future varieties with large basis volatility when signing options with futures companies. The insurance agreements that insurance companies signed with farmers are based on the spot price to determine whether to compensate, and the OTC option agreements negotiated with futures companies are based on the futures price to determine whether to exercise. As there is the basis between spot and future price, taking advantage of basis to obtain revenue is also an incentive for insurance companies. It is suggested that insurance companies should consider not only the impact of the agreement price on their own earnings but also the basis fluctuation to select the best future varieties to increase earnings.



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## 5 Conclusion

This paper studies the mechanism design problem of "insurance + futures" model. Empirical research based on wheat, corn and soybean shows that the return risk of futures companies is positively correlated with the strike price to a certain extent and the strike price should be set as the average future price corresponding to the underlying crop. We suggest insurance companies should not only pay attention to the strike price, but also consider the underlying futures and choose the future varieties with larger basis. "Insurance + futures" model can also be applied to carrying out personalized contract customization corresponding to different regions and products and helping local farmers effectively solve the price risk problem by adjusting the period of insurance, agreement price and time of signing agreements. At the same time, considering that in the absence of corresponding exchange-traded options for some agricultural products, the risk hedging by means of futures simulation and option replication has problems such as high transaction cost and insufficient liquidity, which increases the risk of futures companies, it is suggested to enrich exchange-traded option varieties for agricultural products to reduce the transaction cost and risk.

In the future research, the government can be introduced as the fourth party to study the impact of government subsidies on the expected return or risk of the other three parties. In addition, with the promotion of "insurance + futures" pattern, some regions begin to introduce bank credit financing into this model, and the optimal decision model for introducing bank financing service can be explored later.

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