Optimal agricultural production decision model based on futures hedging

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Abstract: Considering the influence of natural factor on the agricultural production, this paper proposes futures hedging models to solve the optimal production decision-making problems for the risk-averse farmers in cases of basis risk existing or not. Theoretical results show that the marginal cost corresponding to the optimal production equals to the current futures price and the futures position is full-hedge when the natural factor is not accounted for. When the natural factor is not accounted for, the marginal cost corresponding to the optimal production is less than the current value of the futures, and the optimal futures position is less than the optimal expected output (under-hedge) in the case of basis risk not existing. In the case of basis risk and natural factor existing, the marginal cost corresponding to the optimal production is less than the mean value of the spot price. Furthermore, for the prudent farmer, if the spot price is assumed to be a linear function of the futures price and the linear coefficient is smaller than 1, the futures is still under-hedge. In the empirical analysis, the price is assumed to be related to the natural state and the farmer's preference is characterized by a negative exponential utility, this paper deduces the expression of the farmer's utility, then analyzes the influence of decision variable on utility. The empirical results show that using futures for hedging is gainful to improve the farmer's utility. However, the farmer is suggested not to enhance the futures position blindly, but to choose the futures with small basis volatility for hedging.

Keywords: Optimal production decision; futures hedging; risk-averse; negative exponential utility function

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1 Introduction

Small farmers are the main part of China's agricultural production, and also the main contribution force to realize the grain security strategy of our country. Therefore, it is of great significance to improve the production efficiency of small farmers to improve the grain production in China. However, Donovan (2015) pointed out that "small farmers" in the "big market" in a weak position, it is difficult to resist all aspects of risk. When prices of agricultural products decline, farmers have to face with lower prices. While, when the output of agricultural products is surplus and the supply exceeds demand, the agricultural products which farmers get may be wasted in vain. Therefore, in agricultural production, farmers are faced with price risk and demand risk. To reduce these two risks, scholars have put forward some solutions. For example, generally implemented in the practice of protection price mechanism is one of the commonly used methods for farmers to cope with risks. For farmers, this is the most direct and most acceptable contract mechanism, which is also beneficial to farmers. The minimum purchase price not only can help farmers reduce their faces two wholesale market price volatility risk, allowing farmers to concentrate on production, can also help to reduce transaction costs, make the supply chain is more stable. In the long run, the protective pricing mechanism plays a positive role in promoting the development of the order agriculture market. However, the defect of this model is mainly the high default rate of

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the company. According to the survey, in all orders agricultural default event, the leading enterprise default rate reaches 70% (Ma and Xu, 2008). Therefore, scholars have studied how to use game theory to control the behavior of breach of order in agriculture. Bogetoft (2002) presented coordination, incentives, and transaction costs as elements of a design order. Ye and Lin (2012) used revenue sharing contract mechanism to coordinate the supply chain. However, the mechanism of information sharing is also asymmetric. To solve this problem, Lin and Ye (2014) introduced a revenue sharing contract mechanism based on Nash negotiation to coordinate the interests between the company and the farmers. Palsule (2013) put forward a game model of revenue sharing contract, in which supply chain revenue depended on revenue sharing factor. Feng et al. (2014) studied the reliability income sharing mechanism in the N echelon supply chain contract. Although these studies have solved the problem of how to balance and distribute the benefits between farmers and firms to a certain extent, the whole order chain is still in a zero sum game. Risk and income shift between farmers and companies. Therefore, some scholars have proposed methods to transfer part of the risk through the way of government subsidies. Huang et al. (2017) constructed the three stage game model of government, retailers and agricultural enterprises under the subsidy mechanism provided by the government. Subsidies are also widely adopted in large agricultural countries. In China, the government has issued a number of documents on the issue of subsidies for agriculture, rural areas and farmers. But the form of direct subsidy also brings such problems as "cheating subsidies" and "abuse of subsidies", which is not conducive to the healthy development of agriculture. Moreover, direct subsidies may also be difficult to achieve the function of subsidies. Shang (2011) pointed out from economic analysis point of view, in grain subsidy, beneficiary was not grain producers, but food consumers. Castiblanco et al. (2015) studied the subsidy policies of petroleum palm oil and biofuels in Columbia, and found that subsidies were not an effective way to achieve government goals. Based on the above analysis, it can be concluded that farmers are faced with price, demand and natural factor risk in production. The existing order agriculture has problems of a higher default rate and asymmetric information. Government subsidies through external intervention cannot fundamentally solve the problem, then farmers should be innovative with external methods to defuse the risks faced by themselves.

Hedging risk with derivatives such as options and futures is a common method of risk management for decision makers. Ritchken and Tapiero (1986) first introduced option mechanism in inventory research to hedge the fluctuation of product price and quantity fluctuation. Xu (2010) pointed out that under the stochastic output and stochastic demand, the option contract can make the supplier avoid the risk of low demand and low price, and make the manufacturer avoid the risk of high price and low demand. Zhao et al. (2010) proposed a supply chain coordination mechanism based on option and income sharing contract. Li and Li (2001) made a preliminary study on the application of option pricing in evaluating venture capital and guiding the application of contracted agricultural contracts. Shang et al. (2013) took the update time of the demand forecast information as the decision variable, introduce the option ordering, gave the quantity flexibility, and established the two stage productions and order model. But options markets are not well developed in some countries (such as developing countries), and options, especially options based on agricultural products, are rare. At present, there is no formal option for agricultural products in China. There are also many scholars using futures hedging to study production decision problem. The Sandmo (1971) proved that risk averse producers reducing output in the face of uncertain prices to cope with uncertainty risks. When there is a futures market, Holthausen (1979) further studies producer optimal decision problem under the condition of price uncertainty. It is found that futures hedging can improve the firm's output. This also shows that futures hedging can transfer market risks, make up for the shortage of the spot market and optimize the allocation of market resources. Wong (2013) assumes that commodity prices and money forward markets are independent and unbiased, and establishes an exchange rate and commodity futures hedging model to study the optimal production level of firms. Wong (2014) establishes optimal production decision and futures hedging model to hedge the price risk under different delivery methods. Broll (2015) considered the risk on the basis of futures, futures hedging decision problems based on the concept of relying on production. Yang (2011) sets up a market equilibrium model before and after the introduction of futures trading, and examines the conditions for the management of default risk under the "order + futures' model" by model solving and numerical analysis. Although these studies consider the problem of derivative hedging in production decisions, ignoring an important exogenous factor in agricultural production, that is, the influence of natural factors. Natural factors have a great influence on agricultural production. As we know, when farmers are in a bad year, the actual output ratio is expected to yield low. When a good harvest comes, output will increase more than expected. The price of agricultural products is affected by the output to a certain extent, which shows that both the price and the actual output are affected by natural factors. In addition, considering that the development of our country's agricultural futures market is more perfect, there is still a lack of agricultural products option market. Therefore, considering the influence of natural factors, this paper studies how to hedge the price risk faced by farmers by using futures hedging.

Under two frameworks of with or without basis risk, this paper proposes futures hedging model for the risk aversion farmers. In the model, we study the problems of optimal production and the effects of the futures basis risk on the production decision by a comparative analysis. Since the specific form of the utility function is not limited, the results of the study have general applicability. Then, we discuss the effects of risk aversion, futures basis risk and natural factors on the negative exponential utility function. The outline of this paper is as follows. In Section 2, we present the optimal production decision model and give some assumptions. And then, we study the optimal production decision under different cases. In Section 3, a simulation example is given to illustrate the application of the proposed model and analyze sensitivities of the parameters. Finally, we conclude this paper in Section 4.

2 Optimal production decision model

For ease of expression, we call a single farmer or a union of farmers as "the farmer". In this section, we assume that the farmer is risk aversion and present models under different basis risk cases. Then, the uniqueness and existence of the solution of the model are proved, and the conditions of the optimal expected quantity of production and the position of the futures position are given. To begin, we propose some assumptions as follows.

2.1 Basic assumptions and symbolic description

Hypothesis 1. Suppose the futures delivery date is the harvest time of the agricultural products. Let $\tilde{p}$ be the market purchasing price of agricultural products at harvest, and $\tilde{f}$ be the corresponding futures delivery price.

Hypothesis 2. Assume that the futures market is unbiased (i.e. the expected value of the stochastic price on the futures delivery date equals the current value. That is, $E(\tilde{f})=f_0$; If there is no basis of futures price, then the prices of futures and spot are the same on the delivery date, say, $\tilde{p}=\tilde{f}$. We also assume that futures contracts can be traded infinitely.

Hypothesis 3. Suppose farmers have sufficient margin futures. In futures hedging, sufficient margin should be reserved. Otherwise, there will be market to market risk. In fact, farmers can eliminate the insufficient margin concerns by the government. This paper does not consider loaning futures transaction fees.

Hypothesis 4. Assume that the peasant household is risk averse, then its utility function satisfies $U'(\Pi)>0$, $U''(\Pi)<0$, where Π represents the stochastic income of the farmer. In order to avoid the demand risk, it is assumed that the farmer has signed the contract of production and marketing with the company. The contract stipulates that the company will buy all the output of the farmers at the market price, and the specific expected output is determined by the farmers.

Hypothesis 5. At the beginning of the production, the farmer expects the output to be q, and decides to put in production costs according to projected output. The production cost of farmer is related to and expected to yield, which satisfies $C'(q)>0$, $C''(q)>0$. Similar to Ye et al. (2012), we assume that production costs can be written as $C(q)=c_0+c_1q+c_2q^2$, where c_0 is the fixed costs, that is, not to produce, but also to pay costs, such as the farmer's daily consumption, farm tools and so on; $c_1q>0$ is the inputs for the cultivation of agricultural products, such as seeds, fertilizers, pesticides, etc; $c_2>0$ is the cost factor of effort for the farmer, and $c_2q^2>0$ represents the effort costs of farmers to produce agricultural products, including the time and energy spent in production.

Hypothesis 6. Natural random factor $\tilde{s}$ represents the impact of weather on unit projected output. $\tilde{s}<0$ indicates adverse conditions resulting in lower actual output than expected output; $\tilde{s}>0$ represents favorable natural conditions that make actual output higher than projected output. $\tilde{s}=0$ means that natural conditions have little impact, and actual output is comparable to projected output. Thus, the actual yield of the farmer is equal to $(1+\tilde{s})q$. The most extreme natural conditions lead the farmer no gains. So, $\tilde{s}>-1$. Assume that even if a farmer meets a bumper harvest, the actual harvest is at most double the expected output, i.e. $\tilde{s}<1$, and suppose that $E(\tilde{s})=0$.

2.2 The basic model

The farmer needs to determine the optimal expected output q_0^* at the beginning of production, the farmer prepares the production according to the expected output and sells the futures corresponding to the agricultural products in the futures market. Denote futures position as X_0. In the basic model, the effects of natural factors are not taken into account. Under condition of no basis of futures price based on the above assumptions, random gains of the farmer at the end of production are given by

$$\Pi_0 = q_0\tilde{p} - C(q_0) + (f_0 - \tilde{f})X_0 \tag{1}$$

The optimal decision problem of the farmer is described as

$$(P_0).\max_{q_0,X_0} EU(\Pi_0)$$

Because the farmer is risk averse, whose utility function satisfies $U'(\Pi)>0$, $U''(\Pi)<0$, therefore, the optimal decision of the farmer is unique. Under the objective of maximizing the expected utility function, the corresponding first-order conditions are expressed as follows:

$$EU'(\Pi_0^*)(\tilde{p} - C'(q_0^*)) = 0 \tag{2}$$

$$EU'(\Pi_0^*)(f_0 - \tilde{f}) = 0 \tag{3}$$

Adding Equation (2) to Equation (3), it yields $EU'(\Pi_0^*)(f_0 - C'(q_0^*)) = 0$, then we have

$$C'(q_0^*) = f_0 \tag{4}$$

Then the optimal production decision can be obtained according to the cost function of $q_0^* = \dfrac{f_0 - \alpha_1}{2\alpha_2}$.

Furthermore, based on Equation (3) and the unbiased futures market, it follows that

$$Cov(U'(\Pi_0^*),\ \tilde{f}) = 0$$

Then, we have

$$EU''(\Pi_0^*)(q_0^* - X_0^*) = 0$$

That is, $X_0^* = q_0^*$, the optimal futures position is fully hedged.

From the above analysis, it is not difficult to find that when the output is not affected by natural factors based on independent and no basis when farmers futures price optimal production decision and risk aversion. From the discussion above, we can find that when the output does not be affected by the natural factors, and if the futures is unbiased, the optimal production decision is free of risk aversion. The conclusion is general. Generally speaking, natural factors have great impacts on agricultural production. In the following, we will discuss the optimal production decision taking natural factors account for.

2.3 The optimal production decision when there is no basis

Consider the natural factors described in Hypothesis 6, and we assume that the natural factors are independent on the price. If there is no basis, note the output as q_1, the futures position is X_1, then the random profit of the farmer at the end of production is

$$\Pi_1 = (1+\tilde{s})q_1\tilde{p} - C(q_1) + (f_0 - \tilde{f})X_1 \tag{5}$$

The optimal decision problem of farmers is described as follows

$$(P_1).\max_{q_1,X_1} EU(\Pi_1)$$

Proposition 1 If the risk averse farmer intends to hedge price risk with unbiased futures hedging, and the futures market has no basis, then the optimal production of the farmer is $q_1^* < \frac{f_0 - c_1}{2c_2}$. Furthermore, when the farmer is prudent (Kim, 1993), the optimal futures position is under-hedged, that is $X_1^* < q_1^*$. Where referring to Kim, when the position of the futures is smaller than the spot position, it is called as "under-hedged". When the position of the futures equals to the spot position, it is called as "full-hedged". And when the position of the futures is larger than the spot position, it is called as "over-hedged".

Proof: The first-order conditions of model (P_1) are as follows

$$EU'(\Pi_1^*)[(1+\tilde{s})\tilde{p} - C'(q_1^*)] = 0 \tag{6}$$

$$EU'(\Pi^*)(f_0 - \tilde{f}) = 0 \tag{7}$$

From Eq. (6) and Eq.(7), since there is no basis and the mean of $\tilde{s}$ is zero, we have

$$E[U'(\Pi_1^*)\tilde{s}\tilde{p}] = Cov(U'(\Pi_1^*)\tilde{p},\ \tilde{s}) \tag{8}$$

According to the definition of covariance, we have

$$E[U'(\Pi_1^*)\tilde{s}\tilde{p}] + EU'(\Pi_1^*)[f_0 - C'(q_1)] = 0 \tag{9}$$

Therefore, the sign of $E[U'(\Pi_1^*)\tilde{s}\tilde{p}]$ and $\frac{\partial E[U'(\Pi_1)|\ \tilde{s}=s]}{\partial s}|_{q_1=q_1^*, X_1=X_1^*}$ are the same.

Furthermore,

$$\frac{\partial E[U'(\Pi_1)|\ \tilde{s}=s]}{\partial s}|_{q_1=q_1^*, X_1=X_1^*} = E[U''(\Pi_1^*)q_1^*\tilde{p}^2]$$

Then from the condition of $U''(\Pi_1)<0$, it follows that the sign of $\frac{\partial E[U'(\Pi_1)|\ \tilde{s}=s]}{\partial s}|_{q_1=q_1^*, X_1=X_1^*}$ is negative. Furthermore, the sign of $E[U'(\Pi_1^*)\tilde{s}\tilde{p}]$ is positive. Based on Equation (8) and $U'(\Pi)>0$, it yields

$$C'(q_1^*) < f_0 \tag{10}$$

According to Equation (10) and the cost function, we get the optimal output is $q_1^* < \frac{f_0 - c_1}{2c_2}$. By comparing the basic model, it finds that because of the effect of the natural factors, the firm will decrease its expected output. Therefore, if the farmer takes the natural factors into account for, it is suggested to reduce production scale appropriately.

Let X_1^* be the optimal futures position. Then, we have

$$\frac{\partial EU(\Pi_1)}{\partial X_1}|_{X_1=X_1^*} = 0 \tag{11}$$

The derivative function of the expected utility at the optimal output is

$$\frac{\partial EU(\Pi)}{\partial X_1}|_{X_1=q_1^*} = E[U'(\Pi_1^{\Delta})(f_0 - \tilde{f})]$$

Since the futures market is unbiased, we have

$$\frac{\partial EU(\Pi_1)}{\partial X_1}|_{X_1=q_1^*} = -Cov(U'(\Pi_1^{\Delta}),\ \tilde{f})$$

where, $\Pi_1^{\Delta} = \tilde{s}q_1^*\tilde{p} - C'(q_1^*) + f_0 q_1^*$.

Since

$$\frac{\partial E[U(\Pi_1^{\Delta})|\tilde{f}=f]}{\partial f} = E[U''(\Pi_1^{\Delta})\tilde{s}q_1^*] = q_1^* Cov(U''(\Pi_1^{\Delta}), \tilde{s}))$$

and the sign $Cov(U''(\Pi_1^{\Delta}), \tilde{s})$ and $E(U'''(\Pi_1^{\Delta})q_1\tilde{p})$ are the same. Besides, the farmer is prudent, then $E[U'''(\Pi_1^{\Delta})q\tilde{p}] > 0$. Furthermore, we have

$$\frac{\partial EU(\Pi_1)}{\partial X_1}|_{X_1=q_1^*} < 0$$

According to the concavity of the utility function, it follows that $X_1^* < q_1^*$. So, the optimal futures position is under-hedged. Comparing the basic model, we suggest the farmer whose products are highly affected by weather to reduce the futures position.

2.4 The optimal production model when futures basis exists

Generally speaking, although the trend of futures price and spot price the same, there is still the basis. Referring to Benninga (1984), we assume that the relation of spot price and the futures price is

$$\tilde{p} = \alpha + \beta\ \tilde{f} + \theta \tag{12}$$

where the mean of θ is zero, and the variance of θ is finite.

Proposition 2 If the risk averse farmer intends to hedge price risk by using futures hedging, when the relation of spot price and the futures price is described in

Equation (12), the optimal production of the farmer is $q_2^* < \frac{\alpha + \beta f_0 - c_1}{2c_2}$. Furthermore, if the farmer is prudent and β<1, the optimal futures position is over-hedged, i.e., $X_2^* < q_2^*$.

Proof: According to Eqs.(5) and (12), the profit of the farmer can be expressed by

$$\Pi_2 = (1+\tilde{s})q_2(\alpha + \beta \tilde{f} + \theta) - C(q_2) + (f_0 - \tilde{f})X_2 \quad (13)$$

Then, the first-order conditions of the objective function are

$$EU'(\Pi_2^*)[(1+\tilde{s})(\alpha + \beta \tilde{f} + \theta) - C'(q_2^*)] = 0 \quad (14)$$

$$EU'(\Pi_2^*)(f_0 - \tilde{f}) = 0 \quad (15)$$

Adding Eqs. (14) and (15), we have

$$\begin{aligned}&[\alpha + \beta f_0 - C'(q_2)]EU'(\Pi_2) + EU'(\Pi_2\theta) + \\ &E[U'(\Pi_2)(\alpha + \beta \tilde{f} + \theta)\tilde{s}] = 0\end{aligned} \quad (16)$$

Since $EU'(\Pi_2)$<0, and the signs of the second term of Equation (16) and $EU'(\Pi_2)$ are the same, then $EU'(\Pi_2\theta)$<0. Similarly, the signs of the third term of Equation (16) and $EU''(\Pi_2)q_2(\alpha + \beta \tilde{f} + \theta)^2 < 0$ are the same, we have

$$E[U'(\Pi_1)(\alpha + \beta \tilde{f} + \theta)\tilde{s}] < 0$$

According to concavity of utility function and Equation (16), it follows that

$$C'(q_2^*) < \alpha + \beta f_0 \quad (17)$$

Based on Equation (12), we have $\overline{p} = \alpha + \beta \overline{f}$. Furthermore, due to the unbiased futures market, we have $\overline{p} = \alpha + \beta f_0$. Then, $C'(q_2^*) < \overline{p}$. Subsisting the cost function into Equation (17), we can find that the optimal production satisfies $q_2^* < \frac{\alpha + \beta f_0 - c_1}{2c_2}$.

The proof is similar to Proposition 1. One the one hand, at the optimal position, we have $\frac{\partial EU(\Pi_2)}{\partial X_2}|_{X_2 = X_2^*} = 0$. On the other hand,

$$\frac{\partial EU(\Pi_2)}{\partial X_2}|_{X_2 = q_2^*} = -Cov(U'(\Pi_2^\Delta),\ \tilde{f}) \quad (18)$$

where, $\Pi_2^\Delta = [(1+\tilde{s})(\alpha + \beta \tilde{f} + \theta) + f_0 - \tilde{f}]q_2^* - C(q_2^*)$.

Because the sign of $Cov(U'(\Pi_2^\Delta),\ \tilde{f})$ and

$$\frac{\partial E(U'(\Pi_2^\Delta)|\ \tilde{f} = f)}{\partial f} = EU''(\Pi_2^\Delta)(\beta - 1)q_2^* + EU''(\Pi_2^\Delta)\tilde{s}$$

are the same, when the farmer is prudent, the sign of $EU''(\Pi_2^\Delta)\tilde{s}$ and $EU'''(\Pi_2^\Delta)q_2^*(\alpha + \beta \tilde{f} + \theta) > 0$ are the same. Then, when $\beta < 1$, $\frac{\partial EU(\Pi_2)}{\partial X_2}|_{X_1 = q_2^*} < 0$. Thus, according to the concavity of utility function, we have $X_2^* < q_2^*$, i.e., the futures position is under-hedged. Comparing Propositions 1 and 2, we can find that, due to the effect of natural factors on the output and the effect of futures price basis, the farmer will reduce futures positions to meet risks.

3 Numerical simulation

We assume that the farmer exhibits constant absolute risk aversion (CARA). Namely, the farmer possesses the negative exponential utility function. Furthermore, in the theoretical section, the farmer is risk aversion, whose utility function satisfies $U'(\cdot)$>0, $U''(\cdot)$<0, and the negative exponential utility function just satisfies the conditions of $U(\Pi) = -e^{-\lambda\Pi}$, λ>0 is the risk aversion coefficient of the farmer. Larger λ means more risk aversion. In general, natural factors affect the actual output of agricultural products, while the output of agricultural products indirectly affects prices. When the output decreases, the corresponding price increases generally, whereas the price of agricultural products decreases. In this section, we assume that there are three natural states: $\tilde{s} = \frac{1}{a}, 0, \frac{1}{b}$, where a<–1, b>1. $\tilde{s} = \frac{1}{a}$ means that farmers suffer from adverse weather impacts, the actual output is decreases by $\frac{1}{a}$ of the actual output. Assume that the probability of the adverse wealth is p_1. Similarly, $\tilde{s} = \frac{1}{b}$ represents a favorable natural factor that increases actual output over projected output of $\frac{1}{b}$. The probability of the good natural factors is p_2; $\tilde{s} = 0$ means that the natural factors have no effect on the actual output. The probability of the normal natural factors is $1 - p_1 - p_2$. Prices are indirectly influenced by natural factors. We suppose that when $\tilde{s}=0$, then $\tilde{p}=\bar{p}$; When $\tilde{s}=\frac{1}{a}$, $\tilde{p}=(1-1/a)\bar{p}$; And when $\tilde{s}=\frac{1}{b}$, $\tilde{p}=(1-1/b)\bar{p}$. Substituting the relations into Equation (13), we have the expected utility of the farmer is

$$\begin{aligned} EU(\Pi_2) = \exp\{-\lambda[(f_0+\alpha/\beta)X - C(q)] + \frac{\lambda^2 X^2 \sigma^2}{2\beta^2}\}\cdot \\ \{p_1\exp(-\lambda((1+1/a)q - X/\beta)(1-1/a)\bar{p}) + \\ (1-p_1-p_2)\exp(-\lambda(q-X/\beta)\bar{p} + \\ p_1\exp(-\lambda((1+1/b)q - X/\beta)(1-1/b)\bar{p})\} \end{aligned} \tag{19}$$

To analyze the effect of parameters on the target function, we take the following set of parameters:

$\bar{p}=f_0=6$, $\sigma=1$, $p_1=p_2=1/3$, $a=-2$, $b=2$, $\alpha=1, \beta=5/6$.

The methodology to solve the hedging problems can be summarized as follows:

Step 1. Simulate the price dynamics of spot and the futures based on the given parameters.

Step 2. Submit the prices and the parameters into Equation (19) to get the relationship between the utility function of farmers and the futures position and the production quantity.

Step 3. Find the maximum mean of $-e^{-\lambda\tilde{\Pi}}$, and determine the corresponding decision variables.

Figures 1 and 2 respectively describe the affects of futures position and production volume on utility function.

From Figures 1-2, it is not difficult to find that the utility function increases with the increase of the farmer's expected output; with the increase of the futures position, the utility function of farmers increases first and then decreases. From Figure 1, we can also find that when the futures position is set at 0 (That is, without futures hedging), the utility of the farmer is smaller than the use of futures hedging. This shows that futures hedging can improve the utility of a risk averse farmer. As seen from Figure 2, the futures position is not expected to be too large when the production is expected to be small. This is consistent with the conclusion that the futures position is under-hedged. When the expected output increases, the futures position is more, and the utility is larger. Although futures hedging is beneficial to improve the utility of the farmer, it is suggested the farmer appropriately to expand the production scale according to his own production capacity, rather than blindly increase the futures positions.

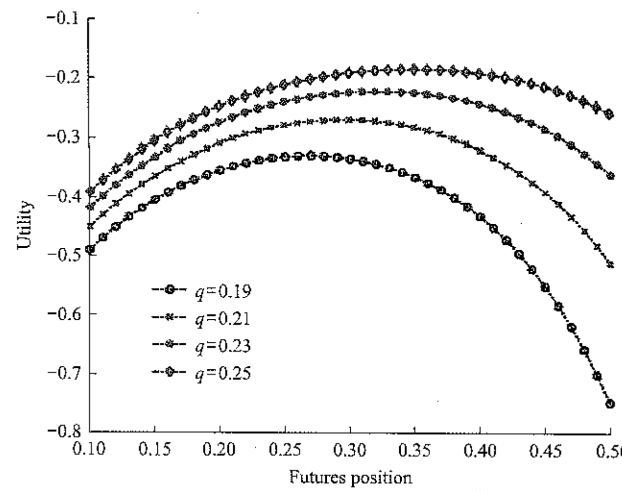

Figure 1 Relation between utility function and futures position

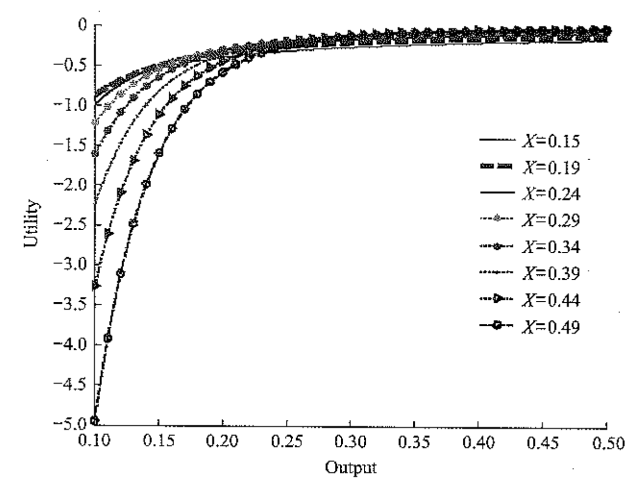

Figure 2 Relation between utility function and output

Figure 3 shows the maximum effectiveness of different risk aversion coefficients when the farmer uses futures hedging. In general, for the same variety of agricultural products, the corresponding futures has basis. If the corresponding agricultural products future does not exist, the farmer often can choose to cross futures hedging, and for cross futures, the basis may be greater. Therefore, take the risk aversion coefficient with 2 as an example to analyze the impact on the farmer's maximum utility as Figure 4.

We can see from Figure 3, with the increase of the farmer's risk aversion coefficient, the maximum utility increases. This shows that the greater the risk aversion coefficient of the farmer the more favorable to use of futures hedging. From Figure 4, as the basis of increased volatility, the maximum utility of the farmer reduces, it means that volatility is not conducive to improving farmer's utility. Therefore, the farmer should choose futures with smaller basis volatility to hedge risk.

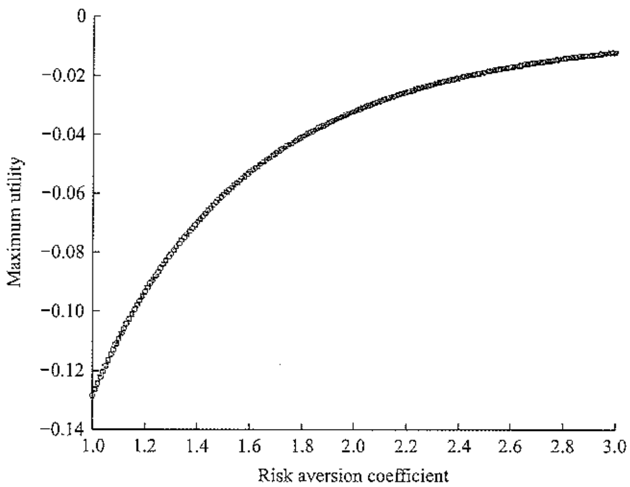

Figure 3 Relationship between maximum utility function and risk aversion coefficient

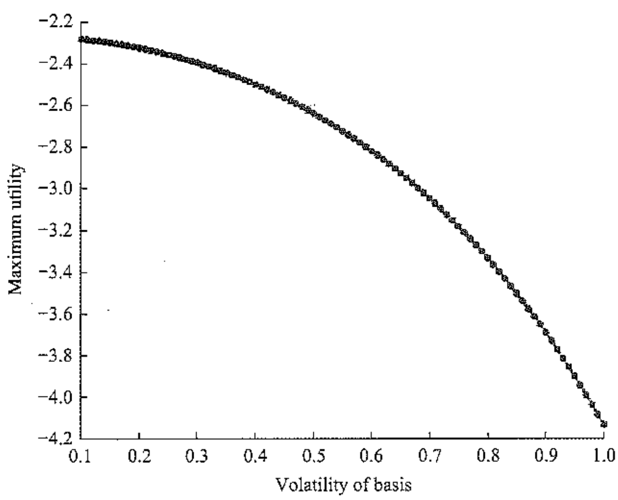

Figure 4 Relationship between maximum utility function and volatility of futures basis

The natural conditions (such as weather, etc.) have great influence on agricultural production. Figures 5-7 show the maximum utility of farmers under different conditions of bad, normal and good weather:

As can be seen from Figures 5-7, the maximum utility of farmers is affected by the probability of bad, normal, and good weather, wherein the greater the probability of good weather, the greater the maximum utility of farmers; Although the probability of bad weather and normal weather is not related to the maximum utility, by observing extreme conditions, it can be found that, when the probability of bad weather or normal weather is very small (close to 0), the maximum utility of the farmer is almost larger, while the probability is very large (near 1), and the utility of farmers is relatively smaller. That is, higher probability of bad weather or normal weather is not conducive to improving the maximum utility of the farmer.

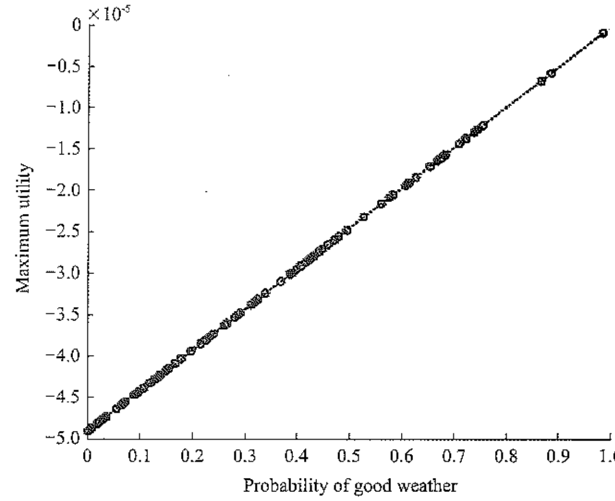

Figure 5 The maximum utility function and the probability of good weather

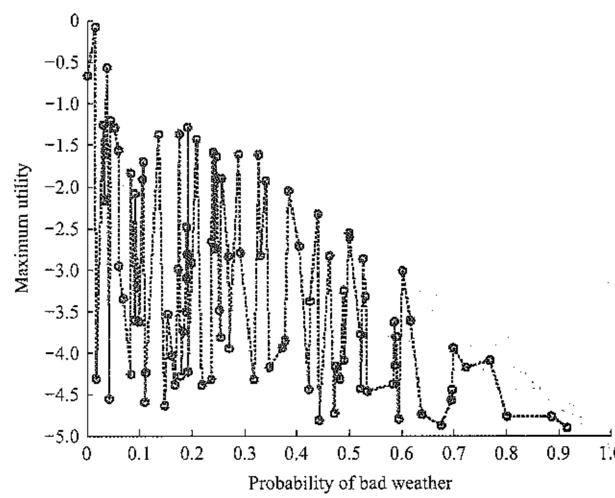

Figure 6 The maximum utility function and the probability of bad weather

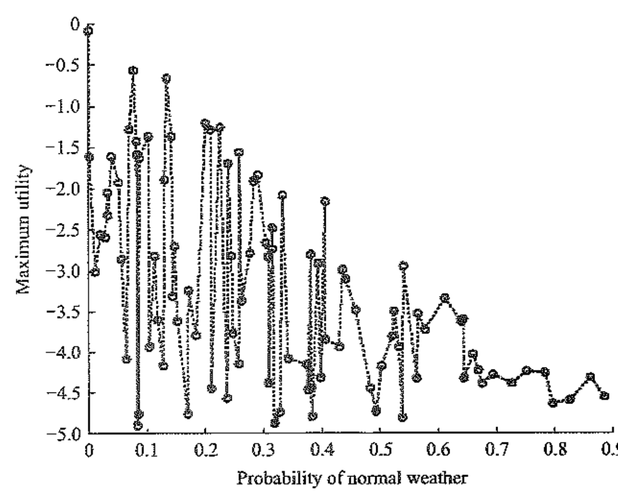

Figure 7 The maximum utility function and the probability of normal weather

4 Conclusion

This study focuses on the risk management of a risk averse farmer, and puts forward the optimal production decisions and futures hedging methods in three different situations. Theoretical research results show that: In the absence of natural factors and futures prices under the condition of no basis, the marginal cost corresponding to the most favorable output of a farmer is equal to the current price of futures, and the optimal futures position is fully hedged; In consideration of the natural factors and the futures price basis does not exist, the marginal cost of the most favorable output of farmers is less than the current price of futures, and the optimal futures position is under-hedged; When the natural factors are taken account for and there exists futures basis, if coefficient between the spot price and futures price is less than 1, the marginal cost of the most favorable output of the farmer is less than the average price of the spot, and the optimal futures position is still under-hedged. Through comparative study, we find that because of the influence of natural factors on actual output, farmers tend to reduce expected output and futures positions to meet risks. Taking negative exponential utility function as an example, the empirical results obtained by futures hedging can improve the farmer especially the greater risk aversion utility, volatility is not conducive to the basis of futures hedging. Probability analysis of different natural conditions occurs that good weather is conducive to the improvement of household utility. We suggest the farmer not blindly to increase futures positions, should be appropriate to select the basis volatility smaller futures for hedging. In this paper, we assume that the farmer's futures margin reserve capital adequacy, which can avoid the marking to market risk. A future research direction is to analyze the impact of the deposit of the opportunity cost of peasant's production decision.

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