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The Optimal Decisions of the "Company + Farmer" Contract-Farming Supply Chain With Nash Bargain Fair Reference

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Abstract

The contract-farming supply chain model consisting of one risk-neutral agribusiness and one risk-averse farmer with fairness concerns is proposed under stochastic yield. The fair reference framework is established according to Nash bargaining game. The impact on the optimal decision of contract-farming supply chain by the risk-averse farmer's fairness concerns. The numerical study illustrates the application of the model, and analyze some parameter influencing the optimal decision between one risk-neutral agribusiness and one risk-averse farmer with fairness concerns.

Key words: Nash bargaining game; Fairness concerns; Contract-farming supply chain; CVaR

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INTRODUCTION

Nowadays, according to "speeding up the development of 'thirty five-years plan' modern agriculture by turning the development pattern and adjusting the structures of agriculture economics", Ke-Ming Qian, the chief economist of ministry of agriculture, admitted that because of "good policy , hard work, and the good weather", our continuous-increasing agricultural product plays an important role in China's social and economic stability development in the past. But as the economy enters the new normal, internal and external environment for the development of agriculture in our country is undergoing profound changes, therefore our country should accelerate the transformation and upgrading of agriculture, promoting agricultural industrialization. So how to realize the agricultural industrialization development? Learning from agricultural development experience at home and abroad, it's not difficult to find contract-farming is the best choice for promoting agricultural industrialization. Contract-farming refers to an agricultural management pattern, the farmer signs a legally binding contract with the company or intermediary organizations in the process of production and operation, thus to determine the relationship between the powers and obligations of both sides, farmers organize production, company or intermediary organizations purchase products manufactured by farmers both according to the contract (Liu, 2003). Since the 1980s of the last century, contract-farming has showed its unique advantages in some aspects, such as solving "the contradiction between small-scale production and big market", reducing farmers' decision-making blindness, reducing operation cost and risk of the industrialization of agriculture and increasing farmers' income, etc.. But it also exposed some problems, such as the lower order execution rate, for this purpose, domestic and foreign scholars apply enterprise organization theory, contract theory, game theory and transaction cost theory doing research on high default rates to explore the method of solving the problem of high default rates.

1. LITERATURE

For the problem of lower order execution rate in the process of contract-farming supply chain, many scholars do researches with enterprise organization theory, contract theory, game theory, transaction cost theory, etc.. For examples, foreign scholar Bogetoft and Olesen (2002) think that contract-farming contract must be designed under the premise of taking coordination, motivation and transaction cost into consideration thoroughly. Burer et al. (2008) has studied on the coordination mechanism of contract-farming supply chain. Zylbersztajn et al. (2008) propose to adopt price strategy to improve the order execution rate. Kazaz and Webster (2005) studied production decision of the agricultural-industrialization organization with the price undering the influence of random output. In the domestic, Guo's empirical study (2006) shows that "guaranteed acquisition and going-rate-pricing" can obviously increase the order execution rate, it also shows that adding specialized input requirements and incentive measures to the provisions has the same work. Zhao and Wu (2009) studied the revenue sharing contract mechanism of agricultural products supplies chain under the condition of random output and demand. Ye (2011) studied the contract-farming supply chain coordination contract mechanism. However, these research reckons without fairness concerns, so the contract performance rate is always low.

In the past 20 years, behavioral economics research shows that people don't only care their own benefit but also care other's interest (Fehr & Schmidt, 1999; Rabin, 1993). A large number of experiments show that no matter what supplier or retailer will be willing to give up their marginal income to achieve the more fair consequence because of fairness concerns (Kumar, 1996). The farmer in the contract-farming exists fairness concerns beyond all questions.

Cui et al. (2007) introduce fairness concerns to newsboy background to study the impact on supply chain contract. Loch and Wu (2008) produce concise fairness concerns utility form to research the problem of supply chain performance. Du et al. (2013) concerns the fair reference point of retailer is Nash bargaining solution in the supply chain, reflecting fair relatively but without agricultural characteristic. In this paper, the contract-farming supply chain model consisting of one risk-neutral agribusiness and one risk-averse farmer with fairness concerns is proposed under stochastic yield, the fair reference point is Nash bargaining solution.

In conclusion, there is few research study the optimal decision of contract-farming supply chain from the perspective of fairness concerns. Existing research only take the absolutely fair into account, but actually fair is relative, so the view of the fairness frame of reference is worth thinking deeply. The fair reference framework is established according to Nash bargaining game. The impact on the optimal decision of contract-farming supply chain by the risk-averse farmer's fairness concerns in this paper.

2. PROBLEM DESCRIPTION

Agricultural products have short life cycles, as well as corrosive uncertainty output characteristics, the contract-farming supply chain model consisting of one risk-neutral agribusiness and one risk-averse farmer with fairness concerns is proposed under stochastic yield in this paper.

Farmers response for the production of agricultural products, the company is responsible for processing and marketing. Before the start of production, the company and farmers signed a mutually agreed to acquire orders in order to ensure market demand, the order specified: At the end of the production company acquire all the agricultural production of farmers at a certain price.

Farmers make the decision of the optimal input according to their own financial situation and the market demand and climatic conditions when agricultural production season coming. In the actual production process of agricultural products also affected by uncontrollable factors such as weather, pests and other natural disasters, there are uncontrollable production risks. The company makes the decision of order price according to the agricultural inputs as well as the retail market price. In the end the agribusiness purchase all the agricultural production from the farmer in the contract according to the order price. After the adoption of processing (cleaning, packaging) process, sale agricultural products according to the retail market price, and retailer market price is impacted with the random output of agricultural production. At this point, "Company + Farmers" contract-farming supply chain complete a whole proceeding cycle.

In this paper, we consider contract-farming supply chain consisting of a farmer and a company, and the farmer is risk-averse while the company is risk-neutral. Meanwhile, taking the impact of weather, climate, natural disasters and other objective criteria into account, we assume that the agricultural output is random. For ease of description, the symbol is defined as follows: Q is the number of inputs of farmers in decision-making, Meanwhile, we assume Q_d and Q_u denote the number of input under normal circumstances and fairness concerns circumstances respectively. c represents the farmer's effort cost coefficient, and the agricultural production costs is related to the number of input Q, we assume that the production cost function is $C(Q)=\frac{1}{2}cQ^2$, is strictly monotonically increasing function of the number of inputs, including the production of agricultural products takes time, energy, etc.. Meanwhile we assume that ω is the contract decided by the company. The agricultural productivity μ is a non-negative random variables, suppose the distribution function and the density function, respectively $F(.)$ and $f(.)$. p is the retail market prices of agricultural products which is effected by the agricultural productivity μ, we can make it $p=a-b(\mu Q)$. Farmer and the company's earnings are π_F and π_E. By the way, we assume that U_F and U_E represent farmer and company's utility respectively.

Signing contract orders can ensure the stable supply of agricultural products, and the residual value of agricultural products is very low in the ending of sales, so out of the loss of agricultural income and final residual value will not be considered. Because farmers face many uncertainties, social systems, cultural constraints and poverty, most of them are risk aversion and fairness concerns. Our farmers are mostly very small scale economic entity, and most farmers rely on very little land resources for simple reproduction, most farmer's income is low, this determines the characteristics of the risk aversion of households and fairness concerns. So we assume the farmer belongs to risk-aversion and fairness concerns, while the company belongs to risk-neutral and fairness-neutral.

The information above is common knowledge for the company and farmer.

3. THE OPTIMAL DECISION OF CONTRACT-FARMING UNDER DECENTRALIZED DECISION-MAKING SITUATION

According to the description of the problem and the basic assumptions, the company and farmer's decision variables are respectively order price ω and the number of input Q. The company acquired all agricultural production of farmers according to the order price in the end of production. The farmer's random revenue function is:

$$\pi_F(Q,\omega)=\omega\mu Q-\frac{1}{2}cQ^2 \quad . \tag{1}$$

At this time, the company's revenue function:

$$\pi_E(Q,\omega)=(p-\omega)\mu Q \, . \tag{2}$$

However, in real life, the farmers tend to be risk averse, so farmers not only need to consider expected revenue but also need to consider the income risk when he decides the number of agricultural input. In this paper, we measure the degree of risk by CVaR, because the average income measured by CVaR lower than η quantile is that the risk-averse farmer really cares about. According to the generalized definition of CVaR, the decision of inputs number of objective function of farmer with risk-aversion characteristics can be described as:

$$\mathrm{CVaR}_\eta\left[\pi_F(Q)\right]=\max_{v\in\mathbb{R}}\left\{v+\frac{1}{\eta}E\left[\min\left(\pi_F(Q)-v,0\right)\right]\right\} . \tag{3}$$

Among them, v represents the η quantile of the random variables μ. E denotes the expected value of the decision variables and $\eta\in(0,1]$ means the degree of risk-aversion (the less is η, the more scared is decision-maker).

Take (1) into (3) and then Simultaneous (2), solve the revenue function for the company and risk-averse farmers with the methods of stackelberg game, we can get the optimal decision-making of risk-neutral company and risk-aversion farmer in the decentralized decision-making problems.

Theorem 1: In the decentralized decision-making problems, risk-averse households and companies make their optimal decision with stackelberg game from the perspective of maximizing their own interests. The optimal order price decided by company is

$$\omega_d^*=\frac{ac\mu_0\eta}{2c\mu_0\eta+2b\int_0^{F^{-1}(\eta)}\mu f(\mu)\,\mathrm{d}\mu\int_0^A\mu^2 f(\mu)\,\mathrm{d}\mu} \, . \tag{4}$$

While the optimal number of input decided by farmer is

$$Q_d^*=\frac{a\mu_0\int_0^{F^{-1}(\eta)}\mu f(\mu)\,\mathrm{d}\mu}{2c\mu_0\eta+2b\int_0^{F^{-1}(\eta)}\mu f(\mu)\,\mathrm{d}\mu\int_0^A\mu^2 f(\mu)\,\mathrm{d}\mu} \, . \tag{5}$$

We take the optimal number of input Q^*_d and optimal order price ω^*_d into (3), then we get the optimal utility of risk-averse farmer in the decentralized situation

$$\mathrm{CVaR}_\eta\left[\pi_F\left(Q_d^*,\omega_d^*\right)\right]=\frac{c\left[a\mu_0\int_0^{F^{-1}(\eta)}\mu f(\mu)\,\mathrm{d}\mu\right]^2}{2\left[2c\mu_0\eta+2b\int_0^{F^{-1}(\eta)}\mu f(\mu)\,\mathrm{d}\mu\int_0^A\mu^2 f(\mu)\,\mathrm{d}\mu\right]^2} \, . \tag{6}$$

Similarly, the optimal utility of the company in the decentralized situation is

$$E\left[\pi_E\left(Q_d^*,\omega_d^*\right)\right]=\frac{a^2\mu_0^2\int_0^{F^{-1}(\eta)}\mu f(\mu)\,\mathrm{d}\mu}{2\left[2c\mu_0\eta+2b\int_0^{F^{-1}(\eta)}\mu f(\mu)\,\mathrm{d}\mu\int_0^A\mu^2 f(\mu)\,\mathrm{d}\mu\right]} \tag{7}$$

4. THE OPTIMAL DECISION OF SUPPLY CHAIN WITH FAIRNESS CONCERNS

4.1 Nash Fairness Concerns Consultative Framework

We assume that the solution of Nash bargaining model is $\left\{\overline{\mathrm{CVaR}}_\eta\left[\pi_F(Q,\omega)\right],\overline{\pi}_E(Q,\omega)\right\}$, which is decision-makers perceiving fairness reference solution. Meanwhile, we assume that the income differences will affect utility, so the utility function of risk-averse farmer and risk-neutral company is as follows

$$U_F=\mathrm{CVaR}_\eta\left[\pi_F(Q,\omega)\right]+\lambda_F\left\{\mathrm{CVaR}_\eta\left[\pi_F(Q,\omega)\right]-\overline{\mathrm{CVaR}}_\eta\left[\pi_F(Q,\omega)\right]\right\} \tag{8}$$

$$U_E=\pi_E+\lambda_E(\pi_E-\overline{\pi}_E). \tag{9}$$

Where λ_F, λ_E denotes the fair concern coefficient of farmer and company, $\lambda_F>0$, $\lambda_E>0$; $\overline{\mathrm{CVaR}}_\eta\left[\pi_F(Q,\omega)\right],\overline{\pi}_E(Q,\omega)$ is the solution that both sides believe that their own fair, that the Equity Solutions. It is clear that

$$\overline{\text{CVaR}}_\eta\left[\pi_F(Q,\omega)\right]+\overline{\pi}_E(Q,\omega)=\overline{\pi}(Q,\omega),$$

$$\text{CVaR}_\eta(Q,\omega)+\pi_E(Q,\omega)=\pi(Q,\omega).$$

According to the axiomatic definition of Nash bargaining game solution, Nash solution is the solution of the model as follows

$$\max_{\text{CVaR}_\eta\left[\pi_F(Q,\omega)\right],\pi_E(Q,\omega)} U_F U_E$$

$$s.t.\ \text{CVaR}_\eta(Q,\omega)+\pi_E(Q,\omega)=\pi(Q,\omega) \tag{10}$$

$$U_F, U_E>0.$$

It is easy to get the solution as follows

$$\overline{\text{CVaR}}_\eta\left[\pi_F(Q,\omega)\right]=\frac{1+\lambda_F}{2+\lambda_F+\lambda_E}\pi(Q,\omega), \tag{11}$$

$$\overline{\pi}_E(Q,\omega)=\frac{1+\lambda_E}{2+\lambda_F+\lambda_E}\pi \quad. \tag{12}$$

Take the Nash negotiation fairness solution as the reference to judge the fairness, because this reference considers the strength and contribution of both sides. Perception is a relatively fair and in line with the actual situation, overcome the concerns of equity that existed in the supply chain study considering only absolutely fair.

4.2 The Optimal Decision of the Fairness Concerns Farmer

According to the assumption, we only consider the risk-averse farmer cares about fairness concerns, while the company is fair-neutral, in other words $\lambda_F=\lambda>0$, $\lambda_E=0$, at this time fair reference solution for risk-averse farmers is

$$\overline{\text{CVaR}}_\eta\left[\pi_F(Q,\omega)\right]=\frac{1+\lambda}{2+\lambda}\pi(Q,\omega). \tag{13}$$

Theorem 2. When the risk-averse farmer concerns fairness, In order to make the supply chain to maximize the utility of both parties, the farmer and company make the optimal decision by Stackelberg game. The optimal order price decided by the company is

$$\omega_u^*=\frac{(\lambda\mu_0+l)\left[2ac\mu_0+ab\lambda+2ab\lambda\mu_0\left(\mu_0^2+\delta^2\right)\right]+ab\lambda l}{(2c\mu_0+b\mu_0+2bl)(2l+\lambda\mu_0)+\lambda b\mu_0(2\lambda\mu_0+2l)\left(\mu_0^2+\delta^2\right)} \tag{14}$$

While the optimal number of input decided by the farmer is

$$Q_u^*=\frac{2l\omega_u^*-\lambda\left(a-\omega_u^*\right)\mu_0}{2c+2\lambda b\left(\mu_0^2+\delta^2\right)}\ . \tag{15}$$

5. NUMERICAL ANALYSIS

In order to observe the impact on the optimal decision of both sides of the contract-farming supply chain by the degree of risk-averse and fairness concerns of the farmer, we take the numerical analysis as follows. And we assume the related reference as follows

a=10, b=2, c=1.8, A=1, μ□$U(0,A)$.

From figure 1, we observe that the optimal order price ω^*_u when λ=0.8 is higher than the optimal order price ω^*_d without fairness concerns through Stackelberg game. It shows that the farmer's fairness concerns will force the company to enhance the order price to achieve the relative fair for the farmer. Meanwhile, Figure 1 shows that weather the farmer is fairness concerns or not, the optimal order price will decrease with the increasing of the degree of the risk-aversion. In the other words, the more caring about the risk, the company will enhance the order price to encourage the farmer to performance positively

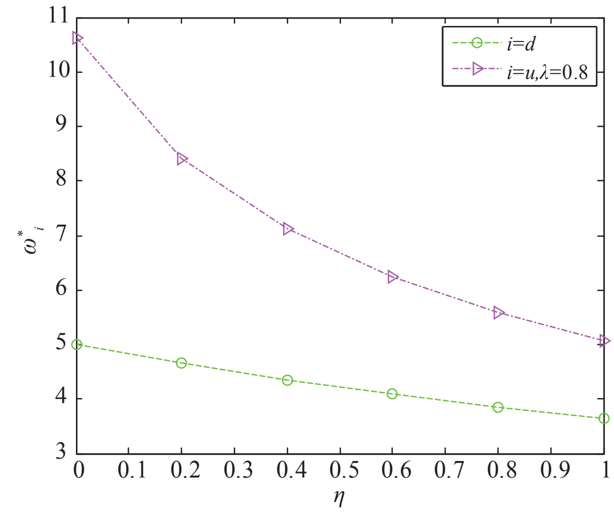

Figure 1
Effect of the Degree of Risk-Averse η on Order Price ω^*_i

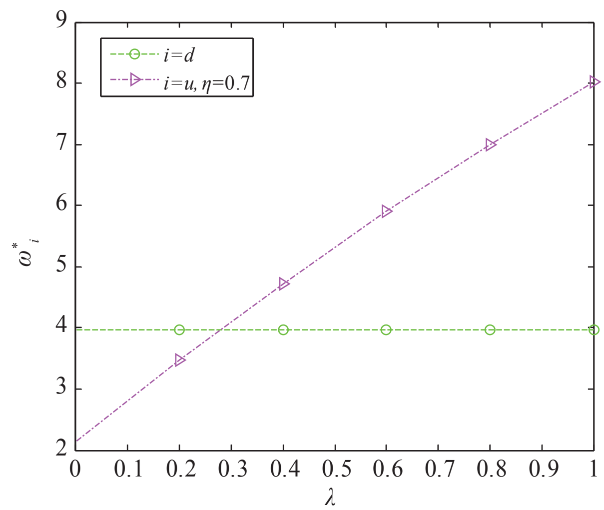

Figure 2
Effect of the Degree of Fairness Concerns λ on Order Price ω^*_i

From Figure 2, when the degree of the risk-averse for farmer η=0.8, the optimal contract price ω^*_u will increase with the increase of the degree of the farmer's fairness concerns. Meanwhile, when we don't consider the farmer's fairness concerns, the optimal contract price ω^*_d is equal to the optimal contract price ω^*_u with λ=0.3. It can clearly be seen that we can't exclude the farmer's fairness concerns thoroughly actually.

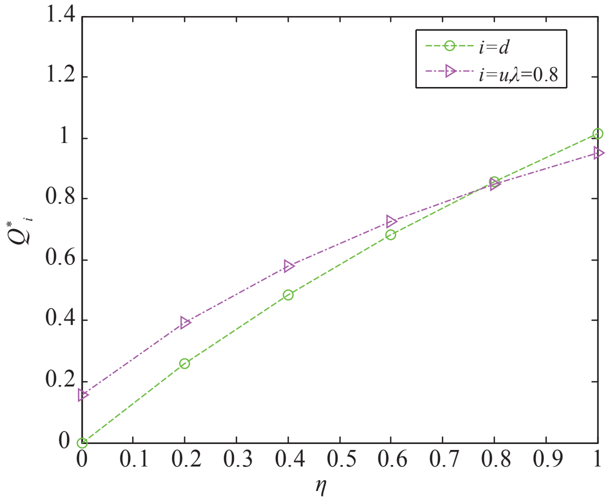

Figure 3
Effect of the degree of Risk-Averse η on the Number of Agricultural Input Q^*_i

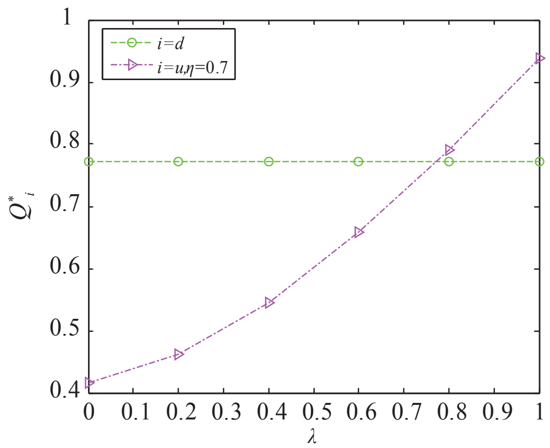

Figure 4
Effect of the Degree of Fairness Concerns λ on the Number of Agricultural Input Q^*_i

From Figure 3, we can observe that the farmer's optimal number of agricultural input Q^*_i will be increasing with the increasing of the degree of the farmer's risk-averse. Meanwhile, when the degree of the farmer's risk-averse η is lower than some value, the farmer with fairness concerns will enhance the optimal number of agricultural input to gain the more fair profit distribution. While when the degree of the farmer's risk-averse is higher than some value, the farmer will decrease the optimal number of agricultural input.

From Figure 4, we can observe that the optimal number of agricultural input Q^*_i will be increasing with the increasing of the degree of the farmer's fairness concerns λ. When we don't consider the farmer's fairness concerns, the optimal number of agricultural input Q^*_d is equal to Q^*_u when the degree of the farmer's fairness concerns is equal to some value.

CONCLUSION

According to the characters of the contract-farming supply chain, we model and analysis the contract-farming supply chain consist of a risk-averse farmer and a risk-neutral company, and then we get the conclusion as follow:

(a) In the framework of consultations Nash fair, the contract-farming supply chain consisting of a farmer with fairness concerns and a fair-neutral company can be able to achieve the equilibrium solution through Stackelberg bargain game.

(b) The farmer's fairness concern will force the company to enhance the order price to achieve the relative fair profit for the farmer. The more caring about the risk, the company will enhance the order price to encourage the farmer to performance positively.

(c) The farmer's optimal number of agricultural input Q^*_i will be increasing with the increasing of the degree of the farmer's risk-averse. Meanwhile, when the degree of the farmer's risk-averse η is lower than some value, the farmer with fairness concerns will enhance the optimal number of agricultural input to gain the more fair profit distribution. While when the degree of the farmer's risk-averse is higher than some value, the farmer will decrease the optimal number of agricultural input.

(d) The optimal number of agricultural input Q^*_i will be increasing with the increasing of the degree of the farmer's fairness concerns λ. When we don't consider the farmer's fairness concerns, the optimal number of agricultural input Q^*_d is equal to Q^*_u when the degree of the farmer's fairness concerns is equal to some value.

We get the significant conclusion through studying the contract-farming supply chain consisting of a risk-averse farmer and a risk-neutral company under fairness concerns. Future research directions include: (a) How will the optimal decision change when the company is also fairness concerns? (b) In this paper, we consider only a company and a farmer, while the contract-farming supply chain is very complex actually, we can study the contract-farming supply chain consisting of more than one company and more than one farmer.

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