Agricultural Supply Chain Options Ordering and Coordination Considering Fairness Concerns and Sales Effort

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Abstract. With the accelerated modernization of China's agriculture and the rapid growth of the agricultural consumer market, supply chain management of agricultural products is of great interest. As the behavior of supply chain members such as sales effort and fairness concerns can have a great impact on the overall supply chain management decisions. Therefore, in this paper, we introduce options contracts to investigate the ordering and coordination strategies of a single-cycle two-stage agricultural supply chain considering that the agricultural retailer is a fair concern and provides sales effort. The results show that in the case where the retailer only orders options, there is a relationship between the effect of the retailer's fair concern on order quantity and the parameters of the option contract, with the retailer's order quantity being an increasing function of fair concern when the option price is less than a critical value, and a decreasing function in the opposite case. In addition, by discussing the supply chain coordination mechanism, it is found that the level of retailers' fairness concern does not change the coordination of options contracts and that under certain conditions, supply chain coordination can be achieved. The results of the study provide some meaningful suggestions for agricultural supply chain management.

Keywords: fairness concerns · sales efforts · options contracts · supply chain coordination

1 Introduction

Agricultural products are edible plants, livestock, fishery products, and their primary processing products, which are the source of most food materials and are very important to people's daily life. The vast majority of agricultural products are perishable and not resistant to storage and transportation. In addition, the production and sale of agricultural products is a very important source of income for rural areas, but due to incomplete information on the supply and demand of agricultural products, unreasonable logistics planning in the distribution process and the lack of promotion means, a

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large number of agricultural products are stagnant and rotten, causing serious losses to farmers. As China's agricultural modernization speeds up and the consumer market for agricultural products grows rapidly, the role of sales efforts becomes increasingly vital. Market demand hinges heavily on sales endeavors, and retailers' sales promotions positively impact agricultural product sales. Retailers' sales efforts include freshness preservation efforts and promotional advertising during the sales process in the selling season. According to Yang et al. (2017), sales efforts can have two impacts: First, they can escalate retailer expenditures; second, they can elevate market demand.

When retailers need to bear the additional costs of the sales effort, they tend to show great concern for fairness, i.e., fairness concern, in contrast to the assumption of complete rationality of decision-makers in traditional studies. When people perceive unfairness, their behavior may be influenced by concerns for fairness, leading them to punish each other at their own expense. Many empirical or experimental studies have confirmed the existence of this behavioral tendency (Bolton, 1991; Rabin, 1993; Loch and Wu, 2008). In the ultimatum game, the accepting party chooses to reject the proposing party's allocation proposal if it considers it unfair (Ruffle, 1998). This phenomenon is both remarkable and engaging.

Option contracts serve as effective tools for managing and hedging uncertainties in supply chain management, such as random demand and output, which are widely used across various industries including telecommunications, IT, semiconductors, and electric power. When considering options in supply chain management, the most crucial decisions involve the ordering strategy, pricing strategy, and coordination of the supply chain. The use of option contracts in agricultural supply chain management has been on the rise in recent years (Wang and Chen, 2017; Zhou et al., 2018; Wang et al., 2020).

Therefore, this paper introduces option contracts into the framework of the newsboy model. Specifically, consider a newsboy who sells agricultural products and faces the need to rely on sales efforts provided by the newsboy in the sales process. A real-life example is the sale of agricultural products in Chinese farmers' markets. The newsboy, or produce vendor, receives a certain number of options by negotiating with the farmer to pay a deposit upfront before the selling period. During the marketing season, when actual demand occurs, the produce vendor compares the actual demand with the size of the option order to determine the amount of the option to be executed. During this process, the produce vendor takes steps to promote sales and incurs a corresponding cost of marketing effort. As a result of the additional cost, the produce trader may no longer be fully rational and may refuse to work with the farmer when informed that the farmer will make a larger profit than he or she would. Therefore, when there is sales effort and fair concern behavior, not only should the retailer consider the optimal sales effort strategy, but the integrated supply chain should also consider whether the retailer's fair concern behavior will have an impact on supply chain coordination. Therefore, the motivation for this paper is to consider the impact of fair concern and sales effort on option ordering and coordination in agricultural supply chains. An agricultural product supply chain in which rational suppliers sell options to fair-concern retailers is studied, and based on establishing a fair utility function for fair-concern retailers, the optimal ordering strategy and optimal sales effort of fair-concern retailers are derived taking into account sales effort and loss of agricultural product distribution, and supply chain coordination conditions are analyzed.

The rest of this article is arranged as follows. Section 2 reviews the relevant literature. The problem is described in detail in Sect. 3. Section 4 discusses the optimal decisions of fairness-concerned retailers. The coordination requirements of the supply chain for agricultural products based on an integrated supply chain are covered in Sect. 5. Section 6 summarizes the conclusions of this paper, and points out the shortcomings of this work, and the future development direction.

2 Literature Review

The management of the supply chain is significantly influenced by the sales effort. Retailers paying sales effort affect market demand and also increases costs, which has an impact on the profitability of the entire supply chain. Many academics have looked into how sales activities affect supply networks. In a supplier-retailer agricultural supply chain where market demand depends on sales effort, Yang et al. (2017) analyze the coordination of call, put, and two-way options and exhibit that both the optimal product order quantity and the optimal number of options rise with the sales effort. The coordination of a two-stage supply chain with a channel coordination problem was explored by Ma et al. (2013) in their study of a retailer and a manufacturer in the said two-stage supply chain. The impact of sales manager efforts on a supply chain consisting of a manufacturer, an agent, and a retailer was investigated by Duan et al. (2021), who developed a game-theoretic model. Their study revealed that the sales effort of the manufacturer's paid sales manager may negatively impact the agent and the retailer due to channel competition. In light of manufacturer promotional efforts and demand uncertainty, Tsao and Yu (2015) look into the sale of a single product from a risk-neutral producer to a risk-neutral retailer. Evidence that supports cost-sharing schemes motivates producers to step up their promotional efforts and merchants to place additional orders for goods. (Farshbaf-Geranmayeh et al., 2019; Cai et al., 2022) both study sales effort supply chain models in the presence of strategic customers, with the former pointing out that the trade-off between the benefits of inducing customers to make early purchases and advertising expenditures is key to achieving optimal advertising decisions for retailers. The latter analyzes the decision differences between the two sales effort models of suppliers making sales efforts and retailers making sales efforts. However, the aforementioned studies assume that supply chain participants are rational, and few studies suggest the impact of irrational decision-maker behavior on sales efforts.

Many empirical or experimental studies have confirmed that decision-makers are not fully rational. Therefore, the concept of fairness concern is introduced. Bolton (1991) was the first to describe the form of fairness concern by establishing a comparative model. Rabin (1993) argues that people's pursuit of fairness is not simply altruistic. Loch and Wu (2008) propose a more concise form of the fairness concern utility function in their study of supply chain performance. The study conducted by Li et al. (2020) aimed to explore the green product design of a supply chain comprising a manufacturer and two retailers and showed that retailers with fairness concerns set higher retail prices and that retailers' fairness concerns always hurt manufacturers' profits. Karsu and Morton

(2015) discussed two fairness-related issues, namely fairness, and equilibrium; three main approaches to fairness issues were discussed. Qin et al. (2016) studied how fairness issues affect supply chain decisions by modifying the classical supply chain model to include utility functions with limited rationality and fairness considerations. In a two-level supply chain with one supplier and two retailers, Nie and Du (2017) analyzed quantity discount contracts. It is demonstrated that quantity discount contracts cannot coordinate this supply chain under the assumption that one retailer has only distributive fairness concerns and the other has both peer-induced fairness concerns and distributive fairness concerns. Zhang et al. (2021) study a dual-channel supply chain where retailers exhibit fairness concerns, both horizontal and vertical. It is noted that retailers' fairness concerns affect only wholesale prices and online channel mode strategies. Although all the above studies consider the fair concerning behavior of supply chain members, few studies introduce options contracts into this supply chain analysis.

Many scholars have recently introduced option contracts into supply chains to study option decision-making and coordination. Cai et al. (2017) introduced option contracts to enhance the operational efficiency of supplier-managed inventory supply chains under output random. It is shown that option contracts are also effective in coordinating supply chains when demand is stochastic. Hu et al. (2018) through a study of two-level supply chain option coordination under stochastic market demand, pointed out that traditional option contract contracts cannot coordinate the supply chain; and suggested that introducing joint pricing in option contracts would benefit both sides of the supply chain. Zhao et al. (2018) studied the application of options for a two-level supply chain for stochastic spot markets and demand information updates. The concept of EUOS (Expected Unit Opportunity Savings) is proposed, revealing that EUOS can be an effective alternative for pricing real options in supply chains. Options contracts, according to Biswas and Avittathur (2019), can coordinate single supplier-multiple buyer supply chain networks and can resolve channel conflicts brought on by concurrent price and inventory rivalry. Chen et al. (2017) studied the optimal decision options for retailers and suppliers with and without two-way option contracts when there is service demand. Arani et al. (2016) developed a novel hybrid option contract to coordinate the retailer-manufacturer supply chain by combining call options and revenue sharing. The hybrid contract is noted to be superior to wholesale price and basic option contracts. (Fan et al., 2020; Liu et al., 2020) both study the application of options in supply chains with risk-averse decision makers, differing in that the former assumes that both buyers and sellers are risk-averse and concludes that total supply chain risk is not affected by price when buyers and sellers have the same risk preferences; the latter assumes only that retailers are risk averse under a conditional value at risk (CVaR) criterion, giving a supply chain coordination condition. In addition, several scholars have studied option decision-making and coordination in supply chains of perishable goods such as agricultural products. Wang and Chen (2017) studied a fresh produce supply chain consisting of suppliers and retailers. It was shown that suppliers' expected profits moved in the same direction as the option price, while retailers' expected profits moved in the opposite direction; this supply chain could be coordinated through a portfolio contract. To compare the fresh produce supply chain's productivity, profit, risk, and information-sharing status under various circumstances, Zhou et al. (2018) proposed option contracts. It demonstrates that the ideal option contract will incentivize retailers to spontaneously inform producers about the market demand. However, few studies have considered options for decision-making and coordination in agricultural supply chains for fairness concerns and sales efforts.

The contribution of this paper focuses on the impact of both retailer sales effort and fairness concern behavior on supply chain risk management by considering the retailer's ordering strategy and sales effort strategy. The impact of retailers' fair concern behavior on supply chain coordination is explored through an analysis of supply chain coordination mechanisms. Additional management insights are provided in specific scenarios. The presence of fair concern behavior is assumed to be more realistic when retailers provide sales effort, and the findings provide some theoretical guidance for realistic agricultural supply chain management.

3 Models and Assumptions

We consider a single-cycle, two-stage agricultural supply chain consisting of a rational supplier and a fairness-concerned retailer. The retailer buys a unit of option at a per-unit o price from the supplier before the marketing season. Each option grants the retailer the choice to exercise the right to purchase one unit of the product at a per-unit e price after determining demand, but not the duty to do so. Produce is provided by the supplier at a cost per unit c, and it is sold by the retailer at a price per unit p. Due to the characteristics of agricultural products that are easily lost during transportation and distribution, we introduce $\beta(0 < \beta < 1)$ to represent the rate of distribution loss during transportation of agricultural products, with the retailer bearing the cost of distribution loss. In the sales process it is assumed that the retailer invests sales effort φ and $C(\varphi)$ is the cost of sales effort. The sales effort invested by the retailer affects market demand, and the demand function is then expressed as $D(\varphi) = \varphi D$. Where, assume that D is E(D) $= \mu$ the continuous nonnegative random variable of market demand with probability density function $f(x)$ and the cumulative distribution function is $F(x)$. At the same time, the perishable nature of the product assumes that there is no residual value at the end of the sale. The retailer's out-of-stock penalty cost is g. To avoid triviality, let $p > o + e > c$, the $g > e$, the symbol $[x]^+ = max(0, x)$.

Table 1 lists the notation of all the parameters and variables used in this paper.

According to Du et al. (2010), fairness concerns are portrayed in the form of profit differences in the utility function. Introducing the parameter λ as the fair concern coefficient, the retailer's expected fair concern utility function can be expressed as

$$u_r(E[\pi_r]) = E[\pi_r] - \lambda(E[\pi_s] - E[\pi_r]) = (1 + \lambda)E[\pi_r] - \lambda E[\pi_s]$$

When $\lambda > 0$ when the retailer is fairly concerned. $E[\pi_r] \geq E[\pi_s]$ when retailer utility increases profit variance; and $E[\pi_r] \leq E[\pi_s]$ when retailer utility decreases with increasing profit variance. When $\lambda = 0$, the retailer is fairly neutral, at which point $u_r = E[\pi_r]$, i.e. equivalent to a traditional supply chain.

For analysis, note $U_r(\pi) \equiv \frac{u_r(\pi)}{(1+\lambda)}$, $\hat{\lambda} \equiv \lambda/(1 + \lambda)$. U_r is an affine transformation of u_r that involves only a change in the magnitude and still measures the retailer's utility. It is easy to see that $\hat{\lambda}$ is an increasing function concerning λ and $\hat{\lambda} \in [0, 1)$ and, when $\lambda = 0$, $\hat{\lambda} = 0$, i.e., the retailer is fair-neutral; when $\lambda \to +\infty$, $\hat{\lambda} \to 1$, i.e., the retailer is

Table 1. Symbols

Symbols	Description
Parameters	
o	The unit option price of agricultural products
e	The unit strike price of agricultural products
c	The unit production cost of agricultural products produced by suppliers
p	The unit sales price of agricultural products sold by retailers
β	The circulation loss rate of agricultural products, and $0 < \beta < 1$
$C(\varphi)$	Cost of the sales effort, of which $C'(\varphi) > 0$, $C''(\varphi) > 0$, $C(0) = 0$, $C'(\infty) = \infty$
$D(\varphi)$	Market demand
$f(x)$	The probability density function of market demand
$F(x)$	The cumulative distribution function of market demand, and $F(0) = 0$
g	Retailers' unit penalty costs for unmet demand
λ	Retailers' fairness concern factor, and $\lambda \in [0, +\infty)$
$\hat{\lambda}$	The fairness concern factor for retailers after affine transformation, where $\hat{\lambda} \equiv \lambda/(1+\lambda)$, and $\hat{\lambda} \in [0, 1)$
π_i	Profit function, where the subscripts $i(i = r, s, I)$ denote the profit of the retailer, the profit of the supplier, and the profit of the integrated supply chain, respectively
$E[\pi_i]$	The expected profit function, where the subscripts $i(i = r, s, I)$ denote the expected profit of the retailer, the expected profit of the supplier, and the expected profit of the integrated supply chain, respectively
$U_r(\pi)$	Retailer's expected fair concern utility function
Decision Variables	
Q_r	Retailers' order quantity
Q_I	Integrated supply chain production quantity
φ	Retailers' sales efforts
φ_I	Integrated supply chain sales efforts

extremely concerned about fairness and is willing to pay a huge cost to maintain fairness. Based on the above transformation, the retailer's expected fair concern utility function can be reformulated as

$$U_r(\pi) = E[\pi_r] - \hat{\lambda} E[\pi_s] \tag{1}$$

4 Fairness-Concerned Retailer's Ordering and Sales Effort Strategy

First, the optimal option ordering strategy of the retailer with fairness concerns is analyzed in the case of offering sales effort. The profit function of the retailer is denoted as π_r, then we have

$$\pi_r = pmin\big[(1-\beta)Q_r, D(\varphi)\big] - emin\big[(1-\beta)Q_r, D(\varphi)\big] \\ - oQ_r - g[D(\varphi) - (1-\beta)Q_r]^+ - C(\varphi) \tag{2}$$

The first term of the above equation represents sales revenue, the second, third, fourth, and fifth terms represent exercise costs, option costs, out-of-stock penalty costs, and sales effort costs respectively. The retailer's expected profit is denoted as $E[\pi_r]$, then we have

$$E[\pi_r] = \big[(p-e+g)(1-\beta) - o\big]Q_r \\ - g\varphi\mu - (p-e+g)\varphi \int_0^{\frac{(1-\beta)Q_r}{\varphi}} F(x)dx - C(\varphi) \tag{3}$$

The profit function of the supplier, denoted as π_s, then we have

$$\pi_s = oQ_r + emin\big[(1-\beta)Q_r, D(\varphi)\big] - cQ_r \tag{4}$$

The first term of Eq. (4) represents option income, while the second and third terms represent exercise income and production costs respectively. The expected profit of the supplier is expressed as $E[\pi_s]$, then we have

$$E[\pi_s] = [e(1-\beta) + o - c]Q_r - e\varphi \int_0^{\frac{(1-\beta)Q_r}{\varphi}} F(x)dx] \tag{5}$$

Based on Eq. (1) (3) (5), the expected utility function of a fair concern retailer is derived, which can be expressed as $U_r(\pi)$, and

$$U_r(\pi) = E[\pi_r] - \hat{\lambda}E[\pi_s] = \big[\big(p+g-e-\hat{\lambda}e\big)(1-\beta) - o - \hat{\lambda}o + \hat{\lambda}c\big] \\ Q_r - g\varphi\mu - \big(p+g-e-\hat{\lambda}e\big)\varphi \int_0^{\frac{(1-\beta)Q_r}{\varphi}} F(x)dx - C(\varphi) \tag{6}$$

The analysis of Eq. (6) leads to Proposition 1 as follows:

Proposition 1. There exists an optimal order quantity that maximizes the expected utility of a fair concern retailer Q_r^* that

$$Q_r^* = \frac{\varphi}{1-\beta} F^{-1}\left[1 - \frac{\mathrm{o} + \hat{\lambda}\mathrm{o} - \hat{\lambda}\mathrm{c}}{\big(\mathrm{p} + g - e - \hat{\lambda}\mathrm{e}\big)(1-\beta)}\right] \tag{7}$$

Proof. According to Eq. (6), we can get $\frac{\partial U_r(\pi)}{\partial Q_r} = \left[\left(p + g - e - \hat{\lambda}e\right)(1-\beta) - o - \hat{\lambda}o + \hat{\lambda}c\right] - \left(p + g - e - \hat{\lambda}e\right)(1-\beta)F\left[\frac{(1-\beta)Q_r}{\varphi}\right]$, $\frac{\partial^2 U_r(\pi)}{\partial Q_r^2} = -\frac{(p+g-e-\hat{\lambda}e)(1-\beta)^2}{\varphi}f\left[\frac{(1-\beta)Q_r}{\varphi}\right] < 0$. It follows that $U_r(\pi)$ is a Q_r concave function, then the optimal ordering strategy for a fair concern retailer exists and is unique. Let $\frac{\partial U_r(\pi)}{\partial Q_r} = 0$, the optimal order quantity (7) equation for the fair concern retailer can be derived. The proof is over.

The impact of option price on the retailer's optimal ordering decision is summarized in Corollary 1.

Corollary 1. $\frac{\partial Q_r^*}{\partial o} < 0$, suggesting that Q_r^* decreases with o increases, this is because of the increase in the option price, and thus the retailer's ordering cost increases, so the retailer will order less.

Proof. Let $H = 1 - \frac{o+\hat{\lambda}o-\hat{\lambda}c}{(p+g-e-\hat{\lambda}e)(1-\beta)}$, $\frac{\partial H}{\partial o} = -\frac{(1+\hat{\lambda})}{(p+g-e-\hat{\lambda}e)(1-\beta)} < 0$, therefore H decreases with o increases. Therefore $\frac{\partial Q_r^*}{\partial o} < 0$. The proof is over.

The impact of the exercise price on the retailer's optimal ordering decision is summarized in Corollary 2.

Corollary 2. $\frac{\partial Q_r^*}{\partial e} < 0$, suggesting that Q_r^* decreases with e increases, this is because of the increase in the strike price, and thus the ordering cost of the retailer increases, so the retailer will have less to order.

Proof. $\frac{\partial H}{\partial e} = -\frac{[(1+\hat{\lambda})o-\hat{\lambda}c](1+\hat{\lambda})}{[p+g-(1+\hat{\lambda})e]^2(1-\beta)} < 0$, where $o > \frac{\hat{\lambda}}{1+\hat{\lambda}}c$, therefore H decreases with e increases. Therefore $\frac{\partial Q_r^*}{\partial e} < 0$. The proof is over.

The impact of agricultural product selling price on the retailer's optimal ordering decision is summarized in Corollary 3.

Corollary 3. $\frac{\partial Q_r^*}{\partial p} > 0$, suggesting that Q_r^* increases with p increases because retailers increase their order quantity to obtain more sales revenue when the sales price increases.

Proof. $\frac{\partial H}{\partial p} = \frac{(1+\hat{\lambda})o-\hat{\lambda}c}{[p+g-(1+\hat{\lambda})e]^2(1-\beta)} > 0$, where $o > \frac{\hat{\lambda}}{1+\hat{\lambda}}c$, therefore H increases with p increases. Therefore $\frac{\partial Q_r^*}{\partial p} > 0$. The proof is over.

Then Corollary 4 will describe how fairness sensitivity affects the retailer's optimal order decision.

Corollary 4. When $o > c\left(1 - \frac{e}{p+g}\right)$, $\frac{\partial Q_r^*}{\partial \hat{\lambda}} < 0$, when $o < c\left(1 - \frac{e}{p+g}\right)$, $\frac{\partial Q_r^*}{\partial \hat{\lambda}} > 0$. For Case 1, when the option price offered by the supplier is high, the more sensitive the fair-concerned retailer is to adverse fairness, the more he/she will reduce the order quantity to avoid such an adverse situation. For Case 2, when the option price is low, the fair-concerned retailer believes that the order cost was lower at that time, and paying a lower order cost will increase the profit and thus reduce the profit difference with the supplier. Therefore, the higher the sensitivity of fairness concerns will in turn stimulate retailers to order more products.

Proof. $\frac{\partial \mathrm{H}}{\partial \hat{\lambda}} = -\frac{e[o+(o-c)\hat{\lambda}]-(c-o)[p+g-(1+\hat{\lambda})e]}{[p+g-(1+\hat{\lambda})e]^2(1-\beta)}$, when $\frac{\partial \mathrm{H}}{\partial \hat{\lambda}} < 0$, we can get $o > c\left(1-\frac{e}{p+g}\right)$, at this point, the H decreases with $\hat{\lambda}$ increases, $\frac{\partial Q_r^*}{\partial \hat{\lambda}} < 0$; when $\frac{\partial \mathrm{H}}{\partial \hat{\lambda}} > 0$, we can get $o < c\left(1-\frac{e}{p+g}\right)$ at this time, the H increases with $\hat{\lambda}$ increases, $\frac{\partial Q_r^*}{\partial \hat{\lambda}} > 0$. The proof is over.

Next, the retailer's optimal sales effort is analyzed according to Proposition 1.

Proposition 2. Substituting Q_r^* into the retailer's expected utility function yields the retailer's optimal sales effort φ^* satisfies the following equation.

$$\left[\left(\mathrm{p}+\mathrm{g}-\mathrm{e}-\hat{\lambda}\mathrm{e}\right)-\frac{\mathrm{o}+\hat{\lambda}\mathrm{o}-\hat{\lambda}\mathrm{c}}{(1-\beta)}\right] F^{-1}\left[1-\frac{\mathrm{o}+\hat{\lambda}\mathrm{o}-\hat{\lambda}\mathrm{c}}{\left(\mathrm{p}+g-e-\hat{\lambda}\mathrm{e}\right)(1-\beta)}\right] - g\mu-\left(\mathrm{p}+g-e-\hat{\lambda}\mathrm{e}\right) \int_0^{F^{-1}\left[1-\frac{\mathrm{o}+\hat{\lambda}\mathrm{o}-\hat{\lambda}\mathrm{c}}{\left(\mathrm{p}+g-e-\hat{\lambda}\mathrm{e}\right)(1-\beta)}\right]} F(x)dx - C'(\varphi^*) = 0 \tag{8}$$

Proof. Bringing Eq. (7) into Eq. (6) yields $\frac{\partial U_r(\pi)}{\partial \varphi} = \left[\left(\mathrm{p}+\mathrm{g}-\mathrm{e}-\hat{\lambda}\mathrm{e}\right)-\frac{\mathrm{o}+\hat{\lambda}\mathrm{o}-\hat{\lambda}\mathrm{c}}{(1-\beta)}\right] F^{-1}\left[1-\frac{\mathrm{o}+\hat{\lambda}\mathrm{o}-\hat{\lambda}\mathrm{c}}{(\mathrm{p}+g-e-\hat{\lambda}\mathrm{e})(1-\beta)}\right] -\left(\mathrm{p}+g-e-\hat{\lambda}\mathrm{e}\right) \int_0^{F^{-1}\left[1-\frac{\mathrm{o}+\hat{\lambda}\mathrm{o}-\hat{\lambda}\mathrm{c}}{(\mathrm{p}+g-e-\hat{\lambda}\mathrm{e})(1-\beta)}\right]} F(x)dx - g\mu - C'(\varphi)$, $\frac{\partial^2 U_r(\pi)}{\partial \varphi^2} = -C''(\varphi) < 0$. It follows that given Q_r^* the case of $U_r(\pi)$ is a concave function of φ, then the optimal sales effort of a fair concern retailer exists and is unique. Let $\frac{\partial U_r(\pi)}{\partial \varphi} = 0$, the equation satisfied by the optimal sales effort of a fair concern retailer can be derived. The proof is over.

Next, we talk about optimal ordering decisions in an integrated supply chain system.

5 Integrated Supply Chain

For the analysis of an integrated supply chain, the whole supply chain is considered as a system, and it is assumed that the production quantity of the whole supply chain is Q_I and the sales effort is φ_I. The whole system seeks to maximize the total profit. Denote the profit function of the integrated supply chain by π_I, and

$$\pi_I = p\min\left[(1-\beta)Q_I, D(\varphi_I)\right] - cQ_I - g[D(\varphi_I)-(1-\beta)Q_I]^+ - C(\varphi_I) \tag{9}$$

The first term of Eq. (9) represents sales revenue, while the second, third, and fourth terms represent production costs, out-of-stock costs, and sales effort costs, respectively. The expected profit of the integrated supply chain is expressed as $E[\pi_I]$, then we have

$$E[\pi_I] = \left[(p+g)(1-\beta)-c\right]Q_I$$

$$- g\varphi_I\mu - (p+g)\varphi_I \int_0^{\frac{(1-\beta)Q_I}{\varphi_I}} F(x)dx - C(\varphi_I) \tag{10}$$

See Yang et al. (2017) to derive Proposition 3 as follows:

Proposition 3. There is a production quantity Q_I^* that is best for maximizing the anticipated profit of the integrated supply chain that

$$Q_I^* = \frac{\varphi_I}{1-\beta} F^{-1}\left[1 - \frac{c}{(p+g)(1-\beta)}\right] \tag{11}$$

Substituting Q_I^* into the expected profit function of the integrated supply chain yields the optimal sales effort φ_I^* of the integrated supply chain satisfying the following equation

$$\frac{1}{1-\beta}\left[(p+g)(1-\beta) - c\right]F^{-1}\left[\frac{(p+g)(1-\beta)-c}{(p+g)(1-\beta)}\right]$$
$$- g\mu - (p+g)\int_0^{F^{-1}\left[\frac{(p+g)(1-\beta)-c}{(p+g)(1-\beta)}\right]} F(x)dx - C'(\varphi_I^*) = 0 \tag{12}$$

To achieve supply chain coordination, according to Proposition 1, Proposition 2, and Proposition 3, when $\varphi = \varphi_I^*$, $Q_I^* = Q_r^*$, the coordination conditions are derived o and e the relationship equation of $o = c\left(1 - \frac{e}{p+g}\right)$. Proposition 4 gives the conditions for supply chain coordination.

Proposition 4. The entire supply chain can be coordinated when the supplier offers an option contract with option price o and strike price e satisfying $o = c\left(1 - \frac{e}{p+g}\right)$.

Proposition 4 shows that if the entire supply chain is to be coordinated, the condition $o = c\left(1 - \frac{e}{p+g}\right)$ must be satisfied. We can see that when the supplier sets a higher strike price, it should lower the option price; or when the supplier sets a higher option price, it should lower the strike price. However, according to Corollary 4, the supplier should set a lower option price to attract the retailer to order more products because of the retailer's sensitivity to fairness concerns.

6 Conclusion

This paper investigates the option ordering and coordination problem for a single-cycle two-stage agricultural supply chain consisting of a rational supplier and a fair concern retailer, in the context of considering the existence of fair concern behavior when the retailer pays sales effort. The optimal ordering decision of the retailer and the optimal sales effort decision is obtained; the coordination conditions are obtained through a discussion of the supply chain coordination mechanism. The following three conclusions are summarized: (1) in the decentralized control system, there is a unique optimal order quantity and optimal sales effort when only options are ordered by agricultural retailers considering sales effort and fair concern; (2) there is a relationship between the effect of retailers' fair concern degree on order quantity and option contract parameters when the option price is less than a critical value, the order quantity of retailers increases with the increase in the degree of fair concern, and conversely when the option price is less than this value, the order quantity decreases with the increase in the degree of fairness concern; (3) the degree of fairness concern of the retailer does not change the coordination of the option contract, and under certain conditions, supply chain coordination can be achieved.

Although this paper presents insights from fairness concerns and sales efforts on option ordering in agricultural supply chains, some limitations can be addressed and expanded upon in the future. For example, the current study has mainly done a foundational analysis of a two-stage supply chain with one supplier and one retailer. Future research could be expanded to include multiple retailer and/or multiple supplier supply chains. Another limitation of the current study is that only retailers' fair concern behaviors are considered. Future research could be expanded to consider situations where other supply chain members are concerned about fairness. Finally, the current work only considers single-cycle supply chains and could be extended in the future to consider the impact of fairness concerns and sales efforts on multi-cycle models. Based on this, we will extend it deeply with practical problems to improve the practicality of the theoretical model.

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References

Yang, L., Tang, R., Chen, K.: Call, put and bidirectional option contracts in agricultural supply chains with sales effort. Appl. Math. Model. **47**, 1–16 (2017)

Bolton, G.: A comparative model of bargaining: theory and evidence. Am. Econ. Rev. **81**(5), 1096–1136 (1991)

Rabin, M.: Incorporating fairness into game theory and economics. Am. Econ. Rev. **83**(5), 1281–1302 (1993)

Loch, C., Wu, Y.: Social preferences and supply chain performance: an experimental study. Manag. Sci. **54**(11), 1835–1849 (2008)

Ruffle, B.J.: More is better, but fair is fair: tipping in dictator and ultimatum games. Games Econ. Behav. **23**(2), 247–265 (2004)

Wang, C., Chen, X.: Option pricing and coordination in the fresh produce supply chain with portfolio contracts. Ann. Oper. Res. **248**(1), 471–491 (2017)

Zhou, L., Zhou, G., Qi, F., Li, H.: Research on coordination mechanism for fresh agri-food supply chain with option contracts. Kybernetes **48**(5), 1134–1156 (2018)

Wang, C., Chen, J., Wang, L., Luo, J.: Supply chain coordination with put option contracts and customer returns. J. Oper. Res. Soc. **71**(6), 1003–1019 (2020)

Ma, P., Wang, H., Shang, J.: Contract design for two-stage supply chain coordination: integrating manufacturer-quality and retailer-marketing efforts. Int. J. Prod. Econ. **146**(2), 745–755 (2013)

Duan, H., Deng, S., Song, H., Xu, J.: The impacts of sales efforts and mode of payment on the competition between agent and retailer. Omega-Int. J. Manag. Sci. **103**, 102416 (2021)

Tsao, C.Y.: Cooperative promotion under demand uncertainty. Int. J. Prod. Econ. **167**, 45–49 (2015)

Farshbaf-Geranmayeh, A., Rabbani, M., Taleizadeh, A.: Cooperative advertising to induce strategic customers for purchase at the full price. Int. Trans. Oper. Res. **26**(6), 2248–2280 (2019)

Cai, J., Dong, R., Zeng, Z., Hu, X.: Supply chain competition models with strategic customers considering sales effort. Comput. Ind. Eng. **172** (2022)

Li, Q., Guan, X., Shi, T., Jiao, W.: Green product design with competition and fairness concerns in the circular economy era. Int. J. Prod. Res. **58**(1), 165–179 (2020)

Karsu, Ö., Morton, A.: Inequity averse optimization in operational research. Eur. J. Oper. Res. **245**(2), 343–359 (2015)

Qin, F., Mai, F., Fry, M., Raturi, A.: Supply-chain performance anomalies: fairness concerns under private cost information. Eur. J. Oper. Res. **252**(1), 170–182 (2016)

Nie, T., Du, S.: Dual-fairness supply chain with quantity discount contracts. Eur. J. Oper. Res. **258**(2), 491–500 (2017)

Zhang, X., Ma, C., Chen, H., Qi, G.: Impact of retailer's vertical and horizontal fairness concerns on manufacturer's online channel mode. Discret. Dyn. Nat. Soc. (2021). https://doi.org/10.1155/2021/6692582

Cai, J., Zhong, M., Shang, J., Huang, W.: Coordinating VMI supply chain under yield uncertainty: option contract, subsidy contract, and replenishment tactic. Int. J. Prod. Econ. **185**, 196–210 (2017)

Hu, B., Qu, J., Meng, C.: Supply chain coordination under option contracts with joint pricing under price-dependent demand. Int. J. Prod. Econ. **205**, 74–86 (2018)

Zhao, Y., Choi, T., Cheng, T., Wang, S.: Supply option contracts with spot market and demand information updating. Eur. J. Oper. Res. **266**(3), 1062–1071 (2018)

Biswas, I., Avittathur, B.: Channel coordination using options contract under simultaneous price and inventory competition. Transp. Res. Part E: Logist. Transp. Rev. **123**, 45–60 (2019)

Chen, X., Wan, N., Wang, X.: Flexibility and coordination in a supply chain with bidirectional option contracts and service requirement. Int. J. Prod. Econ. **193**, 183–192 (2017)

Arani, H., Rabbani, M., Rafiei, H.: A revenue-sharing option contract toward coordination of supply chains. Int. J. Prod. Econ. **178**, 42–56 (2016)

Fan, Y., Feng, Y., Shou, Y.: A risk-averse and buyer-led supply chain under option contract: CVaR minimization and channel coordination. Int. J. Prod. Econ. **219**, 66–81 (2020)

Liu, Z., Hua, S., Zhai, X.: Supply chain coordination with risk-averse retailer and option contract: Supplier-led vs. Retailer-led. Int. J. Prod. Econ. **223** (2020)

Du, S.F., Du, C., Liang, L., Liu, T.Z.: Supply chain coordination considering fairness concerns. J. Manag. Sci. China **13**(11), 41–48 (2010). (in Chinese)