ABSTRACT

This paper takes the dual-channel supply chain as the research background. Online supply adopts pre-sale strategy, while offline supply adopts inventory strategy and faces the newsvendor problem. The retailer is loss averse. We consider the decentralized decision making and retailer decision making and deduce the correlations between order quantity, price deviation and loss aversion. By the numerical analysis, we observed that the loss-aversion of retailer will make the members of the supply chain suffer losses. At last, we have verified that manufacturers cannot coordinate the supply chain with buyback contract. Furthermore, we achieve this goal with GLB which is an improved risk-sharing contract based on buyback and revenue sharing contract under certain conditions.

KEYWORDS
Dual Channel supply chain, Inventory decision, Pre-sale mode, Loss aversion, Supply contract and supply chain coordination.

INTRODUCTION

As a new form of e-commerce, online pre-sale mode can effectively integrate mass production with customers' personalized needs under the uncertain market demand, so as to realize effective inventory control. The pre-sale mode has brought the good opportunity to the online sales of fresh agricultural products. [1]Tmall mall has been pre-selling cherries since early July, when the American cherries come to market. Not limited to agricultural products, many brand manufacturers adopt pre-purchase strategy in Tmall double 11 shopping carnival.

Different from online sales channels, the sales advantage of offline retail brick-and-mortar stores lies in that it enables consumers to see the goods on the spot and get more sales experience. As a result, retailers need to order a batch of products before sales season begins. In the case of uncertain demand, if the order quantity is less than the market demand, the shortage of goods will make the enterprise lose part of consumers, thus reducing the profit of the enterprise. If the quantity ordered is greater than the market demand, it will lead to overproduction. Surplus products will not only form a backlog of inventory, increase inventory costs, will also depreciate. For perishable items, such as produce magazines, which have very little residual value and even have to pay for processing costs,
excess inventory would lead to major losses for retailers[2]. In the face of fluctuating market demand, the determination of reasonable order quantity has always been the focus of scholars.

In the dual-channel supply chain, retailers and manufacturers are faced with both competition between channels and cooperation on traditional channels. Such a complex relationship is more likely to lead to channel conflicts[3]. Therefore, many scholars try to optimize the dual-channel supply chain by discussing marketing modes or introducing contracts on the basis of studying ordering strategies. Zhou Jiaying[4] studied the influence of buyback contracts on supply chain inventory decision-making under the centralized control mode of manufacturers and retailers respectively. A modified revenue sharing contract and gain/loss sharing contract are proposed considering the price competition strategy and order strategy between channels under decentralized decision-making[5], and the role of two contracts in coordinating supply chain are proved. From the perspectives of the manufacturer dual channel and the retailer dual channel, Tang Xiaoyan[6] established two kinds of dual channel types of centralized and decentralized inventory decision-making models and introduced the revenue sharing contract to coordinates the dual channel supply chain. However,[7]some phenomena show that the manufacturer's order quantity decision may deviate from maximizing the expected profit. The above mentioned contracts may not effectively prevent the loss of coordination of the supply chain in practical application, Deng Xin[8] pointed out that one of the important reasons is that the previous studies did not consider the risk attitude of the decision-making managers of the supply chain.

Recently,[9]some researchers in operations and supply chain management have realized the limitation of the assumption of risk neutrality and have called for future research relaxing this assumption. Kahneman and Tversky[10] pointed out that people are more sensitive to losses than to same-sized gains and that the perception of gains or losses is related to a reference point. Considering the loss-averse behavior of supply chain members, analyzing its impact on decision-making and exploring the corresponding coordination contract have become a concern of many scholars, and rich research results have been obtained in the single-channel supply chain[11,12,13]. The literatures on inventory decision-making in dual channels is generally based on the risk-neutral hypothesis, and the influence of loss aversion is rarely discussed. This paper would extend loss aversion to the dual-channel supply chain. Specifically, we assume dual channel supply chain consisting of a risk-neutral manufacturer and a loss aversion retailer.

The remainder of this paper is organized as follows. In section 2, we establish the channel demand and the loss-aversion utility function. In section 3, we study the impact of retailers’ loss aversion on members’ decision-making and supply chain performance. In section 4, we respectively discuss the coordination effect of buyback contract and GLB contract on supply chain, and analyze the feasibility of the contract from the perspective of income. We conclude the research conclusions and suggest directions for future research in section 5.
PROBLEM STATEMENT

Linear demand functions are used to characterize channel demand and have been adopted in studies\[14,15\], and the corresponding demand functions to the manufacturer and the retailer are described as follows:

\[ D_r = \delta D - p_r + \theta p_e = a_r + \theta p_e, \]

\[ D_e = (1 - \delta)D - p_e + \theta p_r = a_e - p_e. \]

\( D_r \) and \( D_e \) denote offline and online demand respectively. We assume that the market demand is random. \( D = (\mu, \sigma^2) \). The pdf and cdf are \( f(x) \) and \( F(x) \), respectively. \( \delta \) denote the denotes the market share of offline retail channels. Manufacturers have strict control over the price of products and have formed a relatively stable offline price system. Therefore, the sales price of offline retail products, \( p_r \), is set to an exogenous variable. In order to avoid the risk of demand uncertainty, manager adopts the pre-sale mode for online sales. The advance selling price, \( p_e \), is a decision variable. \( \theta \) denote the cross-price sensitivity between channels. The channel demand function can be further summarized as follows:

\[ D_r = a_r + \theta p_e, \quad (1) \]

\[ D_e = a_e - p_e. \quad (2) \]

where \( a_r = \delta D - p_r, a_e = (1 - \delta)D + \theta p_r \). Considering the characteristics of online and offline sale modes, we assume supply mode of online channel as make to order and the offline retail channel supply mode as make to stock. \( c \) and \( v \) denote the unit cost and salvage value of the product respectively. To avoid unrealistic and trivial cases, we assume that the following relationship is maintained: \( v < c < w < p \).

The establishment of loss aversion function can accurately reflect the loss aversion behavior and could be applied and deduced. Refer to relevant research (X. Chen, G. Hao, and L. Li,[16]; X. Wang and S. 2007,[17]), the foldable loss aversion utility function is used as follows

\[ U(W) = \begin{cases} W - W_0 & W \geq W_0 \\ \lambda (W - W_0) & W \geq W_0 \end{cases} \]

\( W_0 \) denote the reference level (i.e., initial wealth) of the retailer. \( W \) is the retailer’s final wealth and \( \lambda \) is the loss-averse level. A higher value of \( \lambda \) implies a higher level of loss aversion. There is no additional penalty for unmet demand. For simplicity, let \( W_0 = 0 \).
MODEL DEVELOPMENT

DECENTRALIZED DECISION MAKING

First, we consider the centralized decision-making problem when the manufacturer and retailer belonging to the same enterprise. The goal of the enterprise is to maximize its expected profit on the basis of known information without considering the profit distribution of the supply chain system. The problem of the supply chain members is given as follows:

\[
\max_{q, p, \theta} \{ \pi_e(q, p) \}
\]

\[
E[\pi_e(q, p)] = \int_{x=\theta p}^{\theta p} \left[ p_c (x + \theta p) - cq_e + v(q_e - x - \theta p_e) \right] f(x) dx
\]

\[
+ \int_{x=\theta p}^{\theta p} q_e (p_e - p) f(x) dx + (\mu_e - p_e)(p_e - c)
\]

The Hessian matrix of supply chain’s profit function

\[
H_e[q, p] = \begin{bmatrix}
-(p - v)f(q_e - \theta p_e) & \theta(p - v)f(q_e - \theta p_e) \\
\theta(p - v)f(q_e - \theta p_e) & -\theta^2(p - v)f(q_e - \theta p_e) - 2
\end{bmatrix}
\]

is negative definite. The SC’s profit function is a concave function of \(p_e\) and \(q_e\). Thus, a unique equilibrium solution exists. Taking the derivative with respect to \(p_e\) and \(q_e\),

\[
\frac{\partial E[\pi_e(q, p)]}{\partial q_e} = (p_e - c) - (p_e - v)F(q_e - \theta p_e)
\]

(3)

(4)

By solving equations (3)-(4), we can obtain the optimal strategy which is given as follows

\[
q_e^* = F^{-1} \left( \frac{p_e - c}{p_e - v} \right) + \theta p_e, \quad p_e^* = \frac{\theta(p_e - c) + a_e + c}{2}
\]

RETAILER DECISION MAKING

The integration of online and offline management is an important development direction of the future dual channels. Making retailers who understand the market better manage the online channel, manufacturers can reduce their own operating costs and focus on product development and production. The retailer’s expected profit is:
\[
E[\pi_r (q_r)] = \int_{a_r}^{\theta p_r} \left[ p_r (x + \theta p_r) - w q_r + v (q_r - x - \theta p_r) \right] f(x) \, dx \\
+ \int_{\theta p_r}^{\infty} q_r (p_r - w) f(x) \, dx + (a_r - p_r)(p_r - c)
\]

Let \( \bar{q}_r = q_r - \theta p_r \) denote that the order quantity just meets the market demand.

Let \( \bar{Q}_r = \frac{q_r (w - v)}{p_r - v} - \theta p_r \) denote the breakeven selling quantity function of the retailer. Retailers are equally concerned about revenue from different channels. There is no loss in the online pre-sale mode. Based on the prospect theory, we assume that the loss aversion of retailers just exists in offline channels and will not be affected by the income of online channels. The expected utility of the retailer is

\[
E[U_r (q_r, p_r)] = \pi_r + (\lambda - 1) \int_{\lambda}^{\infty} \left[ p_r (x + \theta p_r) - w q_r + v (q_r - x - \theta p_r) \right] f(x) \, dx + (a_r - p_r)(p_r - w)
\]  

(5)

The Hessian matrix of the retailer’s utility function

\[
H_{U_r [q_r, p_r]} = \begin{bmatrix}
-(p_r - v) f(\bar{Q}_r) - (\lambda - 1)(w - v)^2 f(\bar{Q}_r) & \theta((p_r - v) f(\bar{Q}_r) + (\lambda - 1)(w - v) f(\bar{Q}_r)) \\
\theta((p_r - v) f(\bar{Q}_r) + (\lambda - 1)(w - v) f(\bar{Q}_r)) & -\theta^2((p_r - v) f(\bar{Q}_r) + (\lambda - 1)(p_r - v) f(\bar{Q}_r)) - 2
\end{bmatrix}
\]

is negative definite. Thus, a unique equilibrium solution \((q^*_r, p^*_r)\) exists. Taking the derivative with respect to \(q^*_r\) and \(p^*_r\), we can obtain

\[
\frac{\partial E[U_r]}{\partial q_r} = (p_r - w) - (p_r - v) F(\bar{Q}_r) - (\lambda - 1)(w - v) F(\bar{Q}_r)
\]  

(6)

\[
\frac{\partial E[U_r]}{\partial p_r} = \theta(p_r - v) F(\bar{Q}_r) + \theta(\lambda - 1)(p_r - v) F(\bar{Q}_r) + a_r + w - 2p_r
\]  

(7)

**Property 1.** The correlation between \(q^*_r\) and its loss avoidance degree is as follows

\[
\frac{dq^*_r}{d\lambda} \begin{cases} 
> 0 & \text{if } f(q^*_r, -\theta p^*_r)(p_r - w) (p_r - v) \theta^2 + 2v - 2w < 0 \\
< 0 & \text{if } f(q^*_r, -\theta p^*_r)(p_r - w) (p_r - v) \theta^2 + 2v - 2w > 0
\end{cases}
\]

**Proof** By the implicit function theorem, from (6) and (7), we have

\[
\frac{dq^*_r}{d\lambda} = \frac{T_r (q^*_r, p^*_r)}{H_{U_r [q_r, p_r]}}
\]

\[
= \frac{F_r (p_r - w) (p_r - v) \theta^2 + 2v - 2w}{\left( \theta^2 (p_r - w) (\lambda - 1) f_r + 2(p_r - v) \theta^2 + 2(\lambda - 1)(w - v)^2 f_r \right)}
\]

53
Where
\[
T_i = \frac{\partial^2 E[U_i(q_i, p_i)]}{\partial q_i \partial p_i} \frac{\partial^2 E[U_i(q_i, p_i)]}{\partial q_i \partial p_i} = \frac{-(w-v)F_i}{\theta(p_v-v)F_i - \theta^2(p_v-v)(f_r+(\lambda-1)f_r) - 2}
\]

\[
F_{i2} = F(q_i, p_i), f_i = f(q_i, p_i), f_a = f(q_a, -\theta p_i^*)
\]

If \( f_a(p_r, -\theta p_i)(p_r-v)\theta^2 + 2v - 2w > 0 \), \( T_i(q_i^*, p_i^*) > 0 \), \( \frac{dq_i^*}{d\lambda} < 0 \); on the contrary , \( \frac{dq_i^*}{d\lambda} > 0 \).

**Property 2.** There is a positive correlation between online order quantity and online pre-sale price.

**Proof** By the implicit function theorem, from (6) and (7), we have
\[
\frac{\partial p_r^*}{\partial q_r} = \frac{\partial^2 E[U_i(q_i, p_i)]}{\partial q_i \partial p_i} \frac{\partial^2 E[U_i(q_i, p_i)]}{\partial q_i \partial p_i} = \frac{\theta(p_r-v)F_r + \theta(\lambda-1)(w-v)F_i}{\theta^2(p_r-v)F_r + \theta(\lambda-1)(p_r-v)F_i + 2} > 0.
\]

**Property 3.** The optimal online pre-sale price \( p_r^* \) increases with \( \lambda \).

**Proof** Let \( p_r = p_r^*(q_r^*(\lambda), \lambda) \). Using the chain rule, we obtain
\[
\frac{dp_r^*}{d\lambda} = \frac{\partial p_r^*}{\partial q_r^*} \frac{dq_r^*}{d\lambda} + \frac{\partial p_r^*}{\partial \lambda} = \frac{(p_r-w)(p_r-v)^2 f_r \theta}{(\lambda-1)(\theta^2(p_r-w)^2 (p_r-v)F_r + 2(w-v)^2)F_r + 2(p_r-v)^2 f_r} > 0,
\]
where \( \frac{\partial q_r^*}{\partial \lambda} = \frac{\theta(p_r-v)F_r}{\theta^2((p_r-v)F_r + (\lambda-1)(p_r-v)F_i) + 2} \).

**NUMERICAL ANALYSIS**

The loss avoidance behavior of retailers will have an impact on the decision of members, and what will happen to the profit change of corresponding supply chain members and the overall income? We will analyze it through numerical experiments in this section. Let \( p_r = 25 \), \( w = 15 \), \( c = 10 \), \( v = 2 \), \( \delta = 0.8 \), \( \theta = 0.6 \), \( D_r \sim N(a, 2\nu^2) \).
As shown in Figure 1, the optimal order quantity \( q^* \) under the retailer's decision-making is smaller than that under the centralized decision-making, the optimal pre-sale price \( p^* \) is higher than that under the centralized decision-making. With the increase of loss aversion attitude of retailers, \( q^* \) shows a decreasing trend, and the deviation from \( q^* \) increases gradually. Whereas, \( p^* \) increases with \( \lambda \), which is mainly due to the fact that offline channel, as the main sales channel. By increasing online pre-sale price, which will reduce online demand to a certain extent, but can significantly increase offline sales volume.

As shown in Figure 2, the utility and profit of retailers both decrease with the level of loss aversion increases. Compared with retailers, loss aversion has a stronger negative impact on manufacturers' earnings. Therefore, it is of great significance for manufacturers to guide retailers' decisions and reduce their decision-making deviations through contracts.

**COORDINATING CONTRACTS**

Supply chain coordination is very important to optimize supply chain operation. We will study the coordination effect of the buyback contract and GLB which is a modified contract based on the buyback contract on the supply chain.
BUYBACK CONTRACT

With a buyback contract, the retailer orders a product with the wholesale price \( w \), the supplier pays the retailer \( b (v < b < w) \) per unit remaining at the end of the sale season. The buyback contract makes the supplier share part of the risk brought by the uncertainty of market demand to the retailer, and give the retailer an incentive to increase its order quantity.

With byback contract, retailers’ expected utility function is given as follows

\[
E\left[U^b_r\right] = \lambda \int A \left[ p_r(x + \theta p_r^b) - wq^b_r + b(q^b_r - x - \theta p_r^b) \right] f(x) dx \\
+ \int B \left[ p_r(x + \theta p_r^b) - wq^b_r + b(q^b_r - x - \theta p_r^b) \right] f(x) dx \\
+ \int D q^b_r(p_r - w)f(x) dx + (a_r - p_r^b)(p_r^b - c) \\
= E\left[\pi^b_r\right] + (\lambda - 1) L^b 
\]

Let \( \overline{q}^b_r = q^b_r - \theta p_r^b \), \( \overline{q}^b_r = \frac{q^b_r(w-b)}{p_r - b} - \theta p_r^b \). Retailer’s loss is expressed as

\[
L^b = \int A \left[ p_r(x + \theta p_r^b) - wq^b_r + b(q^b_r - x - \theta p_r^b) \right] f(x) dx.
\]

Taking the first partial derivative of (8) with respect to \( q^b_r \) and \( p_r^b \), we can obtain

\[
\frac{\partial E\left[U^b_r\right]}{\partial q^b_r} = p_r - w - (p_r - b)F\left(q^b_r - \theta p_r^b\right) - (\lambda - 1)(w-b)F\left(\overline{q}^b_r\right) 
\]

\[
\frac{\partial E\left[U^b_r\right]}{\partial p_r^b} = \theta(p_r - b)F\left(q^b_r - \theta p_r^b\right) + \theta(\lambda - 1)(p_r - b)F\left(\overline{q}^b_r\right) + a_r + w - 2p_r^b 
\]

If \( q^b_r, p_r^b \) satisfies Eqs.(9) and (10), \((q^b_r, p_r^b)\) is the retailers’ optimal strategy with this contract.

**Proposition 1.** Manufacturers cannot achieve supply chain coordination through buyback contracts.

**Proof** By bring \( q^b_r \) and \( p_r^b \) into (9), we can obtain

\[
\frac{\partial E\left[U^b_r\right]}{\partial q^b_r} = p_r - w - (p_r - b)F\left(q^b_r - \theta p_r^b\right) - (\lambda - 1)(w-b)F\left(\overline{q}^b_r\right) 
\]

Let (11) equal to zero, we can obtain an equation about \( b \) as follows

\[
b^* = \frac{w(\lambda - 1)(p_r - v)F\left(q^b_r(w-b)\right)(p_r - b) - \theta p_r^b)}{(\lambda - 1)(p_r - v)F\left(q^b_r(w-b)\right)(p_r - b) - \theta p_r^b} + p_r - c
\]
By bringing $b^*, q^e_r, p^c_e$ into (11), we can obtain an equation about $w$ as follows

$$w^* = \frac{(\lambda-1)p_r F q^e_r (w-b) - \theta p^c_e + c}{1 + (\lambda-1)F q^e_r (w-b) - \theta p^c_e} \theta - c.$$  

If $w^* > c$, $w^* > p_r$; If $w^* < c$, $w^* < p_r$. Therefore, there’s not exist a wholesale price $w$ between $c$ and $p_r$ that satisfies

$$\frac{\partial E[U^i_r (q^e_r, p^c_e)]}{\partial q^e_r} = 0, \frac{\partial E[U^i_r (q^e_r, p^c_e)]}{\partial p^c_e} = 0.$$  

**GLB CONTRACT**

In this section, we investigate the role of the GLB contract for supply chain coordination, using the risk-neutral integrated firm’s solution as the benchmark.

GLB contract consists of four parts: $w, b, \gamma$ and $\beta$ [17]. $w$ and $b$ represent the traditional wholesale price contract and buyback contract respectively. Moreover, the manufacturer either shares a fraction $\beta$ of the gain of the retailer or bears a fraction $\gamma$ of its loss.

With GLB contract, retailers’ expected utility function is given as follows

$$E[U_r^e (q^e_r, p^c_e)] = (1 - \beta)(G_r + G_e) + \lambda(1 - \gamma)L^e_r = (1 - \beta)\pi^e_r + (\lambda(1 - \gamma) - (1 - \beta))L^e_r$$  

(12)

where

$$G_r = \int_{q^e_r}^{G_r} [p_r (x + \theta p^c_e) - wq^e_r + b(q^e_r - x - \theta p^c_e)]f(x)dx + \int_{q^e_r}^{b} q^e_r (p_r - w)f(x)dx,$$

$$G_e = (a_r - p^e_e) (p^c_r - c), L^e_r = \int_{q^e_r}^{G_r} [(p_r - v) x + \theta p^c_e (p_r - v) - p^c_e (w - v)]f(x)dx.$$  

Let $\Gamma = \lambda(1 - \gamma) - (1 - \beta)$. Manufacturers’ profit function is given as follows

$$E[\pi^m_e] = (a_r - p^e_r + q^e_r) (w - c) - (b - v) \int_{q^e_r}^{G_r} (q^e_r - x - \theta p^c_e) f(x)dx + \beta(G_r + G_e) + \gamma L^e_r.$$  

Taking the first partial derivative of (8) with respect to $q^e_r$ and $p^c_e$, we can obtain

$$\frac{\partial E[U_r^e]}{\partial q^e_r} = (1 - \beta)\left[p_r - w - (p_r - b) F(q^e_r)\right] - \Gamma (w - b) F(q^e_r)$$  

(13)
\[
\frac{\partial E[U_u^G]}{\partial p_r^G} = (1-\beta)\left[\theta(p_r-b)F(\tilde{Q}_d^G) + a_r + w - 2\rho_r^G\right] + \Gamma \theta(\lambda-1)(p_r-b)F(\tilde{Q}_d^G)
\]  
(14)

**Proposition 2.** A GLB contract with the following conditions can coordinate the supply chain and distribute the expected profit of supply chain between the manufacturer and the retailer by changing the value of \( \beta \).

1. \( \gamma = 1 - \frac{1-\beta}{\lambda} \).
2. \( w = c, b = v \).

**Proof** Let \( \gamma = 1 - \frac{1-\beta}{\lambda} \), we can deduce \( \Gamma = 0 \). Eqs (13) - (14) are simplified as follows

\[
\frac{\partial E[U_u^G]}{\partial q_r^G} = (1-\beta)\left[p_r - w - (p_r-b)F(\tilde{Q}_d^G)\right]
\]
(15)

\[
\frac{\partial E[U_u^G]}{\partial p_r^G} = (1-\beta)\left[\theta(p_r-b)F(\tilde{Q}_d^G) + a_r + w - 2\rho_r^G\right]
\]
(16)

Let \( w = c, b = v, (q_r^*, p_r^*) \) can satisfy \( \frac{\partial E[U_u^G(q_r^*, p_r^*)]}{\partial q_r^G} = \frac{\partial E[U_u^G(q_r^*, p_r^*)]}{\partial p_r^G} = 0 \).

**CONTRACT COORDINATE EFFECT**

The premise of contractual feasibility is to ensure that the participating members can get more benefits than before the contract is implemented. We will analyze the feasibility of the contract through numerical simulation. The base parameters are set as before, \( \lambda = 3 \).

Figure 3. Coordinate effect of GLB contract.
Figure 3 shows that there is a roughly linear correlation between the change of seller’s utility and manufacturer’s profit and the proportion of income distribution $\beta$ when the supply chain is coordinated. With the increase of $\beta$, manufacturers get a higher proportion of channel profits, and their profits tend to increase. When $\beta > \beta_1$, the manufacturer's profit $\pi_m$ under GLB contract exceeds that without contract. For the retailers, the profit and utility will inevitably decrease with $\beta$ increases. When $\beta$ does not exceed $\beta_1$, the corresponding utility that retailers obtained will be higher than the situation before the contract is implemented. Therefore, when other parameters are determined, from the perspective of member benefits, there is an income distribution interval $R_1(\beta_1,\beta_2)$, which makes the contract feasible.

CONCLUDING REMARKS

This paper takes the dual-channel supply chain as the research background, in which online pre-sale strategy and offline traditional inventory sales strategy are adopted. In this paper, the loss aversion behavior of retailers is applied to this scenario, and the corresponding conclusions obtained are summarized as follows

1. The correlations between order quantity, price deviation and loss aversion are deduced.
2. By the numerical analysis, we observed that the loss-aversion of retailer will make the members of the supply chain suffer losses, especially for the manufacturers. Therefore, it is very important for manufacturers to find a feasible contract to coordinate the supply chain.
3. Manufacturers cannot achieve supply chain coordination through buyback contracts. A GLB contract can coordinate the supply chain under some conditions. The retailer and the manufacturer can achieve a win-win situation.

Considering richer business scenarios and exploring the feasibility of contracts at the operational level is a significant topic for future research.

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