Research Article

Supply Chain Contract Choice with Different Behavior Preferences of Retailer

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Retailer may exhibit irrationality when facing the risk of demand uncertainty; therefore, we consider four retailer behavioral preferences: risk neutral (RN), waste aversion (WA), stockout aversion (SA), and stockout-waste aversion (SW). The decision-making and contract choice of upstream and downstream enterprises in cases where demand depends on supplier's effort are studied. The results show that if the retailer has only SA or RN preferences, then the supplier prefers to choose a wholesale price contract, while the retailer does the opposite, if the retailer has only WA, then the supplier prefers to choose a revenue sharing contract, but the retailer's contract choice depends on the degree of waste aversion, and if the retailer has SW, then the contract choice of upstream and downstream enterprises is related to the degree of waste aversion and stockout aversion.

1. Introduction

Because different contracts may bring different benefits to supply chain participants, different participants choose different contracts. The concept of supply chain contract choice comes from the term “prefer” proposed by Cachon and Lariviere [1], who noted that the supplier prefers contracts that is more profitable to him based on different circumstances. However, the research on contract choice is still very limited, and most of the existing literature focuses on the choice between wholesale price contract and revenue-sharing contract, which is also the content of this paper. The reason for choosing the two contracts in this paper is that the two contracts are simple and the two contracts are widely used in real life.

To weigh the advantages and disadvantages of the above two contracts, Cachon and Lariviere [1] analyze the contract selection of upstream enterprises when product quantity and retailer effort influence product price. In addition, Pan et al. [2] study the contract choice problem under different dominant agents using a system constructed by two upstream enterprises and a single downstream enterprise or a single upstream enterprise and two downstream enterprises. Xu [3] discusses the contract choice under a three-level tourism supply chain

dominated by a travel agency. Jin et al. [4] study the contract choice under different agents who make decisions about effort when demand is affected by retail price and effort and the retailer has financial constraints. Chakraborty et al. [5] consider the situation in which the retailer sells two alternative products at the same time and where the market demand depends on the retail price of the two products, and they study the contract choice problem under different power structures. Lu et al. [6] analyze the influence of advertising effort efficiency and channel member patience on contract choice in the context of downstream enterprises leading and advertising having a dynamic influence. Meng and Huang [7] discuss the contract choice of upstream and downstream enterprises in the case of two upstream logistics service providers.

However, the above studies take the participants' perfect rationality as the premise of their research and do not consider the possibility that the participants may have limited rationality [8]. In fact, there is risk in demand [9], and the behavior of decision makers may be affected by demand [10]. In particular, Schweitzer and Cachon [11] point out that retailers may have a waste aversion preference because they do not like carrying excess inventory, or they may have a stockout aversion preference because they dislike shortages.

Therefore, the two behavior preferences are introduced into the supply chain, especially considering that random demand is affected by the supplier's effort (e.g., advertising, quality, services to enhance the physical store, and after-sales service [12–15]). This paper studies the decision-making and contract choice of upstream and downstream enterprises in the supply chain under different behavior preferences of the retailer.

2. Model Assumptions

The model is based on the following assumptions:

- (1) The risk-neutral supplier is the leader.
- (2) Four retailer behavioral preferences are considered: risk neutral (RN), waste aversion (WA), stockout aversion (SA), and stockout-waste aversion (SW).
- (3) Market demand is $D = e\xi$ [12], where e is the effort input level of the supplier and ξ is the random disturbance factor. Because of the complexity of the model structure, the model cannot be solved; to simplify the model and obtain more valuable conclusions, the methods of Taylor [12] and Yu and Wan [16] are used, and ξ is assumed to follow the distribution of $U(0, B)$.
- (4) $p > w > c > v$.

The symbols of this article are summarized in Table 1.

3. Model Construction

3.1. RS Model. Under the RS model, it is assumed that the retailer gives $(1 - \phi)$ times its own sales revenue to the supplier in exchange for a lower wholesale price $w = \phi c$ [1], where $0 < \phi \leq 1$ and $\phi p > v$. When the random demand depends on the effort of the supplier, the retailer's expected sales volume $S(q, e)$, inventory volume $L(q, e)$, and shortage volume $N(q, e)$ are

$$\begin{aligned} S(q, e) &= E[\min(q, e\xi)], \\ L(q, e) &= E(q - e\xi)^+ = q - S(q, e), \\ N(q, e) &= E(e\xi - q)^+ = E(e\xi) - S(q, e). \end{aligned} \quad (1)$$

The expected profits of upstream and downstream enterprises are

$$\begin{aligned} \pi_{S-j}^{RS}(\phi, e) &= (1 - \phi)pS(q, e) - (1 - \phi)cq - ke^2, \\ \pi_{R-j}^{RS}(q) &= \phi pS(q, e) + vL(q, e) - \phi cq, \end{aligned} \quad (2)$$

where $j \in \{RN, WA, SA, SW\}$.

3.1.1. SW Model. If the retailer has an SW preference, then the expected utility of the retailer is as calculated below:

$$U_{R-SW}^{RS}(q) = \phi pS(q, e) + vL(q, e) - \lambda N(q, e) - \beta L(q, e) - \phi cq. \quad (3)$$

From equation (3), we obtain

$$\begin{aligned} \frac{\partial U_{R-SW}^{RS}}{\partial q} &= \frac{q(v - \beta - \lambda - p\phi) + Be[\lambda + \phi(p - c)]}{Be}, \\ \frac{\partial^2 U_{R-SW}^{RS}}{\partial q^2} &= \frac{p\phi - v + \lambda + \beta}{-Be} < 0. \end{aligned} \quad (4)$$

From equation (3), we can see that U_{R-SW}^{RS} is a concave function of q . Therefore, if $\partial U_{R-SW}^{RS}/\partial q = 0$, the unique optimal q_{SW}^{RS*} can be obtained:

$$q_{SW}^{RS*} = \frac{Be[\lambda + \phi(p - c)]}{\phi p + \lambda + \beta - v}. \quad (5)$$

By substituting q_{SW}^{RS*} into equation (2), then

$$\max_{\phi, e} \pi_{S-SW}^{RS} = \frac{Bep(1 - \phi)(2\beta + \lambda - 2v + c\phi + p\phi)[\lambda + \phi(p - c)]}{2(\phi p + \lambda + \beta - v)^2} - \frac{Bec(1 - \phi)[\lambda + \phi(p - c)]}{\phi p + \lambda + \beta - v} - ke^2. \quad (6)$$

From equation (6), we obtain

$$\begin{aligned} \frac{\partial \pi_{S-SW}^{RS}}{\partial e} &= \frac{Bp(1 - \phi)(2\beta + \lambda - 2v + c\phi + p\phi)[\lambda + \phi(p - c)]}{2(\phi p + \lambda + \beta - v)^2} - \frac{Bc(1 - \phi)[\lambda + \phi(p - c)]}{\phi p + \lambda + \beta - v} - 2ke, \\ \frac{\partial \pi_{S-SW}^{RS}}{\partial \phi} &= Be\{2c(p - c)(\phi - 1)(\phi p + \lambda + \beta - v)^2 + p(p - c)(1 - \phi)(\phi p + \lambda + \beta - v)\} \\ &\quad \times (2\beta + \lambda - 2v + c\phi + p\phi) + 2cp(1 - \phi)(\phi p + \lambda + \beta - v)[\lambda + \phi(p - c)] \\ &\quad + p(p + c)(1 - \phi)(\phi p + \lambda + \beta - v)[\lambda + \phi(p - c)] + 2c(\phi p + \lambda + \beta - v)^2 \\ &\quad \times [\lambda + \phi(p - c)] - 2p^2(1 - \phi)(\phi p + \phi c + \lambda + 2\beta - 2v)[\lambda + \phi(p - c)] \\ &\quad - p(\phi p + \lambda + \beta - v)(\phi p + \phi c + \lambda + 2\beta - 2v)[\lambda + \phi(p - c)]. \end{aligned} \quad (7)$$

TABLE 1: Symbols and meanings.

w	Wholesale price
p	Retail price
e	Effort
β	Waste aversion coefficient
RN	Risk neutral
SA	Stockout averse preference
WP	Wholesale price contract
U_{R-i}^j	Under j contract, the expected utility obtained by the retailer him or herself when he or she has i preference
π_{R-i}^j	Under j contract, the expected profit obtained by the retailer him or herself when he or she has i preference
c	Production costs
q	Order quantity
v	Salvage value
λ	Stockout aversion coefficient
WA	Waste averse preference
SW	Stockout-waste averse preference
RS	Revenue-sharing contract
π_{S-i}^j	Under j contract, the expected profit of the supplier when the retailer has i preference $j \in \{WP, RS\}$ and $i \in \{RN, WA, SA, SW\}$

The optimal e_{SW}^{RS*} and ϕ_{SW}^{RS*} can be obtained by making $\partial \pi_{S-SW}^{RS} / \partial e = 0$ and $\partial \pi_{S-SW}^{RS} / \partial \phi = 0$, and the optimal expected profits of the upstream and downstream enterprises are

$$\pi_{S-SW}^{RS*} = \frac{Be_{SW}^{RS*} p (1 - \phi_{SW}^{RS*}) (p \phi_{SW}^{RS*} + c \phi_{SW}^{RS*} + \lambda + 2\beta - 2\nu) [\lambda + \phi_{SW}^{RS*} (p - c)]}{2(\phi_{SW}^{RS*} p - \nu + \lambda + \beta)^2} - \frac{Bec(1 - \phi_{SW}^{RS*}) [\lambda + \phi_{SW}^{RS*} (p - c)]}{\phi_{SW}^{RS*} p - \nu + \lambda + \beta} - k(e_{SW}^{RS*})^2,$$

$$\pi_{R-SW}^{RS*} = \frac{[Be_{SW}^{RS*} [\lambda + \phi_{SW}^{RS*} (p - c)] \{ \nu [\lambda - \phi_{SW}^{RS*} (p - c)] + \phi_{SW}^{RS*} [p(2\beta + \lambda + \phi_{SW}^{RS*} p) - c(2\beta + 2\lambda + \phi_{SW}^{RS*} p)] \}]}{2(\phi_{SW}^{RS*} p - \nu + \lambda + \beta)^2}.$$

3.1.2. *WA Model.* If the retailer is WA, that is, $\lambda = 0$ and $\beta > 0$, then (7) can be used to obtain the optimal e_{WA}^{RS*} and ϕ_{WA}^{RS*} which are given as

$$\frac{4ke(\phi p + \beta - \nu)^2 - B\phi(1 - \phi)(p - c)^2(p\phi + 2\beta - 2\nu)}{\phi p + \beta - \nu} = 0,$$

$$\frac{Be(p - c)\{3p\beta\phi^2 + p^2\phi^3 + (\nu^2 + \beta^2)(4\phi - 2) + \nu[\beta(4 - 8\phi) - 3p\phi^2]\}}{\phi p + \beta - \nu} = 0.$$

At this point, q_{WA}^{RS*} , π_{S-WA}^{RS*} , and π_{R-WA}^{RS*} are

$$q_{WA}^{RS*} = \frac{Be_{WA}^{RS*} \phi_{WA}^{RS*} (p - c)}{p \phi_{WA}^{RS*} + \beta - \nu},$$

$$\pi_{S-WA}^{RS*} = \frac{Be p \phi_{WA}^{RS*} (p - c) (1 - \phi_{WA}^{RS*}) (p \phi_{WA}^{RS*} + c \phi_{WA}^{RS*} + 2\beta - 2\nu)}{2(\phi_{WA}^{RS*} p - \nu + \beta)^2} - \frac{Bec \phi_{WA}^{RS*} (p - c) (1 - \phi_{WA}^{RS*})}{\phi_{WA}^{RS*} p - \nu + \beta} - k(e_{WA}^{RS*})^2,$$

$$\pi_{R-WA}^{RS*} = \frac{Be \phi_{WA}^{RS*} (p - c) \{ \nu \phi_{WA}^{RS*} (c - p) + \phi_{WA}^{RS*} [p(2\beta + \phi_{WA}^{RS*} p) - c(2\beta + p \phi_{WA}^{RS*})] \}}{2(\phi_{WA}^{RS*} p - \nu + \beta)^2}.$$

3.1.3. SA Model. If the retailer is SA, that is, $\lambda > 0$ and $\beta = 0$, then (7) can be used to obtain the optimal e_{SA}^{RS*} and ϕ_{SA}^{RS*} which are given as

$$\begin{aligned} & \frac{Bp(1-\phi)(\lambda-2v+c\phi+p\phi)[\lambda+\phi(p-c)]}{2(\phi p+\lambda-v)^2} - \frac{Bc(1-\phi)[\lambda+\phi(p-c)]}{\phi p+\lambda-v} - 2ke = 0, \\ & Be\{2c(p-c)(\phi-1)(\phi p+\lambda-v)^2 + p(p-c)(1-\phi)(\phi p+\lambda-v) \times (\lambda-2v+c\phi+p\phi) + 2cp(1-\phi)(\phi p+\lambda-v) \\ & [\lambda+\phi(p-c)] + p(p+c)(1-\phi)(\phi p+\lambda-v)[\lambda+\phi(p-c)] + 2c(\phi p+\lambda-v)^2 \times [\lambda+\phi(p-c)] \\ & - 2p^2(1-\phi)(\phi p+\phi c+\lambda-2v)[\lambda+\phi(p-c)] - p(\phi p+\lambda-v)(\phi p+\phi c+\lambda-2v)[\lambda+\phi(p-c)] = 0. \end{aligned} \quad (11)$$

In the same way as above, the optimal q_{SA}^{RS*} , π_{S-SA}^{RS*} , and π_{R-SA}^{RS*} can be obtained.

3.1.4. RN Model. If the retailer is RN, that is, $\lambda > 0$ and $\beta = 0$, then (7) can be used to obtain the optimal e_{RN}^{RS*} and ϕ_{RN}^{RS*} which is given as

$$\begin{aligned} & \frac{Be(p-c)^2[\phi^3 p^2 + v^2(4\phi-2) - 3pv\phi^2]}{2(v-\phi p)^3} = 0, \\ & \frac{B\phi(1-\phi)(p-c)^2(\phi p-2v) - 2ke(\phi p-v)^2}{2(v-\phi p)^2} - ke = 0. \end{aligned} \quad (12)$$

In the same way as above, the optimal q_{RN}^{RS*} , π_{S-RN}^{RS*} , and π_{R-RN}^{RS*} can be obtained.

3.2. WP Model. If WP is adopted between upstream and downstream enterprises, then the decision models under the four different behavior preferences are as follows.

3.2.1. RN Model

$$\begin{aligned} \text{Step 1: } \max_{w,e} \pi_{S-RN}^{WP}(w,e) &= (w-c)q - ke^2 \\ \text{Step 2: } \max_q \pi_{R-RN}^{WP}(q|w,e) &= pS(q,e) + vL(q,e) - wq \end{aligned}$$

3.2.2. WA Model

$$\begin{aligned} \text{Step 1: } \max_{w,e} \pi_{S-WA}^{WP}(w,e) &= (w-c)q - ke^2 \\ \text{Step 2: } \max_q U_{R-WA}^{WP}(q|w,e) &= pS(q,e) + vL(q,e) - \beta L(q,e) - wq \end{aligned}$$

3.2.3. SA Model

$$\begin{aligned} \text{Step 1: } \max_{w,e} \pi_{S-SA}^{WP}(w,e) &= (w-c)q - ke^2 \\ \text{Step 2: } \max_q U_{R-SA}^{WP}(q|w,e) &= pS(q,e) + vL(q,e) - \lambda N(q,e) - wq \end{aligned}$$

3.2.4. SW Model

$$\text{Step 1: } \max_{w,e} \pi_{S-SW}^{WP}(w,e) = (w-c)q - ke^2$$

$$\text{Step 2: } \max_{q,e} U_{R-SW}^{WP}(q|w,e) = pS(q,e) + vL(q,e) - \lambda N(q,e) - \beta L(q,e) - wq$$

If the retailer is SW, let $\partial U_{R-SW}^{WP}/\partial q = 0$; we can obtain

$$q_{SW}^{WP*} = \frac{Be(p-w+\lambda)}{p-v+\lambda+\beta}. \quad (13)$$

By substituting q_{SW}^{WP*} into $\pi_{S-SW}^{WP}(w,e)$, then

$$\max_{w,e} \pi_{S-SW}^{WP}(w,e) = \frac{Be(w-c)(p-w+\lambda)}{p-v+\beta+\lambda} - ke^2. \quad (14)$$

Let $\partial \pi_{S-SW}^{WP}/\partial w = 0$ and $\partial \pi_{S-SW}^{WP}/\partial e = 0$, and we can obtain

$$\begin{aligned} w^{SW*} &= \frac{p+c+\lambda}{2}, \\ e_{SW}^{WP*} &= \frac{B(p-c+\lambda)^2}{8k(p-v+\beta+\lambda)}. \end{aligned} \quad (15)$$

By substituting w^{SW*} and e_{SW}^{WP*} into q_{SW}^{WP*} , π_{S-SW}^{WP} , and π_{R-SW}^{WP} , so you can get the result of the fourth row in Table 2. In the same way as above, the Nash equilibrium for each of the other three behavioral preference models under WP can be obtained by using the reverse induction method; therefore, it is omitted. The results are shown in Table 2.

4. Numerical Simulation Analysis

Due to the complexity of the results obtained under the RS model, we cannot analyze them through theoretical derivation. Therefore, in this section, we use the method of numerical simulation to obtain more valuable conclusions. Without loss of generality, we take $c = 1$, $v = 0.5$, $k = 2$, $B = 50$, and $p = 5$.

From Figures 1–4, we can obtain Lemma 1 and Proposition 1.

Lemma 1. If the retailer has SA, (1) under the WP model, q_{SA}^{WP*} increases with respect to λ , but q_{SA}^{RS*} decreases with respect to λ under the RS, (2) under both the WP and RS models, e_{SA}^{WP*} and e_{SA}^{RS*} are increasing with respect to λ , and (3)

TABLE 2: Optimal value under WP with four behavioral preferences ($j \in \{RN, SA, WA, SW\}$).

Preference	$q_j^{WP^*}$	$e_j^{WP^*}$	$\pi_j^{WP^*}$	$\pi_j^{WP^*}$
RN	$B^2(p-c)^3/16k(p-v)^2$	$B(p-c)^2/8k(p-v)$	$B^2(p-c)^4/64k(p-v)^2$	$B^2(p-c)^4/64k(p-v)^2$
WA	$B^2(p-c)^3/16k(p-v+\beta)^2$	$B(p-c)^2/8k(p-v+\beta)$	$B^2(p-c)^3/64k(p-v+\beta)^2$	$B^2(p-v+2\beta)(p-c)^4/64k(p-v+\beta)^2$
SA	$B^2(p+\lambda-c)^3/16k(p-v+\lambda)^2$	$B(p-c+\lambda)^2/8k(p-v+\lambda)$	$B^2(p+\lambda-c)^4/64k(p-v+\lambda)^2$	$B^2(p-c+\lambda)^3[p^2-p(v+2\lambda)+\lambda(3v-2\lambda)-c(p-v+2\lambda)]/64k(p-v+\lambda)^3$
SW	$B^2(p+\lambda-c)^3/16k(p-v+\beta+\lambda)^2$	$B(p-c+\lambda)^2/8k(p-v+\beta+\lambda)$	$B^2(p-c+\lambda)^4/64k(p-v+\beta+\lambda)^2$	$[B^2(p-c+\lambda)^3\{p^2-p(v-2\beta+\lambda)-\lambda[-3v+2(\beta+\lambda)]-c[p-v+2(\beta+\lambda)]\}]/64k(p-v+\beta+\lambda)^3$

FIGURE 1: Effect of λ on order quantity. FIGURE 2: Effect of λ on effort. FIGURE 3: Effect of λ on supplier's expected profit.

under both the WP and RS models, π_{S-SA}^{WP*} and π_{S-SA}^{RS*} are increasing with respect to λ , while π_{R-SA}^{WP*} and π_{R-SA}^{RS*} are decreasing with respect to λ .

Proposition 1. If the retailer is SA (RN), then compared with the WP model, (1) the retailer orders more under the RS model, (2) less effort (expected profit) is made by the supplier

FIGURE 4: Effect of λ on retailer's expected profit. FIGURE 7: Effect of β on supplier's expected profit. FIGURE 5: Effect of β on order quantity. FIGURE 8: Effect of β on retailer's expected profit. FIGURE 6: Effect of β on effort.

under the RS model, and (3) the retailer has higher expected profit under the RS model.

From Figures 5–8, we can obtain Lemma 2 and Proposition 2.

FIGURE 9: Effect of λ and β on order quantity.

Lemma 2. If the retailer has WA, the following is obtained. (1) Under the WP model, both q_{WA}^{WP*} and e_{WA}^{WP*} are decreasing functions of β . However, under the RS model, both q_{WA}^{RS*} and

FIGURE 10: Effect of λ and β on effort. FIGURE 11: Effect of λ and β on the supplier's expected profit.

e_{WA}^{RS*} are first increasing and then decreasing with an increase in β . (2) Under the WP model, π_{S-WA}^{WP*} is a decreasing function of β . However, under the RS model, π_{S-WA}^{RS*} is first increasing and then decreasing with an increase in β . (3) Under the WP model, π_{R-WA}^{WP*} is a decreasing function of β , while under the RS model, with the increase in β , there is a tendency for expected profit to decrease first, then increase, and then decrease.

Proposition 2. If the retailer has WA, then compared with the WP model, (1) the retailer orders more under the RS model, (2) supplier invests more effort under the RS model, (3) the expected profit of the supplier under the RS model is greater, and (4) the size of the retailer's expected profit between the above two contracts is related to β ; there are thresholds β_1 and β_2 such that $\beta_1 < \beta_2$, and if $\beta < \beta_1$ or $\beta > \beta_2$, its expected profit under the RS is greater, whereas when $\beta_1 < \beta < \beta_2$, the expected profit under the WP model is greater.

From Figures 9–12, we can obtain Proposition 3.

FIGURE 12: Effect of λ and β on the retailer's expected profit.

Proposition 3. If the retailer has SW, (1) the retailer orders more under the RS model, (2) when β is small, then the supplier's effort (expected profit) under the WP model may be greater than under the RS model, and most of the time it is greater in the RS model, and (3) when β is medium and λ is small, then the retailer's expected profit under the WP model may be greater, and most of the time it is greater in the RS model.

5. Conclusion

In this paper, four situations in which the retailer has behavioral preferences are considered in the case of random demand affected by supplier's effort. Based on the WP and RS models, the influence of the retailer's different behavior preferences on the decision-making and contract choice of upstream and downstream enterprises is discussed.

The results show the following. (1) When the retailer only has SA (RN), the supplier's effort investment level under the WP model is higher, and the retailer's order quantity under the RS model is larger. (2) When the retailer only has WA, the supplier's effort input level and the retailer's order quantity under the RS model will be larger. (3) When the retailer has SW, the retailer will order more under the RS model, and the supplier's effort input level between the two contracts depends on the degree of waste aversion and stockout aversion. (4) When the retailer has only SA (RN), the supplier's expected profit under the WP model is greater, while the retailer's expected profit is lower. (5) When the retailer has only WA, the supplier's expected profit under the RS model is greater, but the expected profit of the retailer between the two contracts depends on the degree of waste aversion. (6) When the retailer has SW, the expected profit of both the retailer and supplier between the two contracts is related to the degree of waste aversion and stockout aversion.

Demand is often the private information for retailers [17, 18], so the impact of demand information sharing on

supply chain contract choice can be considered in future studies.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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