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Commitment contract in dual channel drop shipping supply chain

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Abstract: It is a general trend for retailers to develop dual channel to serve different customers. Engaging in internet and drop shipping has raised serious awareness and attention in retailing field. We focus on such supply chain context and propose the commitment contracts for the drop shipping supply chain. In drop shipping supply chain, if the retailer's order quantity achieves decentralized level, the profit of the supply chain can be maximized. The profit of the supply chain can be maximized.

Keywords: supply chain management, commitment contract, drop shipping, dual-distribution channel

1. Introduction

Drop-shipping is a commonly adopted order fulfillment strategy for retailer's online distribution channel or part store-based channel by which the retailer does not keep goods in stock, but transfers customer orders and shipment details to manufacturer, who then delivers the ordered goods directly to the customer. We focus on such complicated dual channel and drop shipping supply chain and consider the coordination methods.

2. Literature Review

Drop shipping is used by online as well as traditional retailers as an order fulfillment strategy. The advantages and shortcomings of drop shipping are studied in (Khouja, 2001). The channel power and coordination in the drop-shipping supply chain with a single supplier and a single retailer is verified in (Khouja & Stylianou, 2009; Netessine & Rudi, 2006).

The impact of customers' stock-out based substitution on the product availability and the channel efficiency of a dual-channel supply chain are investigated in (Chiang, 2007). An infinite-horizon differential game between a manufacturer and a retailer is considered by (Rubel & Zaccour, 2007). A dual channel supply chain in which a manufacturer sell product through a retailer as well as to consumers directly is considered by (Shen & Zhang, 2009; Gan et al., 2010). The dominated manufacturer can benefit from reducing retailer's uncertainty on its in-perception only when the product's profitability is quite small (Wang et al., 2009). The main decision the retailer has to make is to determine the order quantity, taking into consideration risks related to shortage and inventory cost (Hovelaque, 2007).

3. Channel Structures and Assumption

3.1. Demand disruptions with decentralized supply chains

We consider a supply chain in which a supplier sells a product to a retailer. The retailer uses both the physical stores and online channel to the final consumers. The supplier decides commitment fee and wholesale price of drop shipping to optimize profit of itself and the whole supply chain. The notation is summarized as follows:

Parameters	Notation
r	the unit retail price
w_0	the wholesale price
c_0	the supplier’s unit production cost
c	commitment fee for unit drop shipping inventory in contract
w_d	wholesale price for each drop shipping item in contract

Q	the order quantity as its own inventory decided by the retailer
q	the commitment quantity for drop shipping
Q_D	the order quantity as own inventory in decentralized supply chain
q_D	the commitment quantity for drop shipping in decentralized supply chain
π_S , π_R	the expected profit of the supplier, retailer in general model
v_S , v_R	the unit salvage value of finished goods for the supplier and the retailer
p_S , p_R	the unit shortage penalty cost of the supplier and the retailer
D	the demand
$f(x)$	the probability density function of demand
$F(x)$	the cumulative distribution function of demand
Π^D	the total profit of decentralized, supplier-led, supply chain

4. Commitment Contract

4.1. Decentralized Model

In the decentralized supply chain, the supplier decides the unit commitment fee c and the wholesale price of drop shipping units w_d. We assume that the wholesale price w_0 is exogenous. The retailer decides the order quantity Q as its own inventory at the regular wholesale price w_0 and the committed drop shipping quantity q according to (c, w_d). The supplier produces the exact order quantity from (Q, q). The retailer sells the product at a retail price r per unit. The retailer has v_R per unit for the unsold inventory. The retailer's expected profit function is given by:

$$\begin{aligned} E\pi_R(Q,q) &= r\mathrm{E}[D \wedge (Q+q)] + v_R\mathrm{E}[Q-D]^+ - w_d\mathrm{E}[(D-Q)^+ \wedge q] \\ &\quad - p_R\mathrm{E}[D-Q-q]^+ - w_0 Q - cq \\ &= -p_R\mu + (r+p_R-w_0)Q + (r+p_R-w_d-c)q \\ &\quad -(r+p_R-w_d)\int_0^{Q+q} F(x)dx - (w_d-v_R)\int_0^{Q} F(x)dx \end{aligned} \tag{1}$$

The supplier's expected profit is

$$\begin{aligned} E\pi_S &= w_0 Q + cq - c_0(Q+q) + w_d \mathrm{E}[(D-Q)^+ \wedge q] + v_S \mathrm{E}[q-(D-Q)^+]^+ \\ &= (w_0 - c_0)Q + (c + w_d - c_0)q - (w_d - v_S)\int_Q^{Q+q} F(x)dx \end{aligned} \tag{2}$$

Proposition 1: In a decentralized drop shipping supply chain, retailer's optimal order quantity as its own inventory Q_D and the optimal drop shipping committed quantity q_D are satisfied followed:

$$Q_D(w_d, c) = F^{-1}\left(\frac{c + w_d - w_0}{w_d - v_R}\right) \tag{3}$$

$$q_D(w_d, c) = F^{-1}\left(\frac{r + p_R - w_d - c}{r + p_R - w_d}\right) - Q_D \tag{4}$$

The total order quantity of retailer is:

$$(Q_D + q_D) = F^{-1}\left(\frac{r + p_R - w_d - c}{r + p_R - w_d}\right) \tag{5}$$

Proof of Proposition 1:

Taking the first order derivative of the expected profit of retailer (1) with regard to Q and q gives us

$$\frac{\partial \pi_R}{\partial Q} = (r + p_R - w_0) - (r + p_R - w_d)F(Q+q) - (w_d - v_R)F(Q) = 0$$

$$\frac{\partial \pi_R}{\partial q} = (r + p_R - w_d - c) - (r + p_R - w_d)F(Q+q) = 0$$

We have

$$Q_D(w_d, c) = F^{-1}\left(\frac{c + w_d - w_0}{w_d - v_R}\right)$$

$$(Q_D + q_D) = F^{-1}\left(\frac{r + p_R - w_d - c}{r + p_R - w_d}\right)$$

And the Hessian Matrix is negative definite, so the solution under first order conditions are the optimal order quantity in decentralized supply chain. The (3) and (4) are the optimal order quantity for retailer in decentralized drop shipping supply chain.

4.2. Coordinated Supplier-Led Model

In the supplier-led supply chain, the supplier must choose the proper contract parameters (c, w_d) to stimulate the retailer's order quantities equal to the optimal solutions in the decentralized system, i.e. $(Q+q)_D = (Q_D + q_D)$.

Proposition 2: To coordinate total profit in supplier- led supply chain, the supplier's contract parameters must satisfy

$$c = \frac{c_0 - v_S}{r + p_R - v_S}(r + p_R - w_d) \tag{6}$$

Proof of Proposition 2: The total profit of supply chain is

$$\begin{aligned} E\Pi^D &= E\pi_R^D + E\pi_S^D \\ &= (r + p_R - c_0)(Q+q) - (r + p_R - v_S)\int_0^{Q+q} F(x)dx + (v_R - v_S)\int_0^{Q} F(x)dx - p_R\mu \end{aligned}$$

First order condition

$$(r + p_R - c_0) - (r + p_R - v_S)F(Q+q) = 0$$

The second order condition

$\frac{\partial^2 \Pi^D}{\partial (Q+q)^2} = -(r + p_R - v_S) f(x) < 0$, where $f(x)$ is the probability density function.

So the order quantity to maximize the total profit of supply chain is

$$(Q+q)_D = F^{-1}\left(\frac{r + p_R - c_0}{r + p_R - v_S}\right) \tag{7}$$

To coordinate the channel, the supplier' decision variables (c, w_d) must satisfy $(Q+q)_D = (Q_D + q_D)$.

Therefore

$$F^{-1}\left(\frac{r+p_R-w_d-c}{r+p_R-w_d}\right) = F^{-1}\left(\frac{r+p_R-c_0}{r+p_R-v_S}\right)$$

Because the distribution function $F(x)$ is strictly increasing, we can get

$$c = \frac{c_0 - v_S}{r+p_R-v_S}(r+p_R-w_d) \qquad (8)$$

5. Managerial Implications and Conclusion

Engaging in internet and drop shipping has raised serious awareness and attention in retailing field. It is a general trend for retailers to develop dual channel to serve different customers. We focus on dual channel, two kinds of inventory and drop shipping supply chain. We propose the commitment contracts for supplier-led supply chain. The solution provides flexibility to both supplier and retailer to coordinate the supply chain. We find that, in supplier-led supply chain, if the retailer's order quantity achieves decentralized level, the profit of the supply chain can be maximized, and the supplier can inspire the retailer to achieve decentralized level order quantity.

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