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Coordinating Contracts for a Closed Loop Supply Chain under Different Recollection Strategies

Abstract: Globally, manufacturers are increasingly adopting sustainable processes in recognition of environmental concerns and to grow their businesses. In this article, we devise coordination strategies for a closed loop supply chain network based on different collection strategies namely retailer driven, manufacturer driven, and third party driven. Existing literature indicates that enough attention has not been paid to manufacturer third party driven collection strategies

these strategies. Jayaraman (2006) adopted a mathematical programming model and RAPP (Remanufacturing Aggregate Production Planning) approach for designing an aggregate production planning and control model of a closed-loop supply chain with product recovery and reuse. Chung et al. (2008) studied the inventory system with third-party vendor collecting the used products. Huang et al. (2013) analyze optimal strategies for closed-loop supply chains with dual recollection channel; they modeled the reverse supply chain such that the retailer and a third-party vendor competitively collect used products. However, their models do not address the coordination issue. In this article, we study a dyadic closed loop supply chain comprising one retailer and one manufacturer. For the sake of simplicity, we ignore the difference between refurbished product and remanufactured products. We focus on the coordination between the closed loop supply chain members. We analyze three different recollection strategies namely retailer driven, manufacturer driven and third-party driven.

2. Modeling Framework

Figure 1 describes the closed loop supply chain structure adopted in our model. It integrates both the forward and the reverse supply chain. The market demand of the product is λ , where λ represents the total market potential, p is the retail price and c is the own-price

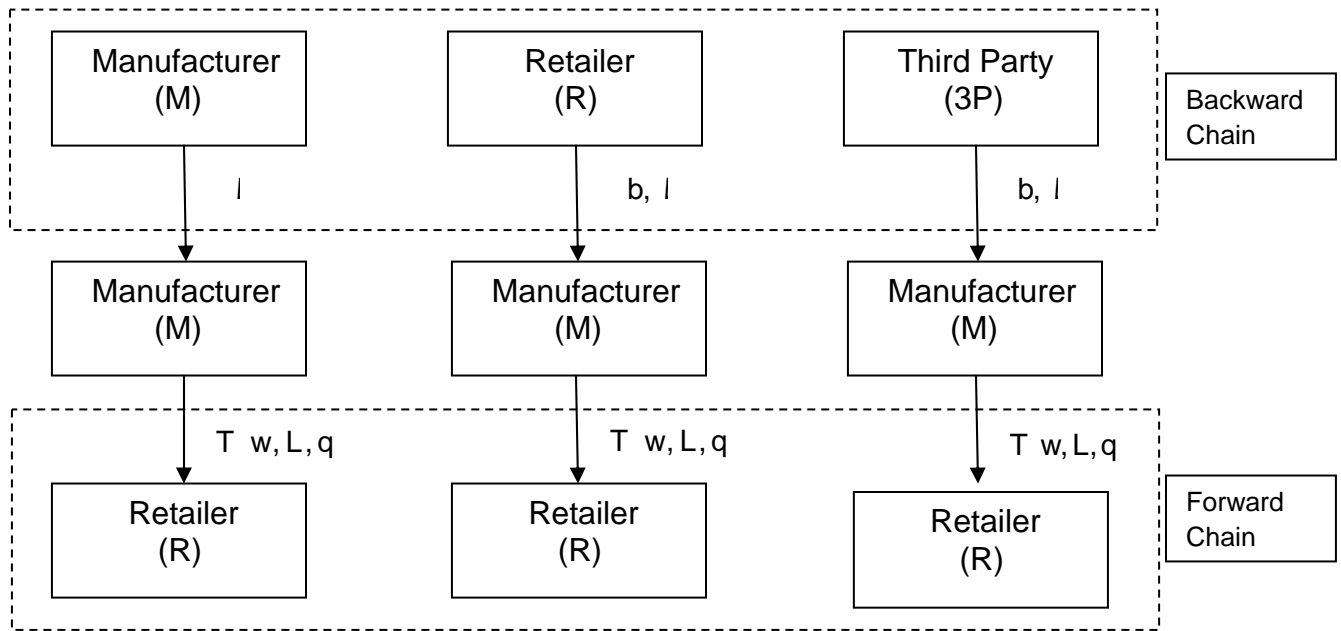


Figure 1. Three Cases of Recollection Strategies

sensitivity of the product. In the forward supply chain, c_m is the unit cost of manufacturing a

LTT	Linear Two-part Tariff Contract
	Sub-script
R	Retailer
M	Manufacturer
3P	Third Party Vendor
$i, j, i \in \{R, M, 3P\},$ $j \in \{R, M, 3P\}$	i : Supply chain agent whose parameter is being determined j : Supply chain agent who is driving the recollection

chain, the manufacturer can drive the collection effort through either the retailer (index: R) or a third-party (index: 3P) vendor or she may decide to collect the used products from the consumers herself (index: S). We analyze these three collection strategies from the perspective of coordination through simple contracts, namely wholesale price (index: WP) and linear two-part tariff contracts (index: LTT). Next, we discuss formulations of the different contractual arguments.

In the decentralized setting most often the manufacturer is the stronger player and would offer contract term(s) to the retailer or the 3P vendor, therefore each contract formulation is done from the perspective of the manufacturer moving. It is evident that the manufacturer acts as a leader and the retailer or 3P vendor acts as a follower in a Stakelberg game setting. In each contract type (WP or LTT), the manufacturer is to move of

Third-Party Vendor Driven Recollection (3P): The manufacturer sources recollection through a 3P vendor and the unit buy price for the used product is w . The manufacturer chooses the contract term W ; the retailer chooses the retail price p ; and the vendor chooses her rate of return for the used products ζ_R . The manufacturer's profit maximization problem can be expressed as:

Problem 2 (P2)

$$\begin{aligned} \max_{w, W} \quad & S_M / (p - w - c_m) W T^2 W \\ \text{st.} \quad & p^* = \operatorname{argmax}_p S_R \\ & \zeta_R / (p - w) \end{aligned}$$

Manufacturer Driven Recollection (M): The manufacturer decides to recollect the used products herself. The manufacturer

Buyback Price

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$$W \text{ argmax}_W \mathcal{S}_R$$

$$\mathcal{S}_R = \int_0^1 p(w) b W T^2 W_{LR} t \mathcal{S}_R$$

Third-Party Vendor Driven Recollection (3P): The manufacturer sources recollection through a third-party vendor and offers her the contract terms (b, p) , where the unit buyback price and the demand

For the purpose of expositional simplicity, we assume the buyback price to be exogenously given for all the sub-problems. For the purpose of consistency with contract parameters, we further assume that the manufacturer offers the lump-sum side payment (L_x and L_{3P}) to the retailer and the third party vendor, respectively. $L_x = 0$ ($x = R$ or $3P$) indicates a franchise fee charged by the manufacturer and $L_x > 0$ signifies that the manufacturer is providing x with a subsidy. The reservation profit level of the retailer and the third party vendor are represented by π_{R0} and π_{3P0} , respectively. Table 4 presents the respective optimal solutions of all the sub-problems related to the linear two-part tariff contract.

Table 4: Optimal solutions of different parameters using two part tariff contract for Decentralized Supply Chain Structures

Parameter	Decentralized Supply Chain Structure		
	Retailer Driven Recollection	Manufacturer Driven Recollection	Third Party Driven Recollection
Retail Price	$\frac{2T - E^2 + L_m}{4T - E^2}$	$\frac{2T - E^2 + L_m}{4T - E^2}$	$\frac{2T - E^2 + L_m}{4T - E^2}$
Order Quantity	$\frac{2i + L_m}{4T - E^2}$	$\frac{2i + L_m}{4T - E^2}$	$\frac{2i + L_m}{4T - E^2}$

In this section we discuss the implications of the optimal solutions of all the six problems discussed in last section. The optimal results are presented in Table 3 and 4. We compare the retail prices, order quantities, recollection effort, and per unit prices across all problems.

a. Per Unit Price, Retail Price, and Order Quantity Decisions

PROPOSITION 1: In case of the WP contract, per unit prices are in the order:

$w_R^{*WP} > w_{3P}^{*WP} > w_M^{*WP}$; in case of the LTT contract, per unit prices are in the order:

$w_R^{*LTT} > w_{3P}^{*LTT} > w_M^{*LTT}$.

Algebraic comparison of the optimal wholesale prices gives the above result. In case of retailer driven recollection, the manufacturer can charge maximum wholesale price. In the context of the WP contract, this particular level of recollection is most desirable from the manufacturer's perspective. Large remanufacturers such as Caterpillar

LTT contract, the optimal order quantities are in the order: $q_R^{*LTT} > q_{3P}^{*LTT} > q_M^{*LTT} > q_C^*$. The retail prices are increasing in α_m , λ , and \bar{r} ; and decreasing in β .

PROPOSITION 3: The retailer's margin follows the order: $m_M^{*WP} > m_{3P}^{*WP} > m_R^{*WP}$; $m_M^{*LTT} > m_{3P}^{*LTT} > m_R^{*LTT} > p_C^* > c_m$.

Algebraic comparison shows that the retailer's margins are: (i) decreasing in α_m , (ii) increasing in λ . m_R^{*WP} is increasing in \bar{r} and decreasing in β . m_M^{*WP} and m_{3P}^{*WP} are decreasing in \bar{r} and increasing in β . In case of the manufacturer driven or vendor driven recollection, the increase in the economic benefit of remanufacturing (β) results in decrease in the average cost of production increasing the corresponding per unit profit margin. In case of the retailer driven recollection, the wholesale price is independent of β . Therefore the characteristics of m_R^{*WP} follows from p_R^{*WP} .

In the context of the WP contract, retailer's margin is largest when the manufacturer is recollecting the used products herself. Clearly from a per unit margin perspective retailer would prefer the recollection effort to be taken up by the manufacturer. However, we shall see subsequently in the profitability analysis that the retailer makes maximum profit through her own recollection drive.

b. Profitability Analysis

In this section we compare the profits of the manufacturer, retailer, and the supply chain under different recollection strategies and contract forms.

PROPOSITION 4: In case of the WP contract, the manufacturer profit levels are in the order:

$\pi_{M R}^{*WP} > \pi_{M M}^{*WP} > \pi_{M 3P}^{*WP}$; in case of the LTT contract, the manufacturer profit levels are in the order: $\pi_C^{*LTT} > \pi_R^{*LTT} > \pi_{M R}^{*LTT} > \pi_{M M}^{*LTT} > \pi_{M 3P}^{*LTT} > \pi_C^* > \pi_R^* > \pi_{3P}^*$.

This proposition indicates that the manufacturer makes minimum profit if she outsources the recollection to a third-party vendor under both the WP as well as the LTT contract. She

recollection. This proposition establishes that the manufacturer would always prefer retailer driven recollection under the assumption of identical types of the recollection agents.

PROPOSITION 5: In case of the WP contract, the profits of the retailer follow the order:

$\pi_{RR}^{WP} > \pi_{RM}^{WP} > \pi_{3P}^{WP}$; in case of the LTT contract, the profits of the retailer follow the order:

$\pi_{RR}^{LTT} > \pi_{RM}^{LTT} > \pi_{3P}^{LTT} > \pi_R$.

Retailer driven recollection is beneficial not only from a manufacturer's standpoint but also from the retailer's perspective. In case of the WP contract, retailer can earn maximum profit by driving the recollection effort herself and she makes minimum profit if the recollection is outsourced to third party vendor. Thus a retailer would be naturally motivated to take up

manufacturer offers the contract

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