Study of Supply Chain Coordination Considering the Participation of Upstream Members of the Supply Chain in Repurchase

Nannan Yan [a], Zhengzheng Tang [b]

School of shanghai Maritime University, Logistics Science and Engineering University, Shanghai 201306, China

[a] nnyan@shmtu.edu.cn, [b] 1123770499@qq.com

Abstract. For the supply chain consisting of a single supplier and a single retailer, the contractual coordination strategy of introducing retailers and suppliers to participate in repurchase is introduced to break the traditional model of supply chain repurchase, and the contractual models of retailers participating in repurchase alone and retailers and suppliers participating in repurchase together are constructed for supply chain coordination. The comparison between the case of retailer participating in repurchase alone and the case of supplier and retailer participating in repurchase at the same time shows that both repurchase models have a coordination effect on the supply chain, it was also found that introducing retailers and suppliers to participate in repurchases at the same time has higher supply chain benefits than retailers participating in repurchases alone.

Keywords: Supply Chain Coordination; Repurchase Contract; Supply Chain Members Participate in Buybacks.

1. Introduction

Traditional supply chain is generally a chain supply chain consisting of suppliers, retailers and customers. Suppliers produce and process goods, provide them to retailers at wholesale prices, and retail numbers are sold to customers at retail prices; it is a supply chain activity driven by the upstream of the supply chain to other members, and suppliers cannot predict market demand, so the extremes of oversupply and undersupply can easily occur. With the development of the economy, the consumption concept of the fast food era is becoming more and more popular, and suppliers start to produce orders according to market demand; retailers predict market demand and send order applications to suppliers, who produce orders according to requirements; these commonly exist in short-cycle products, which are produced and supplied by the downstream members of the supply chain driving the upstream members of the supply chain. The market demand as a client of the downstream of the supply chain is random. Based on the newsboy model, we forecast the random market demand and find the optimal order quantity under the random demand, which effectively reduces inventory accumulation and supply shortage, increases market share and profit, and enhances competitiveness. Short-term products are time-sensitive and demand is uncertain. While avoiding the expansion of losses in the downstream supply chain and appeasing the emotions of the downstream supply chain members, the upstream members of the supply chain can achieve supply chain coordination by buying back products and improving supply chain performance by adjusting the plans and goals of individual enterprises.

Dong Xinglin [1] et al. established a two-stage ordering decision model to buy back unsold products under product market uncertainty and solved the model to find the optimal solution for the ordering strategy. Chunhai Yu [2] et al. constructed a contract model with risk parameters and mean CVaR decision criterion based on retailers' risk attitude to find the optimal order quantity and repurchase price; Yuan Tian [3] et al. constructed a supply chain delayed pricing strategy decision model based on single wholesale price contract and repurchase contract to prove the existence and uniqueness of the optimal order quantity under two contract conditions with delayed pricing strategy. Chengqi Peng [4] studied a two-stage supply chain consisting of a risk-neutral supplier and a loss-averse retailer with financing needs, coordinated the supply chain by adjusting the repurchase price

contract, and calculated the range of repurchase price. Fan, Sang-Yu [5] et al. developed an expected return decision model for the defect-free return problem in a supply chain system consisting of a single supplier and two retailers of the same chain under stochastic demand, and determined the optimal order quantity and optimal effort level of the retailers by comparing the retailer order quantity and the expected profit of each party under centralized and decentralized decisions, and proposed an improved differentiated repurchase contract. Yuan-Yuan Li [6] used repurchase contracts in a supply chain under centralized decision making, and constructed a model of repurchase contracts in a secondary supply chain with loss-averse member participation under the premise of loss aversion, and studied the decision making and coordination process of using repurchase contracts in a supply chain system with different risk-attitude combination member participation, retailer-led and supplier-led, respectively. Ruyu Chen [7] et al. constructed a traditional contractual coordination model with supplier-implemented repurchase and a supply chain contractual coordination model with same-tier competing builders' participation in repurchase for a typical secondary construction supply chain consisting of a single supplier and a single builder, and the 2 repurchase models were compared and analyzed, and sensitivity validation of key parameters was implemented. Based on the newspaper boy model, Li Qunxia [8] studied a single-cycle supply chain system consisting of a single producer and a single retailer under the carbon cap-and-trade policy to analyze how the carbon trading price affects the implementation of the buyback contract. Mi Liyang [9] et al. used the CVaR risk measure to study the coordination of restrictive repurchase contracts in a risk-averse supply chain, improved repurchase contracts by limiting the number of repurchased goods, and gave an analytical expression for the optimal decision of the restrictive repurchase contract supply chain. Jixiang [10] studied the coordination problem of repurchase contracts in a three-level supply chain with demand influenced by price and the coordination problem of repurchase contracts in a three-level supply chain with demand influenced by price and sales effort, and the impact of contract parameters on the profit of the supply chain and each node firm was derived by numerical simulation analysis of the established model.

In this paper, we consider a secondary supply chain consisting of suppliers and retailers, and introduce a contractual coordination strategy with the participation of retailers and suppliers in the repurchase contract, in order to break the traditional model of supply chain repurchase model for the timeliness of short-term products, and build a contractual model with the participation of retailers alone in the repurchase contract and the participation of retailers and suppliers jointly in the repurchase contract for supply chain coordination. The optimal order quantity and total supply chain revenue obtained under the two models are compared.

2. Model Establishment and Assumptions

2.1 Modeling

To establish a basic model for supply chain relationship, let W be the wholesale price from the supplier to the retailer; P be the price offered by the retailer to the customer, which is determined by market competition and is a fixed constant; b: the deposit offered by the retailer to the supplier; the deposit is set individually by the supply chain members. cs: the cost incurred by the supplier to produce and process the goods, which can be called the supply cost; Cf: the marginal cost of the retailer in addition to the purchase of the product, such as the cost incurred in transporting the product, C=Cs+Cf. C=Cs+Cf. gs belongs to the supplier's loss cost, such as the loss caused by the lack of labor operations that result in the inability to provide temporary plus orders of goods. gf: the retailer's loss cost, which is incurred when the retailer has an unexpected event that causes damage to the goods and cannot submit the normal order quantity of goods to the customer. g=gs+ gf. q: the number of orders provided by the retailer to the supplier; D is the market demand, the fact that the demand for reinforcement services generated by the distribution function F (x),density function f (x); F (x) can be subtle and strictly increasing, with F (0) = 0, (x) = 1 - F (x); note that μ = E (D) is the desired demand. The expected value consumed by the customer when the order quantity is q is S(q) = q-; the

expected value of the order quantity is greater than the market demand and generates the cancellation quantity is Q(q) = q- S(q). Assuming no residual value, the supply chain model for order repurchase in the traditional model is shown in Figure 1.

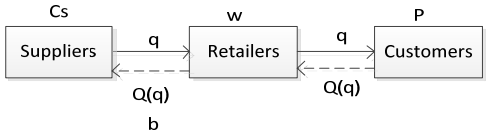

Fig 1. Supply chain model diagram for order repurchase in the traditional model

2.2 Model Assumptions

This paper studies a supply chain consisting of a single supplier and a single retailer. In the face of a random distribution of market demand, the model assumptions for the coordination of the supply chain by introducing temporary supplier and retailer participation in repurchase contracts are as follows

1. Wholesale prices are transparent and fixed between wholesalers and suppliers
2. The wholesale price is greater than the supply cost, and the repurchase price is greater than or equal to the supply cost and less than the wholesale price
3. When other suppliers or retailers are involved in repurchase, they are satisfied first.
4. Retailers order once, no replenishment is allowed

3. Introduction of a Contractual Model of Repurchase with Retailer Participation

Based on the contractual model of builder participation in repurchase in reference [7], the supply chain repurchase contract for short-term products is studied on this basis. When the order quantity is larger than the market demand, the retailer returns the unsold goods to the supplier in the repurchase channel. At this time, Retailer B is in urgent need of a batch of orders and can accept the purchase of the product. The price of Retailer A selling to Retailer B will be greater than the price returned to the supplier by the repurchase channel, so it is proposed that other retailers can perform the act of repurchasing the order.As shown in Figure 2 .Retailer A involved in the order repurchase can be divided into supplier repurchase and retailer B repurchase, supplier repurchase of services accounted for the proportion of all m, so the proportion of retailer repurchase services for n,m + n = 1. Retailer directly through the repurchase channel to return the supplier orders, the supplier will deduct the deposit provided by the retailer, so the supplier to retailer A repurchase price of b, retailer B to retailer A's order When the repurchase is made, the repurchase price is X, and b < X < W < P,

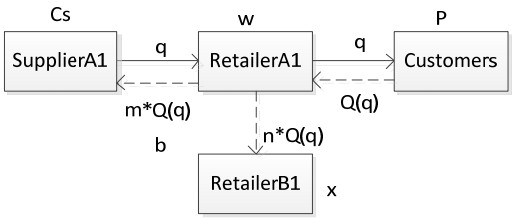

Fig 2. Execution diagram for introducing retailer B2 repurchase

The expected revenue function of the supply chain established by retailer A1, retailer B1, supplier A1, under the retailer participation repurchase contract model is expressed as

$$\begin{aligned}\pi_{零A1} &= P*S(q)+b*m*Q(q)+X*n*Q(q)-Gf*L(q)-Cf*q-wq \\ &= P*S(Q)+b*m*(q-S(q))+X*n*(q-S(q))-Gf*(\mu-S(q))-Cf*q-wq \\ &= (P+Gf-b*m-X*n)*S(q)-(W+Cf-b*m-X*n)*q-\mu*Gf\end{aligned} \tag{1}$$

$$\begin{aligned}\pi_{零B1} &= P*n*S(q)-n*X*Q(q)-Cf*n*Q(q) \\ &= (P-X-Cf)*n*(q-S(q)) \\ &= (X+Cf-P)*n*S(q)-(X+Cf-P)*n*q\end{aligned} \tag{2}$$

$$\begin{aligned}\pi_{供1} &= wq-Cs*q-Gs*L(q)-b*m*Q(q) \\ &= wq-Cs*q-Gs*(\mu-S(q))-b*m*(q-S(q)) \\ &= (Gs+b*m)*S(q)-(Cs-w+b*m)*q-\mu*Gs\end{aligned} \tag{3}$$

The total expected revenue function of the supply chain established by supplier A1, retailer A1, and retailer B1 is expressed as

$$\begin{aligned}\pi_1 &= \pi_{供1}+\pi_{零A1}+\pi_{零B1} \\ &= (P+Gf-b*m-X*n)*S(q)-(W+Cf-b*m-X*n)*q-\mu*Gf \\ &\quad +(X+Cf-P)*n*S(q)-(X+Cf-P)*n*q \\ &\quad +(Gs+b*m)*S(q)-(Cs-w+b*m)*q-\mu*Gs \\ &= (P+G-P*n+Cf*n)*S(q)-(C+Cf*n-P*n)*q-\mu*G\end{aligned} \tag{4}$$

Letting $\pi_{零A1}^{'}$ = 0, the optimal order quantity determined by the customer under the traditional supply chain model is obtained as

$$q_1^{'} = \overline{F}^{-1}\left(\frac{w+Cf-b*m-X*n}{P+Gf-b*m-X*n}\right) \tag{5}$$

Let $\pi_1^{'}$ = 0, the optimal order quantity decided by the whole supply chain system under the traditional supply chain model is

$$q_2^{'} = \overline{F}^{-1}\left(\frac{C+Cf*n-P*n}{P+G-P*n+Cf*n}\right) \tag{6}$$

Theorem 1: The contractual model of retailer participation in repurchase has a coordinating effect on the short-term product supply chain.

Proof: The demand distribution function is monotonically increasing, so there exists a unique optimal solution for the optimal order quantity, so the optimal order quantity of the freight forwarder is equal to the optimal solution for the overall supply chain, when the whole supply chain is coordinated. To achieve overall supply chain coordination, the two parameters (w,b), the wholesale price w from the supplier to the retailer and the deposit b paid by the customer to the freight forwarder, should satisfy for any $\eta \geqq 0$.

$$\eta*(C+Cf*n-P*n) = w+Cf-b*m-X*n \tag{7}$$

$$\eta*(P+G-P*n+Cf*n) = P+Gf-b*m-X*n \tag{8}$$

Substituting equations (7) and (8) into $\pi_{零A1}$, we get

$$\pi_{零A1} = \eta*\pi_1+\eta*\mu*G-\mu*Gf \tag{9}$$

The revenue function of the retailer forms an affine function with the total revenue function of the supply chain, so the optimal order quantity of both is equal, and the supply chain revenue can be adjusted by adjusting η to realize the coordination of the whole supply chain.

4. Repurchase Contract Model with Simultaneous Participation of Supplier and Retailer

When a contingency occurs, under the premise that retailer B participates in the repurchase contract, the repurchase volume of retailer B reaches the maximum, accounting for the proportion of repurchase volume t, and the repurchase volume is t*Q(q). At this time, supplier B proposes the need to purchase a batch of orders, can be out of price Y for procurement, b < Y < X, so proposed to introduce supplier B for repurchase, accounting for the repurchase share of k, repurchase volume of k * Q (q), supplier A's repurchase volume of r * Q (q); t + r + k = 1; The implementation diagram for introducing supplier B2 repurchase is shown in Figure 3.

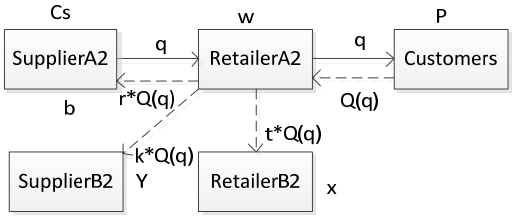

Fig 3. Implementation diagram for introducing supplier B2 repurchase

The expected revenue functions of the supply chains built by retailer A2, retailer B2, supplier A2, and supplier B2 under the simultaneous participation of suppliers and retailers in the repurchase contract model are expressed as

$$\begin{aligned}\pi_{零A2} &= P*S(q)+b*r*Q(q)+X*t*Q(q)+Y*k*Q(q)-Gf*L(q)-Cf*q-wq \\ &= (P+Gf-b*r-X*t-Y*k)*S(q)-(w+Cf-b*r-X*t-Y*k)*q-\mu*Gf\end{aligned} \tag{10}$$

$$\begin{aligned}\pi_{零B2} &= P*t*S(q)-t*X*Q(q)-Cf*t*Q(q) \\ &= (X+Cf-P)*t*S(q)-(X+Cf-P)*n*q\end{aligned} \tag{11}$$

$$\begin{aligned}\pi_{供A2} &= wq-Cs*q-Gs*L(q)-b*r*Q(q) \\ &= (Gs+b*r)*S(q)-(Cs-w+b*r)*q-\mu*Gs\end{aligned} \tag{12}$$

$$\begin{aligned}\pi_{供B2} &= w*k*Q(q)-Y*k*Q(q)-Cs*k*Q(q) \\ &= (Y*k+Cs*k-w*k)*S(q)-(Y*k+Cs*k-w*k)*q\end{aligned} \tag{13}$$

The total expected revenue function of the supply chain established by supplier A2, supplier B2, retailer A2, and retailer B2 is expressed as

$$\begin{aligned}\pi_2 &= \pi_{供A2}+\pi_{供B2}+\pi_{零A2}+\pi_{零B2} \\ &= (P+G+Cf*t-P*t+Cs*k-w*k)*S(q) \\ &\quad -(Cf*t-P*t+C+Cs*k-w*k)*q-\mu*G\end{aligned} \tag{14}$$

Letting $\pi_{零A2}^{'}=0$, the optimal order quantity determined by the customer under the traditional supply chain model is obtained as

$$q_3^{'}=\overline{F}^{-1}\left(\frac{w+Cf-b*r-X*t-Y*k}{P+Gf-b*r-X*t-Y*k}\right) \tag{15}$$

Let $\pi_2^{'}=0$, the optimal order quantity decided by the whole supply chain system under the traditional supply chain model is

$$q_4^{'}=\overline{F}^{-1}\left(\frac{Cf*t-P*t+C+Cs*k-w*k}{P+G+Cf*t-P*t+Cs*k-w*k}\right) \tag{16}$$

Theorem 2: The contractual model of retailer participation in repurchase has a coordinating effect on the short-term product supply chain.

Proof: The demand distribution function is monotonically increasing, so there exists a unique optimal solution for the optimal order quantity. In the coordination of the whole supply chain, the optimal order quantity of the freight forwarder is equal to the optimal solution of the whole supply chain. To achieve overall supply chain coordination, the two parameters, the wholesale price P from the retailer to the customer and the deposit b paid by the customer to the forwarder, should satisfy for any $\theta \geqq 0$.

$$\theta*(w+Cf-b*r-X*t-Y*k)=Cf*t-P*t+C+Cs*k-w*k \tag{17}$$

$$\theta*(P+Gf-b*r-X*t-Y*k)=P+G+Cf*t-P*t+Cs*k-w*k \tag{18}$$

Substituting equations (17) and (18) into $\pi_{零A2}$, we get

$$\pi_{零A2}=\theta*\pi_2+\theta*\mu*G-\mu*Gf \tag{19}$$

The revenue function of the retailer forms an affine function with the total revenue function of the supply chain, so the optimal order quantity of both is equal, and the supply chain revenue can be adjusted by adjusting θ to achieve coordination of the whole supply chain.

Theorem 3: The supply chain revenue of retailers and suppliers participating in repurchase together is greater than the supply chain revenue of retailers participating in repurchase alone.Proof:

$$\begin{aligned}\pi_2-\pi_1=&(P+G+Cf*t-P*t+Cs*k-w*k)*S(q)\\&-(Cf*t-P*t+C+Cs*k-w*k)*q-\mu*G\\&-(P+G-P*n+Cf*n)*S(q)\\&+(C+Cf*n-P*n)*q+\mu*G\\=&(Cf*t-P*t+Cs*k-w*k+P*n-Cf*n)*S(q)\\&-(Cf*t-P*t+Cs*k-w*k-Cf*n+P*n)*q\end{aligned} \tag{20}$$

Retailer B contributes the most to the entire supply chain members and has the highest repurchase price, so it will only let Supplier A and Supplier B repurchase if it satisfies the premise that Retailer B repurchases the most, so n = t. The result is.

$$\begin{aligned}\pi_2-\pi_1=&(Cf*t-P*t+Cs*k-w*k+P*t-Cf*t)*S(q)\\&-(Cf*t-P*t+Cs*k-w*k-Cf*t+P*t)*q\\=&(Cs*k-w*k)*S(q)-(Cs*k-w*k)*q\\=&k*(Cs-w)*(S(q)-q)\end{aligned} \tag{21}$$

Because Cs<W, S(q)<q, k>0, so $\pi_2-\pi_1>0$

The benefits to the supply chain are greater when both retailers and suppliers are introduced to the repurchase contract than when retailers are introduced to the repurchase contract alone.

5. Summary

When the commodity cycle is short and there is an order demand that is greater than the market demand or an unexpected situation that requires cancellation, the retailer participation or the joint participation of the retailer and the supplier can be chosen to increase the benefits of the whole supply chain. The supply chain benefit of joint participation of retailers and suppliers in repurchase is greater than the benefit of only retailers' participation in repurchase. Therefore, when the market forecast deviates or unexpected situations occur, retailers can take buyback measures not only from their own suppliers, but also from other channels, which can also increase retailers' desire to buy and positively promote the coordinated development of the supply chain. The constructed model of simultaneous participation of retailers and suppliers in repurchase contracts is robust and practically feasible, and future supply chain repurchase contracts can be considered for the study of coordination of reticulated supply chains and more application to coordinated supply chain operations.

References

[1] Dong Xinglin, Qi Xin. A study on two-stage ordering strategy based on supply chain repurchase contract [J]. Logistics Science and Technology,2019,42(04): 112-114. DOI: 10.13714/j.cnki.1002-3100. 2019. 04.030.

[2] Yu CHH, Feng SAI, Rong DONGLING. Research on coordination strategy of closed-loop supply chain repurchase contract based on mean-CVaR[J]. Operations Research and Management,2020,29(06):58-64.

[3] Tian Yuan, Chen Wei, Zhao Yuanjun. A study on supply chain coordination strategy based on delayed pricing and repurchase contract[J]. Journal of Huazhong Normal University (Natural Science Edition), 2021, 55(06): 1083-1091. DOI: 10.19603/j.cnki.1000-1190.2021.06.019.

[4] Peng, Chengqi. Loss-averse retailer ordering strategies and supply chain coordination under repurchase contracts [J]. Logistics Engineering and Management,2022,44(01):79-82.

[5] Fan Xiangyu, Hu Boya, Wu Xiaoping. A study of supply chain repurchase contracts for retailer transshipment under consideration of defect-free returns[J]. China Management Science,2021, 29(07): 139-147. DOI: 10.16381/j.cnki.issn1003-207x.2018.1563.

[6] Li, Yuan-Yuan. A study on supply chain repurchase contract based on loss aversion [D]. Yanshan University, 2019. DOI: 10.27440/d.cnki.gysdu.2019.000495.

[7] Chen Ruyu, Zhu Li. Construction supply chain coordination and contingency strategy for construction party participation in buyback[J]. Journal of Railway Science and Engineering,2022,19(01):273-281. DOI: 10. 19713/j.cnki.43-1423/u.t20210083.

[8] Li Qunxia. Coordination of low-carbon supply chain inventory benefits based on repurchase contracts[J]. Logistics Technology,2020,39(06):79-83+105.

[9] Mi Liyang, Shang Chunyan. Supply chain ordering decision under restrictive repurchase contract[J]. Journal of Anhui Normal University (Natural Science Edition),2019,42(05): 428-433.DOI: 10.14182/ J. cnki. 1001-2443.2019.05.004.

[10] Jiji. A study of repurchase contracts in three-tier supply chain with demand influenced by price and sales effort [D]. Yanshan University,2018.