Direct Revenue Sharing Contract in a Three-Tier Supply Chain

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***Abstract*- This paper proposes a new kind of revenue sharing contract for coordinating a three-tier supply chain comprised of a manufacturer, a distributor, and a retailer. The contract requires that the retailer should return partial revenues directly to the distributor and to the manufacturer. A linear model is proposed to determine the parameters of the contract such that channel coordination and a win-win situation can be achieved. We show that any solution within the derived feasible region can achieve the maximum supply chain profit and increase each partner's profit as well. A numerical example is given to demonstrate the application of the contract.**

Keywords*- *Supply Chain Management; Revenue Sharing; Channel Coordination; Collaboration

I. INTRODUCTION

A supply chain (SC) consists of several actors that usually have different and sometimes conflicting objectives. Many coordination mechanisms have been proposed to improve SC performance. They provide incentives for SC partners to achieve optimal global profits while maximizing their own profit; in other words, channel coordination is achieved. Contracts such as quantity flexibility contracts [1]-[3], buyback or return policies [4]-[7], and revenue sharing contracts [8] have been proven effective in SC coordination. Among these SC contracts, revenue sharing (RS) contracts have drawn a lot of attention in recent years. The RS contract is widespread in the video rental industry and has been adopted by companies such as Blockbuster Inc. and Hollywood Entertainment [9]. In a standard RS contract, the supplier charges the retailer a much lower wholesale price in exchange for a percentage of the retailer's revenue.

Most coordination contracts, including RS, consider a two-tier SC. However, the trend of SC management is to enhance the collaboration and to expand the scope of collaboration in order to achieve higher profits. In this study, we propose a new kind of contract, called direct revenue sharing (DRS), for coordinating a three-tier SC. Different from [10], the DRS contract requires that the retailer return partial revenues directly to the distributor and to the manufacturer. The proposed DRS contract is proven to be capable of channel coordination and win-win situation. Moreover, the applicability of the DRS contract is higher than the traditional tier-by-tier RS contracts.

Not only DRS contract, but all revenue sharing contracts encounter the same problem: the retailer may cheat with regards to the sales revenue. This reveals two important factors in supply chain collaboration: trust and information sharing. Like other SC collaborative activities, a successful DRS contract requires high levels of trust and information sharing. Reference [11] states that information transparency requires high levels of trust, and such levels of trust and transparency can be attained only by a great deal of hard work. Once this is accomplished, supply chain partners will find themselves in a virtuous cycle of steadily improving SC performance, leading to even higher levels of trust and transparency, which in turn improves performance even further. Many successful applications of SC collaboration, such as collaborative planning, forecasting, and replenishment (CPFR) as well as vendor managed inventory (VMI) show that more and more companies are realizing the importance of collaboration; they are willing to trust their SC partners and share information in order to achieve better collaboration and higher performance. The rapid development of information technology and e-commerce also increases the information transparency and reduces possible fiddles. Therefore, the DRS contract is very likely to be adopted by SC partners nowadays. In addition, The DRS contract may have a greater chance to succeed if it is initiated by the manufacturer. If the manufacturer initiates the DRS contract, it usually has greater bargaining power, information technology, vision of collaboration benefit, and is willing to trust the distributor and the retailer. The manufacturer can also prevent the retailer from cheating by providing the DRS information system or requiring point-of-sale (POS) data from the retailer. Since the retailer has lower risk, it is likely to accept the DRS contract.

The remainder of the paper is organized as follows. Section II presents a literature analysis, and Section III describes the problem. Section IV derives the model, in which the parameters of the revenue sharing contract can be determined to ensure channel coordination and a win-win situation. In Section V, a numerical example is provided. Concluding remarks are made in Section VI.

II. LITERATURE REVIEW

Many SC coordination mechanisms have been introduced in the Literatures [12]-[13]. In most studies, RS contracts are made between a single supplier and a single buyer. Cachon and Lariviere (2005) study RS contracts and compare RS to a number of other supply chain contracts [8]. They find that RS is equivalent to buybacks in the newsvendor case and to price discounts in the price-setting newsvendor case. Chauhan and Proth (2005) propose an approach to maximize the combined profit and sharing the profit among partners proportionally to their risk [14]. Gupta and Weerawat (2006) compare three different mechanisms that a manufacturer may use to affect its component supplier's inventory decisions [15]. These mechanisms specify component inventory level, offering a share of the earned revenues to the supplier and offering a two-part RS scheme. They show that the two-part RS scheme can lead to supply chain coordination. Qin and Yang (2008) use Stackelberg game to model the RS contract problem [16]. Their study reveals that the party that keeps more than half the revenue should serve as the leader of the Stackelberg game. Bellantuono et al. (2009) present a model that includes RS contract and/or advance booking discount [17]. They analyze the optimal expected channel profit associated with four possible scenarios wherein each program is offered or not. They illustrate the conditions under which the benefit of the joint adoption of RS contract and advance booking discount is higher than the sum of the benefits associated with separate adoptions of these two programs. Hou et al. (2009) consider a two-stage SC, in which the retailer's profit is sensitive to the supplier's lead time and the lead time is influenced by the supplier's target inventory level. The coordination between the two parties is achieved through revenue sharing and bargaining [18]. Linh and Hong (2009) study the RS contract in a two-period newsboy problem [19]. They find that the optimal revenue sharing ratio is linearly increasing in the wholesale prices. Recently, Xiao et al. (2011) develop a game theoretic model to investigate coordination of a supply chain consisting of one manufacturer and one retailer via a revenue-sharing contract, where a product quality assurance policy is provided [20]. Sheu (2011) explores the equilibrium behavior of a basic supplier-retailer distribution channel with and without revenue-sharing contracts under price promotion to end-customers [21]. Palsule-Desai (2013) proposes a game theoretic model for revenue-dependent revenue sharing contracts wherein the actual proportion in which the supply chain revenue is shared among the players depends on the quantum of revenue generated [22].

Some researchers have investigated RS contracts between one supplier and multiple buyers or between one buyer and multiple suppliers. Gerchak and Wang (2004) study the problem of vendor-managed inventory with revenue sharing [23]. They explore a revenue-plus-surplus-subsidy incentive scheme where, in addition to a share of revenue, the assembler also provides a subsidy to suppliers for their unsold components. Using this two-parameter contract, they show that the assembler can achieve channel coordination and increase the profits of all parties involved. Yao et al. (2008) investigate a RS contract for one manufacturer and two competing retailers [24]. They find that an RS contract can obtain better performance than a price-only contract. However, the benefits earned under the RS contract by supply chain partners differ due to the impact of demand variability and price-sensitivity factors. Zhang et al. (2012) study the coordination mechanism of a supply chain with one manufacturer and two competing retailers, and focus on RS contracts when the demands are disrupted. They found that it is necessary to adjust the original revenue-sharing contracts to demand disruptions [25]. Recently, Cao et al. (2013) develops a coordination mechanism with revenue sharing for a supply chain consisting of one manufacturer and several Cournot competing retailers when the production cost and demands are simultaneously disrupted [26].

All above studies focus on the RS contracts in a two-tier SC. It needs further expansion since the trend of SC management is to enhance the collaboration and to expand the scope of collaboration. Unfortunately, few papers have discussed RS contracts in a three-tier SC. Reference [10] proposes a model of RS contracts to coordinate a three-stage SC, consisting of a manufacturer, a distributor, and a retailer. The model can achieve system efficiency and improve the profits of all SC actors, by tuning the contract parameters. In this model, the revenue is partially returned tier-by-tier from the retailer to the manufacturer. In other words, the retailer keeps a quota Φ_A of its revenue, giving the rest $1-\Phi_A$ to the distributor (denoted as RS_{DR} contract). The distributor keeps a quota Φ_B of its revenue, including the returned revenue from the retailer, giving the rest $1-\Phi_B$ to the manufacturer (denoted as RS_{MD} contract). The model is essentially not just a combination of two independent RS contracts; cooperation between three actors is still necessary. Partial revenue of the manufacturer comes from the returned revenue, which is relevant to the revenues of not only the distributor but also the retailer. The RS_{MD} contract is hence not independent of the RS_{DR} contract. In other words, the RS_{MD} contract cannot be installed if the manufacturer does not aware of the parameters of RS_{DR} contract and the retailer's expected revenue. In addition, due to the tier-by-tier revenue sharing, the proposed model is nonlinear and not easy to apply. To the best of our knowledge, no practical implementation of multi-tier *RS* contracts has been reported.

Since the implementation of multi-tier RS contracts require that all SC actors collaborate with each other and settle the contracts simultaneously, we propose a single DRS contract for coordinating a three-tier SC. Because all SC actors are gathered to discuss the contract parameters, the method of information sharing, the potential benefits and other collaboration issues, the DRS contract is easier to implement rather than the traditional tier-by-tier RS contracts, which are composed of several mutual dependent contracts. In addition, our model uses a linear system, which is easy to analyze and to practice. We show that through the DRS contract, channel coordination and a win-win situation can be achieved.

III. PROBLEM DESCRIPTION

A three-tier supply chain, consisting of a manufacturer, a distributor, and a retailer, is considered in this paper. The supply chain provides seasonal or perishable goods to the customers. During a selling season, the supply chain provides a single kind of product to serve the market demand *d*, which is uncertain with a normal probability density function *f*. The supply chain is decentralized, and each SC actor makes decisions by optimizing its own objective. The retailer sells the products at a fixed price *p*, which is determined by the market. The marginal unit costs are c_M, c_D, and c_R for the manufacturer, the distributor, and the retailer, respectively.

Based on the aforementioned settings, the problem faced by the retailer and the distributor is essentially a newsvendor problem [27]. Let *F* be the cumulated probability function of *f*, i.e. $F(q)$ is the probability that demand is not higher than the order quantity *q*. The newsvendor model derives the optimal order quantity by finding *q* that fulfills the following equation:

$$F(q) = \frac{c_u}{c_u + c_o} \tag{1.}$$

where c_u is the underage cost (i.e., the cost associated with each demand that cannot be met) and c_o is the overage cost (i.e., the cost associated with each product that is not sold). In other words, c_u is defined as the marginal profit, and c_o is defined as the marginal cost.

The rest of this section proceeds as follows. Section A presents the centralized SC, in which the total profit is maximized and regarded as the goal of channel coordination. Section B discusses a SC without any coordination, providing minimal profit required for each SC partner. The DRS contract is then introduced in Section C.

A. Centralized Supply Chain Management

In the centralized SC, the manufacturer, the distributor, and the retailer act as the same company. A unique decision-maker determines the optimal order quantity q^* that maximizes the total SC profit. The expected total SC profit π^* can be derived as

$$\pi^* = pE\left[\min\left(q^*, d\right)\right] - \left(c_M + c_D + c_R\right)q^* \tag{2.}$$

where $E\left[\min\left(q^*, d\right)\right]$ is the expected sales and can be calculated as in the Appendix.

In order to maximize the profits, the newsvendor model is used to determine the optimal order quantity. The key variables of the newsvendor model are the underage cost c_u and the overage cost c_o. In this case, c_u equals $p - c_M - c_D - c_R$ and c_o equals $c_M + c_D + c_R$. Therefore the optimal order quantity q^* can be derived such that

$$F\left(q^*\right) = \frac{p - c_M - c_D - c_R}{p} \tag{3.}$$

B. Supply Chain without Coordination

Fig. 1 illustrates traditional transactions in the SC without coordination. The manufacturer sells products to the distributor at price p_M, and the distributor sells products to the retailer at price p_D. The terms $\hat{q}_D$ and $\hat{q}_R$ are order quantities of the distributor and the retailer. To maximize its own profits, the retailer adopts the newsvendor model to determine $\hat{q}_R$. Obviously, the distributor's order quantity $\hat{q}_D$ is equal to $\hat{q}_R$, because the distributor tries to fully satisfy the quantity $\hat{q}_R$ and keeps no extra products in order to maximize its profit in a single selling season. If $\hat{q}_D > \hat{q}_R$, the distributor will have extra cost of $\left(p_M + c_D\right)\left(\hat{q}_D - \hat{q}_R\right)$. If $\hat{q}_D < \hat{q}_R$, the profit of the distributor will decrease $\left(p_D - p_M - c_D\right)\left(\hat{q}_R - \hat{q}_D\right)$. Therefore, $\hat{q}_D$ must equal $\hat{q}_R$. We define $\hat{q}$ to represent the order quantity for both the retailer and the distributor in the SC without coordination.

The expected profits of three SC actors are shown as follows:

$$\hat{\pi}_M = \left(p_M - c_M\right)\hat{q} \tag{4.}$$

$$\hat{\pi}_D = \left(p_D - p_M - c_D\right)\hat{q} \tag{5.}$$

$$\hat{\pi}_R = pE\left[\min\left(\hat{q}, d\right)\right] - \left(p_D + c_R\right)\hat{q} \tag{6.}$$

where order quantity $\hat{q}$ can be derived using the newsvendor model ($c_u = p - p_D - c_R$ and $c_o = p_D + c_R$):

$$F(\hat{q}) = \frac{p - p_D - c_R}{p} \tag{7.}$$

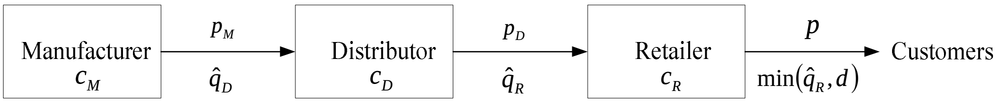

Fig. 1 Traditional transactions in a three-tier SC

C. Direct Revenue Sharing (DRS) Contract

The operation of DRS contract is illustrated in Fig. 2. The manufacturer charges the distributor a wholesale unit price ω_M, and the distributor charges the retailer a wholesale unit price ω_D. After the retailer sells the products, he/she will return a ratio ϕ_M of his/her revenue directly to the manufacturer and ϕ_D of his/her revenue to the distributor. First, the DRS contract must be negotiated and accepted by all supply chain partners. Then, the distributor and the retailer determine their order quantities q_D and q_R before the selling season to maximize their own expected profits.

The expected profits of three SC actors are listed in the following equations:

$$\pi_M = \phi_M pE[\min(q_R, d)] + (\omega_M - c_M)q_D \tag{8.}$$

$$\pi_D = \phi_D pE[\min(q_R, d)] + \omega_D q_R - (\omega_M + c_D)q_D \tag{9.}$$

$$\pi_R = (1 - \phi_M - \phi_D)pE[\min(q_R, d)] - (\omega_D + c_R)q_R \tag{10.}$$

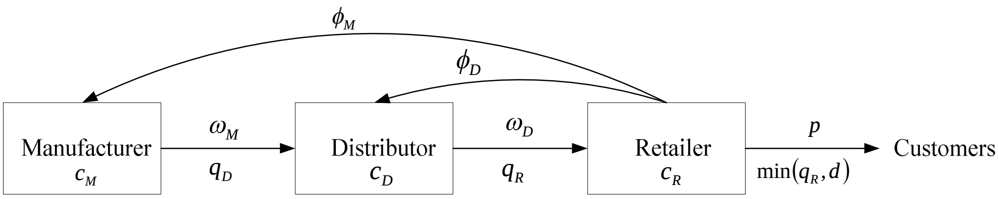

Fig. 2 Operation of the DRS contract

In order to maximize their profits, the retailer and the distributor use the newsvendor model to determine their optimal order quantities. For the retailer, c_u equals $(1 - \phi_M - \phi_D)p - \omega_D - c_R$, and c_o equals $\omega_D + c_R$. For the distributor, c_u is $\phi_D p + \omega_D - \omega_M - c_D$, and c_o is $\omega_M + c_D$. The optimal order quantities q_R and q_D are then derived such that

$$F(q_R) = \frac{(1 - \phi_M - \phi_D)p - \omega_D - c_R}{(1 - \phi_M - \phi_D)p} \tag{11.}$$

$$F(q_D) = \frac{\phi_D p + \omega_D - \omega_M - c_D}{\phi_D p + \omega_D} \tag{12.}$$

Once the parameters ($\phi_M, \phi_D, \omega_M, \omega_D$) of the DRS contract have been determined, the expected profit of each SC actor can be calculated. If these profits are all higher than those before the DRS contract, then the DRS contract is desirable.

IV. MODEL FORMULATION OF THE DRS CONTRACT

Although the distributor and the retailer are free to determine q_D and q_R under the DRS contract, the chosen q_D and q_R will correspond to the q^* that optimizes the total SC profit, if the proper parameters of the DRS contract are designed such that $F(q_R) = F(q_D) = F(q^*)$. Hence, we let Eq. (11) equal Eq. (3) and Eq. (12) equal Eq. (3) to obtain the following equations:

$$\omega_D = (1 - \phi_M - \phi_D)(c_M + c_D + c_R) - c_R \tag{13.}$$

$$\omega_M = \left(\frac{c_M + c_D + c_R}{p}\right)(\phi_D p + \omega_D) - c_D \tag{14.}$$

If the DRS contract conforms to (13) and (14), then the maximum SC profit is achieved regardless of the adopted values of

ϕ_M and ϕ_D. In other words, channel coordination is achieved, and the following equation holds if Eqs. (13) and (14) are fulfilled:

$$q_D = q_R = q^* \tag{15.}$$

From Eqs. (13) and (14), we can see that both wholesale prices ω_D and ω_M are linear functions of revenue sharing ratios ϕ_M and ϕ_D. Therefore, we focus on how to determine ϕ_M and ϕ_D in the DRS contract.

Since the wholesale prices ω_D and ω_M are nonnegative, it follows from Eqs. (13) and (14) that

$$\phi_M + \phi_D \le 1 - \frac{c_R}{c_M + c_D + c_R} \tag{16.}$$

$$(c_M + c_D + c_R)\phi_M - (p - c_M - c_D - c_R)\phi_D \le c_M + c_D - \frac{pc_D}{c_M + c_D + c_R} \tag{17.}$$

The maximum total SC profit can be guaranteed by adopting a proper DRS contract. However, this contract may not be desirable if one SC partner cannot benefit from the contract. In other words, the contract must ensure that $\pi_R \ge \hat{\pi}_R$, $\pi_D \ge \hat{\pi}_D$ and $\pi_M \ge \hat{\pi}_M$. Thus, from (4)-(6), (8)-(10) and (13)-(15), it follows:

$$\phi_M + \phi_D \le \frac{p\left(E\left[\min\left(q^*, d\right)\right] - E\left[\min\left(\hat{q}, d\right)\right]\right) + (p_D + c_R)\hat{q} - q^* \sum_{i \in \{M,D,R\}} c_i}{pE\left[\min\left(q^*, d\right)\right] - q^* \sum_{i \in \{M,D,R\}} c_i} \tag{18.}$$

$$\begin{aligned} & q^* \sum_{i \in \{M,D,R\}} c_i \left(1 - \frac{\sum_{i \in \{M,D,R\}} c_i}{p}\right)\phi_M - \left(pE\left[\min\left(q^*, d\right)\right] - q^*\left(2 - \frac{\sum_{i \in \{M,D,R\}} c_i}{p}\right)\sum_{i \in \{M,D,R\}} c_i\right)\phi_D \\ & \le \left(1 - \frac{\sum_{i \in \{M,D,R\}} c_i}{p}\right)(c_M + c_D)q^* - (p_D - p_M - c_D)\hat{q} \end{aligned} \tag{19.}$$

$$\left(pE\left[\min\left(q^*, d\right)\right] - \frac{q^*}{p}\left(\sum_{i \in \{M,D,R\}} c_i\right)^2\right)\phi_M + q^* \sum_{i \in \{M,D,R\}} c_i \left(1 - \frac{\sum_{i \in \{M,D,R\}} c_i}{p}\right)\phi_D \ge \left(1 - \frac{\sum_{i \in \{M,D,R\}} c_i}{p}\right)(c_M + c_D)q^* + (p_M - c_M)\hat{q} \tag{20.}$$

To conclude, if we adopt revenue sharing ratios ϕ_M and ϕ_D that fulfill Eqs. (16) through (20) and then calculate wholesale prices ω_D and ω_M using Eqs. (13) and (14), then the corresponding DRS contract is acceptable for all SC partners and guarantees that the maximum SC profit is achieved. Note that Eqs. (16) through (20) are all linear inequalities, determining a linear feasible region for ϕ_M and ϕ_D. In addition, if ω_D and ω_M in Eqs. (8) through (10) are replaced with the values in Eqs. (13) and (14), then the expected profits π_M, π_D, π_R are also linear functions of ϕ_M and ϕ_D as in Eqs. (21) through (23). These linear characteristics make the problem easy to solve.

$$\pi_M = \left(pE\left[\min\left(q^*, d\right)\right] - \frac{q^*}{p}\left(\sum_{i \in \{M,D,R\}} c_i\right)^2\right)\phi_M + q^* \sum_{i \in \{M,D,R\}} c_i \left(1 - \frac{\sum_{i \in \{M,D,R\}} c_i}{p}\right)\phi_D - \left(1 - \frac{\sum_{i \in \{M,D,R\}} c_i}{p}\right)(c_M + c_D)q^* \tag{21.}$$

$$\pi_D = -q^* \sum_{i \in \{M,D,R\}} c_i \left(1 - \frac{\sum_{i \in \{M,D,R\}} c_i}{p}\right)\phi_M + \left(pE\left[\min\left(q^*, d\right)\right] - q^* \sum_{i \in \{M,D,R\}} c_i \left(2 - \frac{\sum_{i \in \{M,D,R\}} c_i}{p}\right)\right)\phi_D + \left(1 - \frac{\sum_{i \in \{M,D,R\}} c_i}{p}\right)(c_M + c_D)q^* \tag{22.}$$

$$\pi_R = \left(q^* \sum_{i\in\{M,D,R\}} c_i - pE\left[\min\left(q^*, d\right)\right] \right)\left(\phi_M + \phi_D\right) + pE\left[\min\left(q^*, d\right)\right] - q^* \sum_{i\in\{M,D,R\}} c_i \tag{23.}$$

Since all combination of ϕ_M and ϕ_D within the feasible region are acceptable, the determination of ϕ_M and ϕ_D depends on the relative contractual power of the SC actors. Reference [9] developed an agent-based system model, in which the two agents (i.e. the SC actors) negotiate on the value of the contract parameter that influences the SC profit sharing between them. In order to maintain a good relationship between SC partners, a fair solution is preferable in a long view of the supply chain. In this study, a possible fair solution is derived by evenly distributing the total increased profits of the DRS contract to all SC partners, i.e., $\pi_M - \hat{\pi}_M = \pi_D - \hat{\pi}_D = \pi_R - \hat{\pi}_R$. Thus, we derive the following linear equation system (24) and (25) to obtain a possible solution. However, we also realize that the solution of linear equation system (24) and (25) is not easy to be accepted by SC actors, because a powerful actor always tries to gain more in the contract.

$$\begin{aligned} &\left(pE\left[\min\left(q^*, d\right)\right] + q^* \sum_{i\in\{M,D,R\}} c_i \left(1 - \frac{\sum_{i\in\{M,D,R\}} 2c_i}{p} \right) \right)\phi_M + \left(q^* \sum_{i\in\{M,D,R\}} c_i \left(3 - \frac{\sum_{i\in\{M,D,R\}} 2c_i}{p} \right) - pE\left[\min\left(q^*, d\right)\right] \right)\phi_D \\ &= 2q^* \left(1 - \frac{\sum_{i\in\{M,D,R\}} c_i}{p} \right)\left(c_M + c_D\right) + \hat{\pi}_M - \hat{\pi}_D \end{aligned} \tag{24.}$$

$$\begin{aligned} &\left(2pE\left[\min\left(q^*, d\right)\right] - q^* \sum_{i\in\{M,D,R\}} c_i \left(1 + \frac{\sum_{i\in\{M,D,R\}} c_i}{p} \right) \right)\phi_M + \left(pE\left[\min\left(q^*, d\right)\right] - \frac{q^*}{p}\left(\sum_{i\in\{M,D,R\}} c_i \right)^2 \right)\phi_D \\ &= q^* \left(\left(1 - \frac{\sum_{i\in\{M,D,R\}} c_i}{p} \right)\left(c_M + c_D\right) - \sum_{i\in\{M,D,R\}} c_i \right) + pE\left[\min\left(q^*, d\right)\right] + \hat{\pi}_M - \hat{\pi}_R \end{aligned} \tag{25.}$$

V. NUMERICAL EXAMPLE

To demonstrate the application of the DRS contract in a three-tier supply chain, a numerical test is performed using Microsoft office Excel. For comparison, we use the same parameters in [10]: $c_M = 4$, $c_D = 2$, $c_R = 1$, $p_M = 8$, $p_D = 20$, $p = 30$. The demand follows normal distribution: N(μ, σ^2)=N(100, 900).

A. *Deriving Parameters of the DRS Contract*

From Eqs. (7) and (3), the optimal order quantities before and after the DRS contract, $\hat{q}$ and q^*, amount to 84.27 and 121.84, respectively. According to $\hat{q}$, q^*, and Eq. (A.1) in the Appendix, the expected sales $E\left[\min\left(\hat{q}, d\right)\right]$ and $E\left[\min\left(q^*, d\right)\right]$ can be derived as 78.56 and 95.91, respectively. Therefore, we can establish the feasible region for ϕ_M and ϕ_D using Eqs. (16) through (20) as in the following system of linear inequalities:

$$7\phi_M + 7\phi_D \le 6 \tag{26.}$$

$$49\phi_M - 161\phi_D \le -18 \tag{27.}$$

$$\phi_M + \phi_D \le 0.71 \tag{28.}$$

$$-653.86\phi_M + 1370.66\phi_D \ge 282.23 \tag{29.}$$

$$2678.38\phi_M + 653.86\phi_D \ge 897.52 \tag{30.}$$

The feasible region is illustrated in Fig. 3. Any point within the feasible region is a possible consideration for ϕ_M and ϕ_D; it depends on the relative contractual power of the SC actors. After the revenue sharing ratios ϕ_M and ϕ_D are selected, the corresponding wholesale prices can be determined from (13) and (14) as follows:

$$\omega_D = -7\phi_M - 7\phi_D + 6 \tag{31.}$$

$$\omega_M = \frac{7}{30}\omega_D + 7\phi_D - 2 = -1.63\phi_M + 5.37\phi_D - 0.6 \tag{32.}$$

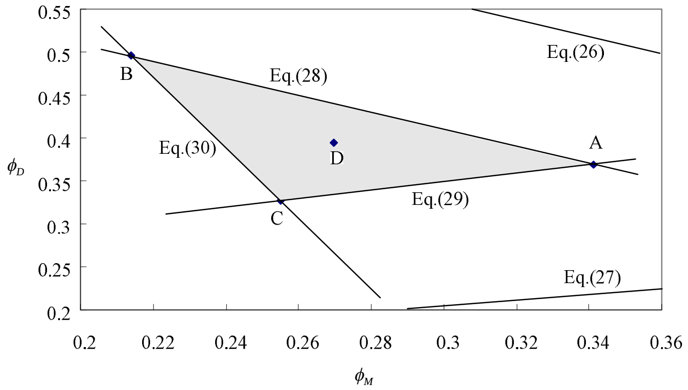

Fig. 3 Feasible region of revenue sharing ratios ϕ_M and ϕ_D

B. *Expected Profits Analysis*

From Eq. (2) and Eqs. (4) through (6), the expected profits of the centralized SC and the SC without coordination are shown in Table I.

TABLE I EXPECTED PROFITS

Centralized SC	SC without coordination			
π^*	$\hat{\pi}_M$	$\hat{\pi}_D$	$\hat{\pi}_R$	Total
2024.52	337.07	842.68	587.08	1766.83

Table I shows that the expected profit of centralized SC π^* is higher than that of SC without coordination. In the DRS contract, the test result shows that the expected total SC profit is the same as π^*, no matter what values of ϕ_M and ϕ_D are chosen. How to distribute the increased profit, about 257.69, depends on the values of ϕ_M and ϕ_D. In Fig. 3, for example, Point A reflects that all increased profits go to the manufacturer; the expected profits of the distributor and the retailer remain the same as before the DRS contract. Similarly, Points B and C reflect that all increased profits go to distributor and retailer, respectively. Any point on the segment $\overline{AB}$ reflects that the retailer's expected profit does not increase in such a DRS contract. Similarly, any point on the segment $\overline{AC}$ or $\overline{BC}$ reflect that the distributor's or the manufacturer's expected profits, respectively, do not increase in such a DRS contract. Point D, derived from (24) and (25), refers to even increased profits and is suggested for choosing ϕ_M and ϕ_D. Note that any point outside the feasible region will decrease the expected profits of some SC partners. The expected profits of these different combinations of parameters are listed in Table II. The expected profits of other combinations of parameters can be derived using Eqs. (21) through (23) as follows:

$$\pi_M = 2678.38\phi_M + 653.86\phi_D - 560.45 \tag{33.}$$

$$\pi_D = -653.86\phi_M + 1370.66\phi_D + 560.45 \tag{34.}$$

$$\pi_R = -2024.52\phi_M - 2024.52\phi_D + 2024.52 \tag{35.}$$

TABLE II DRS CONTRACT PARAMETERS AND THE CORRESPONDING EXPECTED PROFITS

					Expected Profits			
Point	ϕ_M	ϕ_D	ω_M	ω_D	π_M	π_D	π_R	Total
A	34.1%	36.9%	0.82	1.03	594.8	842.7	587.1	2024.5
B	21.4%	49.6%	1.71	1.03	337.1	1100.4	587.1	2024.5
C	25.5%	32.8%	0.74	1.92	337.1	842.7	844.8	2024.5
D	27.0%	39.7%	1.09	1.33	423.0	928.6	673.0	2024.5

Compared to the traditional RS contract proposed in [10], both contracts can achieve maximum total SC profits.

Nevertheless, the feasible region of RS ratios in [10] is nonlinear and not easy to implement, due to mutual dependent RS contracts. Our study proposes a different revenue sharing scheme that is much easier to apply and to analyze. During the process of contract negotiation, the graph of feasible region, like Fig. 3, and the expected profits equations, like (33) through (35), can be very useful to SC partners. If the SC partners agree on the objective of even increased profits, then the solution of ϕ_M and ϕ_D can be easily calculated by solving the linear equation system in (24) and (25).

VI. CONCLUSIONS

The major contribution of this paper is that we propose a new method of revenue sharing and find an easy way to derive the parameters of the DRS contract that is capable of channel coordination and win-win situation. Unlike traditional tier-by-tier revenue sharing contract, the DRS contract requires the retailer to return partial revenues directly to other SC partners. This makes the operation easier and faster, because the distributor does not have to return part of its revenue to the manufacturer. The applicability of DRS contract is also high. Through the DRS contract, the total SC profit is as high as in a centralized SC. Meanwhile, each SC partner’s profit can also increase if proper parameters of the contract are chosen. In other words, the proposed model can achieve channel coordination and a win-win situation. The feasible region for the parameters of the contract can be easily represented as a system of linear inequalities. The expected profit of each SC partner is also simplified as a linear equation of revenue sharing ratios ϕ_M and ϕ_D. The linear model provides the SC coordinator with simple and effective decision support.

Although the DRS contract requires high levels of trust and information sharing, it is practical nowadays because of many other successful SC collaboration experiences as well as the rapid development of information technology and e-commerce. More and more companies are realizing the benefits of SC collaboration and are willing to trust their SC partners and to share information through a common platform. These collaborative activities, such as CPFR and VMI, have improved the performance of many companies. The successful experience of these collaborative activities increases the likelihood that SC partners are willing to adopt the DRS contract. Even so, continuously improving the trust and sharing is always necessary.

The DRS contract may have a greater chance to succeed if it is initiated by the manufacturer since the retailer is likely to accept the contract due to its lower risk and higher profit. On the contrary, if the DRS contract is initiated by the retailer, he or she must have very high bargaining power, or make much effort to be trusted by the distributor and the manufacturer.

Although this paper only discusses the DRS contract between a single manufacturer, a single distributor and a single retailer, it may provide basic knowledge to expand the DRS contract to multiple SC actors. In addition, if the retailer has the power of changing its retailer price to influence demand, how to adjust the DRS contract should be investigated.

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APPENDIX

Suppose that $f(\ )$ and $F(\ )$ are the probability density function and the cumulated probability function, respectively, for normal distribution: N(μ,σ^2). Also let $f_S(\ )$ and $F_S(\ )$ be the probability density function and the cumulated probability function, respectively, for standard normal distribution N(0,1). The expected sales $E[\min(q,d)]$ can be derived as follows:

$$E[\min(q,d)] = (\mu - q)F_S\left(\frac{q-\mu}{\sigma}\right) - \sigma f_S\left(\frac{q-\mu}{\sigma}\right) + q \tag{A.1}$$

Proof:

$$E[\min(q,d)] = \int_{-\infty}^{q} xf(x)dx + \int_{q}^{\infty} qf(x)dx$$

$$= \int_{-\infty}^{q} xf(x)dx + q(1-F(q))$$

$$= \int_{-\infty}^{q} x\frac{1}{\sqrt{2\pi}\sigma}e^{\frac{-1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}dx + q(1-F(q))$$

$$= \int_{-\infty}^{q} x\frac{1}{\sqrt{2\pi}\sigma}e^{\frac{-1}{2}\left(\frac{x-\mu}{\sigma}\right)^2}dx + q\left(1-F_S\left(\frac{q-\mu}{\sigma}\right)\right)$$

Replace $\frac{x-\mu}{\sigma}$ with *z*, then $dx = \sigma dz$. We obtain:

$$E[\min(q,d)] = \int_{-\infty}^{\frac{q-\mu}{\sigma}} (z\sigma+\mu)\frac{1}{\sqrt{2\pi}} e^{\frac{-1}{2}z^2} dz + q\left(1-F_S\left(\frac{q-\mu}{\sigma}\right)\right)$$

$$= \mu\int_{-\infty}^{\frac{q-\mu}{\sigma}} \frac{1}{\sqrt{2\pi}} e^{\frac{-1}{2}z^2} dz + \sigma\int_{-\infty}^{\frac{q-\mu}{\sigma}} z\frac{1}{\sqrt{2\pi}} e^{\frac{-1}{2}z^2} dz + q\left(1-F_S\left(\frac{q-\mu}{\sigma}\right)\right)$$

$$= \mu F_S\left(\frac{q-\mu}{\sigma}\right) + \sigma\int_{-\infty}^{\frac{q-\mu}{\sigma}} z\frac{1}{\sqrt{2\pi}} e^{\frac{-1}{2}z^2} dz + q\left(1-F_S\left(\frac{q-\mu}{\sigma}\right)\right)$$

$$= (\mu-q)F_S\left(\frac{q-\mu}{\sigma}\right) + \sigma\int_{-\infty}^{\frac{q-\mu}{\sigma}} z\frac{1}{\sqrt{2\pi}} e^{\frac{-1}{2}z^2} dz + q$$

Replace $\frac{z^2}{2}$ with *w*, then $dw = zdz$. We obtain:

$$E[\min(q,d)] = (\mu-q)F_S\left(\frac{q-\mu}{\sigma}\right) + \sigma\int_{\infty}^{\frac{1}{2}\left(\frac{q-\mu}{\sigma}\right)^2} \frac{1}{\sqrt{2\pi}} e^{-w} dw + q$$

$$= (\mu-q)F_S\left(\frac{q-\mu}{\sigma}\right) - \sigma\frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{q-\mu}{\sigma}\right)^2} + q$$

$$= (\mu-q)F_S\left(\frac{q-\mu}{\sigma}\right) - \sigma f_S\left(\frac{q-\mu}{\sigma}\right) + q$$

Proof is completed.

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