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Coordinating a Three-level Supply Chain with Service Level Contract and Profit Sharing Contract

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Xun Xu
Washington State University
xun.xu@email.wsu.edu

ABSTRACT

We discuss the coordination mechanism in a three-level supply chain including one supplier, one distributor, and two retailers through using both the service level contract and profit sharing contract. Via numerical studies, we find that both the individual service level contract and profit sharing contract can achieve more profits for the whole supply chain. The profits can be further enhanced if both contracts are used simultaneously. The incentive of stakeholders to use profit sharing contract depends on various service levels. Our findings help stakeholders in the supply chain use centralized decision making to achieve maximal systemic profits through flexible contracts.

KEYWORDS: Supply chain, Coordination, Service level contract, Profit sharing contract

INTRODUCTION

Various contracts are used in supply chains nowadays to govern the activities of the partners of supply chains. Flexible supply chain contracts motivate stakeholders in supply chains to place order quantities and hold inventories that are optimal from a supply chain perspective (Sieke et al., 2012). Therefore, contracts are efficient ways to coordinate supply chain to achieve the maximal profit for the whole distribution system. These contracts include quantity discount contract (e.g. Katehakis & Smit, 2012), buy-back contract (e.g. Dai et al., 2012), wholesale contract (e.g. Xu & Bisi, 2012), revenue sharing contract (e.g., Govindan & Popiuc, 2014) and so on.

This study aims to discuss the coordination mechanism of supply chain through using service level contract and profit sharing contract. Under a service level contract, supply chain partners agree on target service level for customers. This contract incentivizes retailers to place higher orders to achieve more demands (Katok et al., 2008) and is widely used in various industries. For example, dm-drogeriemarkt, one of the largest German drugstore chains, uses service level contracts with its suppliers (Mostberger, 2006). Besides achieving more profit for the whole supply chain, the service level contract can also improve the customer's satisfaction by providing high service levels.
supply chain through meeting more demand directly, enhanced service level also increase more customer satisfaction and loyalty, which could also bring more profits for companies through generating more customer demands (Sun & Kim, 2013).

Another common form of contract used in supply chain is profit sharing contract. Retailers would get a lower wholesale price from suppliers and share a proportion of their profits to suppliers for compensation. Profit sharing contract is also an efficient way to coordinate stakeholders' actions towards maximizing the profit of the whole supply chain and prevent stakeholders to act in their own self-interest in making decisions that are sub-optimal (Sarmah et al., 2007). Therefore, the centralized decision making is achieved through profit sharing contract to obtain higher supply chain performance.

The objective of this study is to discuss the coordination mechanism of a three-level supply chain including one supplier, one distributor and two retailers through service level contract and profit sharing contract. In detail, three research questions are raised: First, whether the service level contract could coordinate stakeholders in the supply chain to achieve more profit for the whole supply chain? Second, whether the profit sharing contract could coordinate stakeholders in the supply chain to achieve more profit for the whole supply chain? Third, whether using both the service level contract and profit sharing contract can increase the profit of the whole supply chain to an even larger extent compared with the profit under single contract?

Overall, this paper contributes to the extant literature in the following ways. First, it is one of the first papers to explore the joint decision of using both service level contract and profit sharing contract and find out its effect on supply chain performance. Previous studies only discuss these two contracts individually (e.g. Sieke et al., 2012; Foros et al., 2009). Second, it is one of the first papers to explore the coordination effect of using service level contract and profit sharing contract in the three-level supply chain including supplier, distributor, and retailers. Most of the previous related studies are based on two-echelon supply chain only including supplier and retailer (e.g. Sarmah et al., 2007; Wang et al., 2002).

The rest of our paper is organized as follows: section two reviews the related literature; section three develops the models; numerical studies are discussed in section four, and conclusions and extensions are provided in the last section.

LITERATURE REVIEW

In this section, we would review some related literature about customer service level and profit sharing contract. There are numerous previous studies discussing about customer service level through theoretical modeling approach in the context of supply chain management. Studies could be categorized into three types.
First, customer service level could be considered as a constraint and companies need to achieve their objective such as getting the maximal profits under the specific service level constraint. For example, Li et al. (2011) discuss a decentralized and decentralized supply chain inventory model, respectively, to maximize the profit of the whole supply chain under controllable lead time and service level constraint. The constraint is faced by the retailer.

Second, previous studies discussed about the influence of various customer service level on supply chain performance. For example, Lejeune (2013) proposes a probabilistic model under multi-period service levels. The supply chain faces a stochastic customer demand and need to construct integrated replenishment plans that satisfy strict stockout-oriented performance. The author reformulates stochastic planning problems based on the multi-period service levels. Fernandes et al. (2013) study labor shifts planning issue using a real options approach. Various service level is set as the target and their model could enable managers to make shift decisions under conditions of uncertainty with the maximum level of flexibility.

Third, service level contract is an efficient way to coordinate the supply chain to maximize the whole profits. Service level contract is used to coordinate the activities of the supply chain partners (Sieke et al., 2012). The review period has an effect on the coordination mechanism through service level contract (Katok et al., 2008). Although service level contract is discussed to a large extent in previous studies, most of them are based on two-echelon supply chain. For example, Xiao and Xu (2013) discuss the service level coordination mechanism for the supply chain with one manufacturer and one retailer selling deteriorating item and under vendor managed inventory. Wang et al. (2002) build on Cohen et al.’s (1999) work and analyze service level differentiation based on a two-echelon distribution system.

Our study extends the previous studies through including another level of supply chain. In detail, two retailers, one distributor, and one manufacturer are included in the supply chain and our study studies the coordination mechanism among the three levels of supply chain using service level contract.

Besides service level contract, there are many other contracts to coordinate supply chain. Profit sharing contract is among these contracts and could be used to coordinate the activities among stakeholders in the different levels of supply chain. For example, Foros et al. (2009) study the effect of the profit sharing contract on channel coordination device. In their study, the upstream firm can prevent destructive competition between downstream firms that produce relatively close substitutes through using profit sharing contract. Kamrad and Siddique (2004) use several flexible contracts including profit sharing contract to examine the dual optimization problem for the suppliers and the producer. Profit sharing contract in special supply chains such as newspaper chain is also discussed to maximize the total profit of the supply chain (e.g., Pearson, 2007).
Besides, profit sharing contract could be used to coordinate the actions in the same level of supply chain. For example, profit sharing contract could be used among manufacturing companies to enable them to maximize the operating profits (Lakhal, 2006). It could also be used between two firms to set up a joint venture. The two firms use profit sharing to determine the fair value for the technologies and knowhow (Du et al., 2006).

Furthermore, profit sharing contract could also be used in a supply network formation (Hennet & Mahjoub, 2010) and business networks setting up (Nigro & Abbate, 2011). Fair issues and risk assessment are always related to profit sharing in the network (Nigro & Abbate, 2011).

Although profit sharing contract is commonly studied in previous literature, most of the paper discusses the effect of the contract on the coordination mechanism between the manufacturer and retailer. For example, Sarmah et al. (2007) focus on the profit sharing between a manufacturer and a retailer and similarly, Leng and Parlar (2009) show that profit sharing contract could make the manufacturer and retailer be better off and have no incentives to deviate from the optimal global solution that maximizes the supply chain’s profit.

Through discussing the profit sharing contract among the stakeholders in the three-level of supply chain that includes two retailers, one distributor, and one manufacturer, our study extends the previous literature. We want to find out whether the effect of profit sharing contract on coordinating the three-level of supply chain is efficient or not. Furthermore, we propose to explore the joint decision of using service level contract and profit sharing contract and find out whether there would be an even higher efficiency of the effect on coordinating the three-level of supply chain through using both of the contracts simultaneously.

**MODEL DESCRIPTION**

**Assumption and Notation**

In our study, the price-demand function is linear (same as Huang et al., 2010). For the relationship between demand and customer service level, Ernst and Powell (1998) state the form as

\[ D(SL) = (1 + \alpha(SL - SL_0))D_0 \]

where \( D \) is the demand, \( SL_0 \) is the initial service level, and \( D_0 \) is the initial corresponding demand. \( SL \) is the service level needs to be decided and \( \alpha \) is the sensitive coefficient. In addition, Ernst and Powell (1998) provide a service-sensitive model in the form similar as linear regression. Based on their discussion, we consider the price and service level as the two main factors to influence demand level and their linear relationship is:

\[ D = a - bp + c \beta + \varepsilon \]

where \( D \) is the demand, \( a \) is the primary demand, \( b \) is the sensitive parameter to the price, \( c \) is the sensitive parameter to the service level, \( \beta \) is the service level,
and $\varepsilon$ is a random factor to show the uncertainty of the demand due to the weather, policy and other uncertain factors. We assume $\varepsilon$ is normally distributed with mean $u$ and standard deviation $\sigma$.

We assume that in the supply chain, there is one manufacturer, one distributor and two retailers. For each party of stakeholders, there is no capacity constraint. The retail price is in the form of $P = x + u$ where $x$ is the price offered by the distributor and $u$ is the marginal profit retailers want to obtain. We assume that the purchase price for the two retailers from the distributor is the same and the marginal profit $u$ is the same for two retailers. For the demand $D_i$ for each retailer, it is related to its service level $\beta_i$. Namely, $D_i(\beta) = \frac{(\beta)^{\gamma_i}}{(\beta^*)^{\gamma_i} + (\beta_{3-i})^{\gamma_i}} D$, where $r_i, r_2 \geq 0$ are parameters representing the service-sensitivity of the customer demand from retailer 1 and 2, respectively, and $D$ is the total demand for the whole market. The same demand form is adopted in Boyaci and Gallego's (2004) study. For simplification and without loss of generality, we set both $r_1, r_2$ equals to 1. Table 1 summarizes the notation of the model.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Variable</th>
<th>Description</th>
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<tbody>
<tr>
<td>$\beta_i$</td>
<td>The service level of retailer $i$</td>
<td>$a$</td>
<td>The primary demand</td>
</tr>
<tr>
<td>$D$</td>
<td>The total demand of market</td>
<td>$b$</td>
<td>Price elasticity to demand</td>
</tr>
<tr>
<td>$D_i$</td>
<td>Demand for retailer $i$</td>
<td>$c$</td>
<td>The sensitive parameter to the service level</td>
</tr>
<tr>
<td>$x$</td>
<td>Price the distributor offers to retailers</td>
<td>$P$</td>
<td>Price each retailer offers to customers</td>
</tr>
<tr>
<td>$u$</td>
<td>Marginal profit of each retailer</td>
<td>$\pi_i$</td>
<td>Profit of the retailer $i$</td>
</tr>
<tr>
<td>$h$</td>
<td>Holding cost coefficient</td>
<td>$\pi_d$</td>
<td>Profit of the distributor</td>
</tr>
<tr>
<td>$r$</td>
<td>Depreciation coefficient</td>
<td>$\pi_m$</td>
<td>Profit of the manufacturer</td>
</tr>
<tr>
<td>$w$</td>
<td>Price the manufacturer offers to distributor</td>
<td>$\varepsilon$</td>
<td>Random factor for demand $\varepsilon \sim N(u_\varepsilon, \sigma_\varepsilon)$</td>
</tr>
<tr>
<td>$c$</td>
<td>Production cost of each item</td>
<td>$\theta$</td>
<td>Profit sharing factor</td>
</tr>
<tr>
<td>$Q_i$</td>
<td>Ordering amount from retailer $i$ from the distributor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
We further assume the salvage value of the product is \((1 - r)P\) if it isn’t sold at the end of the selling period. Without loss of generality, we assume that the selling season is one year and for simplification, holding cost is only accounted for unsold item at the end of the year.

Thus, for each selling season, the profit of retailer \(i\) is as follows:

\[
\pi_i = \min\left(\frac{\beta_i}{\beta_i + \beta_{3-i}}D, Q_i\right)P - xQ_i - h\left[Q_i - \frac{\beta_i}{\beta_i + \beta_{3-i}}D\right]^+ + (1 - r)P\left[Q_i - \frac{\beta_i}{\beta_i + \beta_{3-i}}D\right]^+, \quad (1)
\]

Where \(D = a - bp + \left(\frac{\beta_i}{\beta_i + \beta_{3-i}} + \frac{\beta_{3-i}}{\beta_i + \beta_{3-i}}\right)L_0 + \varepsilon\), \(\beta_i = Prob\left(\frac{\beta_i}{\beta_i + \beta_{3-i}}D \leq Q_i\right)\), and \(\varepsilon \sim N(u, \sigma)\).

The profit of the distributor is:

\[
\pi_d = (Q_1 + Q_2)(x - w). \quad (2)
\]

And the profit of the manufacturer is:

\[
\pi_m = (Q_1 + Q_2)(w - c). \quad (3)
\]

Since the profit functions for the two retailers are symmetric, their strategy to choose the service level \(\beta_i\) is the same. In other words, the optimal \(\beta_i^* = \beta_2^*\). Therefore, we can simplify the profit of retailer \(i\) as follows

\[
\pi_i = \min\left(0.5D, Q\right)P - xQ - h\left[Q - 0.5D\right]^+ + (1 - r)P\left[Q - 0.5D\right]^+, \quad i = 1, 2 \quad (4)
\]

Below we consider four scenarios to show whether the coordination through service level contract, profit sharing contract, or both could enhance the profit of the whole supply chain.

**No Coordination among Retailers, Distributor, and Manufacturer**

In decentralized decision making process, each retailer wants to maximize its own expected profit. For each retailer, the maximized expected profit function is shown as follows:

\[
\max E(\pi_r) = \max\left\{\min\left(0.5E(D), Q\right)P - xQ - hE\left[Q - 0.5D\right]^+ + (1 - r)PE\left[Q - 0.5D\right]^+ \right\}. \quad (5)
\]

The decision variable for each retailer is \(\beta_1 = \beta_2 = \beta\). We denote \(\beta = P(0.5D \leq Q) = f(Q)\),

\[
G(Q) = E[Q - 0.5D]^+ = \int_0^{2Q} (Q - 0.5d)f_d(d)dd, \quad \text{and} \quad g(Q) = \min\left(0.5D, Q\right). \quad \text{Therefore,}
\]
\[ g'(Q) = \begin{cases} 
1 & Q < 0.5D \\
0 & Q \geq 0.5D 
\end{cases} \text{ and } \frac{dG(Q)}{dQ} = (Q - 0.5(2Q))f_D(2Q) \times 2 + \int_0^{2Q} f_D(d)dd. \] (6)

Since \( Q \) and \( \beta \) have the relationship of one-to-one correspondence, we can find the optimal \( \beta^* \) that maximizes each retailer’s profit by finding the corresponding optimal \( Q^* \). Now we set

\[
\begin{align*}
P - x - (h + (1-r)P)\frac{dG(Q)}{dQ} = 0 & \quad Q < 0.5D \\
-x - (h + (1-r)P)\frac{dG(Q)}{dQ} = 0 & \quad Q > 0.5D
\end{align*}
\] (7) (8)

Proposition 1 shows the optimal \( Q^* \) for each retailer under no coordination between each stakeholder in the supply chain.

Proposition 1: The optimal \( Q^* \) for each retailer under no coordination between each stakeholder in the supply chain happens at either the unique solution of \( Q \) for equation (1), the unique solution of \( Q \) for equation (2), or \( Q = 0.5D \).

Proof: See Appendix.

Under this scenario, the decision variable is the service level \( \beta_{un}^* \). We denote the corresponding optimal service level for each retailer as \( \beta_{un}^* = f^{-1}(Q_{un}^*) \) with the optimal \( Q_{un}^* \) and find out the value of \( \beta_{un}^* \) in section 4 of numerical study. In this way, the expected optimal profit for the whole supply chain is:

\[
E(\pi_{un}^*) = 2(\min(0.5E(a-bP+c\beta_{un}^*+\varepsilon), f^{-1}(\beta_{un}^*))(c + (w-c) + (x-w) + u) - \\
(c + (w-c) + (x-w))f^{-1}(\beta_{un}^*) - hE[f^{-1}(\beta_{un}^*) - 0.5(a-bP+c\beta_{un}^*+\varepsilon)] + \\
(1-r)PE[f^{-1}(\beta_{un}^*) - 0.5(a-bP+c\beta_{un}^*+\varepsilon)] + 2f^{-1}(\beta_{un}^*)(x-w) \\
+ 2f^{-1}(\beta_{un}^*)(w-c)) \tag{9}
\]
Coordination among Retailers, Distributor, and Manufacturer through Service Level Contract

In many realities, due to the higher holding cost and lower salvage value of the products, to maximize each retailer’s profit, the optimal service level $\beta^*$ may be relative small to avoid too much surplus. These products are like fashion products. The smaller $\beta^*$ makes the corresponding ordering amount $Q^*$ smaller and therefore yields the relatively small profit of the distributor and the manufacturer. In this section, we want to find out whether the stakeholders could coordinate with each other to enhance the profit of whole supply chain by increasing the service level of the retailers through service level contract. The increasing customer service level can also lead to enhanced customer satisfaction and loyalty. The total profits of the whole supply chain may increase due to the enhanced profit of the distributor and manufacturer although with the decreased retailer’s profit.

So now we maximize the profit of the whole supply chain instead of maximizing the profit for only the retailers. Each stakeholders would make actions towards achieving the maximal systemic profits. The decision variable is service level $\beta^*_d$. We denote the corresponding optimal service level for each retailer as $\beta^*_r = f^{-1}(Q^*_d)$ and find out the value of $\beta^*_d$ in section 4 of numerical study. In this way, the expected optimal profit for the whole supply chain is:

$$E(\pi^*_d) = 2\{\min(0.5E(a-bP+c\beta^*_d+\varepsilon), f^{-1}(\beta^*_d))(c+(w-c)+(x-w)+u) - (c+(w-c)+(x-w))f^{-1}(\beta^*_d) - hE[f^{-1}(\beta^*_d) - 0.5(a-bP+c\beta^*_d+\varepsilon)]^+ + (1-r)PE[f^{-1}(\beta^*_d) - 0.5(a-bP+c\beta^*_d+\varepsilon)]^+ + 2f^{-1}(\beta^*_d)(x-w) + 2f^{-1}(\beta^*_d)(w-c)\}$$

Coordination among Retailers, Distributor, and Manufacturer through Profit Sharing Contract

In our model discussed above, the demand is influenced by both the price and customer service level. In this section, we try to find out whether the whole profit of the supply chain could enhance through the increased demand achieved by the decreased price. The decreased price occurs by using the profit sharing contract. In detail, to increase the demand, the manufacturer would like to offer a wholesale price discount $(1-\theta)$ to the distributor and the distributor would like to offer a wholesale price discount $(1-\theta)$ to each retailer. For compensation, each retailer
need to share \((1 - \theta)\) of its profit to the distributor and the distributor also need to share \((1 - \theta)\) amount of what each retailers share to the manufacturer. In other words, besides their own profits from ordering and selling products, the distributor shares \((1 - \theta)\) \(\theta\) of retailers’ profit and the manufacturer shares \((1 - \theta)^2\) of retailers’ profit. Profit sharing contract can be served as a channel coordination device in many industries such as newspaper chain (Foros et al., 2009; Pearson, 2007).

The service level is the optimal service level \(\beta^*_{m0}\) obtained in the last section, which maximizes retailers’ profit under no coordination. And the same as in the last scenarios, the retailers still want to have the marginal profit for each product at a fix level \(u\). So we now maximize the profit of the whole supply chain using profit sharing contract. The decision variable is profit sharing proportion \((1 - \theta)\). We denote the optimal \(\theta\) in this scenario as \(\theta^*_{ps}\) and find out the value of \(\theta^*_{ps}\) in section 4 of numerical study. In this way, the expected optimal profit for the whole supply chain is:

\[
E(\pi^*_{ps}) = 2\theta^*_{ps}\{\min(0.5E(a - bP + \beta^*_{m0}L_0 + \varepsilon), f^{-1}(\beta^*_{m0}))(c + \theta^*_{ps}(w - c) + \theta^*_{ps}(x - w) + u) - (c + \theta^*_{ps}(w - c) + \theta^*_{ps}(x - w)) f^{-1}(\beta^*_{m0}) - hE[f^{-1}(\beta^*_{m0}) - 0.5(a - bP + \beta^*_{m0}L_0 + \varepsilon)]^T + (1 - r)PE[f^{-1}(\beta^*_{m0}) - 0.5(a - bP + \beta^*_{m0}L + \varepsilon)]^T + 2\theta^*_{ps}(1 - \theta^*_{ps}) f^{-1}(\beta^*_{m0})(x - w) + 2(1 - \theta^*_{ps})^2 f^{-1}(\beta^*_{m0})(w - c)\}
\]

(11)

**Coordination among Retailers, Distributor, and Manufacturer through Both Customer Service Level Contract and Profit Sharing Contract**

In this section, stakeholders have a joint decision for using both the service level contract and profit sharing contract in order to maximize the profit of the whole supply chain. In other words, stakeholders would like to take the advantages of both the service level contract and profit sharing contract as discussed in the previous sections. We denote the optimal service level as \(\beta^*_{co}\) and the optimal profit sharing proportion as \((1 - \theta^*_{co})\). And we would find out the value of \(\beta^*_{co}\) and \(\theta^*_{co}\) in section 4 of numerical study. In this way, the expected optimal profit for the whole supply chain is:
NUMERICAL STUDY

Numerical Study under No Coordination and Coordination through Service Level Contract

Parameter inputs in our numerical study are shown in Table 2. Service level and profit sharing proportion are decision variables. For the real application nowadays, according to different industries, service level varies and profit sharing proportion is usually decided by the decision power of various stakeholders, characteristics of products and industry, market forecast and so on. We use Matlab to run 1,000,000 times interactions to find out the expected profit for each retailer and the whole supply chain in each scenario. The profit for each retailer and the whole supply chain under each service level without profit sharing are shown in Figure 1.

### Table 2: Input Parameters of Numerical Study

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(x)</td>
<td>750</td>
<td>(a)</td>
<td>2000</td>
</tr>
<tr>
<td>(u)</td>
<td>30</td>
<td>(b)</td>
<td>2</td>
</tr>
<tr>
<td>(w)</td>
<td>600</td>
<td>(\varepsilon)</td>
<td>(\varepsilon \sim N(100,50))</td>
</tr>
<tr>
<td>(c)</td>
<td>500</td>
<td>(\beta)</td>
<td>([0.3, 0.99]) (Decision Variable)</td>
</tr>
<tr>
<td>(h)</td>
<td>0.1</td>
<td>(\theta)</td>
<td>([0, 1]) (Decision Variable)</td>
</tr>
<tr>
<td>(r)</td>
<td>0.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
From Figure 1 we can find that each retailer’s profit increases with the increasing customer service level initially but decreases after it gets its maximum point at $\beta = 0.7$. However, the profit of the whole supply chain always increases with the increasing customer service level. Therefore, by coordinating the supply chain through service level contract, the supply chain could get its maximized profit of $1.87 \times 10^{5}$, 11.3% more than the profit corresponding to the service level when each retailer gets its maximal profit. However, each retailer has to suffer the profit loss of $3.25 \times 10^{3}$ (from $7.44 \times 10^{3}$ to $4.19 \times 10^{3}$). Therefore, by redistributing $3.25 \times 10^{3}$ profit to each retailer from the manufacturer and distributor, each stakeholder could benefit its profit.

**Numerical Study under Coordination through Profit Sharing Contract**

Since without profit sharing, when the service level $\beta = 0.7$, retailers get the maximal profits. Therefore, the retailers want to set $\beta = 0.7$ when they are offered by discount and profit sharing factor $(1 - \theta)$. Figure 2 shows the profit for each retailer and for the whole supply chain when using profit sharing contract under the fixed service level $\beta = 0.7$. 

**FIGURE 1: The Profit for Each Retailer and the Whole Supply Chain under Each Service Level without Profit Sharing**

![Graph showing the profit for each retailer and the whole supply chain under each service level without profit sharing.](image-url)
FIGURE 2: The Profit for Each Retailer and for the Whole Supply Chain when Using Profit Sharing Contract under the Fixed Service Level

From Figure 2, we can find that the whole supply chain obtains the maximal profit at the profit sharing proportion $1 - \theta = 1 - 0.9 = 0.1$ and each retailer gets the maximal profit without profit sharing. When having the optimal profit sharing proportion, the whole supply chain gets the profit $1.69 \times 10^5$, which is greater than the profit under no profit sharing contract ($1.68 \times 10^5$).

However, each retailer has to suffer the profit loss $0.6 \times 10^3$ (from $7.44 \times 10^3$ to $6.84 \times 10^3$).

Therefore, through redistributing $0.6 \times 10^3$ profit to each retailer from the manufacturer and distributor, each stakeholder could benefit its profit.

**Numerical Study under Coordination through Both Customer Service Level and Profit Sharing Contract**

In this scenario, both of $\beta$ and $\theta$ are decision variables and we want to find the optimal $\beta^*$ and $\theta^*$ through numerical study. The profit of each retailer and the profit of the supply chain under various $\beta$ and $\theta$ are shown in Figure 3 and Figure 4, respectively.
FIGURE 3: The Profit of Each retailer at Each Service Level
and Profit Sharing Proportion

FIGURE 4: The Profit of the Whole Supply Chain at Each Service Level
and Profit Sharing Proportion
From Figure 3 and Figure 4, we have the following findings:

(1) For each fixed service level, both the profits of the supply chain and retailer decrease with the decreasing profit sharing proportion \((1-\theta)\) when \((1-\theta) \leq 0.9\)

(2) When \(\beta \geq 0.7\), the profit of the supply chain get its maximum at \(1-\theta = 0.9\). When \(\beta < 0.7\), the profit of the supply chain gets its maximum with no profit sharing contract.

(3) When \(\beta \geq 0.5\), the profit of each retailer gets its maximum when there is no profit sharing. However, when \(\beta < 0.5\), the profit for each retailer gets its maximum when \(1-\theta = 0.9\).

Therefore, based on the above numerical results, we know that with lower customer service level (e.g. \(\beta < 0.5\)), only each retailer has the incentive to use profit sharing contract; with moderate customer service level (e.g. \(0.5 \leq \beta < 0.7\)), no stakeholder in the supply chain has the incentive to use profit sharing contract; and with higher customer service level (e.g. \(\beta \geq 0.7\)), only the distributor and manufacturer would like to use profit sharing contract.

For the joint decision of using service level contract and profit sharing contract, we find that the whole supply chain gets its maximal profit when using both of the contracts simultaneously. Namely, \(\beta^* = 0.99\) and \(\theta^* = 0.9\). In this way, the whole profit of the supply chain is \(1.88 \times 10^5\), 16.05\% over than the average level of supply chain profit with random \(\beta\) and \(\theta\), 11.24\% over than the profit when only using profit sharing contract, and 0.53\% over than the profit when only using service level contract. Therefore, coordinating the supply chain through both the service level contract and profit sharing contract is particularly useful and could achieve enhanced profit of the whole supply chain to a larger extent compared with under single contract.

**CONCLUSIONS AND EXTENSIONS**

**Conclusions**

Regarding to our first research question, the answer is yes: Coordination through service level contract can enhance the profit of the whole supply chain. In detail, by using service level contract, the profit of the whole supply chain has a better performance due to the increased profit of the manufacturer and distributor.

Regarding to our second research question, the answer is also yes: Coordination through profit
sharing contract can enhance the profit of the whole supply chain. In detail, by using profit sharing contract among the stakeholders in the supply chain, the whole supply chain generates more profits due to the increased demand of the product.

Regarding to our third research question, the answer is still yes: Using both the service level contract and profit sharing contract can increase the profit of the whole supply chain to an even larger extent compared with the profit under single contract. Specifically, based on the numerical studies, we find that the incentive of each stakeholder using profit sharing contract depends on the service level. Namely, with lower customer service level, only each retailer has the incentive to use profit sharing contract; with moderate customer service level, no stakeholder in the supply chain has the incentive to use profit sharing contract; and with higher customer service level, only the distributor and manufacturer would like to use profit sharing contract and the profit of the whole supply chain is enhanced compared with no profit sharing contract.

**Managerial Implications**

The decisions of the stakeholders in the supply chain should be integrated and thus achieve the maximal profit of the whole supply chain. Using service level contract and profit sharing contract among the stakeholders are proved to be efficient ways to achieve more profits for the supply chain. However, this would incur the profit loss from the retailers. In order to motivate retailers to enhance their service level and accepting profit sharing contract, manufactures and distributors should make these actions beneficial to retailers through redistributing some profits to them. An affiliated contract may need to be used to guarantee this action. In addition, to stimulate the development of business, other stakeholders such as governments could offer some subsidies to retailers to encourage them to increase the customer service level and using profit sharing contract. The enhanced service level could even generate more demand and market share through enhanced customer satisfaction and loyalty, and generate more profits through increased customers' willingness to pay.

However, since the administrative cost of profit sharing contract is greater than that of wholesale pricing contract due to the information asymmetry (Cachon & Lariviere, 2005), in practice, only when the enhanced profits of the supply chain could offset the increased administrative cost, profit sharing contract is valuable. Therefore, information sharing strategy should be utilized at the same time to achieve the long-term and strategic partnerships among the whole supply chain.

**Future Extensions**

Future research could extend our study through the following ways: first, our model could be extended to reflect more complicated supply chains. For example, supply chain with multiple suppliers and distributors could be considered. In this way, specific profit sharing contract may
need to be considered between each supplier and retailer based on their own characteristics. Second, the administrative cost of profit sharing contract may need to be considered and modeled. Further scenarios could be discussed under information sharing, information symmetry, and information asymmetry. Third, the additive effect of increased customer service level through service level contract on enhanced demand and market share through increased customer satisfaction and loyalty may need to be integrated into our model. Also, coordination effect through service level contract and profit sharing contract under retail competition, complementary products, supply chain risks, and other influential factors may be studied. Lastly, more sensitivity analysis can be conducted. For example, future the study can explore whether the cost structure would influence stakeholders' service level and profit sharing proportion decisions. Also, capacity constraint may need to be considered if stakeholders are under space (e.g., warehouse, distribution center) constraint or budget constraint.

APPENDIX

Proof of Proposition 1

Five values of \( Q \) may maximize each retailer's profit, namely, the unique solution of \( Q \) for equation (1), unique solution of \( Q \) for equation (2), the endpoints of the interval:

\[ Q = 0, \ Q = 0.5D, \text{ and } Q = +\infty. \]

Through further consideration, we can get rid of \( Q = 0 \) and \( Q = +\infty \) since the corresponding profit for each retailer is 0 and \( -\infty \), respectively. Therefore, the optimal \( Q^* \) happens at either the unique solution of \( Q \) for equation (1), the unique solution of \( Q \) for equation (2), or \( Q = 0.5D \).

REFERENCES


