

# Decentralized Supply Chain Coordination with Revenue Sharing Mechanism: Transfer Pricing Heuristics and Revenue Share Rates

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Received, March 27, 2009; Revised, August 7, 2009; Accepted, September 2, 2009

**Abstract.** A revenue sharing contract is one of the mechanisms that coordinate decision makers in a decentralized supply chain toward the consensual goal. The transfer prices between different echelons in the supply chain influence the total supply chain profits. The study aims to explore various transfer pricing heuristics on the supply chain coordination in terms of the supply chain profits and their interactions with the revenue sharing rate. A model is proposed for formulating the collaborative production and distribution planning in a decentralized supply chain with the revenue sharing mechanism. Experiment results indicate that the transfer price and the revenue sharing rate affect significantly the coordination. Among the studied pricing heuristics, the variable-cost pricing method led to the best SC profits. Raising the revenue sharing rate reduced the SC profits no matter what heuristics were employed. Furthermore, the experiments provide us clues for finding the optimal transfer price for the supply chain.

**Keywords:** Supply Chain, Coordination, Revenue Sharing, Transfer Pricing Heuristics

## 1. INTRODUCTION

A decentralized supply chain (SC) consists of autonomous members in various echelons. No unbiased decision maker exists to leading the supply chain. Each member identifies its most effective strategy without considering the impacts on other members in different echelons. In practice, a supply chain often operates in a decentralized form (Lee and Whang, 1999). The supply chain involves multiple organizations with different concerns, and it is impossible for a single organization to dominate the whole supply chain (Lee and Kumara, 2007). An example of such a decentralized supply chain is the A-Team alliance which is initiated by bicycle companies Giant, Merida and other bike makers and part suppliers (Tompkins, 2006).

The revenue sharing contract is one of the mechanisms for coordinating members in the decentralized supply chain. The supplier reduces prices of items trans-

ferred to the retailer and the retailer shares part of their revenue with the supplier under the revenue sharing contract. With the contract, the decentralized supply chain can achieve two main objectives: 1) increasing the total profits closer to those of centralized supply chain, and 2) sharing risks among members (Tsay *et al.*, 1999). The revenue sharing contract coordinates decision makers in the decentralized supply chain toward the consensual goal.

Lots of works have been devoted to employing revenue sharing mechanism to coordinate a decentralized supply chain. Most of them focus on designing the revenue sharing schemes to improve the SC profits, such as Chauhan and Proth (2005) and Gupta and Weerawat (2006). However, it remains unclear that how transfer pricing heuristics in practice impact on the coordination and their interactions with the revenue sharing rates in a decentralized supply chain with multi-plants, multi-periods and finite capacity. The considered decentralized supply chain consists of manufacturer and distribu-

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tor echelons. The two echelons interact with each other through the transfer price and the product order. The transfer price is a key variable in the coordination. The transfer price determines the order quantity for the distributors and then affects the total SC profits. In addition, the revenue sharing rate can affect the manufacturer for determining the transfer prices. Understanding the effects of these pricing heuristics and their interactions with revenue sharing rate can help us design better revenue sharing mechanism to put into practice.

In this study, we have proposed a model to formulate the collaborative production and distribution planning in a decentralized supply chain with the revenue sharing mechanism. The model comprises two sub-models. The Production-Distribution sub-model describes the production and distribution planning for the manufacturer echelon of multi-plant, multi-item, multi-period, and finite capacity. The Order Planning sub-model represents the ordering behavior for distributors under uncertain demands. Various pricing heuristics are employed to coordinate the production and distribution in the SC. Their performances have been evaluated in terms of the SC profits. Moreover, how the revenue sharing rate impacts on the coordination under various pricing heuristics are considered in the study. Experiment results indicate that the transfer price and the revenue sharing rate affect a lot the coordination between the manufacturer and the distributor echelons. Among the six pricing heuristics, the variable-cost pricing method led to the best SC profits. Furthermore, the experiments provide us clues for finding the optimal transfer price for the supply chain.

The remaining paper is organized as the following. Literature review is given in the next section. Section three presents the model for collaborative production and distribution planning in the decentralized supply chain with the revenue sharing mechanism. Experiment results are discussed in Section four. The last section is the conclusion.

## 2. LITERATURE REVIEW

In a revenue sharing contract, the buyer reimburses the seller some of its revenues for the discount on the wholesale prices (Simchi-Levi *et al.*, 2008). For instance, Blockbuster shares approximately 30% to 40% of its rental revenues in exchange for reduced wholesale prices, as reported by Mortimer (Mortimer, 2007). In a case study on the video rental industry, Dana and Spier (2001) concluded that the revenue sharing contract can be employed to coordinate the supply chain. Also, the contract induces the retailers to cut down their rental prices under competition. The Gerchak and Wang (2004) used the revenue sharing contract to coordinate a decentralized supply chain in which the decision on the component production quantity for a supplier interacts with that of other suppliers providing complementary components. Their study showed that revenue-plus-surplus-subsidy

scheme can increase the profits for all parties involved.

The revenue sharing provides incentives for retailers to stock more. Cachon and Lariviere (2005) proved that revenue sharing contracts are equivalent to buy back contracts in the fixed-price newsvendor environment; and are equivalent to price discounts in the price-setting newsvendor. However, there are some cases in which revenue sharing contracts are not appropriate, as pointed out by Cachon and Lariviere. Firstly, while revenue sharing contracts coordinate retailers to compete on quantity, it does not coordinate retailers to compete both on price and quantity. Secondly, when the earnings from the revenue sharing contract do not cover the additional administrative expense incurred by such a contract, it is not appropriate to employ revenue sharing contracts to coordinate a supply chain. Thirdly, the revenue sharing contract may not be attractive if retailers can take action to influence demand.

The revenue sharing contract has been designed from many perspectives in the literature. Chauhan and Proth have studied the revenue sharing contract that is proportional to the risks undertaken by the involved parties (Chauhan and Proth, 2005). Gupta and Weerawat (2006) investigated three types of revenue sharing contracts for supplier-manufacturer coordination. The first kind of contract is that revenue sharing depends on the supply lead time. In the second kind of contract, the supplier guarantees a delivery lead time to the manufacturer and incurs an expedited shipping charge if the supplier can not meet the promised lead time. In the last kind of contract, the revenues shared to the supplier rely on the supplier's inventory level. Geng and Mallik (2006) proposed a reverse revenue sharing contract for a distribution system with competing channels. The scheme of such a contract relates to retail prices, switch rates from channels, and the uncertain demand faced by channels along with a fixed franchise fee and a penalty for an unfulfilled order.

In addition to schemes of the revenue sharing contracts, the relationship between the transfer prices and the revenue sharing contracts has deserved lots of attention. Giannoccaro and Pontrandolfo (2004) built revenue sharing models for two- and three-stage supply chains. Their analytical solutions showed that the transfer price for the distributor equals the revenue keep rate times the marginal cost in the two-stage supply chain. Nachiappan and Jawahar (2007) developed a genetic algorithm for identifying the optimal contract prices and the revenue sharing ratio between the vendor and the buyer.

## 3. PRODUCTION AND DISTRIBUTION COORDINATION WITH REVENUE SHARING

### 3.1 Model Overview

The decentralized supply chain consists of manu-

facturer and distributor echelons. The two echelons interact with each other through the transfer prices and the product orders. The manufacturers require deciding the transfer prices for distributors. Next, the distributors identify the orders for manufacturers. Then, the manufacturers produce and distribute products according to the orders.

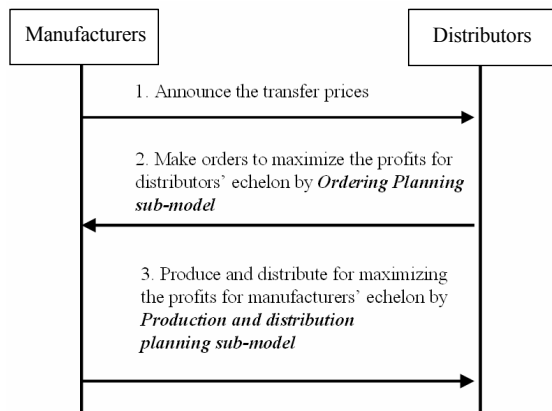
We proposed the production and distribution planning model with revenue sharing (PDP/RS), as shown in Figure 1, for formulating the interactions in the supply chain. PDP/RS consists of two sub-models. The Production-Distribution Planning sub-model identifies the optimal production and distribution plan in terms of the orders given by the distributors. The Ordering Planning sub-model determines the optimal order quantity for each distributor, given the transfer prices from manufacturers. The objective of the whole model is to maximize the total profits of the supply chain.



**Figure 1.** Architecture for production and distribution model with revenue sharing.

Under the architecture, the interactions between manufacturers and distributors echelons can be formulated as shown in Figure 2.

1. Manufacturers announce item transfer prices to distributors.
2. Each distributor uses the Order Planning sub-model to determine an order quantity that maximizes its own expected profit, given the item transfer prices from manufacturers.
3. In manufacturers' echelon, Production-Distribution Planning sub-model is employed to determine a production and distribution plan that maximizes the profits for the entire echelon.



**Figure 2.** The interactions between manufacturers and distributors.

Before presenting the mathematical formulation for the PDP/RS model, required notations are introduced in the following.

### 3.2 Notations

#### Index/Sets

$i$	Index for an item.
$m$	Index for a manufacturer.
$s$	Index for a distributor.
$t$	Index for a given period.

#### Parameters

$\alpha$	Shortage penalty for a product.
$\beta$	Penalty for a unit of idle capacity.
$1/\lambda_{ist}$	Mean of the random demand for an item of a distributor during a given period.
$\phi$	Revenue sharing rate.
$BC_{is}$	Purchasing cost of an item for a distributor.
$\tilde{D}_{ist}$	Demand of an item from a distributor during a period. The demand is a random variable.
$FC_{im}$	Fixed charge on an order for an item for a manufacturer.
$HC_{im}$	Holding cost of an item per period for a manufacturer.
$HC_{is}$	Holding cost of an item per period for a distributor.
$M$	A very large number.
$MC_{mt}$	Maximum capacity of a manufacturer during a given period.
$N_m$	Number of manufacturers.
$PC_{im}$	Production cost of an item for a manufacturer.
$SC_{ms}$	Shipping cost of an item from a manufacturer to a distributor.
$RP_{is}$	Retail price for an item in a distributor.
$SV_{is}$	Salvage value of an item for a distributor.
$UC_{im}$	Consumed capacity of an item in a manufacturer.

#### Variables

$I_{imt}$	Inventory of an item for a manufacturer at the end of a given period.
$O_{ist}$	Quantity of an item ordered by a distributor during a given period.
$QP_{imt}$	Production quantity of an item for a manufacturer during a given period.
$QS_{imst}$	Shipping quantity of an item from a manufacturer to a distributor during a given period.
$TP_{im}$	Transfer price of an item for a manufacturer.
$X_{mt}$	Promised capacity of a manufacturer to the supply chain during a given period.
$Y_{imt}$	Yes/No decision for producing an item by a manufacturer during a given period.

### 3.3 Sub-model of Order Planning

The Order Planning sub-model describes the ordering behavior for a distributor. Given the uncertain demand

and the transfer prices from manufacturers, a distributor determines the optimal ordering quantity. The study formulates the distributor’s ordering problem as a news-vendor problem (Erlebacher, 2000).

Assuming the demand fits the exponential distribution with rate  $\lambda_{ist}$ , the density function for demands is

$$f_{ist}(x) = \lambda_{ist} \exp(-\lambda_{ist}x). \tag{1}$$

When a distributor owns inventory  $y$ , the expected total profits for the distributor in a period is:

$$\begin{aligned} E(y) &= -BC_{is}y + (1-\phi)RP_{is} \left( \int_0^y x f_{ist}(x) dx + \int_y^\infty y f_{ist}(x) dx \right) \\ &\quad + SV_{is} \int_0^y (y-x) f_{ist}(x) dx \\ &= -BC_{is}y + (1-\phi)RP_{is} \left( \frac{1}{\lambda_{ist}} (1 - \exp(-\lambda_{ist}y)) \right) \\ &\quad + SV_{is} \left( y + \frac{1}{\lambda_{ist}} (\exp(-\lambda_{ist}y) - 1) \right) \end{aligned} \tag{2}$$

Since more than one manufacturer can provide the same item to a distributor, we assume that the purchase cost for an item is the average of the transfer prices. That is,

$$BC_{is} = \frac{\sum TP_{im}}{N_m}. \tag{3}$$

The optimal order quantity that maximizes the distributor’s total profits is

$$y^* = \frac{-1}{\lambda_{ist}} \ln \left( 1 - \frac{(1-\phi)RP_{is} - BC_{is}}{(1-\phi)RP_{is} - SV_{is}} \right), \tag{4}$$

given  $(1-\phi)RP_{is} - BC_{is} \geq 0$  and  $(1-\phi)RP_{is} - SV_{is} > 0$ .

Determining appropriate transfer prices is critical to manufacturers. As shown in Equations (3) and (4), transfer prices from manufacturers determines the optimal order quantity. Large transfer prices will make item purchasing costs increased, which lead distributors to decrease order quantities. As a result, manufacturers might receive fewer order quantities and make fewer profits.

### 3.4 Sub-model of Production-Distribution Planning

The manufacturers’ echelon use Production-Distribution Planning sub-model to determine an optimal production and distribution plan, given previously determined transfer prices and distributors’ order quantities. Followings are the objective function and constraints for the sub-model.

#### 3.4.1 Objective Function

Production-Distribution Planning model is to maximize the total profit of the manufacturer echelon. The model contains multiple products and periods. No back-orders are allowed. The revenue and the related costs for manufacturer are defined from Equations (5) to (11).

$$\text{Revenues for manufacturers} = \sum_{i,m,t} \left\{ TP_{im} \sum_s QS_{imst} \right\}. \tag{5}$$

$$\text{Production Cost} = \sum_{i,m,t} (FC_{im} Y_{imt} + PC_{im} QP_{imt}). \tag{6}$$

$$\text{Inventory Cost} = \sum_{i,m,t} HC_{im} I_{imt}. \tag{7}$$

$$\text{Transportation Cost} = \sum_{i,m,s,t} SC_{ms} QS_{imst}. \tag{8}$$

$$\text{Idle Capacity Penalty} = \beta \sum_{m,t} \left( X_{mt} - \sum_i UC_{im} QP_{imt} \right). \tag{9}$$

$$\text{Shortage Penalty} = \alpha \sum_{i,s,t} \left( \sum_m QS_{imst} - O_{ist} \right). \tag{10}$$

$$\begin{aligned} \text{Returns from distributors} \\ = \phi \sum_{i,s,t} \left( RP_{is} \left( \frac{1}{\lambda_{ist}} \left( 1 - \exp \left( -\lambda_{ist} \sum_m QS_{imst} \right) \right) \right) \right), \end{aligned} \tag{11}$$

where  $\frac{1}{\lambda_{ist}} \left( 1 - \exp \left( -\lambda_{ist} \sum_m QS_{imst} \right) \right)$  is the expected selling quantity for a supplier in a period for a product.

Therefore, the profits for manufacturers can be formulated as the following:

$$\begin{aligned} \text{Profits for manufacturer} &= (5) + (11) \\ &\quad - [(6) + (7) + (8) + (9) + (10)] \end{aligned} \tag{12}$$

#### 3.4.2 Constraints

##### Capacity Constraint

$$\sum_i UC_{im} QP_{imt} \leq X_{mt}, \forall m, t. \tag{13}$$

$$X_{mt} \leq MC_{mt}, \forall m, t. \tag{14}$$

##### Inventory Balance

$$I_{imt} = I_{im(t-1)} + QP_{imt} - \sum_s QS_{imst}, \forall i, m, t. \tag{15}$$

##### Demand fulfillment

$$\sum_m QS_{imst} \leq O_{ist}, \forall i, s, t. \tag{16}$$

##### Availability for fulfilling demand

$$\sum_s QS_{imst} \leq QP_{imt} + I_{imt}, \forall i, m, t. \tag{17}$$

##### Production quantity

$$QP_{imt} \leq MY_{imt}, \forall i, m, t. \tag{18}$$

##### Variable domain constraints

All variables are nonnegative and all  $Y_{imt}$  are binary.

The Production-Distribution Planning sub-model inte-

tracts with the Order planning sub-model through distributors' order quantities. Distributors' order quantities become parameters for the model, as shown in Equation (16). A distributor's order quantity is determined by Equation (4), given transfer prices previously determined by manufacturers.

### 3.5 Procedure for Determining the Total SC Profits

The following procedure calculates the total profits for the SC coordinated by a revenue sharing mechanism.

- Step 1: Each manufacturer determines the transfer price for each item. That is,  $TP_m, \forall i, m$  are given by manufacturers by using one of heuristics presented in next section.
- Step 2: Each distributor determines the order quantity for each product according to the transfer prices in the first step. Use Equation (4) to determine the order quantity for each distributor, given  $\lambda_{ist}, RP_{is}, SV_{is}$ , and  $BC_{is}$ . In Equation (4), an item purchasing cost is assumed as the average of transfer prices. Values for variables  $O_{ist}, \forall i, s, t$ , are set in this step.
- Step 3: Solve the sub-model of Production-Distribution Planning given values for variables  $TP_m, \forall i, m$  and  $O_{ist}, \forall i, s, t$ . Then, we can have the production quantity for each product, the transportation quantity, and the planned inventory at the end of each period. In addition, use Equation (12) to obtain the profits for manufacturers.
- Step 4: Calculate total expected profits for each distributor. For each item in each period, a distributor receives a quantity of  $\sum_m Q_{mst}$  from all manufacturers. Then, the expected profit for an item in a period is  $E(\sum_m Q_{mst})$ , according to Equation (2). Adding the expected profits for all items and periods, we can have the total expected profits for a distributor.
- Step 5: Sum the manufacturers' profits in the step 3 and the distributors' profits in the step 4 to obtain the total profits for the decentralize SC.

To solve the two sub-models simultaneously is difficult in terms of time complexity. The combined monolithic model becomes a non-linear programming problem. Equation (5) contains a multiplication of two decision variables. And, Equation (16) changes into a non-linear constraint since the order quantity is replaced by Equation (4). Solving such a complex programming problem might consume lots of time even on a small problem.

Instead of solving the monolithic model, the proposed procedure provides a way to conquer the two sub-models separately. The complex problem reduces to finding transfer prices such that SC total profits are optimized. Hence, with the procedure, we can devote to

identifying efficacious heuristics for determining transfer prices for solving the PDP/RS problem.

## 4. Transfer Prices and Revenue Sharing Rates

In this section, we evaluate various transfer pricing methods on SC coordination and explore their relationships with the revenue sharing rate.

### 4.1 Transfer Pricing Methods

There are two common transfer pricing methods in practice (Horngren, 1982). The variable cost method uses the variable cost of an item as the transfer price. Total cost method uses the sum of the fixed and variable costs of an item as the transfer price. Hence, based on the concepts of these methods, we employed the following heuristics for determining the transfer price:

- Zero cost (ZC): Set the item's transfer price to zero.
- Variable cost (VC): Set the item's transfer price to its variable cost that includes the unit holding cost, the unit production cost, and the average shipping cost of an item.
- Total cost (TC): Set the item's transfer price to the sum of the variable cost and the fixed cost for the item. Use Equation (19) to estimate the fixed cost of an item for a manufacturer.
- Minimum retail price for products (Min): Set the item's transfer price to the minimum retail price in the distributor echelon.
- Medium retail price for products (Med): Use the medium of the retail prices as the transfer price.
- Maximum retail price for products (Max): Use the maximum of the retail prices in the distributor echelon as the transfer price.

$$\text{item fixed cost} = \frac{(\text{Setup cost for producing the item})}{(\text{Average max capacities in all periods})} \times (\text{Capacity utilization for the item}) \quad (19)$$

The transfer prices generated by the previous six heuristics have the following relationships:  
 Zero cost  $\leq$  Variable cost  $\leq$  Total cost  $\leq$  Minimum retail price  $\leq$  Medium retail price  $\leq$  Maximum retail price.

### 4.2 Experiment Settings

We simulated a supply chain composed of two manufacturers and one distributor. The supply chain produced and distributed four items. The planning horizon was four periods. The experiments ran with revenue sharing rates at 10, 50, and 90 percents. Table 1 summarizes other experiment settings. Ten cases were randomly generated.

**Table 1.** Experiment Settings.

Parameters	Ranges
In Distributor Echelon:	
Mean of demands a period (units/period)	20~50
Retail price (\$/unit)	200~250
Salvage value (\$/unit)	10~20
In manufacturer echelon:	
Capacity consumption for a product (time/unit)	1~5
Holding cost (\$/unit/period)	5~15
Production cost (\$/unit)	30~40
Shipping cost (\$/unit)	5~10
Maximum capacity for a period (time)	1500~2000

**Table 2.** Average Profits for manufacturers, distributors, and supply chain at revenue sharing rate 0.1.

Pricing Methods	Manufacturer Profits	Distributor Profits	SC Profits	Service Level
ZC	NGB	0	NGB	1.00
VC	16622.77	44411.49	61034.26	0.81
TC	16691.25	44314.33	61005.57	0.81
Min	1175.21	55.51	1230.72	0.02
Med	0	0	0	0
Max	0	0	0	0

NGB: Negative Big Value (-1.6E11)

**Table 3.** Average Profits for manufacturers, distributors, and supply chain at revenue sharing rate 0.5.

Pricing Methods	Manufacturer Profits	Distributor Profits	SC Profits	Service Level
ZC	-15999980400.00	44275.30	-15999936124.70	1.00
VC	38417.76	12330.59	50748.36	0.63
TC	38381.29	12272.23	50653.51	0.62
Min	0	0	0	0
Med	0	0	0	0
Max	0	0	0	0

**Table 4.** Average Profits for manufacturers, distributors, and supply chain at revenue sharing rate 0.9.

Pricing Methods	Manufacturer Profits	Distributor Profits	SC Profits	Service Level
ZC	-15999947300.00	16639.28	-15999930660.72	1.00
VC	0	0	0	0
TC	0	0	0	0
Min	0	0	0	0
Med	0	0	0	0
Max	0	0	0	0

4.3 Results and Discussion

• **Impacts of the revenue sharing rate on the SC profit**

As indicated by Figure 3, raising the revenue sharing rate reduced the SC profits, no matter what transferring pricing methods were used. When the revenue sharing rate increasing, the service level for a product decreases, according to Equation (20). The decreased service level causes fewer product flow in the supply chain. Consequently, the total SC profits are reduced. In addition, changing the revenue sharing rate altered the profits allocation for the manufacturer and distributor echelons, as shown in Figures 4 and 5. Manufacturer's profits increased as the revenue sharing rate raised. However, the manufacturers' profit started to decreased after the revenue sharing rate over 0.5. With such a high sharing rate, distributors are not willing to order to much. As a result, the total product flow in the supply chain declines and neither the manufacturer or distributor echelon can make any profit in the supply chain.

These results indicate that the revenue sharing rate is a very sensitivite parameter for the coordination. Increasing the revenue sharing rate can not boost the total SC profit. The revenue sharing rate impacts the product flow in the supply chain but also changes the profit allocation between manufacturing and distribution echelons.

• **Increasing the transfer price declines the service level**

The average profits for manufacturers, distributors, and the supply chain are shown in Tables 2 to 4 at revenue sharing rates 0.1, 0.5, and 0.9, respectively. The service level for distributor for a product was drived to zero when the transfer price approached the value determined by the Max pricing method. When the revenue sharing rate was increased, the decreasing rate of the service level sped up. Given the cumulative function for demands  $F(x) = 1 - e^{-\lambda_{ist}x}$ , the service level for order quantity  $o_{ist}$  is:

$$ServiceLevel = \frac{(1-\phi)RP_{is} - BC_{is}}{(1-\phi)RP_{is} - SV_{is}}, \tag{20}$$

where  $BC_{is}$  is the average transfer price. According to the equation, zero transfer price causes the service level exceeding one. Distirbutors will order products as many as they can. However, when the transfer price rising to the maximum of the retail price, the service level become less than zero. In this case, distributors will order nothing.

The result indicated that the transfer price is an important parameter for coordinating the manufacturer and the distributor echelons. The service level for a product determines the product flow in the supply chain. The inappropriate transfer price make the service level low. As a result, profits for manufacturers and distributors are reduced. The result also implies that decrea-

sing the transfer price can increase the total SC profits. Given a revenue sharing rate, the service level rises when we decrease the transfer price. That increases the order quantities from distributors and, as a result, grows the product flow in the SC and the total profits. However, the transfer price can not be set to zero because the SC will suffer from huge shortage penalty.

• **Comparing various transfer pricing methods**

The VC pricing method led to the maximum SC profit, compared with other pricing methods, as shown in Figure 3. The SC profit dropped dramatically when using Minimum, Medium, and Maximum retail prices. In this study, the ZC pricing method resulted in large negative SC profits. Using the ZC transfer price leads service level for each distributor to one. Then, distributors order products as many as they can. As a result, the order quantities exceed capacities of the manufacturer echelon so that the supply chain suffers from the huge shortage penalties in the manufacturer echelon (Equation (10)). The same patterns can be observed at revenue sharing rate 0.5 and 0.9 respectively. Finally, the VC pricing method provides a good heuristic for determining the transfer prices between the manufacturer and distributor echelons.

• **Finding the optimal solutions**

The optimal transfer price may occur in the neighborhood of the price generated by the VC pricing method. The SC profits decline as the transfer prices move away from that value, as shown in Figure 3. The result provides us clues for searching the optimal transfer price. The optimal transfer price may exist between the prices generated by the VC and ZC pricing methods. More efforts are required for finding the optimal transfer price.

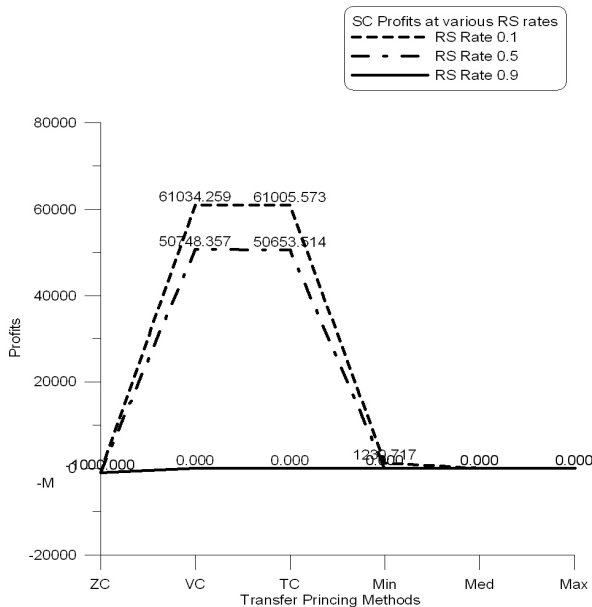


Figure 3. Comparing SC profits as at revenue sharing rates 0.1, 0.5, and 0.9.

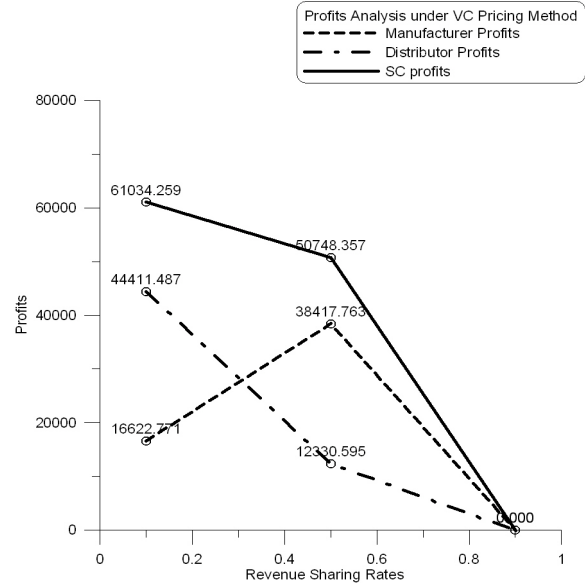


Figure 4. Profit changes for manufacturer echelon, distributor echelon, and supply chain under the VC transfer pricing method.

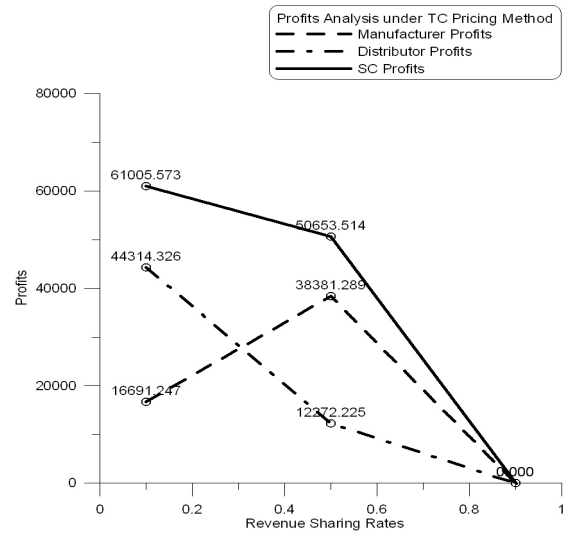


Figure 5. Profit changes for manufacturer echelon, distributor echelon, and supply chain under the TC transfer pricing method.

5. CONCLUSION

In this study, a model was proposed to formulate the collaborative production and distribution planning in a decentralized supply chain with the revenue sharing mechanism. The model comprises two sub-models. The Production-Distribution sub-model describes the production and distribution planning for the manufacturer echelon of multi-plant, multi-item, multi-period, and finite capacity. The Order Planning sub-model represents the ordering behavior for distributors under uncertain demands. The model was employed to investigate various transfer

pricing heuristics on the coordination in the decentralized supply chain.

The transfer price and the revenue sharing rate significantly influence the coordination in a decentralized SC. Raising the revenue sharing rate declined the SC profits, regardless of what transfer pricing methods were used. Too much transfer price reduced the service levels for the distributors. That caused the SC profits declined. Among the six transfer pricing heuristics, the variable-cost pricing method led to the best SC profits in the experiments. The six pricing heuristics were: zero-cost price, variable-cost price, total-cost price, the minimum retail price, the medium retail price, and the maximum retail price.

The transfer price and the revenue sharing rate affect the coordination performance through the service levels for distributors. With this understanding, we can design advanced heuristics to determine the transfer price and the revenue sharing rate for better coordination performance. In the future, the study will devote to developing procedures for identifying the optimal transfer price and other better transfer price methods for coordinating the decentralized SC.

## ACKNOWLEDGE

This research is partially supported by National Science Council, Taiwan, R.O.C. (NSC 96-2416-H-324-005-).

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