INVENTORY COORDINATING MECHANISM FOR MARKETING DECISION IN SUPPLY CHAIN WITH PRICE DEPENDENT DEMAND

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ABSTRACT
In today's market, companies realized that the performance of their businesses depends largely on external collaboration and coordination across the supply chain. Manufacturers are looking for improvement in profitability as well as how to coordinate their replenishment and pricing decisions that will benefit all the contributing parties in the supply chain. The objective of this study was to determine a marketing mechanism in a three scenarios that was beneficial to the partners and the general supply chain profitability. We applied a linear demand model with a deterministic price dependent customer demand where demand was represented as a decreasing function of price with the retail price given. Our results show that the price of 60 francs maximizes the supply chain profit function with 32400 francs for retailer but not for supplier. Also, the retailer's original profit of 32400 at an inventory price of 60 decreases to zero profitas the supplier increases the pricefrom 60Francs to 1000Francs.Our conclusion shows that at a lower price the centralized and joint or partnership scenarios lead to better profit and if the supplier set the price too high, the demand and the SC profit will be zero

Keywords: Supply chain, coordination, Centralized, Decentralized and partnership Scenarios, Integrated supply chain, Nash equilibrium

1. INTRODUCTION

In today's market, companies realized that the performance of their businesses depends largely on external collaboration and coordination across the supply chain. The members of the chain are primarily concerned about their individual interests which may not contribute to the overall supply chain performance. They perceived themselves as stand-alone entities in the businessenvironment. Times have changed where they have to stay competitive in the current complex anddynamic business environment; companies have begun to perceive themselves as part of a chain or network of companies. They are intertwined and dependent on each other since no single company can survive and prosper on its own without cooperation and collaboration (Vijayender, 2008). The problem they are facing is to coordinate and control the basic of managerial decisions of pricing and inventory which are inextricably linked in any supply chain, Harish and Ralph, (2010). The question is what mechanism can be established to profit the members and the general supply chain?

In this study, we used the centralized, decentralized and partnership mechanisms to investigate the best mechanism that can be established in the supply chain which will benefit members of the supply chain and the supply chain in general. We considered that the companies produces a product at a production price and sell it at the company price to a supplier who has a depot and sell to the retailer at the supplier price. The supplier may align either with the manufacturing company or with retailer. The manufacturer-selling price is the centralization; the supplier-selling price is the decentralization

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while the alignment between the supplier and retailer is partnership scenario.

We considered the scenarios as follows:

a) Under the centralized scenario, there is coordination among the Manufacturer, supplier and retailer working together as a single entity with the objective to maximize the supply chain (SC) profit.
b) Under the decentralized scenario, there is collaboration and coordination among the supplier, manufacturer and the retailers. Each member makes his/her decisions by considering from the other member decisions. The manufacturer set her price first followed by the supplier price and then the retailer. With these prices from manufacturer and supplier, the Retailer facing this price determines her own price that maximizes profit before placing an order
c) Under the partnership scenario, the supplier and retailer jointly determine the price and quantity in relation to the manufacturer-selling price.

Our objective is to design a contract mechanism that will yield an improvement in profitability in the supply chain and benefit to all the contributing parties in the supply chain.

We assumed the following:

(i) The mechanism will enable the company to produce enough products and the supplier order enough quantity that will satisfy her demand plus the retailer.

(ii) The mechanisms areused in the business relationship between two or more independent participants to the supply chain.

According to Kannan and Maria, (2011), contracts are valuable tools used in both theory and practice to coordinate various supply chains. In the same manner contract canbe an effective coordination mechanism to motivate and improve the performance all the members in the entire supply chain,Arshinder*et al.*, (2009). Tsay (1999) argued that contract is "a coordination mechanism that provides incentives to all of its members so that the decentralized supply chain behaves nearly or exactly the same as the integrated one (i.ea supply chainwhere an enterprise resource planning approach to the supply chain management.). By specifying contract parameters such as quantity, price, quality and deadlines, contracts are designed to improve supplier-buyer relationship. Cachon (2003) emphasizes that "a contract is said to coordinate the supply chain if the set of supply chain optimal actions is Nash equilibrium, i.e., no firm has a profitable unilateral deviation from the set of supply chain optimal actions.

Ma and Wang (2011) investigated the coordination in a two-stage supply chain with stock-dependent demand, and derived that the buyback contract cannot only coordinate the supply chain, but also attain the win-win situation. Hu, (2008) considered warranty period optimization towards supply chain coordination and provided guidelines for designing a contract between a manufacturer and a retailer so that the supply chain's performance is optimized in terms of the production/ order quantity and the warranty period, while each party in the chain achieves its maximal profit.

The term coordination occurs when information technology is used for flow of essential information between supply chain partnersHarjit *et al,*. (2017). According to Whipple and Russell (2007) the coordination of the process of product supply is the prerequisite for developing between the owner of the resources as well as the efforts of the relationship. They concluded that coordination can greatly benefit centralize, decentralize, partnership (joint), retailer and the whole supply chain, and can achieve an improvement by choosing the appropriate contract parameters such as price.Hematyar*et al*., (2012)investigated coordination of supply chain consisting of one manufacturer and one retailer facing consumer return and stochastic demand that is sensitive to both sales effort and retail price and revealed that when demand is influenced by both retail price and retail sales effort, coordination challenges traditional contracts.

Feihu, et al. 2013, study the coordination consisting of one retailer and two suppliers, (main supplier and a backup supplier), to determine the retailer's optimal ordering policy and the main supplier's production quantity that maximize expected profit of the centralized supply chain. They concluded that coordination can greatly benefit the retailer and the whole supply chain, and can achieve improvement by choosing the appropriate contract parameters in the supply chain.Nikunja et al. (2015) worked on a two layer supply chain composed of one manufacturer and one retailer for single-type product where the demand function of the end customers depends on quality, warranty, and sales price of the product. The profit functions of manufacturer and the retailer are maximized under centralized and decentralized approaches. They concluded that the joint profit in centralized system is always more than the decentralized system and the surplus profit in centralized system is shared according to their profits in decentralized system.

In deriving the coordination among the members of the SC, the replenishment batch size at the upper echelon is an integer multiple of ordering quantity at the lower echelon Burra et al, (2016). The total variable cost of the SC is reduced through the joint determination of inventory replenishment decisions and shipment policies Giri and Roy, (2015).Maryam et al, (2017) modeled coordination in a supplier-retailer supply chain (SC) where the retailer as downstream member manages his inventory system according to the periodic review (T) replenishment system and order-up-to level (R) decision (R, T) under three different decision making structures; decentralized decision, centralized decision model, and coordinated decision making models, respectively. The pricing and periodic review replenishment decisions are coordinated. Their results show that the coordination model will fairly share the obtained profits between two SC members Qing (2008) considered supply chain coordination mechanism as an operational plan to coordinate the operations of individual supply chain members and improve system profit. When supply chain members are separate and independent economic entities, this action plan has to include an incentive scheme to allocate the benefits from coordination among them to entice their cooperation (Li Xiuhui and Wang Qinan, 2007).

Kusukawa, (2010) presented an optimal inventory policy for a supply chain with return handling and profit sharing with the assumption that the product is sold in three consecutive periods; the normal sale period, the clearance sale period and the subsequent leftovers disposal sale period in both centralized and decentralized system. In the decentralized system, they made decision to maximize the retailer's expected profit and in the centralized system, decisions are fully integrated for the joint profits obtained from the sum of the individual party's expected profit. They also discussed coordination effect of the manufacturer-retailer partnership based on profit sharing .They concluded that profit sharing is permitted only in the centralized system as the coordination effect between the manufacturer and the retailer.Chen and Lin, (2010) addressed joint pricing and ordering decisions for a decentralized distribution system. They formulated four profit-maximization models and conducts equilibrium analysis for the two-echelon system with one wholesaler and multiple retailers under various policies, such as the individual replenishment, coordinated replenishment, VMI-only, and VMI coined with consignment contractual arrangements.

In this work, we model an inventory coordination contract mechanism in which we ensure that the supply chain is optimized as if it were a single unit such that all players benefit from working together through the coordinating mechanism (win-win).

2. MATERIAL AND METHODOLOGY

We consider a supply chain with a retailer, supplier and a manufacturer. The manufacturer sells the product to the supplier, the supplier sells a product to the retailer who then sells to the consumers, see Figure 1.

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Figure 1

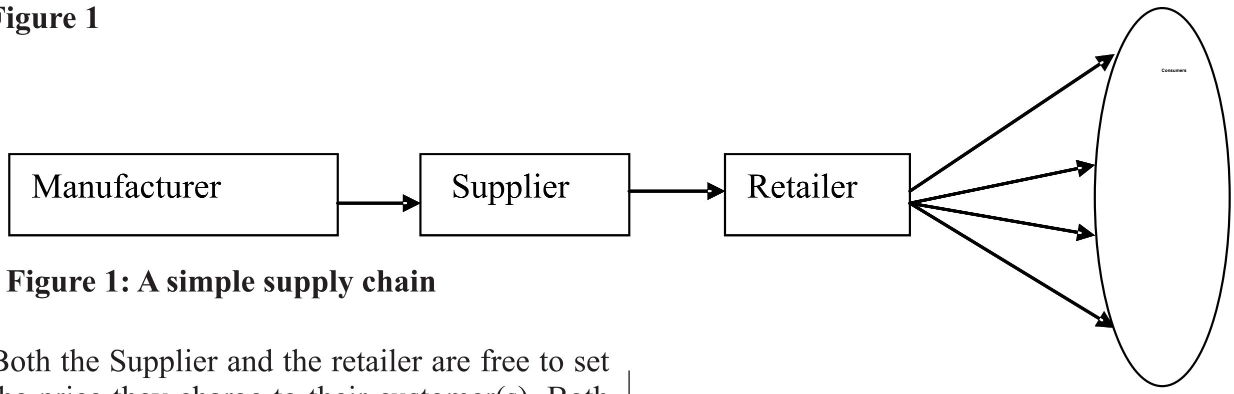

Figure 1: A simple supply chain

Both the Supplier and the retailer are free to set the price they charge to their customer(s). Both the players have symmetric and perfect information as to the demand and the cost functions.

Model Implementation

In order to keep the model mathematically tractable, we consider a simplified framework based on linear demand model as in Vijayender, (2008) andAhmadvand *et al*., (2012) in which game-theoretic framework is applied to obtain the equilibrium solutionsfor each entity in supply chain.

Let first define our basic notations:

F_R = The retailer's Profit

F_S = The supplier's Profit

F_{SC} = The supply chain Profit

D = The demand

p = Price per unit set by retalier

β = Supplier cost price per unit

μ = The retailer's purchasing cost per unit

D_0 = Demand of the supply chain at centralization

F_0 = Supply chain profit at centralization

μ_1 = Supplier price at decentralization

p_1 = Retailer price at decentralization

β D_1 = Demand at supplier price at decentralization

a and b = Constants (where ***a*** is the intercept and ***b*** the gradient)

In this model we considered a deterministic price dependent customer demand where demand is represented as a decreasing function of price with the retail price given by

$$Q = D(p) = \quad -bp \text{ .... } (1)$$

When (a,b) > 0: where *a and b* are constants. Each unit of item costs the retailer *P* francs. This includes the wholesale price, and handling charges. Once the Retailer has set the price *P* , he can observe the demand *D* and places an order of size *Q = D (p)* with the Supplier

Assumption of the Model

The following assumption are adopted as inVijayender, (2008)

(i) Backorders are not allowed since the retailers have to order enough to satisfy all the demand.

(ii) Whenever the retailers placed an order, the supplier is faced with a cost of β per unit (possibly representing the sum of administrative, receiving, and inspection costs) and chargers a wholesale price μ per unit to the retailer

(iii) The retailer does not have any cost associated with his operation other than the purchasing cost of μ per unit.

(iv) Both (supplier and retailer) have symmetric and perfect information.

(v) Also, to ensure realistic values, throughout it is assuming that:

$$O \leqslant \beta < P \leqslant \tfrac{a}{b}; \text{ .... } (2)$$

$$\beta \leqslant P \text{ .... } (3)$$

The profits of the supplier can be express as a function of demand. Note that demand is also an order quantity in a single period problem: i,e

$$F_S(D) = D\,(\mu - \beta) \text{ .... } (4)$$

is maximized.

The retailer has information on the final customer demand (i.e., knows a and b), and is faced with price μ

$$F_R(D) = D\,(p - \mu) \text{ .... } (5)$$

is maximized.

From equation (4) and (5), the supply chain profit is given by

$$F_{SC}(D) = F_T(D) + F_R(D)$$
$$= D\,(\mu - \beta) + D(p - \mu)$$
$$= D\,(p - \mu)$$

That is

$$F_R(D) = D\,(p - \beta) \text{ .... } (6)$$

The above model is under three basic scenarios.

a) The centralized scenario where the retailer, supplier and manufacturer work together as a single entity with the objective to maximize the supply chain profit.

b) The Decentralized scenario where there is no coordination among the supplier and the retailers. Each member makes his/her decisions (price) by considering from the other member decisions. Here firstly the manufacturer sets her price *p*. The Retailer facing price D *(P)* determines her optimal price, i.e., the price that maximizes profit. Then, an order of size $Q = D\,(P)$ is placed to the supplier. We look at this as a game in which one of the members is making the first move which is the leading way. This type of game is known as Stackelberg games.

The partnership-scenario where the supplier and retailer jointly determine the price (P and μ)

As a centralized Scenario:

Both parties are dealing with the objective to maximize the total profit. In the centralized scenario only the optimal order size for the entire supply chain is to be determined. The profit in the system is given by

$$F_{SC}(D) = D(P - \beta) = (a - bp)\,(P - \beta)$$
$$= ap - a\beta - bp^2 + b\beta p$$
$$= D\,(p - \mu)$$

$$\frac{\partial F_{SC}(D)}{\partial \rho} = a - 2b\rho + \beta b$$

$$\frac{\partial F_{SC}(D)}{\partial \rho} = 0 \Rightarrow a - 2b\rho + \beta b = 0$$

$$\rho_0{}^* = \frac{a + \beta b}{2b} \text{ .... } (7)$$

The demand, D, is obtained by substituting

$\rho = \frac{a - D}{b}$ in (6) to have

$$F_{SC}(D) = D\left(\frac{a - D}{b} - \beta\right) \text{ .... } (8)$$

Since $F_{SC}\,(D)$ is concave in D, its maximize value of the supply chain is determine by the first order relation with respect to *D*.

This is $\frac{\partial F_{SC}(D)}{\partial D} = \left(\frac{a - D}{b} - \beta\right) + D\left(\frac{-1}{b}\right)$

For maximum value $\frac{\partial F_{SC}(D)}{\partial D} = 0$

$$\left(\frac{a - D}{b} - \beta\right) + D\left(\frac{-1}{b}\right) = \left(\frac{a - D}{b} - \beta\right) - \left(\frac{D}{b}\right) = 0$$

$$Q_0 = D = \frac{a - b\beta}{2}$$

Thus

$$Q_0{}^* = D_0{}^* = \frac{a - b\beta}{2} \text{ .... } (9)$$

It follows that from equation (4.5.6) the maximal supply chain profit is given by:

$$F_0 = \frac{(a - b\beta)^2}{4b}$$

Therefore the total supply chain profit in the centralized scenario is

$$F_0 = \frac{(a - b\beta)^2}{4b} \text{ .... } (10)$$

As a Decentralized scenario

Under this scenario the supplier makes the first moves and declares the per unit transfer price μ. Note that the supplier's price includes the driver's hourly wages, fueling cost associated with the shipment from the supplier's warehouse to the retailer's location, up-loading and off-loading of the truck, administrative papers, and road settlements. Then the retailer will decide the retail price depending on the supplier's costs. The retailer wants to maximize her profit, i.e., she chooses *P1* such that:

$$F_1(D) = (p_1 - \mu_1)(a - bp_1)$$
$$= ap_1 - bp_1^2 - \mu_1 (a - bp_1)$$

$$\frac{\partial F_R(D)}{\partial \rho_1} = a - 2b\rho_1 + \mu_1 b$$

$$\frac{\partial F_R(D)}{\partial \rho_1} = 0 \Rightarrow a - 2b\rho_1 + \mu_1 b = 0$$

$$\rho_1^* = \frac{a+\mu_1 b}{2b} \quad \ldots\ldots\ldots\ldots(11)$$

It follows from Equation (1) that the optimal order size is:

$$Q_1^* = D_1^* = \frac{a-\mu_1 b}{2} \quad \ldots\ldots\ldots\ldots(12)$$

Given that the optimal price $P_1{*}$ are used; the profits of the retailer from equation (2) can be obtained to be;

$$F_R(\mu_1) = \left(\frac{a-\mu_1 b}{2}\right)\left(\frac{a+\mu_1 b}{2b} - \mu_1\right)$$

$$= \left(\frac{a-\mu_1 b}{2}\right)\left(\frac{a+\mu_1 b - 2b\mu_1}{2b}\right)$$

$$= \frac{1}{4b}(a^2 + \mu_1 ab - 2ba\mu_1 + \mu_1 ba - \mu_1^2 b^2 + 2\mu_1^2 b^2)$$

$$= \frac{1}{4}\left(\frac{a^2}{b} - 2\mu_1 a + \mu_1^2 b\right)$$

$$F_R(\mu_1) = \frac{(a-\mu_1 b)^2}{4b} \quad \ldots\ldots\ldots\ldots(13)$$

for the retailer;

From equation (4)

$$F_S(\mu_1) = D(\mu - \beta) = \left(\frac{a-\mu_1 b}{2}\right)(\mu_1 - \beta)$$

$$= \frac{1}{2}(a\mu_1 - a\beta - \mu_1^2 b + \mu_1 \beta b)$$

$$F_S(\mu_1) = \frac{1}{2}(-a\beta + \mu_1(a + \beta b) - \mu_1^2 b) \quad \ldots\ldots\ldots\ldots(14)$$

for the supplier; and

From equation (6) $F_{SC}(c) = D(\rho - \beta)$

$$F_{SC}(\mu_1) = \left(\frac{a-\mu_1 b}{2}\right)\left(\frac{a+\mu_1 b}{2b} - \beta\right) =$$

$$\frac{1}{4b}(a - \mu_1 b)(a + \mu_1 b - 2b\beta)$$

$$= \frac{1}{4b}(a^2 + \mu_1 ab - 2\beta ab - \mu_1 ab - \mu_1^2 b^2 + 2\beta\mu_1 b^2)$$

$$F_{SC}(\mu_1) = \frac{1}{4}\left(\frac{a^2}{b} - 2\beta a - \mu_1^2 b + 2\beta\mu_1 b\right) \quad \ldots\ldots\ldots\ldots(15)$$

for the total supply chain.

The profits under the decentralized-scenario depend on the Supplier's price μ- to the retailer. Obviously, the supplier would like to choose the price, μ- in which he will maximize his own profit as given in equation (13) since

$$\beta \le \mu_1 \le \rho_1$$

This gives

$$\mu_1^* = \frac{a + \beta b}{2b} \quad \ldots\ldots\ldots\ldots(16)$$

By substituting the value of μ- in equations (13), (14) and (15) we have;

$$F_R(\mu_1{}^*) = \frac{\left(a - \frac{(a+\beta b)b}{2b}\right)^2}{4b}$$

$$F_R(\mu_1{}^*) = \frac{(2a - a - \beta b)^2}{16b}$$

$$F_R(\mu_1{}^*) = \frac{(a-\beta b)^2}{16b} = \frac{F_0}{4} \quad \ldots\ldots(17)$$

In equation (13), we have;

$$F_S(\mu_1{}^*) = \frac{1}{2}\left(-a\beta + \frac{(a+\beta b)}{2b}(a+\beta b) - \left(\frac{a+\beta b}{2b}\right)^2 b\right) =$$

$$\frac{1}{2}\left(\frac{-4ab\beta + 2(a+\beta b)}{4b^2}\right)$$

$$F_S(\mu_1{}^*) = \frac{1}{8b}(-2ab\beta + 2(a+\beta b) = \frac{F_0}{2} \quad \ldots\ldots\ldots\ldots(18)$$

In equation (14), we have;

$$F_{SC}(\mu_1{}^*) = \frac{1}{4}\left(\frac{a^2}{b} - 2\beta a - \left(\frac{(a+\beta b)}{2b}\right)^2 b + 2\beta\frac{(a+\beta b)}{2b}b\right)$$

$$= \frac{1}{4}\left(\frac{2a^2b - 2\beta ab^2 - 4b^2(a+\beta b)^2 + 2b^2(a+\beta b)\beta}{4b^2}\right)$$

$$= \frac{1}{8b}(2a^2b + 2ab^2\beta - 4b^2(a+\beta b)^2 + 2ab^2\beta + 2ab^3\beta)$$

$$= \frac{1}{8b}(2a^2b + 2ab^2\beta - 4b^2(a + \beta b)^2 + 2ab^2\beta + 2ab^3\beta)$$

$$= \frac{1}{8b}(2ab(1+2b\beta) + -4b^2(a+\beta b)^2)$$

$$F_{SC}(\mu_1{}^*) = \frac{1}{8b}(a(1+2b\beta) - 2b(a+\beta b)^2) \quad \ldots\ldots\ldots\ldots(19)$$

Let us assumed that the Supplier had chosen his price to sell the product to the retailer at cost $\mu 1 = \beta$ Substituting into equations (13), (14) and (15), we have

$$F_R(\beta) = \frac{(a-\beta b)^2}{4b} = F_0 \quad \ldots\ldots\ldots\ldots(20)$$

In equation (13)

$$F_S(\beta) = \frac{1}{2}(-a\beta + \beta(a+\beta b) - \beta^2 b) = 0 \quad \ldots\ldots\ldots\ldots(21)$$

And in (14)

$$F_{SC}(\beta) = \frac{1}{4}\left(\frac{a^2}{b} - 2\beta a - \beta^2 b + 2\beta b\right) = F_0 \quad \ldots\ldots\ldots\ldots(22)$$

Comparing equation (14) and (21) shows that the, SC profit in the previous situation is larger.

If we assumed that $\mu_1 = \frac{a}{b}$, then equation (12) gives

$$F_R\left(\frac{a}{b}\right) = \frac{\left(a - \frac{a}{b}b\right)^2}{4b} = 0 \quad \ldots\ldots\ldots\ldots(23)$$

Equation (1) gives

$$F_S\left(\frac{a}{b}\right) = \frac{1}{2}\left(-a\beta + \frac{a}{b}(a+\beta b) - \left(\frac{a}{b}\right)^2 b\right) = 0 \quad \ldots\ldots\ldots\ldots(24)$$

Equation (14)

$$F_{SC}\left(\frac{a}{b}\right) = \frac{1}{4}\left(\frac{a^2}{b} - 2\beta a - \left(\frac{a}{b}\right)^2 b + 2\beta\frac{a}{b}b\right) = 0 \quad \ldots\ldots\ldots\ldots(25)$$

Equations (23), (24) and (25) shows that with price $\mu_1 = \frac{a}{b}$ it is not profitable for the retailer to place an order, hence there is no profit for either the retailer or the supplier: $F_R\left(\frac{a}{b}\right) = 0$ $F_S\left(\frac{a}{b}\right) = 0$ and $F_{SC}\left(\frac{a}{b}\right) = 0$

(iii)**The Joint Scenario**: Under this scenario, the supplier and retailer operate in total cooperation and;

1) Both parties considered that the optimal supply chain profit will be achieve
2) For any wholesale price μ_1 under the decentralized scenario there is a μ_2 under the partnership scenario such that both the retailer and the Supplier have a higher profit in partnership scenario compared to the decentralized scenario.
3) Under this assumption of the retailer and Supplier working together in a full partnership, they are interested in optimizing the SC profit, i.e., they would choose a value for p_2 such that the SC profit

$$F_{SC}(\rho_2) = (\rho_2 - \beta)(a - b\rho_2) \quad (26)$$

is maximized, which is exactly the same as under the centralized scenario, in which the optimal price and order quantity are given by $p_2 = p_0$ and $D_2^* = D_0^*$, resulting in a SC profit $F_{SC_2}(\rho_2^*) = \frac{(a-b\beta)^2}{4b}$

This shows that the optimal SC profit is achieved. The profits for the supplier and the retailer under the partnership do depend on the price μ_2. The relationship can be derived from equations (4). i.e $F_S(D) = D(\mu - \beta)$ and (4.5.5) i.e, $F_R(D) = D(\rho - \mu)$ by substituting in (7) and (8) . That is $\rho_0^* = \frac{a+\beta b}{2b}$ and $D_0^* = \frac{a-b\beta}{2}$

That is in the partnership scenario

$$\rho_2 = \frac{a+\beta b}{2b} \quad (27)$$

And

$$Q_2 = \frac{a-\beta b}{2} \quad (28)$$

Note that $\rho_2 \le \rho_1$ and $Q_2 \ge Q_1$ i.e. if the total supply chain is optimized then the price p is lower and the quantity ordered Q is higher. It may be concluded that the consumers are profiting from the collaboration between the Retailer and the Supplier in the sense that the price for the product is lower.

Substituting p_2 and Q_2 inequations (6), shows that the total supply chain profit in this scenario is

$$F_{SC}(D) = \left(\frac{a-\beta b}{2}\right)\left(\frac{a+\beta b}{2b} - \beta\right)$$
$$= \left(\frac{a-\beta b}{2}\right)\left(\frac{a+\beta b - 2\beta b}{2b}\right)$$
$$= \left(\frac{a-\beta b}{2}\right)\left(\frac{a-\beta b}{2b}\right)$$

$$F_{SC} = \frac{(a-\beta b)^2}{4b} \quad (29)$$

Unlike the total supply chain profit, the profits of the retailer and the supplier do depend on the price μ_2 The exact relation can be derived from (4) and (5) by substituting p_2 *and* Q_2. This given

$$T_{R_2}(\mu_2) = -\left(\frac{a-b\beta}{2}\right)\mu_2 + \frac{(a-b\beta)(a+b\beta)}{4b} \quad (30)$$

For the retailer

$$T_{S_2}(\mu_2) = \left(\frac{a-b\beta}{2}\right)\mu_2 - \frac{(a-b\beta)\beta}{2} \quad (31)$$

for transporter.

Clearly, both $T_{R_2}(\mu_2)$ and $T_{S_2}(\mu_2)$ are linear functions of μ_2 $T_{R_2}(\mu_2) = 0$ if and only if $\mu_2 = \frac{a+b\beta}{2b} = \rho_2 = \mu_1$

At the joint partnership, the retailer and supplier decide for a fair price of μ_2 at which both are better off (i.e., have higher profit) than in the decentralized-scenario. Therefore any price μ_2 is acceptable to the retailer as long as

$$T_{R_2}(\mu_2) > T_{R_1}(\mu_1)$$

Using Equations (4.5.10) and (4.5.17) this is equivalent to:

$$\mu_2 < \frac{-b(\beta)^2 + 2a\mu_1 - b(\mu_1)^2}{2(a-b\beta)} = (\mu_2)^+ \quad (32)$$

Similarly, any price *is* acceptable to the Supplier as long as $T_{S_2}(\mu_2) > T_{S_1}(\mu_1)$

By using Equations (13) and (18) this is equivalent to:

$$\mu_2 < \frac{-b(\beta)^2 + (a+b\beta)\mu_1 - b(\mu_1)^2}{(a-b\beta)} = (\mu_2)^- \quad (33)$$

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Note that

$$(\mu_2)^+ - (\mu_2)^- = \frac{b(\mu_1 - \beta)^2}{2(a - b\beta)} > 0$$

It follows that $(\mu_2)^+ > (\mu_2)^-$ and moreover, that $(\mu_2)^- = (\mu_2)^+$ if and only if $\mu_1 = \beta$

in which case there is no win-win. This implies that there is always a price μ2 such that both the Supplier and the retailer have strictly higher profit in the partnership-scenario than in the decentralized-scenario.

3. RESULTS AND DISCUSSION

In this section, we give a numerical example to illustrate the performance of the supply chain under the decentralized and the centralized supply chain case. The demand faced by the retailer is assumed to be stock-and price-dependent and is modeled as:

$$Q = D(\rho) = 300 - 4\rho$$

The cost parameters are given as follows:

$a = 300\ and\ b = 2$. Let $\beta = 60$

$(\mu_2)^+ = 94\ \ (\mu_2)^- = 83$ and $\mu_2 = 70$

Substituting in equations (7), (9) and (10) in the centralized-Scenario, we have;

$$\rho_0 = 105, Q_0 = 90\ and\ F_{T_0} = 4050$$

And in the decentralized-Scenario, we substituted in equation (6) to get the price in which the supplier would like to choose to maximize his own profit. This price is then substituted in the following equations; (11), (10), (13), (14) and (15) to obtain,

$$\mu_1 = 105, \rho = 128, Q = 45,$$

$$R = 10125, S = 2025\ and\ F_{SC} = 383438$$

Also, substituting in equations (30) and (31) we obtain $R = 3150\ \ S = 900$ and $F_{SC} = 4050$

The results for the numerical example are summarized in the Table 1.

Table 1: Results for the Centralized, Decentralized and partnership scenario

Scenario	Centralize	Decentralize	Partnership	Decentralize(60)	Decentralize (150)
7	/	105	70	60	150
.	105	125	105	105	/
Q	90	45	90	90	/
R	/	1013	3150	4050	0
S	/	2025	900	0	0
F_{SC}	4050	3038	4050	4050	0

Note: Decentralize $\mu_1 = \beta = 60$ and

Decentralize $\mu_1 = \frac{a}{b} = 150$

Form Table 1, we can find that both the optimal ordering quantity under the decentralized supply chain are bigger than that of the centralized case while the optimal retail price under the decentralized supply chain is larger than that of centralized case. Also, the optimal quantity and price under centralization is equal to that of partnership scenario.

We can find that the optimal wholesale price of the retailer under decentralization is smaller than that of the partnership while the profit of the retailer under decentralization is smaller than that of the partnership scenario.

The table also shows that to general supply chain profit under centralization is equal to that of the partnership scenario and when the price is 60 but both are smaller than that of decentralization. That is, when the supplier chooses its price equal to the price of the Manufacturer, say $\mu_1 = \rho$ (i.e,. $\mu_1 = 60$)

the profit of the retailer is equal to the profit of the Partnership scenario and total supply chain while that of the supplier is zero. The value of *p* of centralization is equal to that of partnership, and that of Q of centralization is equal to partnership. When the value of decentralization is $\frac{a}{b} = 150$

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the retailer, supplier and the total supply chain made no profits. That is the value in the profit functions shows all zero. This demonstrates that if the price set by the Supplier is too high, the result is that the demand and the SC profit will be zero.

The results of the decentralized scenario are summarized in Figure 2, which shows that the price $\mu_1 = 60$ maximizes the SC profit function given in (15) with a profit of 32400 francs. This price is also very profitable for the retailer but not for the Supplier.In other words, there is absolutely no incentive for the Supplier to optimize the SC profit. At the price of $\mu_1 = \frac{a}{b} = 150$ Franc the supplier obtained an optimum profit of 2025 frs, this value in the profit functions (13)-(15) shows that in this case all profits are zero

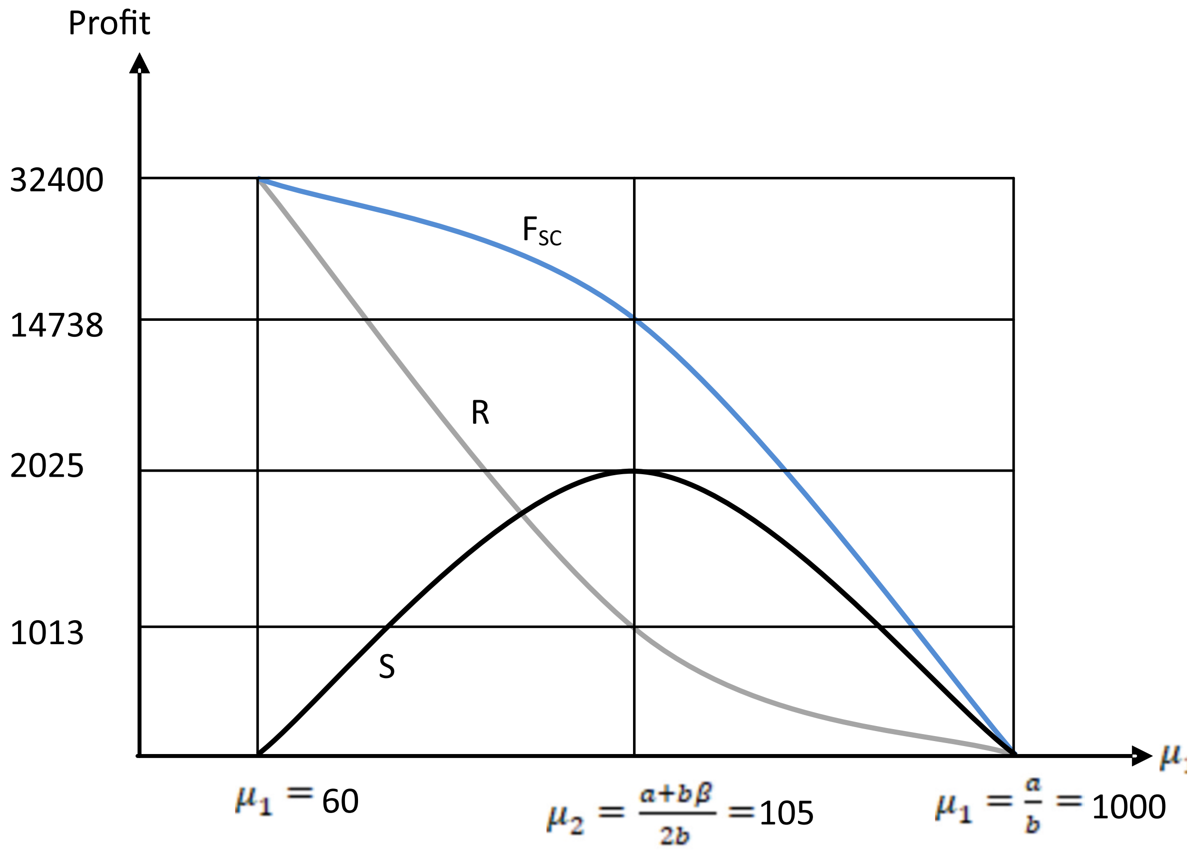

Figure 2: Profits for Retailer (R) Supplier (S) and supply chain (F_{SC}) for various prices $\mu_1 = 105$ ***under the decentralized-scenario.***

This demonstrates that if the price set by the Supplier is too high, the result is that the demand and the SC profit will be zero. When the price is set at $\mu_1 = \frac{a}{b} =$ optimal decisions of both players does not lead to the optimal SC profit.

The profits under the partnership scenario of the Retailer, Supplier and the SC as functions of μ_2 are depicted in Figure 3

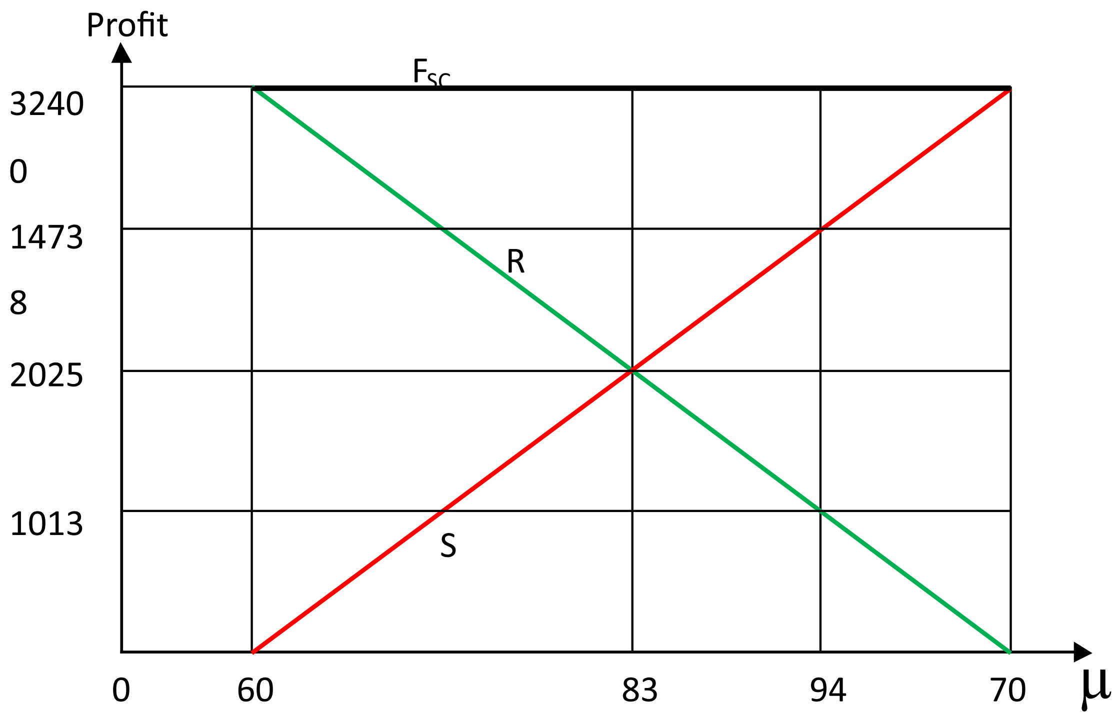

Figure 3 Profits for Supplier (S), Retailer (R) and SC (Fsc) for various wholesale prices $\mu_2 = 70$ under the Partnership-scenario

The partnership scenario leads to the same profit as the centralized scenario and both the retailer and the Supplier have a higher profit under the partnership scenario when compared to the decentralized scenario (win-win).

The above analysis of partnership helps us to conclude that a partnership will always coordinate the SC and provide win-win opportunities. However, in reality partnerships are very difficult to create and sustain and pose several implementation issues.

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