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**Impact of Structure, Market Share and Information Asymmetry on Supply
Contracts for a Single Supplier Multiple Buyer Network**

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Abstract:

Supply contracts have been studied extensively in the context of one buyer and one supplier. In recent times supply contracts literature has also extended to the single supplier multiple buyer and multiple supplier single buyer contexts. However, not much attention has been given to the effect of structure, market share and information asymmetry. This article studies a network consisting of one supplier and two buyers under the setting of complete and partial decentralization. In the former both buyers are independent of the supplier while in the latter the supplier and one buyer form a vertically integrated entity. Both buyers order their optimal quantity from the single supplier and subsequently produce similar product to sell in the same market. The supplier charges the buyer through one of the contracts available to her and the transfer price varies depending on the supply chain structure. From the perspective of the supplier, we discuss two main contract forms i.e. quantity-discount and nonlinear two-part tariff contracts and subsequently whole-sale price and linear two-part contract as special cases, each under symmetric and asymmetric information about buyers' cost structure. Through the discussion of all sixteen scenarios we investigate the influence of network structure, market-share and asymmetry of information on supplier's optimal contract decisions. We further discuss the value of information and cut-off policies under the consideration of reservation profit level for the buyers. We discuss the managerial implications of the analysis and indicate the directions of future research.

Subject Areas: asymmetric information, supply chain, contracts, pricing, competition

1. Introduction

Many established global brands have in recent times sub-contracted their manufacturing to firms in emerging countries in order to reduce costs, and to focus on design and marketing activities. However, some of these firms that supply to these global brands are also established brands themselves. Acer, the Taiwanese manufacturer of computers, is one

example in the electronics industry¹. There are similar such examples in the pharmaceutical and textiles industries. In this paper we investigate the competition between two different firms of similar end products targeting the same market. Both the firms order from a common supplier to fulfill their own customer demand. We consider two distinct supply chain structures: decentralized and partially integrated. In the case of decentralized supply chain all the entities are independent. In partially integrated structure the supplier owns the first firm and these two firms together form a vertically integrated entity; the second firm operates independently. Similar situation arises when one firm markets her product simultaneously through an 'independent traditional retail channel as well as through a firm-owned direct online channel' (Ryan, Sun & Zhao, 2013) or when a monopolist supplier enters a new demographic market, modifying an existing product to meet local needs, she needs to find a local retailer for selling of the product (Corbett, Zhou & Tang, 2004). The second buyer views the supplier controlled first buyer as competition (Ryan et al, 2013). In the smart-phone market we have recently observed a similar phenomenon: Samsung, the provider of the application processor, has overtaken Apple to become the market leader²; Apple has lost her market position to such a competitor who is also the supplier of one of the main components of the phone³. By investigating single supplier multiple buyer supply chain structure under partial integration for different contract types, we study how the market share and the supply chain structure can influence the design of contract itself.

Most of the single supplier multiple retailer supply chain literature attempts to answer the question of whether or not it is beneficial for a supplier to add a direct online channel as well as the associated advantages and disadvantages (Weng, 1995; Bernstein & Federgruen, 2005; Cachon & Lariviere, 2005; Plambeck & Taylor, 2007; Zhao & Atkins, 2008). However, in real life we observe at times an apparel industry is selling the same product through own franchise network and through other retail stores. These business scenarios raise another set of questions: when one supplier is supplying to her own subsidiary and another buyer with the same raw material or end product, then how can the system be designed for achieving supply-chain coordination? Is there a possible mechanism to either reduce or eliminate conflict between the separate channels? Ryan et al. (2013) has looked into the aspects of supply chain coordination when manufacturer has chosen to take a dual-channel approach to distribute her product but does not consider the case of asymmetric information between the supplier and the second buyer. Corbett et al (2004) has considered the case of asymmetric information only the case of a dyadic

¹ Elizabeth Woyke, "The Company Behind Your Laptop", Forbes, 12/04/2009. Retrieved from: <http://www.forbes.com/global/2009/1214/technology-wistron-simon-lin-industrial-innovator.html>, accessed on 16/03/2014.

² John Ribeiro, "Samsung Beats Apple in Smartphone Sales", IDG News Service, 28/10/2011. Retrieved from: http://www.pcworld.com/article/242787/samsung_beats_apple_in_smartphones_sales.html, accessed on 12/03/2014.

³ Eric Pfanner, "Why Samsung quietly cheers when Apple sells an iPhone", New York Times, 25/01/2014. Retrieved from: <http://timesofindia.indiatimes.com/tech/tech-news/hardware/Why-Samsung-quietly-cheers-when-Apple-sells-an-iPhone/articleshow/29350433.cms>, accessed on 11/03/2014.

relationship between a supplier and a buyer. In our work we are going to address these two issues – in case of deterministic demand scenario how to enforce contract so that the second buyer will reveal her cost structure and with change in supply chain structure how the value of the contract changes.

The channel consisting of the supplier and the second buyer faces the classic double marginalization problem. Under the condition of symmetric information the two-part contract where the supplier sells the product at its marginal cost and charges a fixed side payment, can coordinate the channel. However when the buyer has private information about her internal variable costs two-part contract will fail to coordinate the supply chain (Samuelson, 1984; Corbett et al., 2004). In the particular problem setting the supplier-owned first buyer faces horizontal price competition with the second buyer, similar to the case described by Tsay & Agarwal (2000). The supplier further faces vertical price competition with the second buyer. We study the influence of these price competitions on the profits of each firm. Through our work we also seek to understand how the equilibrium behavior of this supply chain will depend on parameters like firm's own price sensitivity, cross-price sensitivity.

The main contributions of this research are twofold. For a dual channel supply chain facing deterministic demand, our study investigates how complete as well as asymmetric information influences choice of contracts, from the perspective of the supplier. In this case we study four types of contract namely quantity-discount contract, wholesale price contract, linear two-part tariff contract and nonlinear two-part tariff contract for a decentralized supply chain. Next, we analyze the same four contract types for a partially integrated supply chain. From the comparison of results we estimate the network structure, underlying market share of each of the buyers and the information asymmetry influences the transfer pricing. Following Cachon and Kok (2010), in a dual-channel supply chain setting we consider the case of linear demand substitution model. Then we determine the equilibrium price and quantity decisions for each channel. These findings provide with important insights to the supply chain managers of the supplier as well as the buyers. The result assists the second buyer to improve her sourcing decisions and the supplier to better coordinate the dual channel at hand.

The remainder of this article is organized as follows. In Section 2 we review the related literature. Then we describe the problem settings and formulation of quantity-discount, wholesale price, linear two-part tariff and nonlinear two-part tariff contract problem with incentive compatibility and individual rationality constraints in Section 3. In Section 4 and 5 we develop the solution in terms of optimal pricing and quantity decisions under the condition of symmetric and asymmetric information for completely decentralized and partially integrated supply chains respectively. We discuss the influence of supply chain

structure, market share, value of information and cutoff policies in Section 6. Finally conclusions and possible future research directions are incorporated in Section 7.

2. Literature Review

Research developments in supply chain coordination through contracts aim at 'establishing business partnership and improving supply chain profits' (Chung et al., 2010). These studies can be categorized as: one supplier–one buyer (1-1) supply chains (Weng, 1995; Tsay, 1999; Taylor, 2002; Cachon & Lariviere, 2005; Taylor & Plambeck, 2007), one supplier–multiple buyer (retailer) (1-N) supply chains (Weng, 1995; Bernstein & Federgruen, 2005; Cachon & Lariviere, 2005; Plambeck & Taylor, 2007), multiple supplier - one buyer (N-1) supply chains (Choi, 1991; Cachon & K'ok, 2010), multiple supplier-multiple buyer (N-N) supply chains (Zhao& Atkins, 2008; Anderson and Bao, 2010).

Since firms are increasingly adopting multiple channel approach for distribution, one supplier–multiple buyer supply chain structure has been studied extensively recent times. Channel coordination can be obtained between one supplier and a group of homogeneous buyers through optimal quantity discount policy and franchise fee however joint profit maximization is not attained (Weng, 1995). Under deterministic demand scenario wholesale pricing mechanisms coordinates a 1-N supply chain for limiting circumstances (Tsay and Agrawal, 2000). Using newsvendor setting for a 1-N decentralized supply chains with competing retailers under demand uncertainty, behavior of buyback contract and related Nash equilibrium has been studied by Bernstein and Federgruen (2005). Cachon and Lariviere (2005) have shown the advantages and disadvantages of employing revenue sharing contract. Optimal quantity flexibility contract for one supplier–multiple buyer supply chain setting is investigated by Plambeck and Taylor (2007).

In order to overcome the problem of double marginalization in bilateral monopoly with full information, first-best optimal solution can be obtained by using two-part contracts (Tirole, 1988). How two-part tariff type contracts help in coordinating a supply chain have been studied by Jeuland and Shugan (1983). Weng (1995) has extended their work in terms of determining optimal pricing policies that can coordinate the channel's activities. Under stochastic demand scenario, wholesale price contract was analyzed by Lariviere & Porteus (2001) using the structure of newsboy problem. With deterministic demand and asymmetric information, two part non-linear contract helps in analyzing the value of information (Corbett and Tang, 1999).

In the first part of our analysis we develop the quantity discount, wholesale price, linear and nonlinear two-part tariff contracts that coordinate the supply chain of one supplier, two buyers under the setting of decentralized supply chain. Then we solve the same contract types for a partially integrated chain. In both cases contract forms are developed for full and asymmetric information.

3. The model

We consider a supply chain network consisting of a single supplier and two buyers. The buyers procure a common raw material or component or semi-finished goods from the supplier and subsequently each of them produce one finished product. These products are partially substitutable and the buyers sell them in a common final market. The supply chain network can be either completely centralised or partially centralised (one buyer and the supplier form a vertically integrated entity) or completely decentralised.

We assume that the overall potential market size of the products is constant and the buyers do not have technology advantage. The marginal production cost c is assumed to be constant for both the buyers and it excludes the cost of supplier's part. The quantity q_i demanded per period in the final market from the i^{th} buyer is a function of retail prices $p_i, i = 1, 2$, and is given by the demand function

$$q_i = \theta k_i - \delta_i p_i + \gamma(p_j - p_i), \quad i = 1, 2, i \neq j, \quad (1)$$

where $\sum_{i=1}^2 k_i = 1$. In this demand function, parameter θ gives the total potential market size and k_i designates the market share of buyer i . Therefore θk_i provides the total potential market size of buyer i . In order to avoid negative demand scenario for individual buyer and overall market we further assume

$$\theta k_i - \delta_i p_i > \gamma(p_i - p_j) \dots i = 1, 2, i \neq j$$

$$\theta > \sum_{i=1}^2 \delta_i p_i \dots i = 1, 2$$

In this particular demand structure, the parameter γ represents 'leakage in demand' (Anderson and Bao, 2010) attributed to switching of customers from one product to another and the total market demand is unaffected by this parameter as $\sum_{i=1}^2 q_i = \theta - \sum_{i=1}^2 \delta_i p_i$. The own-price elasticity for the i^{th} buyer is given by $(\delta_i + \gamma)$.

The buyer selects either the order quantity q_i or the price p_i at which she intends to sell in the market and the other is then immediately determined. The supplier's variable cost is given by s . In a general setting, the supplier does not know the buyer's marginal production cost c but has a prior knowledge about the cost in the following way: (i) the marginal production cost c lies between a finite interval $[c_{min}, c_{max}]$, where $0 \leq c_{min} \leq c_{max} < \infty$; (ii) the probability density function of c is given by $f(c)$ and the corresponding cumulative distribution function is given by $F(c)$. We further assume that all parameters except c are common knowledge.

Here we consider four different types of contracts: whole-sale price contract, linear two-part tariff contract, nonlinear two-part tariff contract and quantity discount contract. Quantity discount and nonlinear two-part tariff are distinctive contract types; wholesale price and linear two-part tariff contracts stem from them respectively as special cases.

We adopt the quantity discount contract structure of Cachon and K ok (2010) for our paper; the corresponding transfer payment function is given as follows

$$T(w, q_i) = \begin{cases} wq_i - \frac{1}{2}vq_i^2 & \dots \text{if } q_i \leq q^* = \frac{w-s}{v} \\ T\left(\frac{w-s}{v}\right) + s\left\{q_i - \frac{w-s}{v}\right\} & \dots \text{otherwise} \end{cases}$$

where w and v designates per-unit price and quantity discount rate respectively; $v \in [0, \bar{v})$ and $\bar{v} = \min\left(\frac{2\delta_1}{\delta_0}, \frac{2\delta_2}{\delta_0}\right)$ and $\delta_0 = \delta_1\delta_2 + \gamma(\delta_1 + \delta_2)$. The quantity discount is assumed to be continuous, differentiable and concave. If the order quantity is more than q^* , the supplier sells the excess units at a per-unit price equal to her own marginal production cost s . By setting $v = 0$, we obtain wholesale price contract, where the transfer payment function assumes a simpler form: $T(w, q_i) = w \cdot q_i$ with w representing the per-unit wholesale price.

In linear two-part tariff contract, the supplier extracts per-unit price w as well as a per-period fixed fee L_i from buyer i ; but w and L_i are independent of the order quantity q_i . In nonlinear two-part contract $\{w(q_i), L_i(q_i)\}$, the per-unit price and fixed fee are both functions of the order quantity q_i . Transfer payment of two-part tariff contract is given by: $T(w, q_i, L_i) = w \cdot q_i + L_i \cdot 1_{[q_i > 0]}$, where the characteristic function is defined as, $1_{[q_i > 0]} = [1 \text{ if } q_i > 0; 0 \text{ otherwise}]$.

The supplier either knows the value of c or the distribution $F(c)$. She then offers any of the aforementioned four contracts; buyer i then chooses an order quantity q_i depending upon her profit optimality condition and pays the supplier according to the relevant transfer payment function $T(\cdot)$. We study four types of contract under full and asymmetric information for complete and partial decentralised supply network, leading to sixteen cases. The cases, nomenclature and their descriptions are given below in Table 1.

Case	Contract Type	Supply Chain Structure		Information Availability
		Buyer 1	Buyer 2	
CF1	Quantity discount	Independent entity	Independent entity	Full information (Supplier knows c)
CF2	Wholesale price			
CF3	Linear Two-part Tariff			
CF4	Nonlinear Two-part Tariff			
PF1	Quantity discount	Integrated with Supplier	Independent entity	
PF2	Wholesale price			
PF3	Linear Two-part Tariff			
PF4	Nonlinear Two-part Tariff			
CA1	Quantity discount	Independent entity	Independent entity	Asymmetric Information (Supplier does not know c)
CA2	Wholesale price			
CA3	Linear Two-part Tariff			
CA4	Nonlinear Two-part Tariff			
PA1	Quantity discount	Integrated with Supplier	Independent entity	
PA2	Wholesale price			
PA3	Linear Two-part Tariff			
PA4	Nonlinear Two-part Tariff			

Table 1: Contracts under consideration

The generalized supplier's optimization problem can be formulated as follows

$$\max(\pi_S) = \max E \left\{ \sum_{i=1}^2 T(\hat{q}_i) - s \sum_{i=1}^2 \hat{q}_i \right\} \quad \dots (2)$$

$$s. t. \hat{q}_i(c) = \operatorname{argmax}_{q_i(q_j)} \pi_{Mi} = \operatorname{argmax}_{q_i(q_j)} \{p_i q_i - T(q_i) - c q_i\}, \forall c \in [c_{min}, c_{max}], i = 1, 2, i \neq j \dots (3)$$

$$\pi_{Mi} = p_i q_i - T(q_i) - c q_i \geq \bar{\pi}_{Mi}, \quad \forall c \in [c_{min}, c_{max}], i = 1, 2, i \neq j \dots (4)$$

π_S designates the total profit of the supplier; π_{Mi} and $\bar{\pi}_{Mi}$ represents the total profit level and the reservation profit level of the i^{th} buyer respectively; $q_i(q_j)$ represents the profit maximizing optimal demand of the i^{th} buyer given a demand choice q_j of buyer j . Incentive compatibility constraint is represented by condition (3), i.e. the buyer will choose \hat{q}_i such that it maximizes her profit and individual rationality is represented by the inequality part of condition (4), i.e. the minimum profit the i^{th} buyer needs to make is $\bar{\pi}_{Mi}$. The buyers' optimization problem and optimal contract designs are discussed in the following sections.

4. Optimal contract design for complete decentralised supply chain

In Case CF1, the supplier offers identical per-unit price w and an exogenously decided discount policy v to both the buyers. Both the buyers try to optimize their corresponding

profit function $\pi_{Mi} = p_i q_i - (w q_i - \frac{1}{2} v q_i^2) - c q_i$ over q_i . Since $q_i = \theta k_i - \delta_i p_i + \gamma(p_j - p_i)$, the solution to this is given by $(\hat{p}_{QDi}, \hat{q}_{QDi})$ for the i^{th} buyer and is expressed by equation (5) and (6).

$$\hat{p}_{QDi} = A_{QDi} + b_{QDi}(w + c) \dots (5)$$

$$\hat{q}_{QDi} = \frac{\delta_i + \gamma}{D_i} \{A_{QDi} - (1 - b_{QDi})(w + c)\} \dots (6)$$

where,

$$A_{QDi} = \frac{\theta \gamma D_i D_j + \theta k_i D_i \{\gamma + \delta_j (1 + D_j)\}}{\prod_{i=1}^2 (1 + D_i)(\gamma + \delta_i) - \gamma^2 \prod_{i=1}^2 D_i}, b_{QDi} = \frac{(\gamma + \delta_i) \{\gamma D_i + (\gamma + \delta_i)(1 + D_j)\}}{\prod_{i=1}^2 (1 + D_i)(\gamma + \delta_i) - \gamma^2 \prod_{i=1}^2 D_i}$$

$$D_i = 1 - v(\gamma + \delta_i)$$

\hat{p}_{QDi} and \hat{q}_{QDi} represent the optimal pricing and quantity decision for the i^{th} buyer under the setting of complete decentralised supply chain network and quantity discount contract. In Case CA1, the buyers solve the same problem. Putting $v = 0$ in these optimal values of price and order quantity, we obtain the optimal solution $(\hat{p}_{Wi}, \hat{q}_{Wi})$ for wholesale price contract, as expressed by equation (7) and (8).

$$\hat{p}_{Wi} = A_{Wi} + (1 - b_{Wi})(w + c) \dots (7)$$

$$\hat{q}_{Wi} = (\delta_i + \gamma) \{A_{Wi} - b_{Wi}(w + c)\} \dots (8)$$

where $A_{Wi} = \{(2\delta_j + \gamma)\theta k_i + \theta \gamma\} / (4\delta_0 + 3\gamma^2)$ and $b_{Wi} = (2\delta_0 - \gamma \delta_j) / (4\delta_0 + 3\gamma^2)$. Results obtained through equation (7) and (8) are of particular importance, since they would be subsequently used in the analysis of linear and nonlinear two-part tariff contracts. In linear two-part contract, the side payment L_i is independent of q_i and hence does not affect the buyer i 's order quantity. Cases CF3 and CF4 are equivalent in nature. In Case CA4, the supplier offers a menu of contracts $\{w(q_i), L_i(q_i)\}$. As q_i is a function of c , therefore the menu can be represented as $\{w(c), L_i(c)\}$. Now as i^{th} buyer reveals her choice of order quantity q_i , according to revelation principle (Baron and Myerson, 1982) there exists an optimal contract under which the supplier can infer buyer's true cost c .

4.1 Contracts under full information

Propositions 1, 2 and 3 describe the supplier's optimal contracts with full information availability for Cases CF1, CF2 and CF3 respectively.

Proposition 1. In Case CF1, for an exogenously decided discount policy (given by v) the optimal per-unit price (\hat{w}_{CF1}) is given by

$$\widehat{w}_{CF1} = \frac{\sum_{i=1}^2 \{(1+vM_i)(K_i - cM_i)\} + s \sum_{i=1}^2 M_i}{\sum_{i=1}^2 M_i \{2+vM_i\}}$$

where $K_i = \frac{\delta_i + \gamma}{D_i} A_{QDi}$ and $M_i = \frac{\delta_i + \gamma}{D_i} (1 - b_{QDi})$.

For a given discount rate v the optimal per-unit price, \widehat{w}_{CF1} is increasing in θ and s , and decreasing in c .

Proposition 2. In Case CF2, the optimal wholesale price (\widehat{w}_{CF2}) and profit of the supplier ($\widehat{\pi}_{S,CF2}$) are as follows

$$\widehat{w}_{CF2} = \frac{\sum_{i=1}^2 A_{Wi}(\delta_i + \gamma)}{2 \sum_{i=1}^2 b_{Wi}(\delta_i + \gamma)} + \frac{1}{2} \cdot (s - c)$$

$$\widehat{\pi}_{S,CF2} = \frac{1}{\sum_{i=1}^2 b_{Wi}(\delta_i + \gamma)} \left\{ \frac{\sum_{i=1}^2 A_{Wi}(\delta_i + \gamma)}{2 \sum_{i=1}^2 b_{Wi}(\delta_i + \gamma)} - \frac{1}{2} \cdot (s + c) \right\}^2$$

Optimal wholesale price, \widehat{w}_{CF2} is increasing in θ and (weakly) in s , decreasing in c ; Optimal supplier profit, $\widehat{\pi}_{S,CF2}$ is decreasing in c and s , increasing in θ .

Under the condition of symmetric own- and cross-price elasticity, the optimal wholesale price assumes simpler form $\widehat{w} = \frac{\theta}{4\delta} + \frac{1}{2}(s - c)$ and it is not dependent on cross-price elasticity. If we allow market share parameter k_i to vary, the demand rates and price elasticities of demand are different across buyers; thereby symmetric elasticity assumption is not very restrictive. This simpler form of wholesale price helps us to understand that the supplier profit decreases in cross-price elasticity.

Proposition 3. In Case CF3, the optimal per-unit price (\widehat{w}_{CF3}) and franchise fee ($\widehat{L}_{i,CF3}$) extracted by the supplier are as follows

$$\widehat{w}_{CF3} = \frac{\sum_{i=1}^2 (\delta_i + \gamma) \{(1 - 2b_{Wi})(A_{Wi} - b_{Wi}c) + b_{Wi}s\}}{2 \sum_{i=1}^2 b_{Wi}(1 - b_{Wi})(\delta_i + \gamma)}$$

$$\widehat{L}_{i,CF3} = (\delta_i + \gamma) \cdot \left[A_{Wi} - b_{Wi} \cdot \frac{\sum_{i=1}^2 (\delta_i + \gamma) \{A_{Wi}(1 - 2b_{Wi}) + b_{Wi}(s + c)\}}{2 \sum_{i=1}^2 b_{Wi}(1 - b_{Wi})(\delta_i + \gamma)} \right]^2 - \bar{\pi}_{Mi}$$

Optimal per-unit price, \widehat{w}_{CF3} is increasing in θ , γ and s , and decreasing in c ; Optimal franchise fee, $\widehat{\pi}_{S,CF3}$ is increasing in θ and decreasing in s , c and $\bar{\pi}_{Mi}$.

Under the condition of symmetric own- and cross-price elasticity, the optimal linear two-part tariff assumes the following simpler form

$$\hat{w} = \frac{1}{2(\delta + \gamma)} \left[\gamma \left(\frac{\theta}{2\delta} - c \right) + (2\delta + \gamma)s \right]$$

$$\hat{L}_i = (\delta + \gamma) \left[\frac{(2\delta + \gamma)\theta k_i + \theta\gamma}{(2\delta + \gamma)(2\delta + 3\gamma)} - \frac{\delta}{2(2\delta + \gamma)(\delta + \gamma)} \left\{ \frac{\gamma\theta}{2\delta} - (2\delta + \gamma)(s + c) \right\} \right]^2 - \bar{\pi}_{Mi}$$

In Case CF4, the supplier offers a flexible contract through nonlinear two-part tariff structure. In Case CF3, it is evident that the supplier is able to extract all profit beyond the reservation level $\bar{\pi}_{Mi}$ from each buyer. As a result, this additional flexibility does not help the supplier to extract more profit compared to Case CF2. Therefore in Case CF4 the optimal contract decision is given by $(\hat{w}_{CF4}, \hat{L}_{i,CF4}) = (\hat{w}_{CF3}, \hat{L}_{i,CF3})$.

4.2 Contracts under asymmetric information

In the case of asymmetric information, supplier only has a prior probability distribution $F(c)$ over the marginal cost c of the buyers. Under such circumstance, the supplier needs to specify contracts such that her own expected profit maximizes. For the purpose of analysis the optimal price and quantity decisions, as expressed by equations (5) and (6), are used to formulate the profit maximization problem of the supplier. Propositions 4, 5, 6 and 7 describe the supplier's optimal contracts for Cases CA1, CA2, CA3 and CA4, respectively.

Proposition 4. In Case CA1, for an exogenously decided discount policy (given by v) the optimal per-unit price (\hat{w}_{CA1}) is as follows

$$\hat{w}_{CA1} = \frac{\sum_{i=1}^2 [(1+vM_i)\{K_i - M_i E(c)\}] + s \sum_{i=1}^2 M_i}{\sum_{i=1}^2 M_i \{2 + vM_i\}}$$

where $K_i = \frac{\delta_i + \gamma}{D_i} A_{QDi}$ and $M_i = \frac{\delta_i + \gamma}{D_i} (1 - b_{QDi})$.

Proposition 5. In Case CA2, the optimal wholesale price (\hat{w}_{CA2}) and profit of the supplier ($\hat{\pi}_{S,CA2}$) are as follows

$$\hat{w}_{CA2} = \frac{\sum_{i=1}^2 A_{Wi}(\delta_i + \gamma)}{2 \sum_{i=1}^2 b_{Wi}(\delta_i + \gamma)} + \frac{1}{2} [s - E(c)]$$

$$\hat{\pi}_{S,CA2} = \frac{1}{\sum_{i=1}^2 b_{Wi}(\delta_i + \gamma)} \left[\frac{\sum_{i=1}^2 A_{Wi}(\delta_i + \gamma)}{2 \sum_{i=1}^2 b_{Wi}(\delta_i + \gamma)} - \frac{1}{2} \{s + E(c)\} \right]^2$$

Proposition 6. In Case CA3, the optimal per-unit price (\hat{w}_{CA3}) and franchise fee ($\hat{L}_{i,CA3}$) are as follows

$$\hat{w}_{CA3} = \frac{\sum_{i=1}^2 (\delta_i + \gamma)(1 - 2b_{Wi})A_{Wi} + \sum_{i=1}^2 b_{Wi}(\delta_i + \gamma)\{s - E(c) + 2b_{Wi}c_{min}\}}{2 \sum_{i=1}^2 b_{Wi}(1 - b_{Wi})(\delta_i + \gamma)}$$

$$\hat{L}_{i,CA3} = (\delta_i + \gamma) \cdot [A_{Wi} - b_{Wi} \cdot \frac{\sum_{i=1}^2 (\delta_i + \gamma) \{A_{Wi}(1 - 2b_{Wi}) + b_{Wi}(s - E(c) + 2c_{min})\}}{2 \sum_{i=1}^2 b_{Wi}(1 - b_{Wi})(\delta_i + \gamma)}] - \bar{\pi}_{Mi}$$

Proposition 7. In Case CA4, the optimal contract is given by the following per-unit price (\hat{w}_{CA4}) and subsequent condition on the franchise fee ($\hat{L}_{i,CA4}$)

$$\hat{w}_{CA4} = \frac{\sum_{i=1}^2 A_{Wi}(1 - b_{Wi})(\delta_i + \gamma) + \sum_{i=1}^2 b_{Wi}(\delta_i + \gamma)\{s - c + b_{Wi}(c + \frac{F(c)}{f(c)})\}}{2 \sum_{i=1}^2 b_{Wi}(1 - b_{Wi})(\delta_i + \gamma)}$$

$$\frac{\partial \hat{L}_{i,CA4}}{\partial c} + 2b_{Wi}(\delta_i + \gamma)[A_{Wi} - b_{Wi}\{c + \hat{w}_{CA4}(c)\}] \frac{\partial \hat{w}_{CA4}(c)}{\partial c} = 0, \quad i = 1, 2$$

Following the argument of ‘decreasing reverse hazard rate’ (Corbett *et al*, 2004) for obtaining tractable solution, in the case CA4 we have assumed that $\frac{F(c)}{f(c)}$ is increasing in c .

5. Optimal contract design for partially integrated supply chain

Under the assumption of partial integration the supplier and buyer 1 form a vertically integrated entity and buyer 2 operates alone. In order to exploit the advantages of integration the supplier transfers the optimal order quantity q_1 to buyer 1 at her marginal production cost s ; however she charges buyer 2 through any of the aforementioned contracts. In Case PF1, the optimal decisions for the two buyers are given below

$$\hat{p}_{PQ1} = A_{PQ1} + (1 - b_{PQ1})(s + c) + c_{PQ1}(w - s) \dots (9)$$

$$\hat{q}_{PQ1} = (\delta_1 + \gamma)\{A_{PQ1} - b_{PQ1}(s + c) + c_{PQ1}(w - s)\} \dots (10)$$

$$\hat{p}_{PQ2} = A_{PQ2} + (1 - b_{PQ2})(w + c) - c_{PQ2}(w - s) \dots (11)$$

$$\hat{q}_{PQ2} = \frac{(\delta_2 + \gamma)}{D_2} \{A_{PQ2} - b_{PQ2}(w + c) - c_{PQ2}(w - s)\} \dots (12)$$

where,

$$A_{PQ1} = \frac{\theta\gamma D_2 + \theta k_1\{(1 + D_2)\delta_2 + \gamma\}}{D}; \quad b_{PQ1} = \frac{(1 + D_2)\delta_0 - \gamma\delta_2}{D}; \quad c_{PQ1} = \frac{\gamma(\delta_2 + \gamma)}{D}$$

$$A_{PQ2} = \frac{\theta\gamma D_2 + \theta k_2 D_2\{2\delta_1 + \gamma\}}{D}; \quad b_{PQ2} = \frac{D_2(2\delta_0 - \gamma\delta_1)}{D}; \quad c_{PQ2} = \frac{\gamma(\delta_2 + \gamma)}{D}$$

$$D = 2(\delta_1 + \gamma)(\delta_2 + \gamma)(1 + D_2) - \gamma^2 D_2; \quad D_2 = 1 - v(\gamma + \delta_2)$$

Again by putting $v = 0$ in these optimal values of price and order quantity, we obtain the optimal solution $(\hat{p}_{PW_i}, \hat{q}_{PW_i})$ for wholesale price contract, as expressed by equation (13) - (16).

$$\hat{p}_{PW1} = A_{W1} + (1 - b_{W1})(s + c) + c_{PW1}(w - s) \dots (13)$$

$$\hat{q}_{PW1} = (\delta_1 + \gamma)\{A_{W1} - b_{W1}(s + c) + c_{PW1}(w - s)\} \dots (14)$$

$$\hat{p}_{PW2} = A_{W2} + (1 - b_{W2})(w + c) - c_{PW2}(w - s) \dots (15)$$

$$\hat{q}_{PW2} = (\delta_2 + \gamma)\{A_{W2} - b_{W2}(w + c) - c_{PW2}(w - s)\} \dots (16)$$

where $c_{PW_i} = \gamma(\delta_j + \gamma)/(4\delta_0 + 3\gamma^2)$. Results obtained through equation (13) - (16) will be used for the purpose of wholesale price contract, linear two-part tariff and nonlinear two-part tariff contract analysis of the partially integrated network under symmetric and asymmetric information.

5.1 Contracts under full information

Corollaries 1, 2 and 3 describe optimal contracts for Cases PF1, PF2 and PF3 respectively.

Corollary 1. In Case PF1, for an exogenously decided discount policy v , the optimal wholesale price is given by

$$\hat{w}_{PF1} = s + \frac{1 + v(\delta_2 + \gamma)(b_{W2} + c_{PW2})}{2 + v(\delta_2 + \gamma)(b_{W2} + c_{PW2})} \left[\frac{A_{W2} - b_{W2}(s + c)}{(b_{W2} + c_{PW2})} \right]$$

Corollary 2. In Case PF2, the optimal wholesale price charged to buyer 2 and profit of the supplier from selling to buyer 2 are as follows

$$(i) \quad \hat{w}_{PF2} = s + \frac{1}{2(b_{W2} + c_{PW2})} \{A_{W2} - b_{W2}(s + c)\}$$

$$(ii) \quad \hat{\pi}_{S,PF2} = \frac{(\delta_2 + \gamma)}{4(b_{W2} + c_{PW2})} \{A_{W2} - b_{W2}(s + c)\}^2$$

Corollary 3. In Case PF3, the optimal per-unit price and franchise fee charged to buyer 2 are as follows

$$(i) \quad \hat{w}_{PF3} = s + \frac{\{1 - 2(b_{W2} + c_{PW2})\}\{A_{W2} - b_{W2}(s + c)\}}{2(b_{W2} + c_{PW2})\{1 - (b_{W2} + c_{PW2})\}}$$

$$(ii) \quad \hat{L}_{2,PF3} = \frac{(\delta_2 + \gamma)\{A_{W2} - b_{W2}(s + c)\}^2}{4\{1 - (b_{W2} + c_{PW2})\}^2} - \bar{\pi}_{M2}$$

Following the argument of Case CF4, the introduction of additional flexibility through nonlinear two-part tariff contract does not improve the supplier's profit in Case

PF4 compared to that of Case PF3. Hence in Case PF4 the optimal contract decision is given by $(\hat{w}_{PF4}, \hat{L}_{2,PF4}) = (\hat{w}_{PF3}, \hat{L}_{2,PF3})$.

5.2 Contracts under asymmetric information

Corollary 4. In Case PA1, the optimal wholesale price charged to buyer 2 and profit of the supplier from selling to buyer 2 is as follows.

$$\hat{w}_{PA1} = s + \frac{1 + v(\delta_2 + \gamma)(b_{W2} + c_{PW2})}{2 + v(\delta_2 + \gamma)(b_{W2} + c_{PW2})} \left[\frac{A_{W2} - b_{W2}\{s + E(c)\}}{(b_{W2} + c_{PW2})} \right]$$

Corollary 5. In Case PA2, the optimal per-unit price and franchise fee are as follows.

$$\begin{aligned} \text{(i)} \quad \hat{w}_{PA2} &= s + \frac{1}{2(b_{W2} + c_{PW2})} [A_{W2} - b_{W2}\{s + E(c)\}] \\ \text{(ii)} \quad \hat{\pi}_{S,PA2} &= \frac{(\delta_2 + \gamma)}{4(b_{W2} + c_{PW2})} [A_{W2} - b_{W2}\{s + E(c)\}]^2 \end{aligned}$$

Corollary 6. In Case PA3, the optimal per-unit price and franchise fee are as follows.

$$\begin{aligned} \text{(i)} \quad \hat{w}_{PA3} &= \frac{1-2m}{2m(1-m)} A_{W2} + \frac{E\{k(c)\} - 2m\tilde{k} + ms}{2m(1-m)} \\ \text{(ii)} \quad \hat{L}_{2,PA3} &= \frac{\delta_2 + \gamma}{4(1-m)^2} [A_{W2} - E\{k(c)\} + 2\tilde{k} - ms]^2 - \bar{\pi}_{M2} \end{aligned}$$

where $m = b_{W2} + c_{PW2}$, $\tilde{k} = c_{PW2}s - b_{W2}c_{min}$, $E\{k(c)\} = c_{PW2}s - b_{W2}E(c)$

Corollary 7. In Case PA4, the optimal contract is given by the following per-unit price (\hat{w}_{PA4}) and subsequent condition on the franchise fee $(\hat{L}_{2,PA4})$

$$\begin{aligned} \text{(i)} \quad \hat{w}_{PA4} &= \frac{1-2m}{2m(1-m)} A_{W2} + \frac{(1-2m)k(c) + ms}{2m(1-m)} + \frac{b_{W2} F(c)}{1-m f(c)} \\ \text{(ii)} \quad \frac{\partial \hat{L}_{2,PA4}}{\partial c} + 2m(\delta_2 + \gamma)\{A_{W2} - m\hat{w}_{PA4}(c) + k(c)\} \frac{\partial \hat{w}_{PA4}(c)}{\partial c} &= 0 \end{aligned}$$

where $m = b_{W2} + c_{PW2}$, $k(c) = c_{PW2}s - b_{W2}c$. Similar to the Case CA4, for this case also we make the usual assumption of ‘decreasing reverse hazard rate’, i.e. $\frac{F(c)}{f(c)}$ is increasing in c (Corbett et al, 2004).

6. Discussion

In the previous sections we have reviewed two main contract types and their special cases. We have established the characteristics to each contract type with either full or asymmetric information under complete decentralized and partially integrated structure of the supply chain. Through the analysis we have also shown that irrespective of the supply chain structure the supplier would always like to offer two-part tariff contract to the independent

buyer i.e. buyer 2. In this section, we compare various outcomes to discuss the effect of supply chain structure, market share, cutoff policies and value of information on different contract types. We also discuss the impact of different contract types on the profit level of individual players with the help of a numerical example.

6.1. Effect of supply chain structure on the profit level

In this section, we explore the effect of supply chain structure and market share on the profit level of individual players and overall supply chain. We set the following parameter values,

$$\theta = 200, \delta_1 = 1, \delta_2 = 1, \gamma = 0.5, s = 10, c = 15, \bar{\pi}_S = 250, \bar{\pi}_{M1} = 100, \bar{\pi}_{M2} = 150$$

Under different contract types, we calculate individual profit as a function of competition intensity, represented by the cross-price elasticity (γ) and the overall supply chain profit as a function of market share (k_1 or $k_2 = 1 - k_1$).

First we consider the individual players with the market share distribution as $k_1 = 0.45$ and $k_2 = 0.55$. Figure 1 show how the profit level of the independent buyer (Buyer 2) changes under wholesale price contract as cross-price elasticity increase from 0 to 1 for different supply chain structures i.e. Cases CF2 and PF2. Decentralized structure of the supply chain works in the advantage of the independent buyer as she stands the chance to make higher profit. Price sensitivity of demand for the other buyer also influences the profit; with increase in price sensitivity of demand, profit margin of the independent buyer also increases.

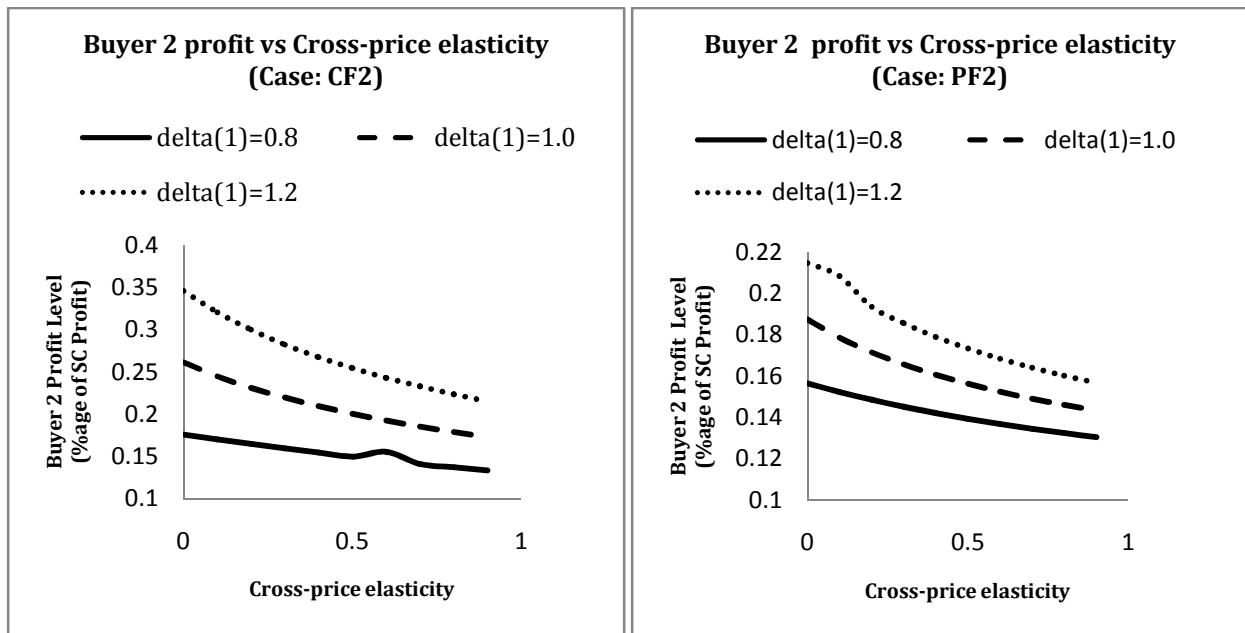


Figure 1. Independent buyer profit (Cases: CF2 and PF2)

Figure 2 shows how the profit level of the supplier varies under similar setting. In the case of partially integrated structure supplier profit designates the total profit of the partially integrated chain. In the case of decentralized setting the supplier profit increases rapidly as cross-price sensitivity increases. In other words, as the competition between the two buyers increases the supplier can extract higher wholesale price leading to increase in more profit. From a supplier's perspective lower price-sensitivity of demand leads to more profit irrespective of the supply chain structure. These observations about the supplier and the buyer are consistent with the results discussed in Anderson and Bao (2010) that the profit level of buyer is strictly decreasing as cross-price elasticity increases.

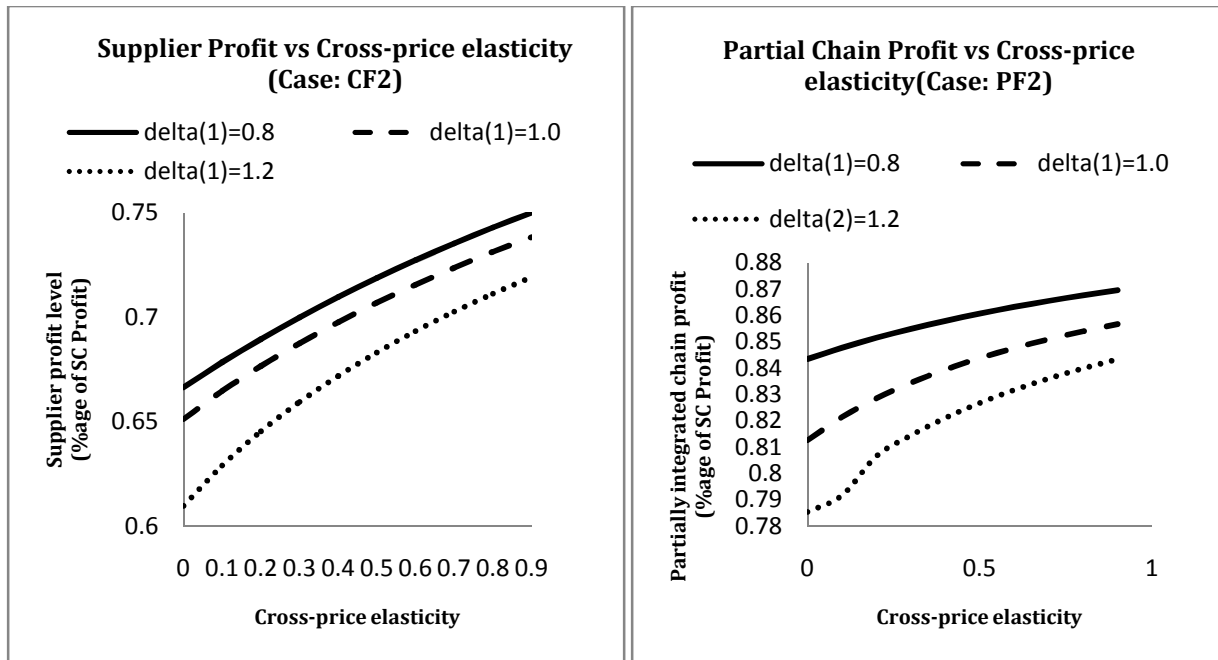


Figure 2. Supplier profit (Cases: CF2 and PF2)

In the case of two-part tariff contract, the cross-price elasticity or price sensitivity of the other buyer does not impact the profit level of the independent buyer. By effecting two-part tariff contract the supplier is able to extract the profit made by the independent buyer apart from her reservation profit.

Figure 3 represents the variation in the profit level of the supplier under the linear two-part tariff contract, against cross-price elasticity for different supply chain structures i.e. Cases CF3 and PF3. In the case of complete decentralization supplier profit is almost unaffected by the cross-price sensitivity. In the case of partially integrated chain, the supplier profit decreases with increase of cross-price sensitivity. In both the cases lower own-price elasticity leads to increase in average profit level for the supplier.

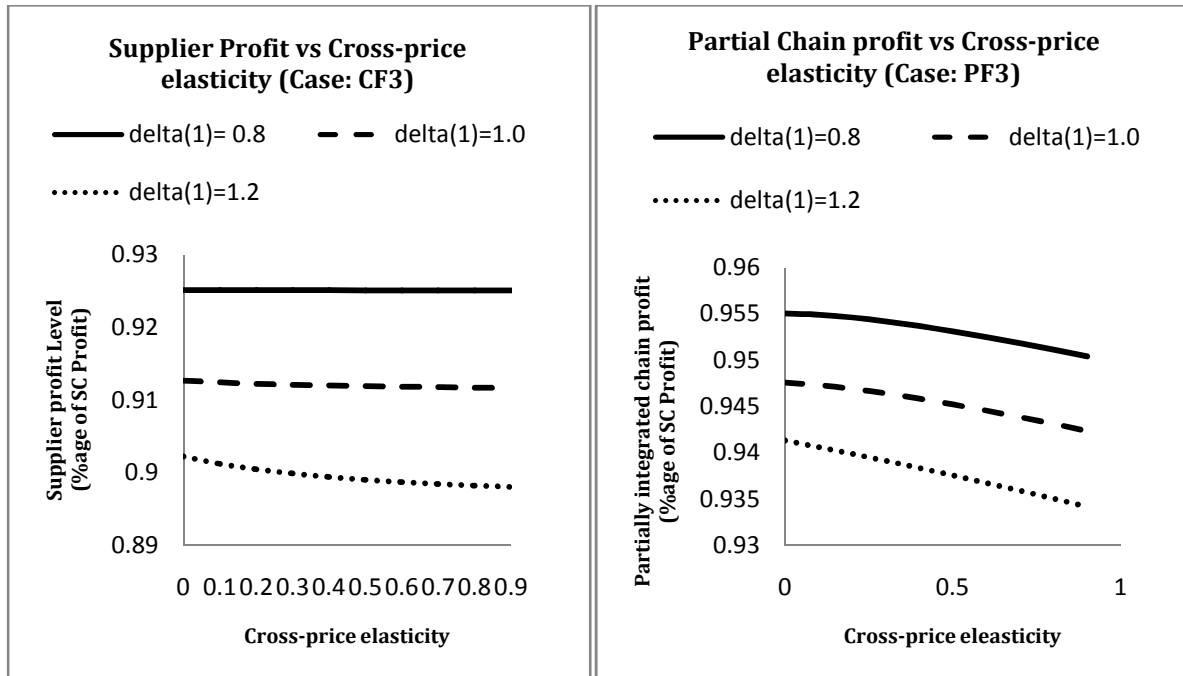


Figure 3. Supplier or Partial Chain Profit (Cases: CF3 and PF3)

Next we consider the variation in overall supply chain profit level with the distribution of market share. Figure 4 presents the variation of overall supply chain profit against the variation of market share for buyer 1. We compare the wholesale price contracts for different supply chain structure i.e. Cases CF2 and PF2; subsequently we compare between Cases CF3 and PF3. In all the cases profit of vertically integrated monopoly supply chain is taken as benchmark for each contract type; the profit of the supply chain is expressed as a percentage of that profit level. In case of two-part tariff contract we find that irrespective of the supply chain structure the variation in overall profit level is identical. In the case of wholesale price contract, lower market share of buyer 1 keeps the overall profit level low for a partially integrated chain compared to complete decentralized chain.

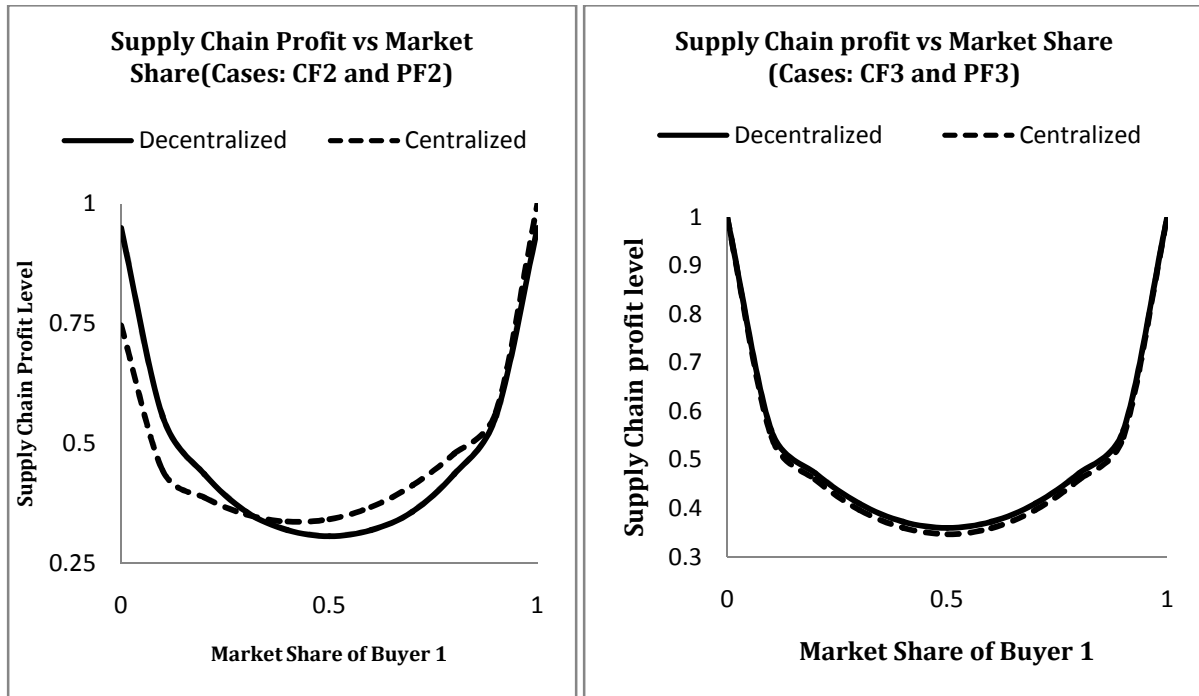


Figure 4. Overall supply chain profit (Cases: CF2, CF3, PF2 and PF3)

Buyer profit strictly decreases as the competition intensity increase. Decentralized supply chain works in the advantage of the supplier in the case of wholesale price contract. However if the cross-price elasticity is low or the independent buyer has higher market share, then it helps the supplier to charge more per-unit wholesale price in the case PF2 compared to the case CF2, as evident from figure 5.

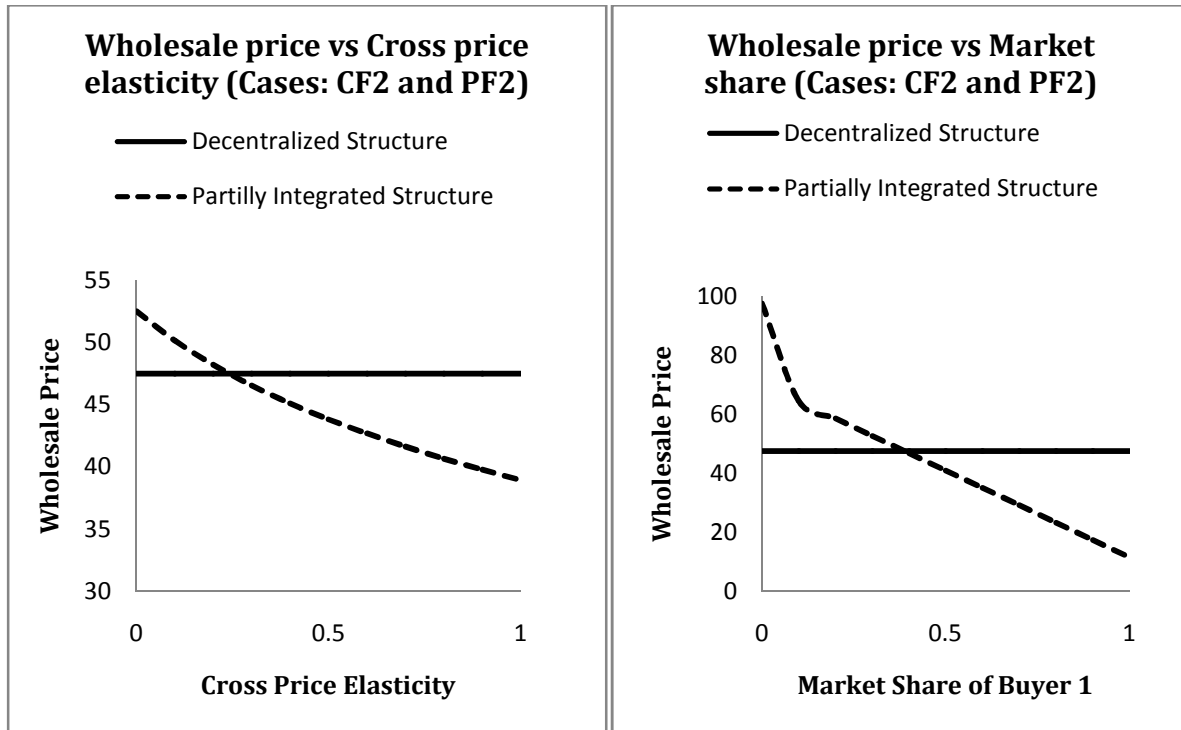


Figure 5. Wholesale price with cross-price elasticity and market share

When the competition among the buyers increases, the profitability of the supplier also increases. In partially integrated chain, if the independent buyer captures the majority of the market share the overall supply chain profit decreases for wholesale price contract; the overall supply chain behaves inefficiently compared to its decentralized counterpart. These observations are consistent with the conclusion drawn by McGuire and Staelin (1983) that supplier is better off in a decentralized supply chain when products are highly substitutable. In the next section we are going to investigate the effect of market share on contract analytically.

6.2. Effect of market share on contract

In this section we compare the contract forms discussed in section 4 and 5 to understand the influence of supply chain structure on different types of contracts from the perspective of the independent buyer. For the purpose of analytical tractability we assume identical own- and cross-price elasticity for the buyers. This assumption is not very restrictive in nature as we allow non-identical market share (k_i) for individual buyer and it leads to different demand rates for the products. The comparison helps us to draw important insight about understanding how the supply chain structure impacts each of the contracts.

The difference between per-unit wholesale prices, as experienced by the independent buyer, due change of supply chain structure from complete decentralization to partial

centralization is given by $\Delta(\widehat{w})_{WP}$ in the case of wholesale price contract under availability of full information. Then $\Delta(\widehat{w})_{WP}$ is as follows,

$$\Delta(\widehat{w})_{WP} = \frac{\gamma(s+c)(\delta+\gamma) - \theta\{2\delta^2(1-2k_2) + 2\delta\gamma(1-k_2) + \gamma^2\}}{2(2\delta^2 + 4\delta\gamma + \gamma^2)}$$

If the substitution effect is very low i.e. $\delta \gg \gamma$ then the difference between wholesale prices is approximated by $\Delta(\widehat{w})_{WP} \approx -\frac{\theta}{2}(1-2k_2)$. For an independent buyer with more than 50% market share i.e. $k_2 > \frac{1}{2}$ the difference in wholesale price $\Delta(\widehat{w})_{WP} > 0$. Hence the buyer has to pay higher wholesale price due to structural change. Therefore finished good price charged by the independent buyer goes up and she loses her competitive advantage in the market. The expression for difference in wholesale price due to structural change holds for the case of asymmetric information as well.

In the case of linear two-part tariff contract and availability of full information, the difference in per-unit price due to structural change of the supply chain is given by $\Delta(\widehat{w})_{LTP}$ and is given by,

$$\Delta(\widehat{w})_{LTP} = \frac{\gamma}{2(\delta+\gamma)} \left\{ \theta \left[\frac{\gamma\{(2\delta+\gamma)k_2 + \gamma\}}{\Delta_1} - \frac{1}{4\delta} \right] + (s+c) \left[1 - \frac{\gamma\delta(2\delta+3\gamma)}{\Delta_1} \right] \right\}$$

where $\Delta_1 = (\delta+\gamma)(2\delta^2 + 4\delta\gamma + \gamma^2)$. It is evident from the expression of $\Delta(\widehat{w})_{LTP}$ if the substitution effect decreases, the difference in per-unit price decreases and the supplier would be able to extract the profit in terms of the franchise fee she charges and she will deliver the products at her own marginal cost. This makes the linear two-part tariff the most effective contractual agreement from the perspective of the supplier, under the setting of full information availability. By similar argument we can show that in asymmetric information scenario, the supplier benefits by enforcing linear two-part tariff contract.

Therefore when asymmetry of information exists the supplier tries to gain maximum possible information about buyer's cost structure in order to optimize her profit. In the next section we are going to discuss the value of information to understand the impact of information on the supplier profit level.

6.3. Value of Information

In this section we compare between various full and asymmetric information cases to find how much the supplier gains from obtaining detailed information regarding the buyers' cost structure. While discussing the value of information, we do not incorporate cutoff policies in order to obtain closed-form expressions.

Without altering the contract form, better information about buyer cost structure can help the supplier to capture more profit. In the model we have assume that none of the buyers have technology advantage. Therefore cost information about any of the buyers would help the supplier to increase her own profit.

In case of wholesale price contract, better information helps the supplier to increase her profit by the amount $\Delta(\pi)_{WPC}$. Then $\Delta(\pi)_{WPC}$ is given by the following expression,

$$\Delta(\pi)_{WPC} = \pi_{S,CF2} - \pi_{S,CA2}$$

$$\Delta(\pi)_{WPC} = \frac{1}{2 \sum_{i=1}^2 b_{Wi}(\delta_i + \gamma)} \left[\frac{1}{2} Var(c) - \left(\frac{\sum_{i=1}^2 A_{Wi}(\delta_i + \gamma)}{\sum_{i=1}^2 b_{Wi}(\delta_i + \gamma)} - s \right) \{c - E(c)\} \right]$$

This expression gives the amount by which the supplier profit will increase in case she obtains complete information about buyers' cost structure. Under the condition of symmetric own- and cross-price elasticity, $\Delta(\pi)_{WPC}$ assumes a simpler form,

$$\Delta(\pi)_{WPC} = \frac{2\delta + \gamma}{4\delta(\delta + \gamma)} \left[\frac{1}{2} Var(c) - \left(\frac{\theta}{4\delta} - s \right) \{c - E(c)\} \right] \dots (17)$$

It is evident from Equation no. 17 that $\Delta(\pi)_{WPC}$ is more sensitive to change in own-price elasticity than cross-price elasticity. Therefore as the demand becomes more price-sensitive the value of information increases for the supplier.

In case of linear two-part contract the supplier profit level increases by $\Delta(\pi)_{LTPC}$ when full information is available. Increase in profit under the condition of symmetric elasticity is given by the following expression,

$$\Delta(\pi)_{LTPC} = \pi_{S,CF3} - \pi_{S,CA3} = [\{c - E(c)\} - 2\delta(2\delta + 3\gamma)(c - c_{min})] \left[\frac{\theta}{2} - \frac{\delta}{\delta + \gamma} (s + c) \right]$$

In this case the value of information is still dependent on the own-price sensitivity. Since $\Delta(\pi)_{LTPC} > \Delta(\pi)_{WPC}$ the value of information to the supplier is higher in the case of two-part contracts. In case of two-part tariff the supplier utilizes each buyer's individual rationality constraint in her own benefit. However she cannot do so in Case CF2 or CA2. Therefore in those cases the supplier can calculate cutoff points to identify whether a transaction satisfies her own or buyer's individual rationality constraint or not.

6.4. Cutoff Policies

All the propositions discussed so far indicate that the supplier's profit is always decreasing in buyer's cost c . In this context it is possible to design cutoff policies for buyers as well as supplier; a cutoff policy denotes the condition(s) where any one of the players (supplier or

buyer) will refuse to trade. We discuss the cutoff policies for wholesale price contract under full and asymmetric information in detail.

Proposition 8a. In the case of wholesale price contract (Case CF2) under the assumption of full information and complete decentralization, different cutoff points are as follows,

(i) The i^{th} buyer's cutoff point (α_{Mi}) is given by

$$\alpha_{Mi,CF2} = \frac{2}{b_{Wi}} \left(A_{Wi} - \sqrt{\frac{\bar{\pi}_{Mi}}{\delta_i + \gamma}} \right) - \left(s + \frac{\sum_{i=1}^2 A_{Wi}(\delta_i + \gamma)}{\sum_{i=1}^2 b_{Wi}(\delta_i + \gamma)} \right)$$

(ii) The supplier's cutoff point (α_S) is given by

$$\alpha_{S,CF2} = \frac{\sum_{i=1}^2 A_{Wi}(\delta_i + \gamma)}{\sum_{i=1}^2 b_{Wi}(\delta_i + \gamma)} - \left(s + 2 \sqrt{\bar{\pi}_S \left\{ \sum_{i=1}^2 b_{Wi}(\delta_i + \gamma) \right\}} \right)$$

where $\bar{\pi}_S$ designates the reservation profit level of the supplier.

Both α_{Mi} and α_S are identically decreasing in s . Both the cutoff policies are decreasing in their respective reservation profit levels i.e. α_{Mi} is decreasing in $\bar{\pi}_{Mi}$ and α_S is decreasing in $\bar{\pi}_S$. Supplier's cutoff point α_S is absolutely increasing in θ and buyer's cutoff point α_{Mi} is increasing in θ under the condition $\frac{2\{(2\delta_j + \gamma)k_i + \gamma\}}{b_{Wi}} > \frac{\sum_{i=1}^2 \{(2\delta_j + \gamma)k_i + \gamma\}(\delta_i + \gamma)}{\sum_{i=1}^2 b_{Wi}(\delta_i + \gamma)}$. If both the buyers have identical own-price elasticity then with increase in the market size θ , the cutoff point decreases for the buyer with lower market share.

Proposition 8b. In the case of wholesale price contract (Case CA2) under the assumption of asymmetric information and complete decentralization, supplier's cutoff point ($\alpha_{S,CF2}$) is given by the following condition,

$$\begin{aligned} & \left\{ \sum_{i=1}^2 (\delta_i + \gamma) A_{Wi} - (2w - s) \sum_{i=1}^2 (\delta_i + \gamma) b_{Wi} \right\} \frac{F(\alpha_{S,CF2})}{f(\alpha_{S,CF2})} - \frac{E(c|c < \alpha_{S,CF2})}{f(\alpha_{S,CF2})} \sum_{i=1}^2 (\delta_i + \gamma) b_{Wi} \\ & = (w - s) \left\{ \sum_{i=1}^2 (\delta_i + \gamma) A_{Wi} - (w + \alpha) \sum_{i=1}^2 (\delta_i + \gamma) b_{Wi} \right\} - \bar{\pi}_S \end{aligned}$$

In this case any buyer would be willing to trade if her own profit satisfies the condition, $\pi_{Mi} = (\delta_i + \gamma)[A_{Wi} - b_{Wi}\{\hat{w}(\alpha_{S,CF2}) + \alpha_{S,CF2}\}]^2 \geq \bar{\pi}_{Mi}$.

7. Conclusion

This paper focuses on the influence of competition, market structure and supply chain structure on the performance of the supply chain. We have also calculated the value to a supplier of different types of contract; in case of information asymmetry we have shown the value of obtaining more accurate information about the buyer's cost structure. We have analyzed the problem both from the perspective of a specific player of the supply chain and also from the broader perspective of the entire supply chain performance i.e. the total profit made by all the players.

One contribution of this paper is that our research is able to link the contracts with the reservation profit level of individual players, market share of individual buyers and the effect of competition. Focusing on a single supplier two-buyer supply chain set up we have drawn important insights about how the profit level changes with contract type and market share distribution among different buyers.

Through our analysis we demonstrate that supplier benefits from competition intensity in both decentralized and partially integrated setting of the supply chain. In case of highly price sensitive demand, either of the buyers stands the chance to loose on their profit level as cross-price elasticity increases. In the case of linear and nonlinear two-part tariff contract we have critically examined the influence of reservation profit level on the contract structures. Our investigation shows how the supplier can compute the value of information in the case of information asymmetry and how much additional profit can be made by obtaining accurate information about cost structure of the buyer. In the case of wholesale price contract, we have incorporated the concept of supplier reservation profit to design the cutoff policies for the supplier. In the case of wholesale price contract we have shown how market share influences the wholesale price as the supply chain structure shifts from complete decentralization to partially integrated one. This result indicates that a buyer with larger market share can be adversely affected if the supplier acquires the smaller buyer or gets into a collusive arrangement.

One of the primary limitations of our model is the assumption of linear demand function. Another limitation is that the overall problem is designed for one time period. Analysis of nonlinear deterministic demand under the condition of asymmetric information, formulation of similar problem in multi-period setting and the formulation under stochastic demand scenario are left for future work.

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