



Price Competition Between Two Leader-Follower Supply Chains, A Case Study

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ABSTRACT

We develop a model for a real-world case problem as a price competition model between two leader-follower supply chains that each of them consists of a manufacturer and a retailer. The manufacturer produces partially differentiated products and sells to the market through its retailer. The retailer sells the products of the manufacturer to the market by adding some values to the products and gains margin as a fraction of the all income of selling products. We use a two-stage Stackelberg game model to investigate the dynamics between these supply chains and obtain the optimal prices of products. We explore the effect of varying the level of substitutability coefficient of two products on the profits of the leader and follower supply chains and derive some managerial implications. We find that the follower supply chain has an advantage when the products are highly substitutable. Also, we study the sensitivity analysis of the fraction of requested margin by retailer on the profit of supply chains.

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1. Introduction

Development of technology and globalization of economy enforce the supply chains (SC) to compete strictly with each other in their common target market. In the supply chain management (SCM) literature, it is well known that coordination among supply chain partners using the tools such as information sharing will improve the overall supply chain performance (e.g. [1]) but the majority of this literature ignores the competition from other external supply chains and hence, there is no guaranty for improving the supply chain performance in the existence of other coordinated supply chains [2].

In this paper, we focus on two real-world competing supply chains selling either identical or highly

substitutable products into the same market. Here, the term of “competition” is used to mean the actions undertaken by one supply chain to increase its own sales may directly decrease the demand faced by another.

These two supply chains have not symmetrical power in market and there is a leader-follower relationship between them. For example, in the case of introducing a new product to the market, a company analyzes its own and competing supply chain capabilities to decide whether to enter the market early or late. Because of the effective role of pricing in the business behavior and success in the final market, in this paper, we suppose that the competition occurs in the product price. Regarding to these considerations, the price competition model between two real-world leader-follower supply chains is developed in two stages, in stage 1, the leader supply chain determines its optimal prices of products and then, in stage 2, the follower supply chain determines its optimal decisions regarding

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to the decisions given in stage 1. In fact, this game is a two-stage Stackelberg game that can be solved using backwards induction. How will these supply chains compete in the market? What are the optimal product prices for them? What is the impact of the competition parameters such as the substitutability coefficient of products on the profits of these competing supply chains? The answer to these questions is the subject of this paper. The rest of the paper is organized as follows. A summary of competition literature between supply chains is reviewed in Section 2. In Section 3, we explain the real-world case. We develop the model for the problem and derive the profit functions of the supply chain partners in Section 4. Calculations of the optimal prices using a Stackelberg game approach is presented in Section 5. Numerical examples and sensitivity analysis are presented in Section 6. Finally, Section 7 concludes the paper.

2. Literature Review

The price competition has been investigated in the

SCM literature. McGuire and Staelin [3] investigate equilibrium supply chain structures for the duopoly market, in which two competing manufacturers sell their products through their exclusive retailers. They developed a price competition model with deterministic parameters and considered product substitutability with no inventory considerations to obtaining the wholesaler's equilibrium distribution structure (vertical integration versus decentralized distribution). McGuire and Staelin [3] showed that the equilibrium distribution structure depends on the degree of product substitutability, which determines the intensity of retail price competition.

After McGuire and Staelin [3], their works have been extended by some researchers (i.e. Coughlan [4] and Moorthy [5]). On the other hand, Lee and Staelin [6] and Trivedi [7] attempted for providing some models, in which two manufacturers interact with two common retailers. By reviewing the literature, we summarize the previous studies in competition between two supply chains in Table 1.

Tab. 1. The summary of literature review in competition between two supply chains

	No. of competing SCs	Each SC consisted of	Move sequence of SCs	Modeling/Solving approach
Wu and Chen [Article in preparation]	2	one manufacturer with two exclusive retailers.	Simultaneously	Game Theory
Boyaci and Gallego [2]	2	one wholesaler and one retailer.	Simultaneously	Game Theory
Zhang [8]	arbitrary	Different number of tiers	Simultaneously	Mathematical Programming
Qian [9]	2	a manufacturer and a retailer.	SC1 moves first, and then moves SC2.	Game Theory
Liu and Wang [10]	2	one upstream firm and one downstream firm.	Simultaneously	Game Theory
Xiao and Yang [11]	2	one risk-neutral supplier and one risk-averse retailer.	Simultaneously	Game Theory
Ha et al. [12]	2	one manufacturer selling to one retailer	Simultaneously	Game Theory
Ha and Tong [13]	2	one manufacturer and one retailer.	Simultaneously	Game Theory
Baron et al. [Article in preparation]	2	one manufacturer and one retailer.	Simultaneously	Game Theory
Shou et al. [Article in preparation]	2	one retailer and its exclusive supplier.	Simultaneously	Game Theory
Wu et al. [14]	2	a manufacturer and a retailer.	Simultaneously	Game Theory
Anderson and Bao [15]	n	one manufacturer and one retailer.	Simultaneously	Game Theory
Xiao and Yang [16]	a supply chain facing an outside integrated competitor	one risk-neutral manufacturer and one risk-averse retailer.	Simultaneously	Game Theory
Liu et al. [17]	2	Each SC consisted of one manufacturer selling product to the two retailers which are common between two SCs.	Simultaneously	Game Theory

From table 1, it can be found that game theory is the dominant approach for modeling the competition between two supply chains and derive optimal decisions under different assumptions. In the literature, except the work of Qian [9], all the previous studies consider the situation in which the competing supply chains determine their strategies simultaneously. Similar to Qian [9], in this paper, there is a leader-follower relationship between two competing supply chains. Also, no previous study has investigated the competition between supply chains in the real-world and all the researchers have had the efforts to develop the competition models just from the theoretical viewpoint. In fact, to the best of our knowledge, no previous supply chain study has investigated the price

competition between two leader-follower supply chains as a case study in the real-world.

3. The Case

Solico Group is a great Iranian business group with many active companies. The most famous companies of this group are Kalleh Dairy Co., Kalleh Amol Meat Co., Aris Amol Co., Tehran Meat Products Co., and many others. These companies operate in different industry sectors such as dairy, process meat, ice cream, beverage, dressing, packaging, and import & export. As a case study the competition between Kalleh Amol Meat Co. (Kalleh) and Tehran Meat Products Co. (Solico) has been investigated in this paper. These are two completely separated supply chains that compete

with each other throughout the country. Kalleh has a brand advantage than Solico and has a relative advantage of accessing customers due to a better brand, position, reputation, quality, and so on. On the other hand, we face with a Stackelberg game in which Kalleh acts as Stackelberg leader and Solico acts as Stackelberg follower. The supply chains of Kalleh and Solico each composed of a manufacturer of meat products and one sales organization (retailer). The retailer buys the products from manufacturer and performs all other activities such as advertising, marketing, transportation and delivering the product to the final market. Here, it is assumed that the retailer adds some values to the product by the unit cost c_r .

4. Modeling

In this section we attempt to define the profit functions of the supply chain partners. The subscripts 1 and 2 are used to differentiate between the leader (Kalleh) and follower (Solico) supply chains respectively ($i, j=1, 2$ ($j \neq i$)). The manufacturer produces partially differentiated products with a unit production cost c_i^m (superscript m represents manufacturer) and sells to market through his retailer. The retailer sells the products of manufacturer to market by adding some values to the product with a unit cost c_i^r (superscript r represents retailer). We suppose that these unit costs are common knowledge for all partners in two supply chains who play a one-shot game within a single period. The retailers of Kalleh and Solico gains margin as a fraction of the all income of selling products. The following notation is used in the paper

- a_i : the market base for supply chain i (we suppose here $a_1 = a_2 = a$);
- c_i^m : the unit production cost of manufacturer i;
- c_i^r : the unit cost of adding some values to the product by retailer i;
- d: the substitutability coefficient of products (the cross-price sensitivity of retailer), $0 \leq d \leq 1$;
- b_i : the self-price sensitivity of retailer, $0 \leq d \leq b_i$;
- p_i : the price of product determined by manufacturer i (the retail price of retailer i);
- t_i : the fraction of requested margin by retailer i, $0 < t_i$;

$$\pi_i^r > 0 = (t_i \times p_i - c_i^r)(a - p_i + dp_j) \Rightarrow (t_i \times p_i - c_i^r) > 0 \Rightarrow t_i > \frac{c_i^r}{p_i}, \quad (7)$$

$$\pi_i^m = ((1 - t_i) \times p_i - c_i^m)(a - p_i + dp_j) \Rightarrow ((1 - t_i) \times p_i - c_i^m) > 0 \Rightarrow t_i < 1 - \frac{c_i^m}{p_i}, \quad (8)$$

So, the interval for t_i is

$$\frac{c_i^r}{p_i} < t_i < 1 - \frac{c_i^m}{p_i}, \quad (9)$$

In this study, it is assumed that $p_i > c_i^m + c_i^r$.

We study the competition through retail price as the only important factor which affects the market demand. In this paper, we use the linear demand function in which the market demand for retailer i is

$$q_i = a - b_i p_i + d p_j, \quad i, j=1, 2, \quad j \neq i. \quad (1)$$

Here, generally we suppose that the market demand of each supply chain is decreasing with the supply chain's own retail price and increasing with its rival's retail price. Because the linear price-dependent demand function is tractable, it is used in many SCM studies (e.g. [15], [18] and [19]). Similar to Anderson and Bao [15], for convenience in this paper, we will use a single substitutability coefficient of two products (d) to capture competitive effects for each pair of products. We also suppose that $b_1 = b_2 = 1$ to focus on the competition viewpoint between Kalleh and Solico. Since we do not have negative demand then we assume

$$a - p_i > -d p_j, \quad i, j=1, 2, \quad j \neq i. \quad (2)$$

We define the profit functions of manufacturer and retailer (represented by π_i^r and π_i^m) as

$$\pi_i^r = (t_i \times p_i - c_i^r)(a - p_i + d p_j), \quad i, j=1, 2, \quad j \neq i. \quad (3)$$

$$\pi_i^m = ((1 - t_i) \times p_i - c_i^m)(a - p_i + d p_j), \quad i, j=1, 2, \quad j \neq i. \quad (4)$$

The profit functions of the Solico and Kalleh which is the sum of π_i^r and π_i^m are

$$Kalleh = (p_1 - c_1^m - c_1^r)(a - p_1 + d p_2) \quad (5)$$

$$Solico = (p_2 - c_2^m - c_2^r)(a - p_2 + d p_1) \quad (6)$$

In Kalleh and Solico the fraction of requested margin by retailer (t_i) is determined by head of two supply chains (central decision maker). In each supply chain, the manufacturer determines the price of product. The lower and upper bound of t_i (regarding to $(a - p_i + d p_j) > 0$) be calculated as

5. Calculating Optimal Prices

In this section we attempt to obtain the optimal prices of products in Kalleh and Solico. To do so, we first propose a lemma to prove that the profit functions

of manufacturers are concave. Then, by using this lemma we obtain the optimal prices.

Lemma. The profit function π_i^m is a concave function on p_i .

Proof. We have

$$\pi_i^m = ((1 - t_i) \times p_i - c_i^m)(a - p_i + dp_j) \tag{10}$$

We take the first and second derivatives of π_i^m as follows

$$\frac{\partial \pi_i^m}{\partial p_i} = (1 - t_i) \times (a - p_i + dp_j) - ((1 - t_i) \times p_i - c_i^m) \tag{11}$$

$$\frac{\partial^2 \pi_i^m}{\partial p_i^2} = -2 \times (1 - t_i) \tag{12}$$

From “Eq. (12)” we conclude that $\frac{\partial^2 \pi_i^m}{\partial p_i^2} < 0$. From the first-order condition of π_i^m we have:

$$\pi_1^m = ((1 - t_1) \times p_1 - c_1^m) \left(a - p_1 + \frac{1}{2} \times \frac{d \times (-a - d.p_1 + a.t_2 + t_2.d.p_1 - c_2^m)}{-1 + t_2} \right) \tag{16}$$

from the first-order condition of π_1^m (“Eq. (16)”) we have:

$$\Rightarrow p_1^* = -\frac{1}{2} \times \frac{1}{(-1 + t_2)(-2 + d^2)(-1 + t_1)} \times (2a - 2a.t_2 + d.a - d.t_2.a + d.c_2^m - 2a.t_1 + 2a.t_1.t_2 - t_1.d.a + t_1.d.t_2.a - t_1.d.c_2^m + 2c_1^m - 2c_1^m.t_2 - c_1^m.d^2 + c_1^m.d^2.t_2), \tag{18}$$

by substituting “Eq. (18)” in “Eq. (15)” we have:

$$\Rightarrow p_2^* = \frac{1}{2} \times \frac{1}{(-1 + t_2)} \times \left(-a + \frac{1}{2} \times \frac{1}{(-1 + t_2)(-2 + d^2)(-1 + t_1)} \times (d \times (2a - 2a.t_2 + d.a - d.t_2.a + d.c_2^m - 2a.t_1 + 2a.t_1.t_2 - t_1.d.a + t_1.d.t_2.a - t_1.d.c_2^m + 2c_1^m - 2c_1^m.t_2 - c_1^m.d^2 + c_1^m.d^2.t_2)) + t_2.a - \frac{1}{2} \times \frac{1}{(-1 + t_2)(-2 + d^2)(-1 + t_1)} \times (t_2.d \times (2a - 2a.t_2 + d.a - d.t_2.a + d.c_2^m - 2a.t_1 + 2a.t_1.t_2 - t_1.d.a + t_1.d.t_2.a - t_1.d.c_2^m + 2c_1^m - 2c_1^m.t_2 - c_1^m.d^2 + c_1^m.d^2.t_2)) - c_2^m \right) \tag{19}$$

by substituting p_1^* and p_2^* in “Eq. (5)” and “Eq. (6)”, we can obtain the optimal profits of Kalleh (leader supply chain) and Solico (follower supply chain).

6. Numerical Example

Amidst the varied range of products we have chosen one sausage product for the study. These kinds of products have short life cycle (about 30 days). The

$$\frac{\partial \pi_i^m}{\partial p_i} = 0, \tag{13}$$

$$\Rightarrow p_i = \frac{(1 - t_i) \times d \times p_j + a \times (1 - t_i) + c_i^m}{2 \times (1 - t_i)} \tag{14}$$

To prevent Eq. (14) to be undefined, non-zero condition should be holded for the denominator. Regarding to $0 < t_i < 1$ the denominator is not equal to zero. Thus, the profit function π_i^m is a concave function on p_i and the solution satisfying the first-order condition of π_i^m (Eq. (14)) is optimal. □

For finding the optimal prices, we will solve the Stackelberg game between the leader (Kalleh) and follower (Solico) supply chains using backward induction. Regarding to the Lemma, from the first-order condition of π_2^m (Eq. (14)), we have:

$$p_2 = \frac{(1 - t_2) \times d \times p_1 + a \times (1 - t_2) + c_2^m}{2 \times (1 - t_2)} \tag{15}$$

by substituting “Eq. (15)” in π_1^m we have:

$$\frac{\partial \pi_1^m}{\partial p_1} = 0 \tag{17}$$

demand of these products is very sensitive to price and the appropriate pricing could lead to decreasing the spoiled products and increasing the profits of supply chain partners.

Hence, the role of pricing is very vital for the supply chain. To capture the effects of product substitutability, here we assume that Kalleh and Solico are symmetric in the value of the following parameters $a = 3000, c_1^m = c_2^m = c^m = 1500, c_1^r = c_2^r = c^r = 100,$

With these values, we can consider two supply chain prices and profits as a function of the substitutability coefficient of products (cross-price effect). Figures 1 and 2 show the sensitivities of the optimal prices and supply chain profits with respect to cross-price effect parameter in Kalleh and Solico when $t_1=t_2=0.1$. In these figures, we show that cross-price effect has a positive impact on equilibrium prices and optimal profits of Kalleh and Solico. As shown in these figures, the optimal product prices and profits of follower supply chain (Solico) are higher than the leader supply chain (Kalleh) and the difference increases as substitutability coefficient of Kalleh and Solico products increases.

In this example we can observe that the follower supply chains give an advantage when the products are highly substitutable.

Figures 3 and 4 show the impact of the fraction of requested margin by retailer on the profits of Kalleh and Solico supply chains when $d=0.7$. As shown in figure 3, by increasing the retailer's margin fraction of Kalleh when $t_2=0.1$, the total profit of Kalleh begins to decrease. In figure 4, the total profit of Solico supply chain starts to increase by increasing the retailer's margin fraction of Solico when $t_1=0.1$, but then, at a certain level of retailer's margin fraction, the profit of Solico begins to decrease. Also, in these figures, the maximum profit of Solico is higher than the maximum profit of Kalleh.

This numerical example shows that under some conditions, the follower company (with weaker brand position in the market) could obtain more profit share. An example of this subject which has been seen in the recent years is the copying from the leader product for decreasing the R&D investigations by the follower company.

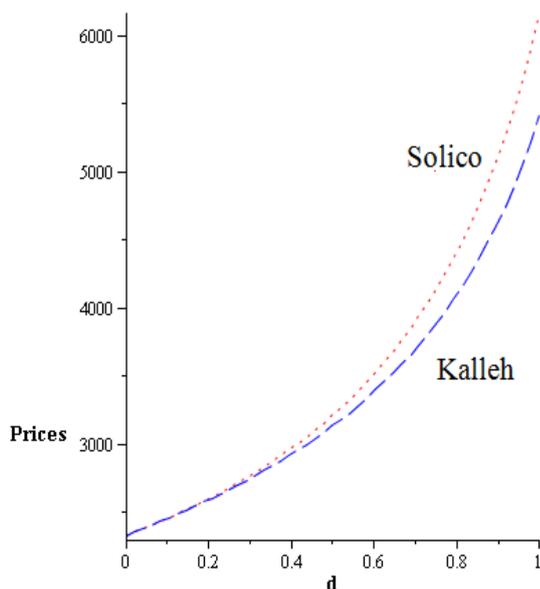


Fig. 1. The optimal prices of products of Kalleh and Solico when $t_1=t_2=0.1$

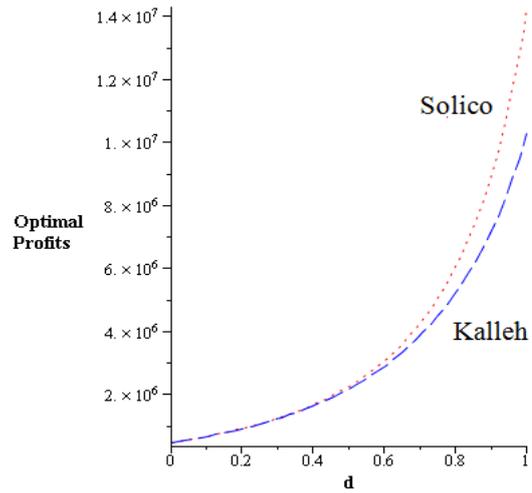


Fig. 2. The optimal supply chain profits of Kalleh and Solico when $t_1=t_2=0.1$.

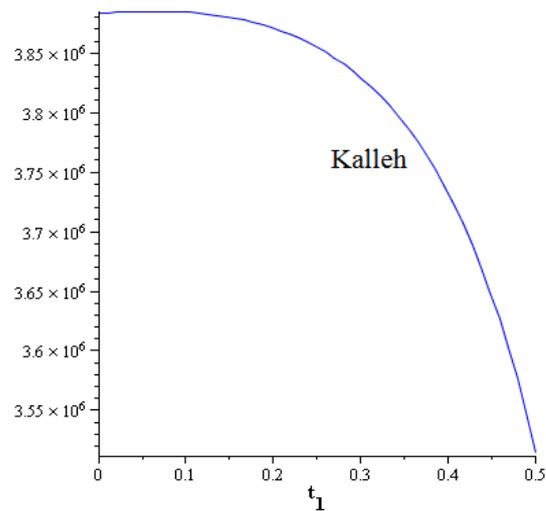


Fig. 3. Kalleh optimal supply chain profit versus the fraction of requested margin by his retailer when $t_2=0.7$

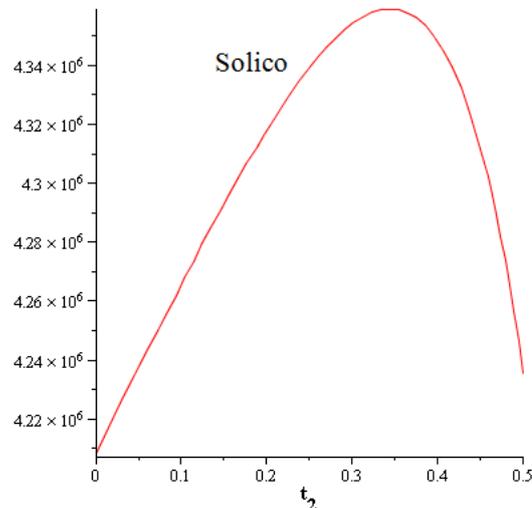


Fig. 4. Solico optimal supply chain profit versus the fraction of requested margin by his retailer when $t_1=0.7$.

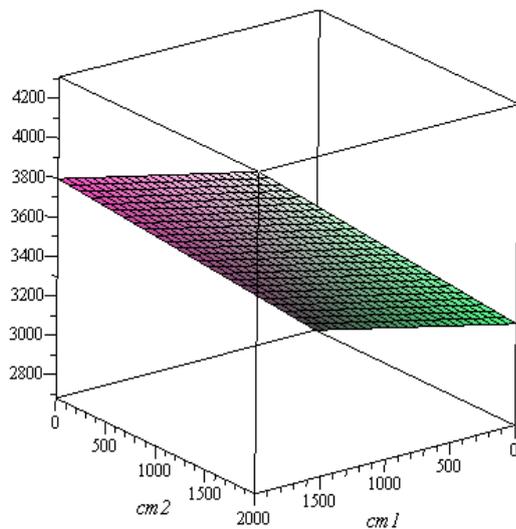


Fig. 5. The optimal prices versus production costs for Kalleh when $d=0.7$ and $t_1=t_2=0.1$.

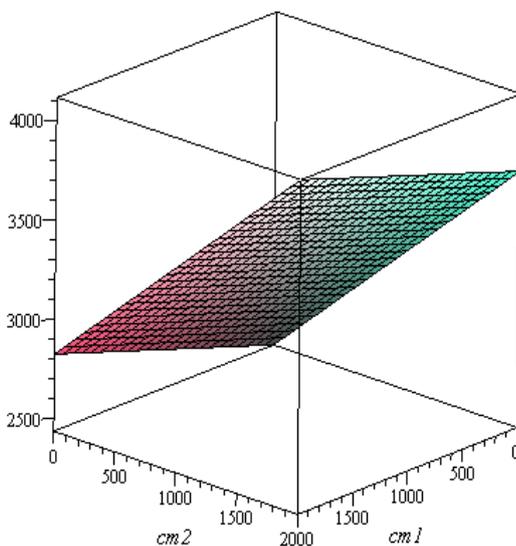


Fig. 6. The optimal prices versus production costs for Solico when $d=0.7$ and $t_1=t_2=0.1$.

Figures 5 and 6 show the sensitivity of optimal prices versus the production costs for Kalleh and Solico when $d=0.7$ and $t_1=t_2=0.1$. These figures show increasing the production costs in the leader and follower supply chain lead to the increase the prices of products.

7. Conclusions

Price competition is one of the major aspects of supply chain versus supply chain competition in real world. As a case study the competition between Kalleh Amol Meat Company and Tehran Meat Products Company (Solico) has been investigated in this paper.

These are two completely separated supply chains that compete with each other in the food industry. Kalleh has a brand advantage than Solico and hence considered as a leader supply chain. The supply chains of Kalleh and Solico each composed of a manufacturer of meat products and one sales organization (retailer). The retailer buys the products from manufacturer and gains margin as a fraction of the all income of selling products.

We study this price competition case using a two-stage Stackelberg game model and obtain the optimal prices of products. We mainly discussed the effects of varying the level of substitutability coefficient of two products on the profits of the leader and follower supply chains and showed that the follower supply chain has an advantage when the products are highly substitutable. Also, we studied the sensitivity analysis of the fraction of requested margin by retailer on the profit of supply chains.

A future research direction for this study can be the extension of it to the case with risk-averse manufacturers. As another case, investigating price competition between supply chains with other shapes of profit and demand functions can be considered.

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