Decision Science Letters 1 (2012) 69–86

Contents lists available at GrowingScience

Decision Science Letters

homepage: www.GrowingScience.com/dsl

Introducing a model for competitiveness of suppliers in supply chain through game theory approach

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A R T I C L E I N F O

Article history:
Received September 9, 2010
Received in revised format June 5, 2012
Accepted 31 July 2012
Available online
August 10 2012

Keywords:
Game theory
Supply chain
Supplier
Competitiveness

A B S T R A C T

The purpose of the present study is to introduce a model for competitiveness of suppliers in supply chain through game theory approach in one of the automobile companies of Iran. In this study, the game is based on price and non-price factors and this company is going to estimate the real profit obtained from collaboration with each of supply chain members. This happens by considering the governing competitive condition based on game theory before entering a bit for purchase of α piece as spare part among 8 companies supplying this piece as the supply chain members. According to experts in this industry, the quality is the main non-price competitiveness factor after price. In the current research models, the model introduced by Lu and Tsao (2011) [Lu, J.C., Tsao, Y.C., & Charoensiriwath, C. (2011). Competition Under manufacturer Service and retail price. Economic Modeling, 28,1256-1264.] with two manufacturers- one distributer, being appropriate for the research data, has been considered as the basis and implemented for case study and then it has been extended to n-manufacturers-one common retailer. Following price elasticity of demand, potential size of market or maximum product demand, retailer price, production price, wholesale price, demand amount, manufacturer and retailer profit are estimated under three scenario of manufacturer Stackelberg, Retailer Stackelberg and Vertical Nash. Therefore, by comparing them, price balance points and optimum level of services are specified and the better optimum scenario can be determined. Sensitivity analysis is performed for new model and manufacturers are ranked based on manufacture profit, Retailer profit and customer satisfaction. Finally, in this research in addition to introducing N-person game model, customer satisfaction, which has been presented in the previous models as a missed circle are analyzed.

1. Introduction

Sometimes due to unfamiliarity with cooperative perspectives (collaboration/ competition) and non-collaborative, also lack of strategic situation and non-existence of proper scenario, the profit of every member and the whole chain will be endangered. In many cases it is observed that the winner/s of an agreement like bid and auction don't satisfy the expectations of the end user at the time of advancing the project, the consequences of which lead to loss of the partners. The reason why some companies

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doi: 10.5267/j.dsl.2012.08.001

become unipolar, especially in strategic industries, is the removing of small institutions which if entered into their industry's supply chain based on correct criteria, their stability in supply chain would be guaranteed. The base of this research by considering non-concentrated supply chain with manufacturer, retailer and customer structure is to provide a model for determining the competitiveness of suppliers in supply chain and how to penetrate in them after entering the chain. In what follow, some of the main researches related to the subject are introduced. Tsay and Agrawal (2000) investigated distribution system in which the manufacturer distributes the common product to two main wholesalers.

Demand is definite and depends on wholesale prices and services. In this paper it is illustrated that the competition density plays a significant role based on each dimension of competition which is similar to partnership between wholesalers. They investigated a supply chain with one manufacturer and two retailers under competitive factors of services and price. In this survey, the retailers offer some services to customers in addition of selling products. The researchers investigate the effect of competition on prices, services and interests and determine coordination mechanism for supply chain. In year 2000, so has investigated the guarantee of delivery time as the competitive factor of supply chain members.

Hall and Porteus (2000) investigated the capacity of services to customers as the competitiveness factor of supply chain members. Vilcassim et al. (2000) explained the collaborations of wholesale-manufacturer channels and the implications related to channel power. They proved that high profit rate in the channel is related to more power of channel. Boyaci and Ray (2003) investigated the role of capacity costs in shaping optimum distinguishing strategy in Seller Company for two different models of the same product, one is special and the other is ordinary and common. Delivery time is a service factor which has been considered beside general cost based on decisions related to distinction. Boyaci and Gallego (2004) have considered one market with two competitive supply chains; each one includes a retailer and a wholesaler. Costumer service is the considered competitive item.

Boyaci and Gallego (2004) define services level as fill-rate or deficit of customers whose demands don't face deficiency. They have analysed two supply chains, each has one manufacturer and one retailer, under competitive factor of service level of inventory policy. In this paper, some insurance companies with various risks contracts have been selected in such a way that if one of them is in need for prevention of bankruptcy, other companies work more seriously and agree upon it, and any deficiency is supplied from external sources for a short time. This model has been investigated under insurance network and solved as a limited multi-person dynamic game and through Nash equilibrium; and within a certain condition it transfers to a unique Nash equilibrium. In their study entitled "Using Game Algorithm in Buyer, Seller Supply Chain" Esmaeili et al. (2009) has used different models as cooperative and non-cooperative approaches and considered cost competitive factor and estimated non-cooperative game through Stackelberg strategy and cooperative games through Pareto efficient method. The abovementioned calculations have been done in two conditions of Seller- Leader, Buyer- Follower and vice versa.

Esmaeili, and Zeephongsekul (2010) in their paper entitled "Seller buyer models of supply chain management with an asymmetric information structure" have determined the relation between seller and buyer in supply chain with non-collaborating Stackelberg game, while the buyer is leader and the seller is follower and conclude that some factors including: organizational structure of sellers, purchase price, unknown and unpredictable factors related to buyers and unknown information have meaningful difference with market demand. Since this competition has been investigated both by confirming the desirability of lost Pareto of each company and by confirming desirability of lost Pareto of all companies.

2. **Statement of the problem**

Lack of strategic situations and proper knowledge of market, non- existence of related scenario with industry status and lack of awareness of cooperative and non- cooperative perspectives which exist in supply chains in the competitive world of today, endanger the profit and profit of every member and the whole chain. Weak awareness of many entrepreneurs, suppliers and manufacturers of considered industry's competitive factors, unfamiliarity of suppliers from structure and perspective of supply chain, not constant penetration of suppliers to supply chain after entering it, lack of attention of supply chain members to the customer satisfaction and lack of practical investigation and studies about game theory in the country made this study to be as a pattern for other supply chains to increase their competitive power by using this theory and extending other models in supply chain specially in automobile company as a case study. Since the model provided by Lu and Tsao (2011), whose supply chain includes two manufacturers- one common distributor, is the basis of this study. However, due to the fact that in today competitive market, a model should be proposed in which n manufacturers could simultaneously compete with one another, and the optimum values for every member could be calculated simultaneously and the whole chain could reach equilibrium. This study is going to develop the proposed model. Of the weaknesses of previous models is that they don't refer to criteria based on which manufacturers are prioritized. So the significance of knowing method, identifying and prioritizing high- profit achieving manufacturers before entering the chain is very important that should be considered. One of the other main points which can be regarded as a missed circle in the previous studies is not paying attention to the role and significance of customer satisfaction which will be discussed hereafter. This paper is consisted of four main sections:

First section: in this study, first game strategies of this research will be briefly discussed and then the fundamental model estimated by Lu and Tsao (2011) will be introduced.

Second section: due to weaknesses, especially in operational execution of the model, the way the model has been developed will be discussed and the relations of developed model will be compared with the present model.

Third section: to make sure of the developed model in making proper management decisions in the supply chain and finding optimum points, sensitivity analysis has been estimated against the change of industry parameters.

Fourth section: customer satisfaction or end user has been considered for final ranking of manufacturers.

For testing the efficiency of developed model in a real industry, implementation of model in one of the automobile industries of Iran and 8 dependent supplier companies have been done.

3. Game Strategy

Game theory or competitive strategy is a theory which relates to competitive situations where two or more organizations with different goals are going to make decision. The basis of game theory is on min-max principle, based on which each competitor acts in a way that minimizes his maximum loss. The considered game in this research is dynamic game; in this study balanced solutions for supply chain are calculated and compared based on three main hypothesis of bargaining power. When the retailer has more bargaining power, it can purchase the product with lower price from manufacturer and deliver it to customer with higher price. So in this situation, the profit of manufacturer decreases and predicted profit of retailer increases.

This point is very important that the role of bargaining power of retailers/ distributors to be investigated on interest, demand and balanced prices functions. Bargaining power issue can have a significant effect on balanced and optimum points of price and interest, e.g. Choi (1991). For this purpose, in this study the following three indices are used: Manufacturer Stackelberg, Retailer Stackelberg (RS) and Vertical Nash (VN). Recognizing which chain element has more bargaining power is the determiner of follower- leader in models. As mentioned, theories in the market indicate high bargaining power of retailers in general and overall situation. In manufacturer-retailer collaboration as Stackelberg game, one of the leader partners starts and can encourage its strategy on the follower and continue the game. The leader does the first move and the follower, by doing the best proper move, reacts. The leader goal is to design its move in such a way that it can maximize its income after considering all reasonable movements that the follower can do Esmaeili, Zeephongsekul (2009).

3.1 Definition of variables

a_j, a_i: the market of product manufacturer i and potential of the market or the maximum product demand even if the product price is considered zero. It is assumed that this value is big enough that prevents Q_i from becoming negative.

b_p:Market demand sensitivity toward price of product *i*

θ_p: Market demand sensitivity to price difference of product *i*

b_s: Market sensitivity to the services which manufacturer provides

θ_s: Market sensitivity to services differences

p_j,p_i, retailer prices of products *i, j*

s_j, s_i: Service level related to manufacturers of products *i* and *j* (one of the prior competitive factors)

c_j, c_i: cost of *i,* product manufacturing

3.2 Estimation of demand function

There are three hypotheses here: (Tsao, 2011)

First hypothesis: first the demand structure between two products is asymmetrical

Second hypothesis: decrease of retailing price or increase of service level is the result of two phenomena: first, group of costumers decide not to buy other products. Second, a group of costumers stop purchasing temporary and in case of price decrease or service level increase, they get ready to repurchase it.

Third hypothesis: each part of supply chain is going to maximize their interests and in case they have proper information from market demand or cost structure, they behave reasonably.

In this case the demand function of product *i* will be as follow:

$$Q_i(p_i, p_j, s_i, s_j) = a_i - b_p p_i + \theta_p(p_j - p_i) + b_s s_i - \theta_s(s_j - s_i). \tag{1}$$

where $a_i > 0, b_p > 0, b_s > 0, \theta_s > 0, i = 1,2,$ and $j = 3 - i.$

This equation is like demand function found by Tsay and Agrawal (2000). However, the difference of their works is in the number single manufacturer.

In case of constant reaction on part of manufacturers and retailers, the market size doesn't change with θ_s, θ_p change. So in this condition, the above equation can be written as:

$$Q_i(p_i, p_j, s_i, s_j) = a_i - b_p p_i + \theta_p p_j + b_s s_i - \theta_s s_j \tag{2}$$

4. The Proposed model

Although the relations and formula to which Jye-chyi, Yu-Chung (2011) referred in their paper has high precision in determining the priority of manufacturers, there are some weaknesses in their paper. For example, considering the fact that markets are competitive, it seems improbable to find a chain with two members, where just two manufacturers compete. If the real market is considered with more than two manufacturers and it is decided to use the above model for evaluation and comparison of manufacturers, since the comparison is done between pairs and in each comparison other manufacturers are not present anymore, it is not possible to determine the equilibrium condition of market, wholesale cost, retail price and service level in a way that the whole chain is balanced.

So a model should be proposed in which n manufacturer can compete simultaneously, and optimum values can be calculated for every member and the whole chain find equilibrium. In 2- person game, since the comparison is done in pair wise and in each comparison other manufacturers are not partner, it is not possible to determine market equilibrium situation, wholesale price, retailer price and service level in such a way that the whole chain is in balance. So it seems that solving chain model with n-manufacturers (n=8) and one distributor is important, this section of case study is new and almost it is not in other studies. This method is called "Simultaneous Method", and 2-person game formulas and hypothesis constitute the base of n-person game. In order to develop and extend the game with two manufacturers- one common distributor to n manufacturer- one distributer and extracting game model, it is necessary to add another hypothesis to Lu and Taso (2011) model:

Fourth Hypothesis:

The fourth hypothesis assumes that those customers who turn from i manufacturer to others, as well, might choose j manufacture to the same degree. So

$$\sum_{j \neq i} \theta_p p_j / (n-1) - \sum_{j \neq i} \theta_s s_j / (n-1) \tag{3}$$

Is added to obtained demand function from three previous hypotheses. In other words, those customers who have turned away from j^{th} manufacturer due to price increase are divided between other manufacturers equally.

4.1. Demand Function

Considering related literature to the subject and the problem, one can rewrite the demand function for each manufacturer as follow:

$$Q_i = a_i - (b_p + \theta_p)p_i + \sum_{j \neq i} \theta_p p_j/(n-1) + (\theta_s + b_s)s_i - \sum_{j \neq i} \theta_s s_j/(n-1) \quad i = 1, 2, 3, 4, \dots n \tag{4}$$

Definitions of all variables are exactly the same as demand function of the model with two manufacturers- one common retailer/ distributor. However, some points should be mentioned about these definitions in comparison with previous definitions, in definition of $\theta_p$which is indicative of customers' incline toward other manufacturers, in case the manufacturing cost's increase is just one unit, these customers don't leave the chain and just move from one manufacturer to other. Also, in b_s definition which expresses the dependability of demand on service level, if the manufacturer increases and promotes the level of services one unit, its demand increases b_s units (this customer is of the other manufacturers' customers). $\theta_s$is demand increase value against one unit increase in service level, this demand results from other manufacturers' customer incline toward this manufacturer. In this section, like the previous one, it is assumed that demand increase results equally from other manufacturers' demand.

4.2 Profit Function for Manufacturers:

It is assumed that manufacturing cost of product for each manufacturer is c_i, and the wholesale cost of selling to retailer is w_i. Furthermore , in order to increase service level to *i/2* and based on quadratic function, investment should be done based on s_i. Profit function for *i* manufacturer is provided by the below equation:

$$\Pi_{M_i} = (w_i - c_i)Q_i - \frac{\square_i s_i^2}{2} i = 1, 2, 3, 4, \dots n \tag{5}$$

4.3 Profit function for retailer

In case the manufacturer purchase the product by wholesale price of w_i from manufacturer and sell it to customer by p_i, Retailer profit can be calculated as follow:

$$\Pi_R = \sum (p_i - w_i)Q_i, i = 1, \dots, n \tag{6}$$

$$I\Pi_R = \sum \left(p_i - w_i(p_i, p_j, \dots, p_l)\right) Q_i(p_i, p_j, \dots, p_l) \tag{7}$$

4.4 Manufacturing Stackelberg Game

4.4.1 Decisions and Retailer Response Function

First the retailer/ distributor, assuming to know wholesale price and service level of each one of n manufacturers, determines retailing cost in such a way that it can optimize its profit function.

$$p_i^* \in argmax_{p_i} \Pi_R\left(p_i, p_j^*, p_k^*, \dots, p_l^* \middle| w_i, s_i, w_j, s_j, \dots, w_l, s_l\right) \tag{8}$$

In a way that $\Pi_R\left(p_i, p_j^*, p_k^*, \dots, p_l^* \middle| w_i, s_i, w_j, s_j, \dots, w_l, s_l\right)$ is retailer profit when retail costs of P_i, P_j,P_k … have been determined based on the manufacturers' decisions which are $w_1, w_2.., s_1, s_2$.

$w_1, w_2.., s_1, s_2$values are simultaneously offered to retailer by manufacturers. Then in the next stage the following function is determined and constructed:

$$II_R = \sum_{i=1}^{i}(p_i - w_i)\left(a_i - b_p + \theta_p\right)p_i + \sum_{j\neq i}\theta_p p_j/(n-1) + (\theta_s + b_s)s_i - \sum_{j\neq i}Q_s S_j/(n-1)) \tag{9}$$

$$i = 1, 2, 3, 4, \dots n$$

After constructing the above function, optimum status of order or first stage differential, is determined:

$$0 = \frac{\partial II_R}{\partial_{P_i}}, 0 = \frac{\partial II_R}{\partial_{P_j}}, 0 = \frac{\partial II_R}{\partial_{P_k}}, \dots 0 = \frac{\partial II_R}{\partial_{P_l}} \tag{10}$$

In order to compute P vector in the above equation, it suffices to take the partial differential of $\Pi_R$with respect to p, so by solving the obtained equations the optimum expression for p will be obtained. The obtained expression depends on w and s, by substituting it in Q, demand can be expressed as a function of s and w. For optimality analysis, Hessian matrix assuming $b_p > 0$ and$\theta_p > 0$. Then response function of retailer will be obtained by optimum status of first and second orders.

4.4.2 Manufacturer's decisions

After determining retailer's response function, it is possible to estimate wholesale optimum cost and optimum level of service delivery of manufacturers. Here according to the principles of manufacturer Stackelberg game, after estimation of retailer response function *i* manufacturer selects wholesale price W_i* and service level S_i* for maximization of his own interest. Considering the fact that manufacturers act and decide simultaneously, we have Nash point here in this status:

$$w_i^* \in argmax_{w_i}\Pi_{M_i}\{w_i, w_j^*, w_k^*, \dots, w_l^*, s_i^*, s_j^*, s_k^*, \dots, s_l^*\} \tag{11}$$
$$s_i^* \in argmax_{w_i}\Pi_{M_i}\{w_i^*, w_j^*, w_k^*, \dots, w_l^*, s_i, s_j^*, s_k^*, \dots, s_l^*\} \tag{12}$$

While $\Pi_{M_i}\{w_i, w_j^*, w_k^*, \dots, w_l^*, s_i^*, s_j^*, s_k^*, \dots, s_l^*\}$ means profit function of manufacturer *i*, when manufacturers have determined wholesale price in w_i, $, w_j, w_k$…values and service level in S_i, S_j, ….

Then, in the next stage, the following function is constructed:

$$II_{M_i} = (W_i - C_i)Q_i\left(p_i, p_j, \dots, p_1, s_i, s_j, \dots s_1\right) - \frac{\eta_i s_i^2}{2} \tag{13}$$

After constructing the above function, the derivations of first stage or optimum status of the order is constructed:

$$\frac{\partial II_{M_i}}{\partial_{w_i}} = 0, \frac{\partial II_{M_i}}{\partial_{s_i}} = 0, \frac{\partial II_{M_J}}{\partial_{w_j}} = 0, \frac{\partial II_{M_j}}{\partial_{s_j}} = 0, \dots, \frac{\partial II_{M_l}}{\partial_{w_l}} = 0, \frac{\partial II_{M_l}}{\partial_{s_l}} = 0 \tag{14}$$

In order to calculate the optimum value of wholesale price $w_i$and S_i by using optimum status of first and second order, the response function of manufacturer is produced. For optimality analysis, Hash matrix is examined assuming $\theta_p > 0$ and $b_p > 0$. In order to obtain the above optimum values, first take referential of $\Pi_{M_i}$with respect to s and w, and by solving the resulting equation, their optimum values are computed. The procedure of doing calculation is exactly the same as 2- person games.

4.5 Retailer Stackelberg game

4.5.1 Decisions and response function of manufacturer:

Every manufacturer tries to maximize its interest:

$$II_{M_i} = (W_i - C_i)Q_i(p_i, p_j, \dots, p_1, s_i, s_j, \dots, s_1) - \frac{\eta_i s_i^2}{2} \tag{15}$$

$$p_i = W_i + A$$

A: desirability which is called Retailer profit, this desirability is per manufacturer i.

$$i = 1, 2, 3, 4, \dots n$$

In order to win in this competition, manufacturer *i* selects wholesale price w_i and service level S_i such that it can maximize its profit function. So for each manufacturer *i* we have:

$$w_i^* \in argmax_{w_i} \Pi_{M_i}\left(w_i, s_i^*, w_j^*, s_j^*, \dots, w_l^*, s_l^* \middle| p_i, p_j, \dots, p_l\right), \tag{16}$$
$$s_i^* \in argmax_{s_i} \Pi_{M_i}\left(w_i^*, s_i, w_j^*, s_j^*, \dots, w_l^*, s_l^* \middle| p_i, p_j, \dots, p_l\right), \tag{17}$$

where $\Pi_{M_i}\left(w_i, s_i^*, w_j^*, s_j^*, \dots, w_l^*, s_l^* \middle| p_i, p_j, \dots, p_l\right)$ expresses the profit of *i* manufacturer in this stage. Wholesale price w_1, w_2, …and service level s_1 , s_2, … are calculated based on earlier decisions of retailer on retail price p_1 , p_2, …. In this scenario, first the manufacturer maximizes its profit assuming that he knows the retailer's cost and calculate *s* and *w* vectors as a function of retailer's cost. In order to calculate optimum vectors of *s* and *w*, the partial differential of $\Pi_M$in respect to*w* and *s* is calculated as follow:

$$0 = \frac{\partial II_{M_i}}{\partial w_i} = Q_i + (w_i - c_i)\frac{\partial Q_i}{\partial p_i}\frac{\partial p_i}{\partial w_i}$$
$$0 = \frac{\partial II_{M_i}}{\partial s_i}, \quad 0 = \frac{\partial II_{M_i}}{\partial w_j}, \quad 0 = \frac{\partial II_{M_j}}{\partial s_j}, \dots, 0 = \frac{\partial II_{M_l}}{\partial w_l} \quad , \quad 0 = \frac{\partial II_{M_l}}{\partial s_l} \tag{18}$$

After solving the equation, optimum values for *s* and *w* are obtained. For optimality analysis, Hash matrix is investigated assuming $\theta_p > 0$ and $b_p > 0$.

4.5.2. Decisions and response function of retailer

Having the information related to response function of manufacturer, the retailer can maximize its interest.

$$\Pi_R = \sum \left(p_i - w_i(p_i, p_j, \dots, p_l)\right) Q_i(p_i, p_j, \dots, p_l) \tag{19}$$

$$II_R = (p_1 - w_1(p_1, p_2, \dots, p_l))\, Q_1(p_1, p_2, \dots, p_l) + \left(p_2 - w_2(p_1, p_2, \dots, p_l)\right)Q_2(p_1, p_2, \dots, p_l) + \cdots$$

$$+\left(p_l - w_l(p_1, p_2, \dots, p_l)\right)Q_l(p_1, p_2, \dots, p_l)$$

In this game the retailer should select the retailing cost of p_1^*, p_2^*, … by maximizing its interest. So we have:

$$p_i^* \in arg\max_{p_i} II_R\left(p_i, p_j^*, \dots, p_l^*\right) \tag{20}$$

In such a way that $II_R\left(p_i, p_j^*, \dots, p_l^*\right)$ is the Retailer profit with retail price of p_1, p_2, … in this stage. By solving first degree differential equation $\Pi_R$in respect to$p$ vector, it is possible to calculate wholesale optimum price for distributor/ retailer as follow:

$$0 = \frac{\partial II_R}{\partial_{p_i}} = \tag{21}$$

$$\left(1 - \frac{\partial w_i(p_1, p_2, \dots, p_l)}{\partial_{p_i}}\right)Q_i(p_1, p_2, \dots, p_l) + \left(p_i - w_i(p_1, p_2, \dots, p_l)\right)\frac{\partial Q_i(p_1, p_2, \dots, p_l)}{\partial_{p_i}} +$$

$$\left(-\frac{\partial w_j(p_1, p_2, \dots, p_l)}{\partial_{p_i}}\right)Q_j(p_1, p_2, \dots, p_l) +$$

$$\left(p_j - w_j(p_1, p_2, \dots, p_l)\right)\frac{\partial Q_j(p_1, p_2, \dots, p_l)}{\partial_{p_i}} + \dots + \left(-\frac{\partial w_l(p_1, p_2, \dots, p_l)}{\partial_{p_i}}\right)Q_l(p_1, p_2, \dots, p_l) +$$

$$\left(p_l - w_l(p_1, p_2, \dots, p_l)\right)\frac{\partial Q_l(p_1, p_2, \dots, p_l)}{\partial_{p_i}}$$

$$0 = \frac{\partial II_R}{\partial_{p_i}} \quad , \quad 0 = \frac{\partial II_R}{\partial_{p_k}}, \dots, \quad 0 = \frac{\partial II_R}{\partial_{p_1}} \tag{22}$$

For optimality analysis, Hash matrix is investigated assuming $\theta_p > 0$ and $b_p > 0$.

4.6 Nash Equilibrium

In Nash Equilibrium scenario manufacturer and retailer has simultaneous effect on chain decisions in a way that everyone can maximize its profit by having knowledge of competitor strategy. In this condition, the decisions affect one another continually and decision makers seek to find an equilibrium point for decision making. In game theory this point is called Nash Equilibrium point.

Response function of retailer for wholesale price w_i,w_j, w_k, …and service level s_i, s_j, s_k,… is obtained from manufacturer's Stackelberg and response function of manufacturer including optimum wholesale price and service level is obtained from retailer Stackelberg.

Simultaneous solving of the abovementioned equation which will be referred to later provides Nash solution. In other word, in order to calculate Nash equilibrium point, partial differential of Π_M vector should be calculated in respect to s and w vector and $\Pi_R$in respect to p and simultaneously solve the equation related to first degree differential:

$$w_i^* \in argmax_{w_i} \Pi_{M_i}\{w_i, w_j^*, w_k^*, \dots, w_l^*, s_i^*, s_j^*, s_k^*, \dots, s_l^*, p_i^*, p_j^*, \dots, p_l^*\} \tag{23}$$
$$s_i^* \in argmax_{s_i} \Pi_{M_i}\{w_i^*, w_j^*, w_k^*, \dots, w_l^*, s_i, s_j^*, s_k^*, \dots, s_l^*, p_i^*, p_j^*, \dots, p_l^*\} \tag{24}$$
$$p_i^* \in argmax_{p_i} \Pi_R\{w_i^*, w_j^*, w_k^*, \dots, w_l^*, s_i^*, s_j^*, s_k^*, \dots, s_l^*, p_i, p_j^*, \dots, p_l^*\} \tag{25}$$

For optimality analysis, Hash matrix will be examined assuming $\theta_p > 0$ and $b_p > 0$.

When manufacturers have the most bargaining power, customers received the least services. Furthermore the above equation show that the best discount for customers is when there is no dominant power between retailers and manufacturers.

5. Sensitivity analysis of developed model

For making proper decisions to compete with competitors in the market, one should investigate response sensitivity to studied parameters and found optimum points for break-even of manufacturers. In this section, sensitivity analysis of the responses in n-person game will be investigated "considering the information related to 8 supplying companies in software program for n=8). Since in all previous models, equilibrium profit of the chain (including manufacturers and retailer/ distributor) in Nash equilibrium had the maximum values, this analysis is done for Nash equilibrium model.

Range of changes for a is$\bar{a} \pm 2\sigma_a$and for c is $\bar{c} \pm 2\sigma_c$ and has been divided to 10 points.

5.1 Sensitivity analysis of manufacture profit in respect for "a" changes

The curve related to changes in manufacturers' profit in respect to changes in the market basis for A manufacturer will be investigated as a sample. The change curve indicates that increase in market basis leads to profit increase for all manufacturers. This increase for the manufacturer whose market basis has increased is much more than others. By increase of *a* for each manufacturer its profit increases, so increase in the profit for other manufacturers is due to increase in the number of those customers who turn from market basis toward other manufacturers due to sensitivity to cost and services. This leads to increase in the manufacturers' interest. This decision might be welcomed much in managerial level in such a way that each manufacturer, assuming the constant level of competitors' market, can reach its economic level of market basis by increasing the scope of its own market.

$$0 < \frac{\partial II_{M_j}}{\partial a_i} < \frac{\partial II_{M_i}}{\partial a_i} \qquad\qquad i = 1, 2, 3, 4, \dots n \tag{26}$$

5.2. Sensitivity analysis of manufacture profit in respect to change in c

The change curve related to manufacturers' profit in respect to changes in manufacturing costs for manufacturer A will be investigated as an example. The change curve indicates that decrease in manufacturing cost lead to increase in profit for manufacturer. While the profit for other manufacturers decrease in this situation. This change is much more for the manufacturer whose manufacturing cost has decreases. However, it is not improbable that by decrease of *c* for each manufacturer the profit increases, so decrease in profit for other manufacturer is due to increase in the number of customers who have leaved the other manufacturers due to price sensitivity and services and join the intended manufacturer. This diagram can be considered as a strategy to overcome the competitors. This decision can be welcomed in managerial level to a great extent; this level is significant in that decrease in production costs raise other costs, which some manufacturers are not able to pay these costs in the highest level.

$$0 < \frac{\partial II_{M_j}}{\partial c_i} < -\frac{\partial II_{M_i}}{\partial c_i} \qquad i = 1, 2, 3, 4, \dots n, \tag{27}$$

5.3 Sensitivity analysis of Retailer profit in respect to changes in a

Profit sensitivity graph for the market changes of manufacturer A has been investigated as an example. Retailer's/ distributor's profit increases with increase in market basis the same as manufacture profit. Increase in market basis results in increase in Retailer profit due to collaboration with other manufacturers, which happens in two ways:

1. Increase in profit due to increase of retailing cost: although wholesale price of manufacturer increases following increase in market basis and demand increase, but due to increase in services' level for making equilibrium in game the distributor is able to increase the retailer's price increase more powerfully. Consequently, the value of $(p_i - w_i)$ increases.
2. Increase in profit due increase of sale volume: certainly, increase in market basis influence sale volume to a great extent and increases it. Retailer's/ distributor's profit is also an ascending function of sale volume.

Sensitivity analysis done can be regarded as one of competitive decisions of manufacturers.

$$0 < \frac{\partial II_R}{\partial a_i} i = 1, 2, 3, 4, \dots n \tag{28}$$

5.4 sensitivity analysis of Retailer profit in respect to changes in c

Certainly the retailer profit increases due to decrease in manufacturing costs as a result of decrease in wholesale costs. So, in order to preserve its status within retailer and improve its competitive position, the manufacturer should seek to decrease manufacturing costs. This process can help competitive advantages of manufacturer more than increase in market basis. Since in this condition, profit for other manufacturers has been decreasing which leads to improving of competitive status of the manufacturer. Profit decrease of other manufacturers is mostly related to decrease in their demand, since the intended manufacturer got more demand rather than its competitors by decreasing wholesale costs.

$$\frac{\partial II_R}{\partial c_i} > 0 \qquad i = 1, 2, 3, 4, \dots n \tag{29}$$

6. Customer Satisfaction

Of the main weak points in previous studies, ignoring of customer satisfaction in supply chain can be accounted which is like a missed circle in the related literature. How customer satisfaction is defined and how game theory uses customer satisfaction in prioritizing manufacturers are the focus of the present study.

6.1 Measuring customer satisfaction

In order to measure customer satisfaction, a model or a method should be designed with an organized infrastructure and some indices should be considered through which it becomes possible to measure customer satisfaction. According to the researchers in economic sciences, the methods for measuring customer satisfaction are divided to 1. objective and 2. Conceptual or theoretical. Due to validity of theoretical method in comparison with objective method, in this study it is preferred to make use of customers' view in measuring customer satisfaction. In order to have access to criteria for measuring customer satisfaction the following steps have been considered:

First step: in the present study in order to identify competitive factors, the key criteria are extracted from recent studies and are listed as follows.

Delivery terms and time, technical ability of supplier, previous performance of supplier, after sale services, supplier reputation, financial status of supplier, manager's view, product cost, current and future production capability, credit and guarantee, supplier's speed in improvement and development, qualitative level of product, supplier organizational resources, supplier's geographical position, educational services' offering by supplier, supplier communicative system, advertisement

Second step: For identification of effective factors on competitiveness among the above mentioned factors in the automobile industry, by having a statistical hypothesis first a sample consisting of 105 subjects have been randomly selected through questionnaires. Then by quadratic test and statistical data analysis obtained from filled questionnaires, and in case the test being meaningful for negative and positive comments (p-value< 0.05) it was concluded that the intended factor is effective from respondents' point of view.

Based on the results of this test, 6 factors have been extracted among 20 factors as being effective on customer satisfaction issue.

- Delivery term and time t
- After sale services q
- Product cost p
- Qualitative level of the product ss
- Credit and guarantee g
- Advertising m

Non-price factors are defined as follow: quality level of the product, delivery time and term, after sale services, credit and guarantee type and finally advertisement.

Third step: In what follows, customer satisfaction measurement requires finding the weight and value of effective criteria obtained from previous step by the customers themselves.

In order to prioritize these criteria, paired comparison matrix is used. For this purpose a questionnaire has been designed based on priority comparison from respondents' point of view and then for determining the final weight of criteria, group decision matrix has been constructed. And for determining incompatibility of weights in this matrix, incompatibility calculation has been done.

Forth step: In this comparison, the ratio of customer satisfaction is considered for n-person game as a result. Customer satisfaction is calculated from the following formula for each subject:

$$w_1\left(p_i/\sum p_i\right)+w_2\left(ss_i/\sum ss_i\right)+w_3\left(t_i/\sum t_i\right)+w_4\left(q_i/\sum q_i\right)+w_5\left(g_i/\sum g_i\right) + w_6\left(m_i/\sum m_i\right)+1 \qquad (30)$$

w_n: weight of criteria

6.2. Sensitivity analysis toward customer satisfaction in n-person games

In all markets demand is considered as the driver force. Manufacturers seek to get customers' satisfaction. In sensitivity analysis of game, customer has been viewed in terms of irritability toward price and services. In other word, customer is able to change the game just by changing demand. The customer has never been seen directly along with price decrease or services increase. However, sensitivity toward price and services enter the costumer to the game to some extent. In what follows, more attention is focused on analyzing customer's decision to determine whether he shows sensitivity toward changes the same as two decision makers (manufacturer and retailer) or not. In this section, sensitivity analysis of responses in n-person game has been studied (considering the data related to 8 supplier companies in related software for n=8). Since in all previous models, chain balanced profit (including manufacturers and distributor) has the maximum effect in Nash equilibrium scenario, this analysis is done for Nash equilibrium. Customer satisfaction is calculated based on the expression which has previously been provided. Range of changes for ***a*** is $\bar{a} \pm 2\sigma_a$ and for ***c*** is $\bar{c} \pm 2\sigma_c$ and it is divided into 10 points.

6.2.1. Sensitivity analysis of customer satisfaction in respect of changes in a

Since customer satisfaction is a relative comparison between manufacturers, increase in satisfaction toward one manufacturer certainly leads to decrease of relative satisfaction for other manufacturers (although price and service level for other manufacturers improves individually, since the growth speed toward the manufacturer whose market basis is increasing is much lesser, it shows relative change of decrease). This graph is mostly significant for the manufacturer in order to preserve its competitive position in the market in customer's view.

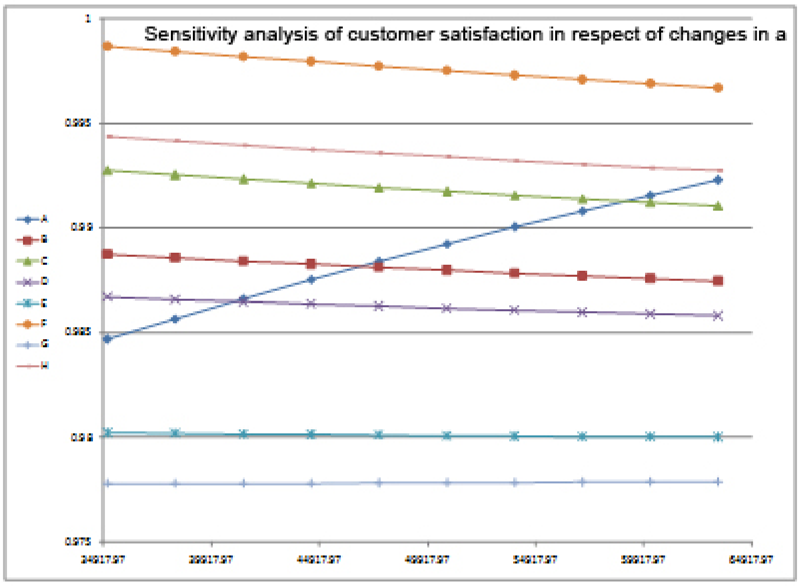

Fig.1. Change in customer satisfaction toward change in market basis for manufacturer A in Nash equilibrium

6.2.2. Sensitivity analysis of customer satisfaction toward changes in c

Change in customer satisfaction in the condition where manufacturer reduces its production cost, lead to improve in its competitive condition more than increase in market basis. This is certainly due to the fact that in this condition, by reducing production costs the manufacturer simultaneously doesn't lead to improvement of other competitors. While in previous analysis the increase of market demand improved competitive condition of competitors to a lower extent.

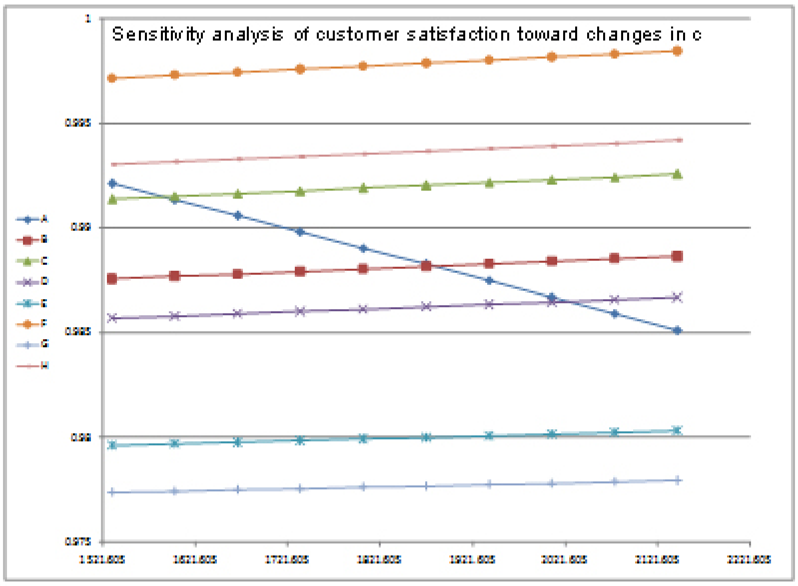

Fig.2. Change in customer satisfaction in respect to changes in manufacturing costs for manufacturer A in Nash equilibrium

7. Case study of game theory based on competition in supply chain with n manufacturers- common retailer (simultaneous)

7.1 Data related to case study

Table1
Data related to α piece

Manufacturer	Coefficient of services cost	Manufacturing cost of product	Market	Cost		Services level	Market sensitivity toward			
				Retailer	Wholesale		Cost	Cost difference	Services	Services difference
	η_i	C_i	a_i	p_i	w_i	S_i	B_p	Θ_p	B_s	θ_s
A	1000	2000	42000	4500	2800	15	8	6	5	4
B	1200	1800	58000	5000	3000	15	8	6	5	4
C	1100	1750	60000	4500	2800	10	8	6	5	4
D	1050	2100	49000	4500	3000	6	8	6	5	4
E	1600	1800	45000	4520	2800	15	8	6	5	4
F	800	1900	50000	4200	3000	16	8	6	5	4
G	2000	1700	40000	4500	2500	5	8	6	5	4
H	1000	1650	50000	4200	3000	10	8	6	5	4

For simplicity, each of non-price factors can be used for determining service level. Service level (s) is of the main factors which has a significant role in customers' decisions in supply chains. Considering the limitation of information, just it was possible to have access to information in quality level. So in following case study service level in game means quality. That is, manufacturing high quality product is considered a competitive advantage. After solving the model, manufacturers are ranked according to three criteria of retailer/ distributor's interest, customer satisfaction and manufacture profit. In addition, customer satisfaction is considered in the model and will be regarded as the basis of decision making when selecting suppliers.

1. Based on manufacturing interest: in this comparison, the manufacture profit for n- person game is regarded as the result.
2. Based on customer satisfaction: in this comparison, the ratio of customer satisfaction for n-person game is regarded as a result. Customer satisfaction is calculated by Eq. (30) for each subject. Considering the fact that among non-price factors, just quality information is available, we have:

$$w_1\left(p_i/\sum p_i\right)+w_2\left(s_i/\sum s_i\right)+1 \tag{31}$$

where w_1 is cost weight and w_2 is service weight for customer which is quality.

3. Based on retailer interest: in this comparison the profit that the distributor obtains from each manufacturer is regarded as a result for n- person game.

7.2 Weighting and prioritizing the effective factors on competitiveness in supply chain in automobile company

In order to weight and prioritize the effective factors on competitiveness in supply chain in automobile company, paired comparison matrix has been used. For this purpose a questionnaire is designed based on comparison of priorities in respondents' point of view and finally for determining final weight, criteria for group decision matrix have been constructed.

The procedure for determining each weight has been summarized as follow:

1. Determining effective factors on determining the manufacturer considering related literature
2. Selecting compatible criteria with the studied chain considering the terms and comments of experts
3. Designing proper questionnaire for gathering decision maker's views
4. Determining 125 decision makers randomly
5. Informing the decision makers of the criteria and discussing them, also pairwise decision making for preventing incompatibilities in decision.
6. Determining incompatibility for decisions of every decision maker. In this process, if compatibility of each matrix is more than 0.1, criteria and terms of decision making is explained to decision makers again and the questionnaires have been filled.
7. Determining resultant matrix of 125 decision makers by the offered formula
8. Determining the weight of each criteria considering resultant matrix

Table2
Prioritizing competitive factors

W vector for resultant decision of 125 participants					
Product cost	Credit and guarantee type	Advertisement	After sale services	Delivery time and terms	Quality level of the product
.3099	.1112	.0369	.1462	.1819	.2139

Considering the above table it can be seen that the product cost has the highest weight and quality level is the next. So a game can be proposed that cost and quality are considered as competitive advantage in it.

7.3 Optimum output based on defined game in case study

In the following table the summary of calculation and prioritization of manufacturers in 8-person game has been provided based on manufacture profit.

Table3
Prioritization of manufacturers based on manufacture profit

Game type	A	B	C	D	E	F	G	H
Present status	4726586	18095057	25140800	11639443	8594571	19888686	3129514	24398886
MS	10832274	25816034	28493091	14659502	14733392	17535941	12190211	20376825
VN	7853869	20293143	22553339	10980868	11044446	13355993	8960815	15724486
RS	5420304	12919522	14261916	7336026	7368377	8781361	6094406	10199763
Priority in three comparisons	8	2	1	6	5	4	7	3

In the following table the summary of calculation and prioritization of manufacturers in 8-person game has been provided based on customer satisfaction. Furthermore in this comparison, for service level the product quality is considered and the product price is -0.3099 and the quality level of product is 0.2130.

Table4
Prioritization of manufacturers based on customer satisfaction

Game type	A	B	C	D	E	F	G	H
Present status	0.921621	0.890631	0.854778	0.801303	0.920382	0.953584	0.787934	0.873372
MS	0.878203	0.868731	0.888331	0.869107	0.835064	0.933564	0.825659	0.907621
VN	0.870949	0.87084	0.892118	0.864181	0.831941	0.931283	0.822032	0.908084
RS	0.878107	0.868596	0.888221	0.869	0.834908	0.933583	0.825509	0.907544
Priority in three comparisons	4	6	3	5	7	1	8	2

In the following table the summary of calculation and prioritization of manufacturers in 8-person game has been provided based on retailer interest.

Table5
Prioritization of manufacturers based on distributor's profit

Game type	A	B	C	D	E	F	G	H
Present status	10283057	30383429	40793200	19430571	15092263	21808457	7886286	21732343
MS	9828066	19485457	21124462	12409638	12452307	14292592	10749884	16100842
VN	14450188	30508918	33274123	18695854	18761703	21823840	15955371	24834755
RS	15255007	32414045	35397088	19753255	19824817	23085912	16846623	26310519
Priority in three comparisons	8	2	1	6	5	4	7	3

8. Conclusion

The results of game in simultaneous status for 8 manufacturers confirm the prioritization of comparison based on manufacturer and retailer interests in the condition when the results obtained from 2-person game (due to high volume of output of 2-person games, these results have not been included in this study and just references are made to them). However there is a little difference in prioritization from customer's view between two methods. This might be due to the fact that in pair wise comparison status, wholesale price and service level for each manufacturer is not provided in supply chain in equilibrium status and these differences can and confirm this little difference.

The comparison of 2- person and n- person game results show that when b_s, $\theta_s>0$, it is not possible to compare the results of manufacturer's Stackelberg with others, the same as 2-person game. This is due to the fact that the values of b_s and θ_s can influence the nature of competition. When b_s and θ_s are meaningfully bigger than θ_p and b_p, two manufacturers focus on service competition. On the other hand if θ_p and b_p are meaningfully bigger than b_s and θ_s, the manufacturers will focus on cost competition. So the relative values of cost and service level in MS can be very different to others. The game results obtained from case study in this study is as follow:

Table 6
Comparison of n-person game results

Scenario	(a) $If\ b_s\ and\ \theta_s > 0$	(b) $If\ b_s\ and\ \theta_s = 0$
Retail Price	N/A	$p^{MS} < p^{VN} < p^{RS}$
Demand	$Q^{MS} < Q^{RS} < Q^{VN}$	$Q^{MS}, Q^{RS} < Q^{VN}$
Wholesale price	$w^{MS} > w^{VN} > w^{RS}$	$w^{MS} > w^{VN} > w^{RS}$
Manufacturer Profit	$II_M^{MS} > II_M^{VN} > II_M^{RS}$	$II_M^{MS} > II_M^{VN} > II_M^{RS}$
Retailer Profit	$II_R^{MS} < II_R^{VN} < II_R^{RS}$	$II_R^{MS} < II_R^{VN} < II_R^{RS}$

In 8-person game it can clearly be seen that taking into account that θ_p and b_p are bigger than b_s and θ_s, (not so much meaningful), manufacturers focus on price competition is to some extent higher than their focus on services. So the similarity of equations to the condition that $b_s\ and\ \theta_s = 0$is somehow justifiable. Although the dual method implemented based on Jye-Chyi Lu, Yu- Chung Tsao, 2011 model is of high precision for determining the priority of manufacturers and incompatibility of paired comparison matrix in it is low. Meanwhile since comparison is done in pairwise and in each comparison other manufacturers don't participate, so it is not possible to determine wholesale price, retail price and service level for equilibrium condition in such a way that the whole chain is in equilibrium. So regarding this issue, n- person game model has been proposed which is not mentioned in previous studies.

From the analyses it can be argued that manufacturer and retailer profit in respect to changes show similar reaction. In other words‹ the manufacturer could be make similar decisions for preserving competitive condition by both investors point of view and distribution networks but sensitivity of customer‘s decision (base on price and service level) defines different conditions. Its prioritization is different from investors and distribution networks and ranking based on their decision‹ is not completely the same. Also it was proved that changes in manufacturing price can help improvement of competitive condition of manufacturer more than changes in the market basis. That is, in the condition where manufacturer has not paid attention to reducing its manufacturing price and manufacturing price is much more than that of competitors, and by increasing market basis it can help other competitors even more than its own growth. So, reduction of manufacturing price improves competitive condition of manufacturer more than improving market basis. Maybe it can be said that the advantage of this model to previous models is that its software is designed in such a way that in case of information availability related to all six factors including price, quality, advertisement, after sale services, delivery term and time, credit and guarantee type the model is executable and model outputs are appropriate for managerial analysis. Finally manufacturing institutions or suppliers are ranked based on manufacturer, retailer profit and customer satisfaction. The main finding of this paper or the strength point is expansion of 2-person game model to n-person. In this model one can introduce simultaneously the information of n manufacturer in the game. Finally when the complex reaches equilibrium, equilibrium profit and demand function related to manufacturer, retailer and investor, also customer satisfaction will be simultaneously provided in three games of manufacturer Stackelberg, retailer Stackelberg and Nash equilibrium.

Recommendation for further research

- Solving two manufacturers- two retailers model in single period and multi period situations

- Using non-linear functions instead of linear functions
- Using and combining Fuzzy method in solving main equations of game theory
- Prediction of product demand in an uncertain way in supply chain

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