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Presenting a pricing model for the producers of steel with application of Game theory

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Abstract

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One of the most prevalent issues for managers is pricing. Pricing is one of the variables in the marketing mix and this parameter is directly associated with business income and is a fixable variable in the marketing mix. Therefore, management should be so sensitive about this variable because at this time market is in fierce competition. Most pricing studies in marketing assume that there is a stable relationship between a product's price and its demand.
Game theory is one of the methods that can guide the manager to find the best action and reaction as well as the best strategy that could lead to the most beneficial business.
In this paper, we apply game-theoretical models (Stackelberg and Bertrand) to study competition and pricing management strategies to obtain optimal pricing strategies for the corresponding price gains under each strategy. We compare and contrast price gains under these two pricing strategies. Our results indicate that the optimal pricing strategy for competitive firms is governed by the Stackelberg model.

Keywords: Pricing, Marketing, Game Theory, Stackelberg Model, Nash equilibrium.

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1. Introduction

At this time, one of the most prevalent issues for the entire is to supply low-material products for a long period of time. This problem causes an uncertain situation for management firms in the decision-making of pricing strategy but Iran has the second rank of mineral and natural gas resources in the world and this advantage provides a good situation for management in Iran to invest in pricing strategy appropriately. According to the report of the World Steel Association, Iran was ranked seventeenth in the production of Crude steel in the world and has the second rank of Crude steel in the Middle East after Turkey [1]. Pricing is one of the variables in the marketing mix and this parameter is directly associated with business income and is a fixable variable in the marketing mix. Therefore, management should be so sensitive about this variable because at this time market is in fierce competition. Most pricing studies in marketing assume that there is a stable relationship between a product's price and its demand. Thus, their typical focus is on the identification of the functional form of the price demand relationship, estimation of relevant parameters, finding the "optimal" prices using the estimated demand functions, and analyzing the effects of price competition [2].

In the current era, competition is more intense and each firm must identify competitors in its market and consider the action and reactions of competitor firms and forecast their behavior and choose the best strategies that achieve the most benefit for them. Game theory is one of the methods that can guide the manager to find the best action and reaction as well as the best strategy that could lead to the most beneficial business.

To estimate the price and advertisement strategies of Coca-Cola and Pepsi-Cola firms, different strategies for each firm were investigated by means of the Game Theory approach [3]. Game Theory was applied to wheat, barley, maize, chickpea, sesame, cotton and peanut production in the Antalya province of Turkey. It was concluded that the pistachio and cotton were candidates with a high risk of investment [4]. Game Theory was used to determine the most efficient selling times for some storable field crops, vegetables, fruits as well as beef and milk in Turkey [5]. Ahmet Sahin and Ibrahim Yidirim applied game theory to create different strategies for chicken meat producers to protect it against market price risks. The optimum selling months and the corresponding market prices, which will be received by producers, were also determined [5]. Ruiliang (2009) used game theory to provide a framework to help competitive firms find optimal pricing and brand management strategies in order to maximize their respective profits [6]. Chan Choi and Sharan Jagpal employed game theory to develop a duopoly pricing model in which firms market differentiated products in a world of uncertainty. Results show that the predictions of standard strategic pricing models may not hold when firms face parameter uncertainty and are risk averse [2]. Mohammad Ghorbani has attempted to compare the effect of the market sale and contract strategies on yield, using 90 survey data from tomato farmers in Khorasan-Razavi province, Iran in 2007 and has applied the game theory approach [7]. For more information, readers can study [8-14].

In this paper, we apply game-theoretical models (Stackelberg and Bertrand) to study competition and pricing management strategies to obtain optimal pricing strategies for the corresponding price gains under each strategy. We compare and contrast price gains under these two pricing strategies. Our results indicate that the optimal pricing strategy for competitive firms is governed by the Stackelberg model.

The rest of our paper is organized as follows. Section 2 provides the game theory information. Section 3 describes our modeling framework. Section 4 studies pricing strategy and firm performance treated under two models (Stackelberg and competitive pricing). Finally, Conclusions and managerial implications are presented in Section 5.

2. Game theory information

Game theory is a decision-making or strategy choice against uncertainties. It is a technique used to solve the problems of competition where a conflict of interest occurs among the decision-makers [5]. A game is a theory of rational behavior for others so that players stick to their equilibrium strategies. In a game, several agents of strategies are called a (strategic) equilibrium if, given that strive to maximize their (expected) utility index by choosing particular courses of action and each final utility payoff depends on the profile of the courses of action chosen by all agents.

The interactive situation, specified by the set of participants, the possible courses of action of each agent and the set of all possible utility payoffs, is called a game; the agents 'playing' a game is called the player's strategy. An implicit assumption of game theory is that whenever an optimizing agent expects a reaction from other agents to his own actions, his payoff is determined by other players' actions as well while he is playing a game. In fact, game theory provides general methods of dealing with interactive optimization problems; its methods and concepts, particularly the notion of strategy and strategic equilibrium find a vast number of applications throughout social sciences [7].

Monthly information of two exchange firms founded from 2002 to 2007 in Iran was extracted and this information is the main material in this study.

In this market, there were two firms that produce steel and sell it in the stock market. One of them is Esfahan Steel Company and the other is Iran National Steel Industrial Group. Two firms compete with each other to sell products to the same market.

The frame for the steel market of Iran is:

In this market, two firms exist. (1)

$$N = \begin{Bmatrix} \text{Esfahan Steel Company} \\ \text{Iran National Steel Industrial Group} \end{Bmatrix}$$

The demand functions for the two firms are as follows:

$$Q_1 = f_1(p_1, p_2) \quad (2)$$

$$Q_2 = f_2(p_1, p_2) \quad (3)$$

The cost functions for the two firms are depicted here:

$$TC_1(Q_1), C_1(Q_1) = cte_1 + C_1Q_1 \quad (4)$$

$$TC_2(Q_2), C_2(Q_2) = cte_2 + C_2Q_2 \quad (5)$$

The Revenue functions for the two firms are indicated below:

$$TR_1(P_1, P_2) = P_1.Q_i \quad (6)$$

$$TR_2(P_1, P_2) = P_2.Q_i \quad (7)$$

The profit functions for the two firms are indicated below:

$$\pi_1(P_1, P_2) = P_1 f_1(P_1, P_2) - C_1(Q_1) \quad (8)$$

$$\pi_2(P_1, P_2) = P_2 f_2(P_1, P_2) - C_2(Q_2) \quad (9)$$

Where Q_i is the demand for product i and P_i is the price of product I, C_i is variable cost for product I, Cte_i is fixed cost for product I, TC_i is the Total Cost for product I, TR_i is the Total Revenue for product I and π_i is Net Profit of product i.

3. Presenting a pricing model for the producers of steel

Customer can purchase their needs from two firms and they will compare both prices with each other and finally, they will choose the best price associated with the quality of goods consideration. We contemplate that both firms will apply Game Theory. The demand of both firms

related to their own price and the price of the rest firms can be found as follows:

$$q_i = (a - bp_i + dp_j) \quad (10)$$

Where qi is the demand and pi is the price of product i, b and dare parameters to represent the level of product substitutability, and b is a parameter capturing the market potential. This type of linear function has been widely used in the marketing literature.

We considered two types of Game Theory for our market, Namely Stackelberg and Competitive pricing.

3.1. Pricing strategies in the Competitive pricing

The Competitive pricing model is a model of price competition between duopoly firms that results in charging the price for each that would be charged under perfect competition. According to this model, firm 1 and firm 2 compete in price and choose their respective prices. Specifically, firm 1 determines its price p1 to maximize its profit p1. Similarly, firm 2 determines its price p2 to maximize its profit p2. There is no price leader in this market, and both firms make price decisions independently.

$$Q_1 = (a - bp_1 + dp_2) \quad (11)$$

$$\pi_1 = TR - TC \quad (12)$$

$$\pi_1 = Q_1 p_1 - cQ_1 \quad (13)$$

$$\pi_1 = p_1 (a - bp_1 + dp_2) - c(a - bp_1\ bp_2) \quad (14)$$

Firm 1 maximized its profit for optimum pricing as below:

$$\frac{\partial \pi_1}{\partial p_1} = a - 2bp_1 + dp_2 + cb = 0 \quad (15)$$

$$p_1 = \frac{a+cb}{2b} + \frac{d}{2b} p_2 \quad (16)$$

The same goes for the second firms.

$$p_2 = \frac{a+cb}{2b} + \frac{d}{2b} p_1 \quad (17)$$

Nash equilibrium occurs when we consider the best reaction of pricing for 2 firms in contrast to each other.

$$\begin{cases} * p_1 = \frac{a+cb}{2b} + \frac{d}{2b} p_2 \\ * p_2 = \frac{a+cb}{2b} + \frac{d}{2b} p_1 \end{cases} \quad (18)$$

3.2. Pricing strategies in the Stackelberg competition

The Stackelberg competition is a model of the duopoly in economics. In game theory terms, the players in this game are a leader and a follower who compete with each other. The leader moves first, choosing a price to maximize its profit. The follower observes the leader's choice and then picks a price to maximize its profit. In this paper, we consider two firms, acting as the market leader, move first and set its price, independent of any competing firm. The second firm acts as the market follower and sets it price, taking into account the price set by the market leader. Stackelberg firms have made sequential pricing decisions. Suppose Firm 1 is the leader and Firm 2 is the follower. In the first step, Firm 1 determines Firm 2's reaction function. Then Firm 1 uses this information to determine its "optimal" price. In the second step, Firm 2 (the follower) observes the leader's price and determines its "optimal" price.

In this paper, at first, we have determined the monopoly pricing power of each firm. Because the first mover has an advantage and can determine the higher price than the follower. The monopoly pricing power indicates which firm has the most power to lead the market's price and other firms must be a follower in this market.

This paper applied Inverse Elasticity of Demand to determine monopoly-pricing power for each firm in this market.

$$E = \frac{\sum \Delta q}{\sum \Delta p} . \frac{p}{q} \quad (19)$$

$$\text{Inverse elasticity of demand} = \frac{1}{E} \quad (20)$$

The upper Inverse elasticity of demand shows that the power of each firm is higher than the other firm and this firm can consider the highest price for its product more than other firms.

According to the Stackelberg model, Firm 1guesses the best action of firm2 as follows:

$$p_2 = \frac{a+cb}{2b} + \frac{d}{2b} p_1 \quad (21)$$

Firm1 puts his guess in his demand function to optimize his price.

$$Q_1\ (p_1, p_2) = a - bp_1 + dp_2 \quad (22)$$

So:

(23)

$$Q_1\ (p_1, p_2) = a - bp_1 + d\left(\frac{a+cb}{2b} + \frac{d}{2b}p_1\right)$$

and

$$\pi_1 = TR - TC \quad (24)$$

$$\pi_1 = q_1 p_1 - cq_1 \quad (25)$$

at a result:

$$\pi_1 = p_1\left(a - bp_1 + \frac{da}{2b} + \frac{dc}{2} + \frac{d^2}{2b}p_1\right) - c\left(a - bp_1 + \frac{da}{2b} + \frac{dc}{2} + \frac{d^2}{2b}p_1\right) \quad (26)$$

Firms 1 maximized its profit for optimum pricing as below:

(27)

$$\frac{\partial \pi_1}{\partial p_1} = a - 2b\ p_1 + \frac{da}{2b} - \frac{dc}{2} + \frac{d^2}{b}p_1 + cb - \frac{cd^2}{2b} = 0$$

Thus:

$$*p_1 = \frac{a+\frac{da}{2b}+\frac{dc}{2}+bc-\frac{cd^2}{2b}}{2b+\frac{d^2}{b}} \quad (28)$$

Firm 2 will put its guess about firm 1's optimal price based on its demand function.

$$q_2 = (a - bp_2 + dp_1) \quad (29)$$

and

(30)

$$\pi_2 = p_2(a - bp_2 + d\frac{a+\frac{da}{2b}+\frac{dc}{2}+bc-\frac{cd^2}{2b}}{2b+\frac{d^2}{b}}) - c(a - bp_2 + d\frac{a+\frac{da}{2b}+\frac{dc}{2}+bc-\frac{cd^2}{2b}}{2b+\frac{d^2}{b}})$$

and

$$\text{Max}\ \pi_2 = \frac{\partial \pi_2}{\partial p_2} = a - 2bp_2 + \left(\frac{ad+\frac{d^2a}{2b}+\frac{d^2c}{2}+dbc-\frac{cd^3}{2b}}{2b-\frac{d^2}{b}}\right) + bc \quad (31)$$

and

$$p_2{}^* = \frac{a+\frac{ad+\frac{d^2a}{2b}+\frac{d^2c}{2}+dbc-\frac{cd^3}{2b}}{2b-\frac{d^2}{b}}+bc}{2b} \quad (32)$$

Nash equilibrium occurs when we consider the best reaction of pricing for two firms in contrast to each other.

$$\begin{cases} p_1{}^* = \frac{a+\frac{da}{2b}+\frac{dc}{2}+bc-\frac{cd^2}{2b}}{2b+\frac{d^2}{b}} \\ p_2{}^* = \frac{a+\frac{ad+\frac{d^2a}{2b}+\frac{d^2c}{2}+dbc-\frac{cd^3}{2b}}{2b-\frac{d^2}{b}}+bc}{2b} \end{cases} \quad (33)$$

3.3. Nash equilibrium

When the best reaction of each player opposes each other, the Nash equilibrium will be achieved. Then the Nash equilibrium refers to the pair of prices such that both reaction functions are simultaneously satisfied. Thus, at the Nash equilibrium, no firm has an incentive to unilaterally change its strategy given the other's equilibrium strategy.

We estimated the Nash equilibrium price for each model.

3.4. The equilibrium prices for different models

Stackelberg Model Competitive Pricing Model Optimal price for Firm 1:

$$p_1 = \frac{a+cb}{2b} + \frac{d}{2b}p_2 \quad (34)$$

then:

$$p_1 = \frac{a+\frac{da}{2b}+\frac{dc}{2}+bc-\frac{cd^2}{2b}}{2b+\frac{d^2}{b}} \quad (35)$$

Optimal price for Firm 2:

$$p_2 = \frac{a+cb}{2b} + \frac{d}{2b}p_1 \quad (36)$$

So:

$$p_2 = \frac{a+\frac{ad+\frac{d^2a}{2b}+\frac{d^2c}{2}+dbc-\frac{cd^3}{2b}}{2b-\frac{d^2}{b}}+bc}{2b} \quad (37)$$

4. Implicational models

4.1. Pricing Strategies in the Competitive-pricing Model

According to this model, Esfahan Steel Company and Iran National Steel Industrial Group compete in price and choose their respective prices. Specifically, Esfahan Steel Company determines its price p1 to maximize its profit p1. Similarly, Iran National Steel Industrial Group determines its price p2 to maximize its profit p2.

4.2. Pricing Strategies in the Stackelberg Competition Model

At first, we determined monopoly pricing power with the method of Inverse Elasticity of Demand in this market.

The results show that the Inverse Elasticity of Demand for the product of Esfahan Steel Company is 6.06 and for Iran National Steel Industrial Group is 3.57. Based on the obtained results, Esfahan Steel Company can be the leader of this market because it has higher Inverse elasticity of demand and it can be more effective on the pricing in this market while Iran National Steel Industrial Group can be a follower because it has a lower Inverse elasticity of demand.

The result shows that Esfahan Steel Company is a leader and Iran National Steel Industrial Group is a follower in this market. In the first step, Esfahan Steel Company determines Firm Iran National Steel Industrial Group's reaction function. Then Esfahan Steel Company uses this information to determine its "optimal" price. In the second step, Iran National Steel Industrial Group observes the Esfahan Steel Company's price and determines its "optimal" price.

The best choice for each firm assesses each other to determine Nash equilibrium.

4.3. The equilibrium prices for different models

Stackelberg model competitive-pricing model

Firm 1's price

$p_1 = 260 + 1.16c$, $p_1 = \frac{210 + 1.8p_2 + 1.4\,c}{2.8}$

Firm 1's price

$p_2 = 185 + 0.97c$, $p_2 = \frac{190 + 0.98p_1 + 1.2}{2.4}$

Firm 1's Nash price 85558082

Firm 2's Nash price 71106932

In Nash equilibrium for Stackelberg Model, Firm1 and Firm2 can consider 8555 Riyal and 7110 Riyal for each kilo of steel for their product, respectively. The results show that Esfahan Steel Company can determine the highest price in the Stackelberg Model because Esfahan Steel Company is a leader in that market and the leader in the Stackelberg Model have a first mover advantage and it can determine the highest price more than the follower.

In the Nash equilibrium for Competitive-pricing Model, Firm1 and Firm2 can consider 8082 Riyal and 6932 Riyal for each kilo of steel for their product, respectively.

The results show that Firm1 (Esfahan Steel Company) can consider the highest price in both models.

4.4. MSE Method

This method indicates which models can describe reality more precisely. The results of the two models were compared with reality by MSE Method. Mean Square Error indicates the Dispersion number s-th an average number. Although the MSE of the model were the lowest, it showed that this model can describe reality better.

$$\mathrm{MSE} = \frac{\sum(\mathrm{X}-\bar{\mathrm{X}})^2}{\mathrm{N}} \qquad (38)$$

MSE (Stackelberg Model) =13451650

MSE (Competitive-Pricing Model) =22044795

Results show that MSE for Stackelberg Model is lower than that of the Competitive Pricing Model. According to Sultre, it is revealed reality can better describe the Stackelberg Model than the Competitive Pricing Model.

5. Conclusion

This study describes the behavior of the steel market in Iran with two models; namely Stackelberg and competitive-pricing Models. The results of the two models exhibit virtually the same data but results show that pricing with the Stackelberg model can provide higher price than competitive pricing. A firm, that started the game, can determine the highest price because of the first mover advantage but also this advantage exists only for the Stackelberg model because this model is sequential. The results of the two models are then compared with reality. The method of this comparison was MSE (Mean Square Error). MSE output showed that pricing with the Stackelberg method is more proximate to act and this method can describe reality better. This result can guide the manager to find the competitive advantage for their product to be one of the best producers in their market and they can be the leader and use the advantage of first mover advantage in pricing strategy to present the highest price in the market.

If producers want to compete with each other, the price will be lower than when they are a leader in the market and they can compete their price up to MC (Marginal Cost).

This study has some limitations. In this paper, all the information is complete and known but it may be incomplete and unknown. There were some information constraints to add different parameter in the demand curve for example price of international steel and the price of exported steel, which at a higher level suggest the researchers consider this parameter. The game theory that was used in this paper is static but can also be dynamic.

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