Equilibrium Product Positioning and Pricing when the Number of Firms in the Market Changes: A Marketing-Production Perspective

Hadjinicola George[1*], K. Ravi Kumar[2]
1 Department of Public and Business Administration, School of Economics and Management
University of Cyprus, Nicosia, Cyprus
2 KAIST Business School, Seoul, Korea
[*]EMAIL: bageorge@ucy.ac.cy

Abstract: The paper presents a model that incorporates marketing and production variables and exhibits the existence of a Nash equilibrium in prices and product positions. Given that the market can reach an equilibrium in prices and product positions, we then examine how the number of firms in the market affects prices and product positions at this static equilibrium.

Keywords: Marketing-Production Interface, Pricing, Product Design, Nash Equilibrium.

I. Introduction

Markets are dynamic environments where competing firms are engaging in a continuous struggle to maintain their market position. Often, firms that have established their presence in the market, are forced to confront new firms attempting to enter the market. Incumbent firms have an arsenal of methods to defend their market position, the majority of which are defensive marketing strategies. Defensive marketing strategies have been very well researched and applied in the marketplace. Such strategies include changes in the marketing mix such as price reductions, increased advertising and distribution expenditures, and product redesign, often referred to as product repositioning. Defensive manufacturing strategies have also been applied such as maintaining excess capacity to signal price war in the event of entry, locating facilities in crucial areas to deter entry, acquiring flexible manufacturing technology to adapt the product mix in a speedy and cost efficient manner in response to attacking products, and by adopting make-to-stock policies to be more responsive to customer needs. Nevertheless, defending the firm's position is not the sole responsibility of a single function. All functions should be involved in the decision making process since functional decisions are interrelated and the level of coordination among the functions determines the success of the defensive strategy. Kumar and Hadjinicola [12] provide a discussion on defensive marketing and manufacturing strategies as well as ways on how to coordinate the two functional strategies in defending the firm's market position.

In this paper, our effort is to address management's concerns on how to adapt its pricing and product policies when the number of competitors in the market increases. As such, we address the following question: "When the number of firms in the market increases, how should a firm change its product design and price when both marketing and production factors are considered?" Even though past research by Robinson [18] has shown that product redesign is not one of the first reactions used by firms when competition intensifies, it is important for firms to understand the long-term direction of product design when more competitors are present in the marketplace.

Note that product design is also referred to as product position, and henceforth these two equivalent definitions will be used interchangeably. Product designs are a focal concern for production managers since product designs affect the production process and eventually the overall production cost. To address the above question, we need a modeling framework that incorporates elements from marketing and production, and at the same time, facilitates the existence of a Nash equilibrium in prices and product positions. The presence of an equilibrium for any number of firms in the market is a prerequisite to examine the firm's product positioning and pricing decisions when the number of competitors in the market increases.

II. Literature

The seminal paper by Hauser and Shugan [10] which describes the "Defender" model, laid the groundwork for the prediction of market outcomes in dynamic competitive scenarios when there is market entry. The Defender scenario, which included consumer choice models, profit optimization, and industry interaction models depicting competitive gaming behavior among firms, analyzed the reactions of incumbent firms with respect to price, product position, advertising and distribution. Hauser and Shugan's results on defensive response to entry include price reductions for markets where consumer tastes are uniformly distributed. They also identify the existence of cases where defensive response to entry implies price increase. Furthermore, they identify conditions for product repositioning away (product improvement) and towards the attack. Subsequently, Kumar and Sudharshan [13] and Gruca et al. [8] investigate full equilibrium reactions under functional response representation for advertising and distribution and corroborate defensive price reductions. In a similar vein, Ansari et al. [2] deal with the issue of competitive pricing and positioning in an industry where consumer preferences are allowed to be non-uniform. They use the Defender model to evaluate static equilibrium outcomes in environments with two, three, and four firms entering simultaneously. They also allow these firms to enter sequentially and predict equilibrium outcomes for dynamic scenarios wherein entry-deterrent behavior is allowed. They show that under certain conditions, neither minimal nor maximal differentiation in product positioning may be the equilibrium outcome.

A drawback of the above stream of research is the inability to deal with positioning equilibrium for an arbitrary number of firms. For example, Hauser and Shugan's [10] positioning results are in partial equilibrium even though Hauser and Wernerfelt [11] establish the existence of equilibrium for prices in the Defender model. The absence of a proof for the existence of an equilibrium in product positions is coupled with the complexity in the model which makes the analytical extraction of equilibrium (assuming it exists) impossible. For example, Ansari et al. [2] have to resort to search procedures using symbolic algebra software to establish existence of, and determine, equilibria. The non-existence of positional equilibrium is suggested even in the three-firm case when consumer preferences are highly polarized.

Similarly, Kumar and Sudharshan [13] and Gruca et al. [8] do not “allow” repositioning, using the argument that in the short run, repositioning is very expensive; the original positioning equilibrium is ensured by using sequential entry of firms [14]. Gruca et al. [8] prove the existence of a Nash equilibrium in prices, advertising, and distribution expenditures. In addition, in the product positioning literature, the notion of sequential games has been used to ensure the existence of an equilibrium in prices and positions. In these games, firms choose the product positions first and then their prices [17, 21]. Carpenter [4] performed a sensitivity analysis in a competitive environment and observed changes in prices upon a firm's product repositioning. In his analysis, the price equilibrium was obtained after product positions were chosen for a two-dimensional, two-brand market.

Sequential games have been used because product redesign is a long-term strategy, where as price changes are easier to achieve. Robinson [18] found that only 4% of incumbent firms react aggressively with product redesigns during the first year of entry and only 20% do so during the second year of entry. However, simultaneous decisions on product design and prices, and thus the need to reach a market equilibrium in prices and product positions, is becoming an imperative in services and the peripheral services that accompany a product. For example, in e-commerce, we often observe changes in mortgage and insurance products when competition intensifies. “Enhanced products” that are surrounded by services (e.g. financial and delivery/logistics) may not be redesigned right after the entry of competitors. Redesign may more easily occur on these peripheral services. E-tailing provides such examples where clothing products are accompanied by payment and delivery services that are frequently adjusted to deal with new competitors. As such, in these industries, firms need to achieve a new equilibrium in prices and product positions in a rapid way.

Only the economics literature on spatial competition includes work on the simultaneous existence of an equilibrium point in prices and product positions. Specifically, using the logit model an equilibrium can be shown to exist in prices and positions. This equilibrium though is purile in terms of defensive reactions. The position chosen by all firms in this equilibrium is the same, the center of the market, and prices are equal for all firms. Therefore, using this modeling approach will not assist us in determining the reaction of incumbent firms upon entry, since the attacker would position himself in the center of the market and price his product at the same level as the incumbent firms. Anderson et al. [1] present an excellent review on spatial competition and the existence of equilibria in prices and positions.

The aim of this paper is twofold. First, present a model that incorporates marketing and production variables and exhibits the existence of a Nash equilibrium in prices and product positions. In other words, present a model that allows firms to simultaneously make product design and pricing decisions. Second, given that the market can reach an equilibrium in prices and product positions, examine how the number of firms in the market affects prices and product positions at this static equilibrium.

To accomplish the above, the paper includes a modeling framework that adopts notions from marketing such as ideal points to dictate the attraction of the product to consumers, market shares, and pricing issues. The model also incorporates the production cost of the product which depends on the level of the product's attributes. Note that the existing literature on reactions to entry mentioned above, does not explicitly use production variables. Instead, production comes in the picture through the constant per unit cost of production.

The modeling framework facilitates the existence of a Nash equilibrium in prices and product positions for any number of competing firms. The number of firms in the market is exogenously defined. Given that the market can reach an equilibrium, we analytically show that when the number of competing firms increases, firms at this static equilibrium lower their prices and more importantly, design their product with features closer to the market's ideal point. Even though product redesign may not be performed immediately after the entry of a new competitor, the results of this paper set the long-run direction that a firm should follow for its product design policy if competition intensifies. Numerical examples show that the profits of firms decrease when the number of firms in the market increases.

III. Model Formulation

Products can be abstractly represented as a set of coordinates in an attribute space. Each dimension in the attribute space designates a product characteristic, for example, the level of sweetness of a chocolate which translates into the per unit volume sugar content. Realizations of these attribute dimensions in the form of coordinates should be meaningful to both users and manufacturers. Shocker and Srinivasan [19, p.922] stated that attributes should be actionable, that is, "indicate specific actions the manufacturer must take to build the product." Under this framework, each consumer is assumed to have a set of most preferred attributes termed the *ideal point*. The greater the proximity of the product offering in the attribute space to the consumers' ideal point, the greater the product *attraction* (appeal), and in general, the propensity/probability that consumers will purchase the product. Attraction has also been assumed to be a function of other factors such as price where, for example, attraction decreases when price increases.

For the formulation of the model we use the following notation:
k: firm index
N: number of competing firms
i: attribute index
L: number of attributes
b: price elasticity of demand
Y: consumers' average income
Q: market sales potential
x*: an L X 1 vector containing the attribute coordinates of the market's ideal point. Its elements are denoted by x_i^*
W: an L X L diagonal matrix whose diagonal elements w_i denote the weight consumers place on attribute i
$\boldsymbol{\beta_k}$: an L X 1 vector containing the costs for furnishing a product with one unit of a specific attribute by firm k. Its elements are denoted by β_{ki}
P_k: price of the product offered by firm k
$\mathbf{x_k}$: an L X 1 vector containing the attribute coordinates of the product offered by firm k. Its elements are denoted by x_{ki}.

Market share models have been used to predict a firm's market share in a competitive environment and appear in linear, multiplicative, and exponential forms. These three forms of market share models are not *logically consistent* [15] a property which states that market share models should predict market shares between zero and one and also sum to unity. As described by Cooper and Nakanishi [6], logically consistent market share models use the relationship (us/(us+them)) to capture the market share of a firm in a competitive environment. We model competition between firms through Multiplicative Competitive Interaction market share models, also known as attraction models [8]. Specifically, we employ the model

$$M_k = \text{Attr}_k / \sum_{k=1}^{N} \text{Attr}_k, k = 1, \ldots, N,$$

where M_k is the market share and Attr_k is the product attraction of firm k. Attraction can be viewed as a measure of the "willingness" of consumers to purchase a product, and in studies by Cooper and Nakanishi [6], Kumar and Sudharshan [13], and Gruca et al. [8] has been modeled as Attr=f(**x**)g(P), where f(**x**) is a function of the product position relative to the ideal point (the smaller the distance, the higher the value of the function) and g(P) is a down sloping function of price. In this model, we neglect the effects of advertising and distribution in order to simplify the analysis. We define the product attraction for firm k to be given by

$$Attr_k = f_k(x_k) g_k(P_k)$$
$$= [1 - ((x^* - x_k)' W (x^* - x_k) / (x^{*\prime} W x^*))][1 - (bP_k / Y)].$$

Firms are assumed to adopt a profit maximization objective with the profit function of firm k (k=1, …, N) given by

$$\Pi = [P_k - \beta_k' \cdot x_k] M_k Q.$$

In the above formulation we assume that the cost of production depends in a linear fashion on the nature of the product, determined by its position (coordinates) in the joint attribute space. This is based on the fact that furnishing a product with a larger quantity of a particular attribute should require higher cost. Similarly, Bachem and Simon [3] and Choi et al. [5] present product positioning models that utilize a cost function which increases linearly with increasing attribute levels. Firm k will attempt to maximize its profits through the selection of its optimal product position and pricing policy. The profit maximization program of firm k is given by Max $_{P_k, x_k}$ Π_k, k=1,…,N.

IV. Results

In our framework, N firms compete in a non-cooperative way in a single market by selecting their price and product position. The notion of Nash equilibrium [15] in a non-cooperative game states that, at Nash equilibrium no firm has the incentive to change its strategy. Friedman [7, p.64] describes an N-person non-cooperative game and provides conditions and assumptions for the existence and uniqueness of a Nash equilibrium. Specifically, he shows that the existence of a Nash equilibrium is based on three conditions: (1) the strategy space of each player (firm) is compact and convex; (2) the payoff function of each player, in our case the profit function, is continuous; (3) the payoff function of each player is quasiconcave in its strategy, in our case its product's price and position. Hadjinicola and Kumar (2007) provide the details for the existence of the Nash equilibrium in prices and product positions.

Theorem. *Consider a market where a Nash equilibrium in prices and product positions exists for the firms already in the market. When the number of firms at this static equilibrium increases, firms decrease their prices and increase the features of their products closer to the market's ideal point.*

The important result presented in the above theorem is that intensification of competition in the form of increasing number of firms in the market results in products with higher product attributes, closer to the market's ideal point. When the number of firms in the market increases, firms tend to increase the features of their products in an effort to increase the attraction of their product which will assist them to remain competitive and retain their market share. This result sets the long-term product policy for a firm that expects competitors to enter the market. The literature on reactions to entry, which implies an increase in the number of firms in the market has similar results. For example, Hauser and Shugan [10] suggest that upon entry, and under certain conditions, product improvement by the incumbent firms implies a profit increase. Nevertheless, their result was not obtained in the presence of equilibrium after entry.

In addition, the theorem suggests that when the number of firms in the market increases, equilibrium prices decrease. This result is also consistent with the price reductions upon entry found in the literature examining entry [8, 10, 13]. When the number of firms in the market increases, firms attempt to sustain the attraction of their products in the presence of intense competition through lower prices.

To illustrate the effect of the number of firms on equilibrium product positions and prices, we present five scenarios where there are 2, 3, 4, and 5 competing firms in the market. The production capabilities of the firms as reflected in different unit costs of furnishing a product with one unit of an attribute. For the numerical examples, the following set of parameter values is used:
$b=1.6$, $Y=100, Q=300, w_1=1.0, x_1^*=5.5$, $\beta_{11}=2.0$, $\beta_{21}=3.0$, $\beta_{31}=4.0$, $\beta_{41}=1.5$, $\beta_{51}=1.4$.

The table that follows presents the Nash equilibrium in prices and product positions for the cases where the market has 2, 3, 4, and 5 competing firms. These values are obtained from the solution of the set of nonlinear first order conditions of all competing firms, in terms of their prices and product positions, using *Newton's successive relaxation method* [19, p.224]. The programs providing the solutions have been implemented using the software MATLAB.

Firm (k)	Product (x_{k1})	Price (P_k)	Profit (Π_k)
1	3.9348	44.7390	5732.53
2	3.3520	44.5979	4991.93
1	4.1522	41.4046	3601.50
2	3.5776	41.7808	3098.69
3	3.1099	41.9675	2698.61
1	4.2472	39.6066	2465.66
2	3.6805	40.2911	2112.22
3	3.2059	40.7160	1832.50
4	4.5578	39.1263	2674.76
1	4.2927	38.6517	1865.39
2	3.7309	39.5052	1595.35
3	3.2536	40.0607	1382.09
4	4.5963	39.0729	2025.44
5	4.6579	37.9432	2059.61

If we consider firm 1 which is present in all cases, we observe that when the number of firms in the market increases, its price decreases and the features of its product increase, approaching the ideal point. This also applies for the other firms when competition intensifies. Table 1 also indicates that when the number of firms in the market increases, profits decrease. This is a natural outcome of the lower prices and the more enhanced products that have a higher product cost. Firm profits are simply a function of the production capability of the firms present in the equilibrium. The table also shows that number of firms that the market can sustain is endogenous to the problem and depends on the cost of entry.

V. Conclusions and Future Research

One of the problems identified in the area of product positioning and modeling reactions to entry, is the inability to establish a simultaneous equilibrium in prices and product positions for an arbitrary number of firms. In this paper, we present a modeling framework that incorporates marketing and production variables and exhibits the existence of a Nash equilibrium in prices and product positions. Furthermore, we examine how the number of firms in the market affects prices and product positions at this static equilibrium. We show that when the number of competing firms increases, firms lower their prices and more importantly, design their product with features closer to the market's ideal point.

Our numerical analysis illustrates the fact that our model allows symmetric equilibrium, i.e., firms with similar capabilities price equally and produce identical products (unlike other economic models where product differentiation can emerge in equilibrium to relax price competition). In our model, only different firm capabilities gives rise to product and price differentiation. This leads to some rather interesting questions: does increased asymmetry in firms' capabilities increase or decrease competition and profits?

Our numerical examples hint at lower competitive strategies (higher prices, lesser desirable product positions and increased profits) when faced with a competitor having higher production cost. Future research could provide a rigorous analytical basis for such intuition.

Similarly, changes in consumer tastes over time are natural in maturing markets and lead to differing weights placed on attributes. How do companies cope with this? Our numerical analysis hints at a complex dynamic between consumer weights, cost to manufacture and pricing potential in the ensuing equilibrium. Analytical foundation and basis for making these trade-offs would be very valuable. In our framework, N firms compete in a non-cooperative way in a single market by selecting their price and product position.

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Background of Authors

Hadjinicola George is an associate professor and co-director of the MBA Program at the University of Cyprus. He received his B.Sc. degree in Electrical Engineering, an M.Sc. in Computer Engineering, an M.Sc. in Statistics, and a Ph.D. in Business Administration, from the University of Southern California, USA. His research interests include the marketing-production interface, product positioning methods, and multistage production systems.

K. Ravi Kumar is a professor and the Dean of KAIST College of Business, in Korea. He received his B.Sc. degree in Mechanical Engineering from the Indian Institute of Technology in Madras and his Ph.D in Operations Research with application in Microeconomics from Northwestern University. His research interests include the marketing-production interface, defensive marketing strategies, and strategy**,** EMAIL: Kumar@business.kaist.ac.kr.