The impact of production cost on first-mover advantages and time-to-market

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ABSTRACT

The research explores the impact of production cost on first-mover advantages and time-to-market decision in a duopoly setting. The paper determines each firm's optimal design strategy and provides criteria under which the first entrant enjoys first-mover advantages. The results show that the first-mover may always charge a higher price but may not always enjoy higher profit than the late-mover. First-mover's low production cost would defer the entry of late-mover and push it away from the most attractive position of the market.

Keywords: first-mover advantages, time-to-market, production cost, product design, operation management.

1. INTRODUCTION

Time-to-market has been a major strategic concern for product development. First-movers are considered to have advantages, which mainly are higher market shares and higher profits than late entrants (Urban, et. al 1986, Lieberman and Montgomery 1988). However late entrants have less risk in product development, and often can more easily implement new technologies, thus achieving lower production costs. The situation is even more complicated when firms try to foresee their competitors' moves while making their own decisions. Emerging new technologies have made production processes more flexible, allowing firms to adjust their product mix and production volumes in response to competitors' actions. These advantages and disadvantages usually manifest in a multi-period decision-making environment.

This paper investigates the impact of production cost on first-mover advantages and time-to-market in an environment where customers are making repeat purchases. This paper considers the issue of product introductions in a duopoly setting and the time horizon is divided into two periods. Two firms enter the market sequentially. Competition starts from the beginning of the second period when the late mover enters the market. As a response to the new entrant the first mover has a chance to adjust its product.

Using a game-theoretical model, this research answers the following questions: What are the firms' optimal product design strategies; When does the first-mover enjoy advantages; How should the late entrant choose the entry timing; What are the effects of production cost on the first-mover's advantages and the late entrant's entry timing?

In the next section, the extant literature is reviewed. The model is described in Section 3. Section 4 summarizes the research and suggests directions for further work.

2. LITERATURE REVIEW

The research encompasses two important issues, time-to-market and first-mover advantages. Time-to-market decision often plays an important role in whether a new product succeeds. Many papers model product development level as a function of the time of entry and study the trade-off between them. Morgan, et. al (2001) address a multi-generation product development situation with fixed and variable production costs. In their model, products are introduced more frequently than in the single period model although the firm enters the market later. In their single generation model, variable costs are more important, while fixed costs play a more important role in product development cycle time with multiple generations. This research is further extended by Klasorin and Tsai (2004). They assume that the order of entry is a function of two competitors' product design levels and capabilities. The first entrant enjoys a monopoly period, but once the duopoly situation begins, both firms set their prices simultaneously with knowledge of each other's product design level. The expected price competition forces the firms to position their products far away from each other. The model in this paper shows that the first mover does not always achieve greater market share or earn more profit. Assuming the competitor's production cost is a decreasing function of time-to-market, this research confirms that the pioneer may not have first-mover advantages if its production cost is much larger than the late entrant's.

Extant literature addresses first-mover advantages from many different aspects. Lieberman and Montgomery (1988, 1998) define first-mover advantages as the ability to earn profit. They also identify the mechanisms that lead to first-mover (dis)advantages. These mechanisms often arise from the first-movers' endogenous nature. There is a considerable amount of theoretical and empirical work (Urban, et. al 1986, Lambkin 1988, Kalyanaran and Urban 1992, Golder and Tellis 1993, Brown and Lattin 1994, Bowman and Gatignon 1996, Lee, et. al 2000). These articles support the notion that generally the first mover enjoys a permanent market share advantage and, further, that there is a positive correlation between the order of entries of all competitors and market shares. This paper supports this result by showing that the pioneer usually retains higher market share and higher profit unless the late entrant has a very superior production cost.

3. MODEL

Consider two firms, A and B, competing on one attribute, which is referred to as "quality". Both firms have full knowledge about each other: they know each other's cost and can foresee each other's move. Each firm wants to determine its product position and price to maximize its total profit over a finite time horizon.

A two-period model is developed, which incorporates the firms' positioning and pricing strategies. Let q_{A1}, q_{A2} denote firm A's product qualities and p_{A1}, p_{A2} denote the prices in periods 1 and 2 respectively. Let q_B denotes firm B's product quality and p_B denote the price. Firm A, a monopolist in the first period, first enters the market by introducing a new product with quality q_{A1} and price p_{A1} at time 0. Firm B chooses a time to enter the market, denoted by α, positions its product at q_B, and charges a price of p_B. Firm B's entry marks the beginning of the second period. As a response to firm B's entry, firm A changes its price to p_{A2} at time α and its product design to q_{A2} to gain a better position in the market.

Hotelling's framework is used to model customers' choices. Customers' ideal points are distributed uniformly in $[a,b]$. Firms position their products on the real line $\Re$, which follows Lilien, et. al (1995), Tabuchi and Thisse (1995), and Tyagi (2000). Customers with ideal point t value a product q using utility function $u(q,t) = R-(q-t)^2$, where R is the reservation price of customers, which is assumed to be the same for all customers and high enough so that all customers buy (Tyagi 2000). Note that in Hotelling's model, a higher value of quality does not imply a better product. Hence more quality does not imply more utility. A quality level simply denotes a position in the market with respect to a set of heterogeneous customers.

When there are two firms in the market and each offers a product with quality q_i at price p_i, $i = 1,2$, customers with ideal point t would prefer q_1 to q_2 (assuming $q_1 < q_2$) if and only if $R-(t-q_1)^2 - p_1 \geq R-(t-q_2)^2 - p_2$ which implies $t < \dfrac{p_2 - p_1}{2(q_2 - q_1)} + \dfrac{q_1 + q_2}{2}$. Note that $q_1 < t < q_2$.

So those customers whose ideal points are in $[a,t]$ will choose product q_1, and customers whose ideal points are in $[t,b]$ will choose product q_2. The boundary between the markets held by the two firms is at t which is denoted as c_p.

Assume that customers' ideal points are distributed uniformly in $[-1/2,1/2]$. Also assume $q_{A2} < q_B$, throughout the paper. The analysis for $q_{A2} > q_B$ is symmetric and is not covered here.

The whole time horizon is normalized to 1 and the lengths of periods 1 and 2 are denoted by α and $1-\alpha$, respectively. The value of α is a decision variable made by firm B.

At time 0, firm A's unit production cost is c_A, while firm B's unit production cost is c_B, which are determined by the technologies and equipment then required for the firms to produce desired products. Assume the initial investments are exogenous and hence the production costs at time 0 are given. Once the firms enter the market, their production costs will not change. As firm B waits for time period α to enter the market, its production cost changes to $c_B(1-\alpha)$ which is a decreasing function of the decision variable α. The cost reduces because of advances in process technology that firm B is able to enjoy on account of its late entry time. Call c_B the initial production cost and $c_B(1-\alpha)$ the actual production cost of firm B.

Let Π_i^j, $i \in \{A, B\}$, $j \in \{1,2\}$ denote firm i's profit in period j; Π_i, $i \in \{A, B\}$ denote firm i's total profit for the planning horizon.

Next period by period formulations and solutions are provided

Period 1: Firm can position its product anywhere along the attribute space, cover the whole market and charge a price as high as it can as long as $R-(t-q_{A1})^2 - p_{A1} \geq 0$ for all customers. Hence firm A is facing the following problem:

$$\max_{q_{A1}, p_{A1}} p_{A1} - c_A$$

$$\text{subject to: } R - p_{A1} - (t-q_{A1})^2 \geq 0, \text{ for all } t \in [-1/2, 1/2]$$

It is easy to see that firm A reaches its maximal profit when $q_{A1}^* = 0$ and $p_{A1}^* = R - 0.25$ and the optimal profit is $\Pi_A^{1*} = R - c_A - 0.25$.

The value of R will affect the magnitude of firm A's optimal profit in this period and thus the total profit over the whole time horizon but will not affect the nature of decisions.

Period 2: The firms' profits, Π_A^2 and Π_B, are now given by equations

$$\Pi_A^2 = (1-\alpha)(p_{A2} - c_A)\left(\frac{1}{2} + \frac{p_B - p_{A2}}{2q_B} + \frac{q_B}{2}\right)$$

$$\Pi_B = (1-\alpha)(p_B - c_B(1-\alpha))\left(\frac{1}{2} - \frac{p_B - p_{A2}}{2q_B} - \frac{q_B}{2}\right)$$

To solve the problem, prices are found first for any given α, q_{A2} and q_B and after inserting for the optimal prices, α^*, q_{A2}^* and q_B^* are determined. Since Π_A^2 is a concave function of p_{A2} and Π_B is a concave function of p_B, from the first order conditions,

$$p_{A2}^* = q_B + \frac{1}{3}q_B^2 + \frac{2}{3}c_A + \frac{1}{3}c_B(1-\alpha) \qquad (3.1)$$

$$p_B^* = q_B - \frac{1}{3}q_B^2 + \frac{1}{3}c_A + \frac{2}{3}c_B(1-\alpha) \qquad (3.2)$$

Substitute p_{A2}^* and p_B^* into Π_B. Differentiating Π_B with respect to q_B and α, by the first order conditions,

$$\alpha^* = 1 - \frac{9 + 10c_A - 3\sqrt{9-5c_A}}{25c_B} \qquad (3.3)$$

$$q_B^* = \frac{3+\sqrt{9+12c_B(1-\alpha^*)-12c_A}}{6} = \frac{3+\sqrt{9-5c_A}}{5} \qquad (3.4)$$

Following (3.3) and (3.4), the results are thus stated as following.

Proposition 1. (i) $p_{A2}^* \geq p_B^*$ for all valid c_A, (ii) $c_p > 0$ and $\Pi_A^{2*} \geq \Pi_B^*$ if and only if $c_A \leq \frac{27}{16}$.

Proof: (i) Note that $p_{A2}^* - p_{B2}^* = \frac{27+5c_A+9\sqrt{9-5c_A}}{75}$. Hence $p_{A2}^* - p_{B2}^* \geq 0$ is equivalent to $-27 \leq c_A \leq 9/5$, which always holds.

(ii) $c_p^2 = \frac{p_{B2}^* - p_{A2}^*}{2q_B^*} + \frac{q_B^*}{2} = \frac{27-20c_A+9\sqrt{9-5c_A}}{30(3+\sqrt{9-5c_A})}$. Hence $c_p^2 \geq 0$ is equivalent to $c_A \leq \frac{27}{16}$.

The difference between the profits of the two firms in period 2 is a one-variable function of c_A and is given by $\frac{\Pi_A^{2*} - \Pi_B^{2*}}{\beta} = \frac{54-40c_A+18\sqrt{9-5c_A}}{75}$. It is easy to verify that $\Pi_A^{2*} - \Pi_B^{2*} \geq 0$ is equivalent to $c_A \leq \frac{27}{16}$.

Firm A's production cost plays an important role in both firms' decisions. In period 2, firm A is always able to charge a higher price than firm B. But this price advantage does not necessarily bring firm A higher market share and profit; Specifically when $c_A > \frac{27}{16}$, firm A has the price advantage but lower market share and lower profit than firm B. However, for most values of c_A ($c_A \leq \frac{27}{16}$) whenever firm A has higher market share it also has higher profit which implies firm A enjoys first mover advantages in this period.

Proposition 2. The higher firm A's cost is, (i) the earlier firm B enters the market; (ii) the closer firm B positions to the most attractive location.

Intuitively, as firm A's cost becomes larger, it is easier for firm B to gain a cost advantage over firm A. Hence it enters earlier. Also it lowers firm B's need to buffer price competition from firm A, which allows it to locate closer to the most attractive location.

Note that firm B's actual production cost $c_B(1-\alpha^*) = \frac{9+10c_A-3\sqrt{9-5c_A}}{25}$ is independent of c_B and is a function of c_A only while the timing of its entry is affected by both. Firm B's actual cost needs to be lower than c_A regardless the value of initial cost c_B to gain a cost advantage over firm A so that firm A's first-mover advantage can be offset. Hence firm B's actual cost only relates to c_A but not c_B. To have a lower cost, firm B needs to wait for the right entry time. Intuitively, the higher c_B is, the longer it waits; the lower c_A is, the longer it waits. Hence α relates to both. This independence also explains why q_B^* is independent of c_B -- the influence of both firms' actual costs is captured by c_A solely and not the initial cost of firm B.

4. CONCLUSION

This paper considered two competitors who enter a market sequentially and compete on product positions and prices. A two-period game-theoretical model is developed to explore the product introduction decisions of entry timing, designs, and prices, and to investigate the effect of production cost on first-mover advantages. Analytical results for optimal product and pricing strategies are presented.

This paper showed that the pioneer generally enjoys first-mover advantages in terms of achieving higher prices, higher market shares, and higher profits. But when the late entrant has a superior cost structure, these advantages are offset. The late entrant waits until it obtains a low cost. The pioneer may adjust its product strategies in response to the late entrant's entry. The results showed that the first-mover may always charge a higher price but may not always enjoy higher profit than the late-mover. First-mover’s low production cost would defer the entry of the late-mover and push it away from the most attractive position of the market.

The research can be extended in many ways. The use of more realistic nonlinear production costs should improve the usefulness of this work, as will giving the first mover freedom to time its adjustment to its product strategies after the competitor enters the market. It will also be interesting to study the case in which the first-mover incurs a switchover cost when adjusting its price and product positions.

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