Strategic Product Innovations and Dynamic Pricing Models in Oligopolistic Market

Min-Ren Yan*

*Institute of International Business Administration, Chinese Culture University, Taipei 106, Taiwan, ROC

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Product innovations are one of the most critical driving forces for business developments and competitive advantages. However, commercialization of innovations and a proper pricing strategy for the innovative products is needed to pursue the market value as well as the premium profits. A firm’s pricing decision is regarded as one of the most business challenges in a competitive market, especially in dual competition and oligopolistic market. Although previous studies have addressed the tactics of price competition with diverse models, there is a need for systematic analyses regarding the dynamic price competition and a firm’s strategic decision for innovative products. In this paper, System Dynamics (SD) methodology was adopted to propose a simulation-based Strategy Dynamics Pricing Model (SDPM) as a decision support system. Through iterative computer simulations, the impact of product innovations and the dynamic price competition in oligopolistic market could be systematically analyzed. Strategic pricing decisions for product innovations and market competition would be enhanced with the analysis for better innovation management.

Keywords: Competition, Decision Support, Oligopoly, Pricing, Simulation, Strategy, System Dynamics.

Introduction

While product innovations could generate business opportunities, commercialization of innovations and a proper pricing strategy for the innovative products is needed to pursue the market values. Pricing decision is regarded as one of the most business challenges in a competitive market, especially in dual competition and oligopolistic market. With economic theories, diverse pricing models and game theoretic models were proposed for price competition\(^1\)\(^-\)\(^10\). However, few studies were made regarding the price competition for innovative products in a dynamics context. To fill the gap, this paper proposes a simulation-based Strategy Dynamics Pricing Model (SDPM) that helps to systematically analyze the strategic roles of product innovations and the dynamic price competition in an oligopolistic market.

The Strategy Dynamics Pricing Model

With the principles of System Dynamics (SD) methodology, Warren\(^1\) proposed Strategy Dynamics approach that integrates simulation model-based management and resource-based view for analyzing how a firm’s strategy and resource utilization drive performance over time. As an integration of the methodological framework to enhance the analytic capability for strategic product innovations and dynamic pricing decisions, the proposed SDPM is shown in Figure 1. The proposed model indicates that the firms’ strategic outcome in term of its profitability is the results of its effects of product innovation and pricing strategy decisions on market demand and competition intensity with rival in the constraints of its cost structure. The relationships between variables and firms’ strategic outcomes are modeled and described in the subsequent sections.

Modeling the strategic impacts to competition and switching behaviors

Bertrand duopoly models with Nash non-cooperative equilibrium concept are one of the principal oligopolistic models\(^12\). In the model, the duopolistic competition is referred as a situation where two firms produce identical or differentiated products with constant and equivalent marginal costs, and prices can be considered as strategy variables by assuming fixed price from rivals. In industrial level, the duopolistic competition is generally occurred where only two firms have dominant control over a specific market segment. When competing for a subset of an industry’s products or services, duopolistic firms encourage the customers switching
from the rival and should simultaneously prevent the reverse flow due to the negative effects of customer switching behavior. Bolton and Lemon argued that the economic determinants of customer switching behavior are economic satisfaction, perceived price levels, and price-value ratios. In addition, Klemperer proposed that switching costs prevent customers from switching to another supplier. Jones et al. identified switching costs and perceived relative attractiveness as two types of switching barriers which make customers more difficult or costly to change suppliers. Switching costs are defined as customer perceptions of the time, money, and effort involved in changing supplier or costs that a customer incurs when making the change. Perceived relative attractiveness refers to customer perceptions regarding the extent to which the value offered by the supplier compared with the alternative value offered by their rivals. Garcia-Acebron et al. argued that perceived value is a customer’s conjunction of two constituents including the total achieved benefits and total sacrifices arisen from the transaction with a supplier. In business-to-business context, firms typically maintain a regular level of demand from their long-time collaborative manufacturers (buyers) who regularly make orders (by units) for the industrial products and services. Therefore, the amount of regular orders from customers could be defined as a strategic resource. As the number of firm’s regular orders from customers (\(FO\)) is a stock that varies with time and depends on its previous volume, the value of its inflow – “customer’s regular orders switched from the rival to the firm” (\(OSF\)) as well as its outflow – “customer’s regular orders switched from the firm to rival” (\(OSR\)), this paper applies the standardized stock-flow formulating technique in SD to propose the \(FO\) function by an integral equation as follows:

\[
FO(t) = \int_{0}^{t} (OSF - OSR) + FO(0) dt 
\]

\[... (1)\]
Where $F_{O(0)}$ indicates the initial value of $F_O$. Similarly, $R_O$ could be estimated by the same logic. The function of $OSF$ comprises the level of customer’s perception on indifference ($PI$) and the fraction of customer’s regular orders won by the firm from rival ($FWF$). $PI$ function suggests that customer’s perception on indifference will take a small fraction of customers’ purchasing volume and randomly varies with time in the range of $PI$. The functions of $FWF$ are defined as follows:

$$FWF = \max \left\{ 0, \left[ \frac{F_Q \times R_P}{R_Q \times (FP + SC)} \right]^2 - 1 \right\} \times FSC \quad \ldots (2)$$

Where $FSC$ represents the customer’s perception on fraction of switching consideration, $SC$ represents customer’s switching cost, $F_Q$, $FP$, $R_Q$ and $RP$ represent firm’s perceived quality and price, and rival’s perceived quality and price, respectively. Similarly, the fraction of customer’s regular orders won by rival from the firm ($FWR$) could be estimated by the same logic.

**Modeling the strategic impacts to market demand**

Increased level of customer satisfaction and improved customer’s perceived value could foster customer’s demand$^{15}$. Customer’s past experience and non-experiential information are the sources of their expectations$^{21}$. Accordingly, the quantity per customer’s regular order of a firm could be adjusted by the level of customer’s satisfaction on the firm. While expectations has a negative influence on satisfaction by a perceived gap between current perceived value and expectations, the firm’s quantity sold per customer’s order ($FQO$) could be estimated by the following equation:

$$FQO = AQO \times \left[ 1 + SCD \times \left( \frac{FP}{FP \times EVF} \right)^2 - 1 \right] \quad \ldots (3)$$

Where $AQO$ represents customer’s average quantity per order, $SCD$ represents the sensitivity of customer’s demand based on the degree of satisfaction, $EVF$ represents the level of value expectation toward the firm. Similarly, the rival’s quantity sold per customer’s order ($RQO$) could be estimated by the same logic.

**Modeling the strategic impacts to supplier’s cost and business performance**

As the firm’s accumulated profit ($FAP$) is a stock that varies with time and depends on its previous volume and the value of its net change in profit in a period of time, which is estimated by an integral equation as follows:

$$FAP(t) = \int_0^t \left[ (FP - FUVC) \times FQT - FFC \right] + FAP(t_0) \quad \ldots (4)$$

Where $FAP(t_0)$ represents the initial value of $FAP$, $FQT$ represents the quantity sold in a period of time, $FUVC$ and $FFC$ are firm’s unit variable cost and total fix cost respectively. Similarly, the rival’s accumulated profit ($RAP$) could be estimated by the same logic.

**Model Validation and Simulation Analysis**

In this section, we validates the model applications with a demonstrated dual competition of two Japanese brands of portable gasoline engine market in Taiwan, Mitsubishi and Honda. A firm with major market share has the cost leadership advantage and conventionally sales at lower price level, while the rival has superior brand image in product quality and sales at higher price level. The firm has the options to propose a new product with its eco-friendly technology innovation and adjust its price, while the rival kept the persistent price. Based on the proposed model, simulation analysis could help to evaluate the impacts of different pricing and quality awareness with product innovations. Based on the same assumptions and settings for simulations, the estimated market share between two firms and their total profit after 2-year competition in each case are shown in the Table 1. The sensitivity analysis suggests that the firm could obtain more market share when lowering its price and expected profit. However, an over-reduced pricing decision could lead the firm as well as its rival to suffer negative profitability such as the result shown in Case A1. In addition, in despite of the losing of market share when the firm increases its price, its profit can be increased. In Case A3, the firm’s relative market share would be reduced to 50% but the firm could obtain a better profitability than the original price setting. The case A4 reflects the scenario that if the firm merely attempts to increase its price for more profit, at certain level, the sacrifice of market share won’t convert to increasing its profitability. In this case, the firm could not gain better profit compared with the current price setting while losing too much market share. The market sacrifices of the firm clearly lead better results in term of relative market share and accumulated profit of its rival. From the analysis, we found that there is an optimal pricing zone in which the firm could gain
more profit without hurting its rival profitability. Similar sensitivity analysis on quality with four different settings was conducted. The simulation results are equally shown in Table 1. The analysis results from the case B1 and B2 suggest that if Mitsubishi fails to maintain its original quality level, it would simultaneously lose the market share and decrease its profitability. In these cases, business performance of its rival would be improved both in market share and profitability. Case B3 reflects the assumption when the firm successfully improves its quality level that equivalent to its rival. In this case, the firm would obtain the better market share and profitability in the same time. The Case B4 also reflects the scenario that Mitsubishi invested more in R&D activities and boost its quality level even better than its rival. The scenario would lead the firm gain higher market share as well as higher profitability. In summary, the functions of product innovation and quality to market share and profit are represented by sensitivity analysis. The practical challenges for the firm is about the investment required for improving quality level, while the cost of R&D activities will affect the impact of the merely quality strategies on the business outcome.

**Conclusions**

When technology is ready for innovative products, pricing decisions and the responses from the demand side and market competition are critical issues for innovation management and business developments. The promotions of innovative products and associated pricing strategies require systematic models reflecting the interconnected determinant factors and dynamic outcomes for supporting business decisions in the changing environments. To improve business planning and strategic decisions, this paper proposes a scientific decision support model and demonstrates the functions to the industrial practices. Equipped with the simulation-based model, firms are able to test their intended policies as well as the competitive strategies, and improve the rationale of their decisions based on the quantified assessments of potential market share and profitability. Although the proposed model focused on specific variables and made assumptions to deal with practical issues from the benchmarked case, the model boundary as well as research limitations could be extended accordingly. The framework of the proposed model contributes to future studies on strategic product innovations and dynamic pricing models.

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