Determining Optimal Price and Order Quantity Under the Uncertainty in Demand and Supplier’s Wholesale Price

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ABSTRACT

Manufacturers in a high-tech durable product industry may have to make operational decisions in the presence of uncertainties associated with product demand and supplier’s wholesale price. In this paper, the authors investigate the impact of such uncertainties on the activities of a manufacturer and its supplier and develop an optimization model that describes how the manufacturers should reflect the uncertainty issues in their pricing and order quantity policy to achieve a desirable profit. In the modeling process, three important managerial problems are discussed, i.e., the effect of coordination between a manufacturer and its supplier in dealing with uncertainties on product demand and supplier’s wholesale price, strategies for mitigating both errors in demand forecasting and supply risk, and modeling frameworks to determine the optimal solution for price and order quantity based on the varying levels of coordination. To identify best operational decisions under market uncertainty, the authors use the stochastic optimal control theory.

Keywords: Demand Uncertainty, Optimal Price, Optimal Order Quantity, Supply Chain Coordination, Wholesale Price Uncertainty.

INTRODUCTION

In recent years, manufacturers in the high-tech durable product industry (e.g., personal computers, digital music devices, plasma and LCD TVs) have experienced some emerging changes in the environment. Due to the rapid advancements in technology, the life cycle of high-tech durable products tends to be shorter and the obsolescence rate of these products gets faster, similar to fashion items. In order to respond properly to the shifting markets, manufacturers have to continuously bring in-
novative product ideas into the markets and make an effort to quickly employ the newly available technology for reducing operational costs. The recent advent of Internet technology, for example, helps find cost-effective suppliers on a global basis, which enables manufacturers to offer better prices to their customers. This means that the customers in this particular market segment become increasingly sensitive to price and the competition of high-tech durable products at the retail level has become more complex and tougher than ever before.

One of the important factors that determine a manufacturer’s competitiveness in the high-tech durable product industry is product availability at a reasonable price. However, it is difficult for manufacturers to decide the most profitable levels of production and pricing because of the uncertainty associated with the supplier’s wholesale price as well as product demand. Suppliers may have to change their unit wholesale price to be profitable as the factors in the external environment change. A supplier’s unit wholesale price $S(t)$ at time $t$, for instance, can be affected by uncertain factors, such as the exchange rate at the time when the manufacturer buys the materials, the volatility of sourcing prices from foreign suppliers, the price changes of raw commodities, and fluctuation in manufacturer’s demand. This also leads to manufacturers’ retail price adjustments because the changes in the supplier’s wholesale price $S(t)$ affect the production costs. Therefore, without building a close long-term strategic partnership with key suppliers, manufacturers can hardly satisfy an ever-changing marketplace and create values for customers.

In this paper, we are concerned with the two major types of uncertainty that are associated with product demand and in supplier’s wholesale price. After we investigate how such uncertainties can disrupt the activities of a manufacturer and a supplier, we attempt to develop an optimization model that describes how the manufacturer should reflect the uncertainty issues in their pricing and order quantity policy to achieve a desirable profit. In the modeling process, three important managerial problems are discussed: 1) the effect of coordination between a manufacturer and its supplier in dealing with uncertainties on product demand and supplier’s wholesale price; 2) strategies for mitigating both errors in demand forecasting and supply risk; 3) modeling frameworks to determine the optimal solution for price and order quantity based on the varying levels of coordination in the given time. To identify best operational decisions under market uncertainty, we use the stochastic optimal control theory.

The remainder of this paper is organized as follows: Section 2 contains a brief literature review. Section 3 studies decision-making problems and demonstrates the models for optimal stocking and pricing policies. The numerical examples that support the model and the analytical discussions are presented in Section 4. Finally, Section 5 summarizes conclusions reached.

**LITERATURE REVIEW**

Most of the supply chain management literature (Hwang et al., 1967; Bensoussan et al., 1974; Pekelman, 1974; Hartl & Sethi, 1984; Feichtinger & Hartl, 1985; Gaimon, 1988) has focused on understanding how to balance production, inventory, and price under demand uncertainty. Levy (1995) examined the demand uncertainty and supplier reliability, Lee and Tang (1998 a, b) examined the trade-off between the consignment and turnkey arrangement under demand uncertainty, and Iyer and Berger (1997) were interested in the effect of demand uncertainty in the apparel industry and studied how Quick Response in the manufacturer–retailer channel could solve decision problems. In Iyer and Berger’s model, two dimensions of demand uncertainty, initial demand and post-initial time demand were used. Iyer and Berger assumed normal distribution of the two types of demand and measured the uncertainties of demand by the variances. Emmons and Gilbert (1998) examined a multiplicative model of demand uncertainty and demonstrated how uncertainty could lead to an increase in retail prices. By us-
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