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Optimal pricing and inventory strategies with multiple price markdowns over time

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ABSTRACT

We study a multiple period discount problem for products that undergo several price cuts over time. In the high-technology sector, electronic component suppliers are often able to offer pre-announced price cuts to buyers due to technological innovation that allows them to produce existing components at lower costs. In this context, suppliers are primarily concerned with the optimal pricing decisions for the components over their life spans in order to achieve the highest possible revenues. Accordingly, the buying firms (i.e., manufacturers or retailers) also need to identify the corresponding optimal retail prices and order quantity for the finished products that utilize the components for which discounts are offered frequently. In this research, we develop a multiple-period price discount model that addresses this issue. Extant research in the price discount literature focuses on supply chains' pricing and inventory decisions in the presence of a single price discount. The proposed model, in contrast, offers a systematic decision tool for identifying the optimal strategies throughout a product's life span. Our results show that a decentralized supply chain characterized by multi-period discounts over a product's life typically achieves 75 percent supply chain efficiency. We undertake a series of numerical experiments based on the model and discuss their managerial implications.

1. Introduction

Price discount is a fundamental strategy in different types of businesses including the consumer packaged goods sector (breakfast cereals, dairy products), the service sector (cell phone service, and others), and the high-technology sector (PC assemblers) among others. Price discount problems exist in various contexts. In the personal computer (PC) assembly sector of the PC industry, electronic component suppliers are often able to develop newer components with higher speed or better performance due to technological innovation, which also allows them to produce existing components at lower costs (Lee, Padmanabhan, Taylor, & Whang, 2000). An excellent example is Intel's central processing unit (CPU) price-breaks (see Fig. 1). Intel reduces CPU prices approximately once a quarter; these price reductions are normally announced in advance. When the new price becomes effective, PC makers pay a lower price for the CPUs, regardless of the purchase quantity. PC makers then reduce the price of PCs in responding to CPU price cuts offered by Intel. Besides Intel, many other electronic component manufacturers, such as Seagate, Western Digital (Hard drive disks), Hitachi, Sony (optical drives), Micron, Hynix, Samsung (memory modules), and LG/Philips (LCD) also offer pre-announced price discounts due to technological innovation regularly (Chung, Narasimhan, & Talluri, 2012). As a result, the retail prices of PCs continually decrease over time. Importantly, consumers are, in general, unaware of such price reductions on PCs in advance. They normally learn about PC price reductions after the new, lower prices become effective through retailers' advertisements in newspaper or surfing on retailers' websites.

In this research, we study a problem involved with multiple price discounts over a product's life that is common in the high-tech sector. Generally, electronic components enter the market initially as high-end products commanding premium prices. However, over time, their prices gradually decrease, as newer, more advanced products replace them in the market. They eventually become a low-end product towards the end of their life cycles, and subsequently will be phased out of the market completely (Fig. 2).

In this context, electronic component suppliers are primarily concerned with the optimal price discount schemes for the components over their life span, a series of critical decisions for achieving the maximum possible profit. Accordingly, buying firms (e.g., manufacturers or retailers) also need to identify a series of corresponding optimal retail prices for the finished products in order to achieve the highest profit.

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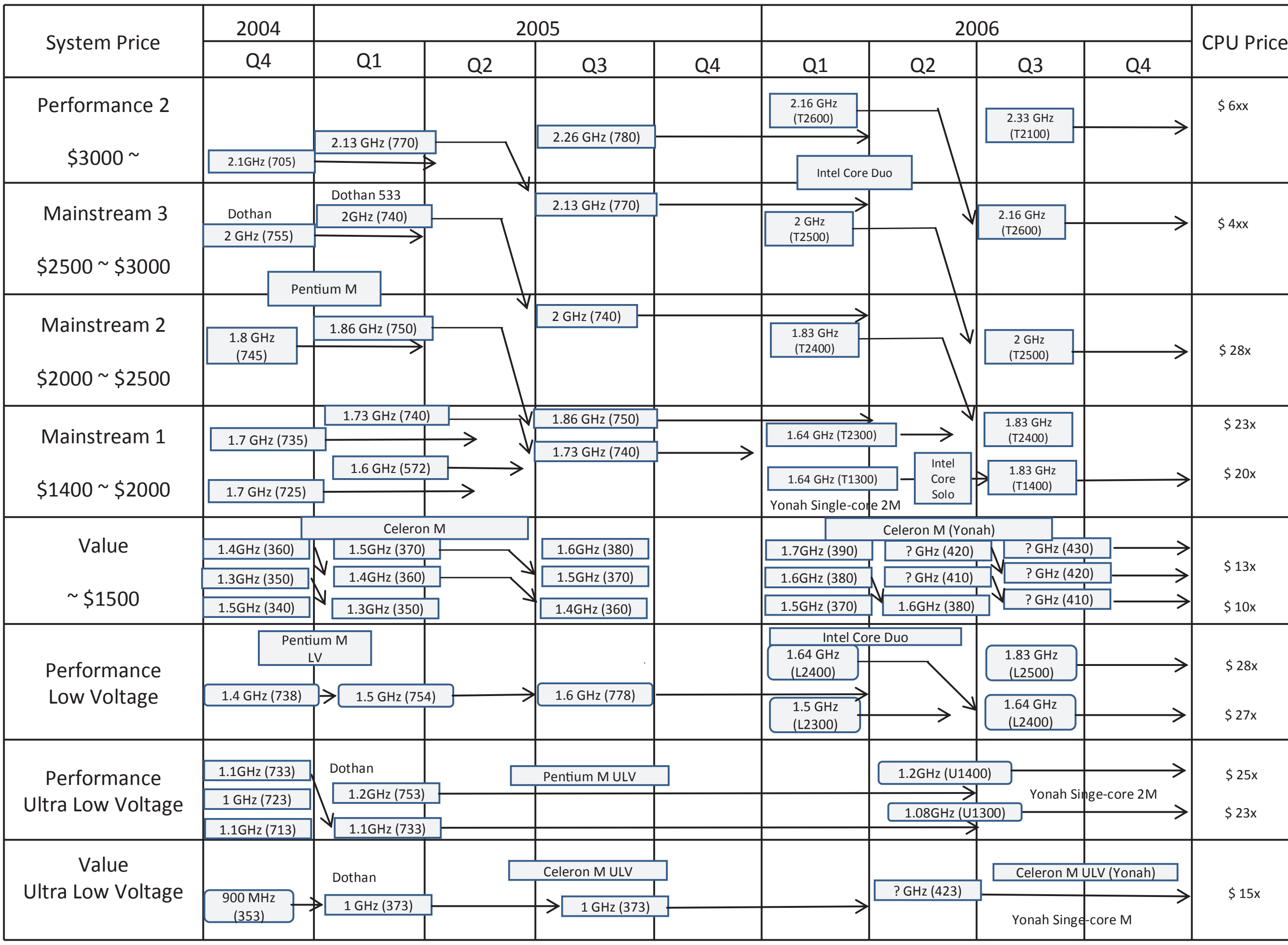

Source: Revised from Intel's CPU roadmap

Fig. 1. Intel mobile CPU roadmap.

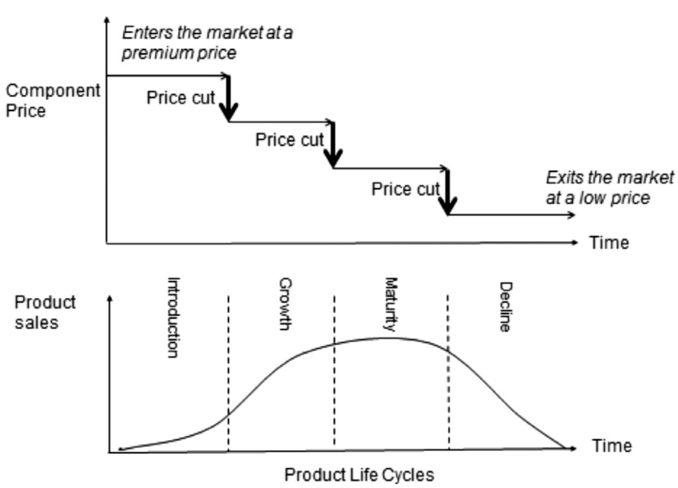

Fig. 2. Multiple period price cuts and product life cycle.

Demand for a product may increase when firms adjust (reduce) the price in the early stages of its life. Therefore, another key decision that buying firms have to make is to the optimal order/production quantity in each period to cope with demand stimulated by price cuts. Understanding these issues allows supply chain managers to better respond to such instances. Extant price discount research mostly focuses on supply chain members' price or/and inventory decisions in the presence of *a single price discount* (Bernstein, Chen, & Federgruen, 2006; Chung et al., 2012; Erhun, Keskinocak, & Tayur, 2008; Hu & Munson, 2002; Khouja, 1995; Weng, 1995). Our research, in contrast, considers the supplier's and buyer's price and inventory decisions throughout a product's life, giving rise to *a multiple-period price discount problem*.

Demand of a product that has relatively short life will not only be affected by its prices but also by the innovative position relative to other products in the market. Several demand functions that describe the patterns of product life cycle have been proposed in the literature (Aytac & Wu, 2013; Solomon, Sandborn, & Pecht, 2000), most of which are generated numerically by adopting the simulation approach. Although our research intends to study the pricing and inventory decisions of a product across multiple stages in its life, modeling product life cycles is not within the scope of this study. Rather, we incorporate such patterns in numerical experiments by adopting representative parameter values to mimic demand patterns in different stages of a product's life.

The remainder of this article is organized as follows. We first review literature related to the focus of our study in Section 2. We present the problem settings and formulate the multiple-period price markdown model in Section 3 and develop the optimal pricing and ordering decisions for the buyer and the supplier in Section 4. We further investigate the efficiency of such a decentralized supply chain and identify room for improvement in Section 5. We provide