



Decision Support

Integrating dynamic time-to-market, pricing, production and sales channel decisions



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ABSTRACT

This paper studies a firm's time-to-market decision and subsequent sales channel, pricing and production decisions under three main sources of uncertainty: possibility of qualifying for lucrative sales channels, competitors' time-to-market behavior and price-sensitive uncertain demand. In particular, we consider a firm that can potentially sell through two distinct channels. Selling through the primary channel requires the firm to first get its product qualified. The secondary channel does not require qualification. Prior to market entry, the firm performs product and process design activities which improve manufacturing yield and the chances of getting qualified for the primary sales channel. A long delay in market entry allows competitors to enter the market before the firm, reducing the firm's market share. This delay also affects the firm's sales channel strategy. While deciding when to enter the market, the firm also needs to decide what price to charge and how much to produce at each period of a finite planning horizon. Demand distributions depend on the product's price through general stochastic demand functions. Pricing and production decisions can be specified dynamically as a function of the state of the system and they are intertwined with the time-to-market decision. The paper provides a unified model that captures the key relationships and trade-offs among time-to-market, sales channel, pricing and production decisions. Explicitly modeling the linkages among these key decisions enables us to characterize and quantify their joint role in profit generation. This paper provides managers with a tool and a process that can guide them in determining an optimal policy for market-timing, pricing and production decisions that maximize firms' expected profits.

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1. Introduction

A firm's profitability depends, to a large extent, on determining the right time to market its product, the right sales channel to sell through, the right price to charge and the right quantity to produce during the product's life cycle given the uncertainties in the development process, demand and competitor behavior. This paper studies the decisions faced by a firm that develops a new product (such as hard disk drives) that is integrated to the firm's key customers' product line (such as a personal computer, or a mainframe). To be a qualified supplier, the firm is required to go through stringent tests to ensure manufacturing process integrity and fit for the customer's end product within a *qualification time window*. The customer tests the product for performance and manufacturing integrability; audits the firm's production sites as well as its suppliers; and verifies whether the firm is ready for mass production. Demand realized through this channel constitutes the firm's primary sales channel. The firm can also

sell its product through distributors that do not require qualification. Demand from such distributors constitutes the firm's secondary sales channel. This paper studies such a firm's key decisions and trade-offs in deciding an optimal time to market its product, sales channel mix, pricing, and production decisions.

The market timing decision during an arduous product development process depends on whether the firm should invest more time in *manufacturing* process design and improvement or push the product to market before competitors. This trade-off impacts various profit drivers and functional areas within a firm. From the marketing perspective, early entrance to market translates into a large market share. Depending on the success of the product, a dynamic pricing strategy can be used to increase revenue. From the manufacturing perspective, delaying market entry results in higher production yields and lower costs. The time window prior to market entry is the opportune time to improve manufacturing yields. From the research and development perspective, process improvement activities resulting from minor tweaks in product design increase the likelihood of getting the product qualified per the customer's stringent requirements. Only the qualified firm can sell its product to key customers, which constitute the firm's primary sales channel. However, a long delay may

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cause the firm to miss the qualification window altogether. Unqualified product can only be sold through a secondary channel, which is often used to salvage product development efforts. From the accounting and finance perspective, the opportunity cost of building and carrying the new product is weighed against not entering the market at all. To better manage these trade-offs, we provide an integrated framework and policy for optimal dynamic time-to-market, sales channel, pricing and production decisions.

Several suppliers of key components from various industries face these trade-offs. Our study was originally motivated by our close collaboration with Hitachi Global Storage Technologies (currently known as HGST). The company recruited us to help them streamline their new product introduction processes and develop a tool to quantify the impact of related decisions on profitability. To do so, together with HGST we identified key tradeoffs associated with their market timing, sales channel, pricing, and production decisions. Hitachi Global Storage Technologies had a well-established place in the hard disk drive industry. It was founded in 2003 and was formed as a result of the strategic merger of IBM's global storage technology business. In 2012, Western Digital acquired HGST, while keeping the brand name intact. At the time of our engagement, HGST produced hard disk drives for all three of mobile computer, desktop computer and server segments. In each segment, HGST had three to ten product families. Each product family had one to five product lines. HGST mainly manufactured two types of products: generic hard drives and custom drives. Generic hard drives were sold to multiple customers, including manufacturers and distributors. For these products, the prevailing market determined prices that were paid for generic hard drives. Custom drives were sold to specific group of customers for whom the product was specifically developed. Custom drives were sold through both primary (if qualified) and secondary channels. The company had some flexibility in setting prices and adjust them over the product's life cycle. This paper focuses on a custom component sold through two channels and the firm that produces it has the flexibility to set prices throughout the product's life cycle. We refer the reader to the case study on HGST by Özer (2009) and Özer and Uncu (2013) for a detailed account of challenges faced in introducing a new hard-disk drive to market. We remark that suppliers of key components from various industries from telecommunication, semiconductors, to automotive, face similar trade-offs (see, for example, Gerling, Preussger, & Wulfert, 2002). We occasionally refer to the above case only to help conceptualize the trade-offs.

From the research and development perspective, a firm that invests more time in manufacturing process design prior to market entry is more likely to qualify and satisfy the customer's requirements. Hence, firms in various industries have well structured product development procedures, check points and contingency plans. Özer and Uncu (2013) provide an extensive discussion of qualification and post-qualification production processes in the hard disk drive industry. Gerling et al. (2002) describe the qualification process and the technical requirements for semiconductor companies. Terwiesch and Bohn (2001) describe the detailed processes required to transition from pilot production runs to mass production after a firm is qualified. Although these procedures and check points reduce the uncertainty around the process of new product development, they do not eliminate it. The qualification process involves lengthy, extensive and costly procedures. Hence, the firm often has one opportunity to apply for qualification and the outcome cannot be predicted in advance. Missing the qualification time window or failing to qualify is a possibility.

From the marketing perspective, when introducing a new product the primary goals are establishing market share, relationships with the customer and effective pricing policies. In addition, the firm may establish a secondary sales channel that does not require qualification. This secondary channel is often used to salvage new product development efforts in case of an unsuccessful product qualification

for the primary customer. Hence, the firm sells through two types of channels: a primary channel that requires qualification and a secondary sales channel that does not require qualification. In both channels, the firm's market share depends on the order of market entry. Early entrants make headway in establishing relationships and contractual agreements which positively affect their market share (e.g., Lieberman & Montgery, 1988). Hence, the order of entry into a market is inversely related to market share (e.g., Özer & Uncu, 2013; Robinson, 1988; Urban, Carter, Gaskin & Mucha, 1986). Note, however, that it is not obvious how the firm can use the early entrant market share advantage because competitors' time-to-market decisions are almost always uncertain. Hence, marketing divisions tend to favor early entry. Nevertheless, the firm can obtain some information about the likelihood of competitors' time-to-market through trade show information, analyst reports and past competitive behavior (e.g., Bayus, 1997). As a result, the firm often has some information about the likelihood of a competitor entering the market. For some products (such as custom hard drives), the firm can also dynamically adjust prices in response to available inventory, uncertain demand and remaining product life. Such pricing and revenue management practices are known to improve profits significantly (Özer & Phillips, 2012; Talluri & van Ryzin, 2005).

From the manufacturing perspective, the firm needs to establish production processes, prepare facilities for production ramp up, improve manufacturing yields for profitability prior to market entry and decide on how much and when to produce during the life of the product. Prior to market entry, the firm improves manufacturing yields through better manufacturing process design that allows faster assembly, less manual labor, fewer parts and lower overhead costs. The firm builds prototypes, tests them for any assembly issues, checks performance and manufacturing related issues and prepares the facilities for the qualification and production process. For example, in the hard disk drive industry, the manufacturing yield improves if more time is allocated to manufacturing process design prior to market entry. Similar yield improvements prior to market entry are observed in various industries from pharmaceutical industry and information technology (Pisano, 1996; Sambamurthy & Subramani, 2005). This improvement is due to accumulative learning experiences prior to mass production, widely known as *learning-before-doing*. After market entry, the firm ensures effective transition and replication of processes and yield achievements from pilot runs to actual production. During actual production, the yield also improves because accumulated experience in manufacturing processes reduces costly errors. This improvement is referred to as *learning-by-doing*, and is also empirically observed in industries such as semiconductor, automobile assembly, chemical processing and hard disk drive manufacturing (Hatch & Mowery, 1998; Lieberman, 1984). Given imperfect yield and uncertain demand, the firm needs to decide how much and when to produce.

Developing a new product requires several years starting from concept design to initiating mass production. During this time, the firm faces numerous decisions from product portfolio selection, product design, investment decisions, supplier and production site selection to manufacturing process design and so on. This paper cannot and does not aim to study all trade-offs and decisions involved in new product development. Instead, we focus on the final stage of product development just before mass production. This stage is sometimes referred to as launch readiness. The firm freezes majority of design related decisions before this final stage. During launch-readiness stage, final revisions to execution plans are made before market introduction. For example, Hitachi GST fills out a cross-functional checklist database to ensure proper progress is made in all aspects of manufacturing process design and qualification readiness. Prototypes of the product are produced in small and large volumes and tested for any issues in manufacturing and assembly processes. During this time window, cross-functional business analysis teams study the

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