Columbia Business School Research Paper Series

“Dynamic Targeted Pricing in B2B settings”

Jonathan Z. Zhang, Oded Netzer and Asim Ansari

Dynamic Targeted Pricing in B2B settings

Jonathan Z. Zhang*
Oded Netzer
Asim Ansari

February 2011

Jonathan Zhang is an Assistant Professor at the Michael G. Foster School of Business, University of Washington (email: zaozao@uw.edu). Oded Netzer is the Phillip H. Geier Jr. Associate Professor of Business at Columbia Business School (email: on2110@columbia.edu). Asim Ansari is the William T. Dillard Professor of Business at Columbia Business School (email: maa48@columbia.edu).

Abstract

We model the multifaceted impact of pricing decisions in B2B contexts and show how a seller can develop optimal inter-temporal targeted pricing strategies to maximize long-term customer value. We empirically model the B2B customer's purchase decisions in an integrated fashion. In order to facilitate targeting and to capture the short and long-term dynamics of B2B customer purchasing, our modeling framework weaves together in a hierarchical Bayesian manner, multivariate copulas, a non-homogeneous hidden Markov model, and control functions for price endogeneity. We estimate our model on longitudinal transactions data from an aluminum retailer. We find that customers in our dataset can be best represented by two latent states - a "vigilant" state characterized by heightened price sensitivity and a cautious approach to ordering, and a more "relaxed" state. The seller's pricing decisions can transition customers between these two states. An optimal dynamic and targeted pricing strategy based on our model suggests a 52% improvement in profitability compared to the status quo. Furthermore, a counterfactual analysis which examines the optimal policy under fluctuating commodity prices reveals that the seller should pass much of the costs to customers when commodity prices increase, but hoard most of the profit when commodity prices (seller's costs) decrease.

1. Introduction

Despite the major role of the business-to-business (B2B) sector in the U.S. and world economy, marketing modelers have paid scant attention to B2B issues. While the B2B sector commands more than 50% market share of all commerce in the U.S. (U.S. Department of Commerce 2007), only a small fraction (approximately 3.4%) of the articles in the top four marketing journals deal with B2B contexts (LaPlaca and Katrichis 2009). Among the different marketing decisions, pricing in B2B environments is particularly under-researched (Reid and Plank 2004). In this paper, we address this imbalance by developing an integrated framework for modeling the multiple impacts of pricing in B2B contexts. We then illustrate how our framework can aid sellers in implementing first-degree and inter-temporal price discrimination for long-run profitability.

Pricing decisions in B2B contexts are different from those within business-to-consumer (B2C) environments on multiple facets. First, B2B settings are often characterized by highly variable costs of goods and order sizes, the prevalence of product and service customization, and the reliance on personal selling to cement transactions. These factors create a fertile environment for implementing first degree and inter-temporal price discrimination. Sellers in many B2B situations can easily vary prices across buyers and can even change prices between subsequent purchases of the same buyer. This flexibility generates significant opportunities for sellers to pursue long-term profitability. In contrast, B2C retailers rely on a restricted set of targeted price discrimination mechanisms (such as coupons), and targeted pricing is difficult, in general, because of logistical and ethical concerns.

Second, the B2B environment involves evolving long-term relationships between buyers and sellers (Morgan and Hunt 1994). The development of trust in such relationships can impact price sensitivities over time. Pricing decisions, in turn, can play a vital role in developing and sustaining such relationships (Kalwani and Narayandas 1995). Third, transactions in B2B markets exhibit greater complexity as the business customer typically makes several inter-related

decisions. Specifically, B2B buyers not only choose what, when, and how much to buy, but also decide on how to buy. In B2B settings, buyers often choose whether to ask for a price quote (offering the seller the opportunity to provide a price quote) or whether to order directly from the seller without asking for a price. Such requests for a price quote allow sellers to observe demand and price sensitivity even when a sale is not made (i.e., when a bid is made and the buyer rejects the bid). Such data are rarely observed in B2C settings (Khan et al. 2009). Similarly, the buyer's decision to order directly from the seller (without observing the price) indicates the strength of relationship. Our modeling approach accommodates this unique aspect of the buying process.

Finally, decision makers (buyers and sellers) in B2B settings are often assumed to behave rationally (Reid and Plank 2004). Thus, while behavioral pricing theory suggests that internally constructed reference prices play an important role in customer purchase decisions, and that loss aversion should be considered in modeling reference price effects (Kalyanaram and Winer 1995), it is not clear whether such behavioral effects are operant in the B2B domain.

In this paper, we develop a modeling framework that incorporates these distinguishing aspects of the B2B environment. Our framework models customer decisions on each potential purchasing occasion in an integrated fashion using different model components. It uses hierarchical Bayesian copulas (Nelsen 2006; Pitt et al. 2006; Trivedi and Zimmer 2007) to flexibly model the four decisions (purchase timing, purchase amount, quote request, and quote acceptance) jointly. It accounts for heterogeneity in customer preferences and behaviors to facilitate targeting, incorporates asymmetric reference price effects and other behavioral effects, handles price endogeneity using a Bayesian analog of control functions (Park and Gupta 2009; Petrin and Train 2010), and accommodates purchase dynamics and the short and long-term effects of pricing using a multivariate non-homogeneous hidden Markov model (Montoya et al. 2010; Netzer et al. 2008; Schweidel et al. 2011).

We apply our framework using longitudinal transaction data from an aluminum retailer selling to industrial buyers. We identify two latent buying behavior states: a vigilant state characterized by high customer price sensitivity and a cautious approach towards ordering, and a

relaxed state that is characterized by more direct orders and lower price sensitivity. We also find strong evidence for asymmetric reference price effects including loss aversion and gain seeking. Consistent with the hedonic adaptation theory (Frederick and Lowenstein 1999), we find that buyers not only weight price losses more than gains, but also take longer to adapt to losses than to gains. To the best of our knowledge, this is the first empirical evidence for the hedonic adaptation theory using secondary data. We also find that the proposed model exhibits superior out-of-sample predictive ability relative to several benchmark models.

We illustrate how our model can be used for computing optimal individual targeted prices that maximize long-term customer value. The optimal pricing policy balances between short- and long-term perspectives. In the short-term, the price is determined by the tradeoff between converting orders to sales and the desire to increase margins. In the long-term, the seller balances the wish to reduce prices to retain customers in the relaxed state and the wish to keep prices high to avoid reducing internal reference prices. The optimization indicates that the optimal dynamic targeted pricing policy can increase the seller's profitability by as much as 52% compared to the status-quo. We also use a counterfactual analysis to examine the firm's optimal pricing policy in the presence of a volatile aluminum commodity market. Volatility in the aluminum commodity market alters the cost structure for the seller while also changing the external reference point for buyers. Consistent with the dual entitlement principle, our simulation results indicate that when the commodity prices increase, the seller should pass to the buyers much of the cost increase. However, it can "hoard" some of the benefits of a cost decrease when the commodity market prices decrease.

In summary, our research pushes forward the pricing literature in several directions. On the methodological front, it provides a state-of-the-art and unique hierarchical Bayesian framework that weaves together a multivariate non-homogenous HMM, copulas, heterogeneity, and control functions to effectively capture relevant aspects of the B2B settings. More importantly, on the substantive front, it yields insights about how the short- and long-term effects of behavioral demand parameters such as loss aversion, reference price, and latent buying

behavior states shape customer demands in what is traditionally considered to be "rational" purchasing activity. Furthermore, our findings provide strong evidence for the potential to employ value-based pricing policies, even in a traditional B2B industry characterized by cost-plus pricing practices.

The rest of the paper is organized as follows: Section 2 highlights the challenges and opportunities in investigating pricing decisions in B2B settings. Section 3 describes the data from an industrial metal retailer. Section 4 outlines the modeling framework. Section 5 illustrates the application of our modeling framework to the data. Section 6 describes the dynamic targeted pricing optimization based on the estimated model and Section 7 concludes by discussing practical implications, theoretical contributions, and future directions.

2. Targeted Pricing Decisions in B2B Settings

Our research lies at the intersection of multiple research streams involving pricing in B2B markets, targeted pricing, pricing dynamics and reference prices. In this section, we briefly review these literatures.

2.1 Pricing in B2B Markets

The majority of the research on B2B pricing is conceptual and survey based (Johnston and Lewin 1996), and scant attention is given to quantitative pricing models. The overall neglect could stem from conflicting views about the role and importance of pricing relative to other attributes in B2B contexts (see Lehmann and O'Shaughnessy 1974; Wilson 1994 and Hinterhuber 2004). In this paper, we empirically investigate the multifaceted impact of pricing using data from a B2B seller.

2.2 Dynamic and Individually Targeted Pricing

Targeting and customization are emerging topics in academic research and are immensely relevant to the world of practice. The empirical literature on targeting, however, has primarily focused on non-price marketing actions such as catalog mailing (Gönül and Shi 1998; Simester et al. 2006), coupons (Rossi et al. 1996; Shaffer and Zhang 1995), digital marketing campaigns

(Ansari and Mela 2003), B2B communication contacts (Venkatesan and Kumar 2004) and pharmaceutical detailing and sampling (Dong et al. 2009; Montoya et al. 2010) as these marketing actions are viewed as being naturally customizable and targetable at the individual level. In contrast, empirical research on *individually* targeted pricing has been relatively sparse, possibly due to the logistical, ethical, and legal issues concerning price discrimination in traditional (B2C) settings. Exceptions include Zhang and Krishnamurthi (2004) and Lewis (2005) who study pricing and promotion targeted at the segments level. Khan et al. (2009) demonstrate the importance of individually targeting consumers and the value of both inter-temporal and cross-sectional targeting for a mix of promotional activities. The authors note that one of the limitations of their study is the inability to observe purchase intents that did not result in a purchase. They also highlight the logistical problem of individually targeted pricing in the B2C brick and mortar context.

Dynamics can be incorporated in pricing models using different mechanisms. Winer (1986) uses reference prices to capture dynamics. Greenleaf (1995) and Kopalle et al. (1996) study the implications of reference prices for the firm's dynamic pricing policy, Lewis (2005) incorporates customers' forward looking expectations about future prices, and Chan and Seetharaman (2004) model the relationship between state-dependence and pricing decisions. We differ from these studies on several aspects. First, we use a multivariate non-homogenous HMM to allow for dynamic pricing and to capture the enduring impact of reference prices. Second, we leverage these dynamics to target prices both at the *individual level*, as well as *temporally,* over repeated transactions for the same customer. Finally, most pricing models investigate the effect of the firm's pricing on brand choices or on a single purchase decision. In contrast, we investigate the impact of the seller's pricing policy and the resulting reference prices on a sequence of inter-related customer decisions that are typical of B2B environments.

2.3 Reference Prices in Customer Buying Behavior

The notion that consumers use reference prices in assessing the attractiveness of offers is well established within marketing (Hardie et al. 1993; Kalyanaram and Winer 1995; Kalwani et al.

1990; Krishnamurthi et al. 1992; Winer 1986). The literature distinguishes between "internal" and "external" reference prices (Mayhew and Winer 1992). External reference prices (e.g., MSRP, and prices of other brands) are generally observable and common to all customers, whereas internal reference prices are assumed to be individual-specific and are often constructed based on the customer's observed prices on previous purchase occasions. Briesch et al. (1997) compares several external and internal reference price mechanisms and concludes that internal reference prices have greater empirical support.

A rich body of experimental and empirical work demonstrates the behavioral underpinnings of reference price effects (Kalawani et al. 1990; Wedel and Leeflang 1998). Erdem et al. (2010), in contrast, proposes a "rational" explanation for reference price effects based on quality signaling and price expectations. In behavioral pricing, the observed price in relation to a reference price is often encoded as either a loss or a gain and can thus have an asymmetric impact on brand choice (Kalwani et al. 1990; Putler 1992), purchase timing (Bell and Bucklin 1999), and purchase quantity (Krishnamurthi et al. 1992).

Despite the voluminous literature on reference prices, these have found little application in B2B pricing models based on the presumed "rationality" of B2B decision makers (Kalayanaram and Winer 1995). Internal reference prices, however, can play an important role in B2B purchasing because transactions are formally recorded by most buyers and relationships are typically long-term in nature. In addition, we know little about the impact of ignoring reference prices on targeting policy and performance as they have not been studied in conjunction with targeted pricing. We further the reference price literature along several dimensions by studying the asymmetric impacts of internal reference prices in multi-decisional contexts which permit first-degree and inter-temporal price discrimination. We also investigate the possible long-term effects of reference prices in a B2B context. Next, we describe our dataset and the business context in which the seller operates.

3. Data

Our data come from an East Coast local aluminum retailer that supplies to industrial clients such as machine shops and fabricators operating in its geographical trading area. This dataset is typical of what is found in B2B selling in commodity markets. The data contains customer-level information on purchase events over a 21 month period from January 2007 to September 2008. A *purchase event* begins with the need for a certain quantity at a given point in time. Given this need, the buyer either places a direct order without asking for a price quote, or may request a price quote (usually via the phone or fax). For example, a typical direct order may be received by the morning via a fax saying: "Send me four aluminum sheets A inch by B inch and thickness of C inch by tomorrow afternoon". Direct orders are generally fulfilled immediately and the customer is charged a price determined by the seller. Alternatively, if the customer requests a quote (i.e., an "indirect order") the firm bids for the customer's business, and can only "win" the business if the customer accepts the quoted price.[1] Thus, in our setting, purchase events include not only completed transactions but also lost transactions involving quotes that were not accepted, thus allowing for a better understanding of customer price sensitivity.

The company has a large number of SKUs that are defined based on the shape, thickness and customizable size of the aluminum. Furthermore, the wholesale cost of aluminum changes on a daily basis following the London Metal Exchange (LME). Therefore, as is typical in this industry, the company does not maintain a price list and determines the price to charge or quote on a case by case basis. Because of the variation in order quantities and the large number of SKUs, a common measure for prices in this industry is a "price per pound" measure that incorporates the cutting costs and complexity of the order. As is typical of most customer relationship management (CRM) datasets in B2B settings, our dataset does not include

[1] Discussions with the management and sales personnel in the company that provided the data revealed that negotiations, beyond the request for the price quote and the firm initial bid, are not common. Analysis of the price and bid quantity relative to price and quantity on the order invoice confirmed that both price and quantity rarely changed from the original bid to the final order. This provides empirical evidence for minimal negotiation beyond the bid process.