Why Markdown as a Pricing Modality?

Elodie Adida[†] Özalp Özer[⋆]

[†]School of Business, University of California at Riverside, elodie.goodman@ucr.edu

[⋆]Jindal School of Management, University of Texas at Dallas, oozer@utdallas.edu

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Markdown as a pricing modality is ubiquitous in retail whereas everyday-low-price (EDLP) remains relatively rare (despite its several advantages, such as simplicity). Using a stylized model, we explore whether and why retailers can use either of these pricing modalities as an effective defense against a competitor entering the market with the alternative pricing modality to sell an identical product. Various studies have shown that consumers are strategic and heterogeneous in their valuation of a product. Consumers are also shown to be regret-prone and anticipation of regret affects their purchase decisions. They may experience availability regret when unable to purchase a product due to a stockout, and high-price regret when missing an opportunity to purchase the product at a low price. Considering such factors, consumers decide whether, when and from which retailer to purchase the product. In such a market environment, we find that the possible entry of a competitor should deter retailers from using the EDLP pricing modality, but not markdown. We also identify a new reason for the markdown retailer to ration stock (in addition to the reason of discouraging consumers to wait and attempt a purchase at the discounted price). In particular, we show that inventory rationing can be used to preclude a cutthroat competition and bankruptcy after the entry of an EDLP retailer. We also quantify how consumer regret affects *both* retailers' decisions and resulting profits. In particular, because of competition, the EDLP retailer is indirectly affected by consumer regret and cannot simply disregard consumer regret. We show that high-price regret and availability regret have complementary effects on the markdown retailer's rationing strategy and the EDLP retailer's price decision. Finally, using a proprietary price data set from a large department store, we show that ignoring regret factors causes the markdown retailer to leave up to 20% of its profits on the table. In addition, in a competitive market, the markdown retailer rations too aggressively when regret is ignored, and as a result leaves some of the forgone profit to its competitor – the EDLP retailer. Retail industry is often characterized by its slim profit margins. In such an environment, aforementioned results also suggest that retailers should seriously consider investing in developing the capacity to estimate and quantify the role of regret in consumers' purchase decisions.*

Key words: pricing, markdown, everyday-low-price, competition, regret

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1. Introduction

The way that products are priced, that is, the *pricing modality* – the mechanism by which buyers, sellers and intermediaries determine the price for a transaction in a market – has evolved over time. Most products today are assigned a "price tag". However, neither all products are sold with a price tag today, nor has pricing modality always been this way. For example, the price of a car is routinely subject to consumer negotiation. Purchasing a home likewise involves a series of offers and counteroffers that continues until the seller and the buyer converge (if at all) at a certain purchase price. Indeed, until about 150 years ago, bargaining or haggling was the common way of determining the price at which a product would be purchased. Fixed pricing was introduced by Rowland H. Macy when he founded the famous department store, Macy's, which needed to establish a faster and more systematic way of selling high volumes in the store.

In retail, markdown appears to be a pervasive *pricing modality*. The use of markdowns, also known as price skimming, started in the 1920's, and has grown steadily since the late 1960's (Pashigian 1988; Pashigian and Bowen 1991). Kaufmann et al. (1994) report that in 1988, products sold at discounted prices accounted for over 60 percent of department store sales volume, a figure that had grown to 75 percent only three years later. In the apparel industry, moreover, 50 percent of merchandise on average is sold at a price below the list price (Hardman et al. 2007). Today, markdowns are ubiquitous. Seasonal products are commonly sold at a discount near the end of the selling season, and even products that are not subject to seasonality effects, such as non-perishable food products, are regularly discounted. D'Innocenzio (2012) reports that "a typical retailer sells between 40 and 45 percent of its inventory at a promotional price."

Exceptions to this pricing modality do exist. Some retailers, such as Trader Joe's, Sam's Club and Walmart, instead implement the everyday-low-price (EDLP) pricing modality, that is, continuing to sell a product at the same price throughout the entire selling season. These practices remain unusual, however, and some implementations of the EDLP pricing modality have famously ended in failure. For example, J.C. Penney's sales plunged after abandoning its existing markdown pricing modality and adopting a new "fair and square" EDLP pricing modality in 2012; the company notoriously returned to the markdown pricing modality in 2013 (Mourdoukoutas 2013). Overall, while a few retailers use EDLP, the vast majority continues to employ the markdown pricing modality. This paper uses the structure of a competitive market equilibrium to help explain the predominance of markdown as a pricing modality when consumers are regret-prone and forward-looking. Specifically, we investigate how the threat of entry of a competitor can affect the choice of a pricing modality in the presence of strategic and regretful consumers.

While markdowns are common, they have frequently been characterized as a wasteful practice. Sayner (2011) explains that "taking too many markdowns represents failure in some area or another. Overbuying, duplication, poor timing of deliveries, and bad assortment planning are all recognized causes of markdowns." Markdowns are sometimes employed because of "bad" inventory or pricing decisions, such as having poor insight into consumer valuation trends due to long lead times (Pashigian and Bowen 1991; Elmaghraby and Keskinocak 2003; Hardman et al. 2007), stocking too large a quantity of a product, setting too high an initial price, or making poor merchandising choices, involving, for instance, how products are displayed or the inclusion of a superior product in an assortment (Phillips 2012, p. 16).

So, why then markdown continues to be preferred as a retail pricing modality? With the help of advanced pricing software, experienced managers should be able to avoid most pricing, inventory and merchandising errors necessitating the use of markdowns. Business analytics and technologically sophisticated pricing, forecasting and procurement tools have emerged to help managers make better decisions. Some research indicates that, even though there are certain situations when markdowns may be useful, when consumers are forward-looking, the markdown pricing modality may be inferior to the EDLP pricing modality (Aviv and Pazgal 2008). Both empirical, experimental and anecdotal evidence suggest that most consumers are indeed forward-looking, anticipating future discounts from retailers (Soysal and Krishnamurthi 2012; Li et al. 2014; Mak et al. 2014; Moon et al. 2017). In addition, the marketing literature has identified a number of advantages associated with the EDLP pricing modality, including pricing credibility, simplicity and consistency; ease of advertising and of establishing brand image; low managerial costs due to ease of price selection; low operating costs due to ease of implementation; simple inventory planning because of stable demand; and lower labor costs due to less frequent changeovers (Hoch et al. 1994). Yet, as Hoch et al. (1994) note, "in spite of these apparent advantages, most retailers have not adopted EDLP."

We offer three possible explanations for the persistence of a particular pricing modality in retail industry. One is institutional history and path-dependence, which apply when changing from an established pricing modality would be impractical or very costly. Analyzing the costs supermarkets face when switching from one pricing modality to another, Ellickson et al. (2012) find that the high long-term repositioning cost of moving from a promotional to the EDLP pricing modality, as well as a revenue drop resulting from the switch, may help explain retailers' hesitation in adopting EDLP. Another possible reason, if the pricing structure has sociological roots, is economic sociology: Davis (2013), for example, explores the role of promotions in industrial history, markets and the behavior of market participants from a sociological perspective. A third potential reason is related to market equilibrium, that is, profit-driven decisions given the market characteristics. For example, Su (2007) shows that markdowns can increase profitability as a price discrimination tool when consumers are heterogeneous in their valuations and patience. All such factors may play a role (see Phillips 2012 for more on the choice of pricing modality). In this paper, we focus on and investigate how market equilibrium may explain the persistence of markdown as the dominant retail pricing modality. Specifically, we aim to understand the role of market equilibrium for markdown as a pricing modality in a competitive setting in which a retailer with different pricing modality (in our case EDLP) enters the market.

Retailers often supplement markdowns with inventory rationing when consumers are forward-looking (Mattioli 2012). Rationing can serve as a strategy to induce consumers to purchase the product at a regular price. Consumers may anticipate a future markdown, and delay a purchase in order to buy at a lower price. Retailers, therefore, can limit the available quantity of a product so consumers have an incentive to purchase products at the regular full price without delay (DeGraba 1995; Gallego et al. 2008; Liu and van Ryzin 2008; Su and Zhang 2008). Indeed, when available quantities are limited, a consumer who has a high reservation price for the product will not be willing to take the risk of waiting for a markdown only to find that the product is out of stock. Hence, inventory rationing together with the markdown pricing modality can be understood as a way to encourage full-price first-period sales. In this paper, we also explore how the presence of competition affects a markdown retailer's reason to ration inventory. Note that inventory rationing does not, by contrast, typically play a part in the EDLP pricing modality as EDLP retailers enjoy stable, predictable demand and thus can avoid stockouts (Sullivan and Adcock 2002; Thain and Bradley 2012; Shapiro 2016). Indeed, part of the reason EDLP retail venues appeal to consumers is that they do not intentionally create scarcity and hence there are no anticipated stockouts.

Typically, consumers are neither fully myopic nor lacking emotions in their purchasing behavior. Indeed, many consumers behave strategically, anticipating that retailers will mark prices down in the future, and potentially delay purchases to take advantage of the low prices. In addition, non-pecuniary considerations, such as the potential for regret, can also affect consumer decision (e.g., Simonson 1992; Zeelenberg 1999; Özer and Zheng 2016). Regret arises when consumers, using counterfactual thinking, compare the outcome of their decision with the potential outcome of an unselected option (Roese 1994). Consumers experience regret when, having bought a product at a certain price, they realize they had an opportunity to purchase the product at a lower price and thus to gain extra surplus (high-price regret). Consumers may also experience regret when they wait for the markdown period but find the product sold out at that time and end up not purchasing the product at all (availability regret). Anticipated regret reduces the utility that consumers gain from purchasing the product, in that consumers choose the retail venue and time of purchase to maximize their expected utility. Özer and Zheng (2012, 2016) and Murphy and Hayes (2016) attribute J.C. Penney's EDLP failure to consumers' behavioral biases, such as regret. In practice, some retail venues are also cognizant of such regret effects; for example, to take advantage of the potential for consumer price and availability regret, airlines and websites selling air tickets provide information such as "only 2 seats left at this price," while online retailers such as amazon.com often display messages such as "only 3 left in stock – order soon."

Explicitly studying the impact of regret on pricing modality in a competitive setting is important for at least two reasons. First, consumer regret plays a key role in the choice of one pricing modality over the other. In the absence of regret factor, the consensus in the pricing and revenue management literature prior to 2010 was that the presence of strategic consumers hurts the profitability of dynamic pricing practices (e.g., Besanko and Winston 1990; Nair 2007; Aviv and Pazgal 2008; Levin et al. 2009) and leads to the optimality of a single-price policy (Coase 1972; Stokey 1979; Wilson 1988; Su 2007; Gallego et al. 2008). The implicit assumption in this literature was customers do not experience regret in their purchase decisions at all. In other words, given these results, a retailer should not consider the markdown pricing modality in the presence of strategic customers because the optimal pricing modality would be EDLP in this case. As a result, one should not (or perhaps very rarely) observe the markdown pricing modality in practice. However, scholars have recently realized and hence shown that consumer regret is a key factor for why a retailer uses the markdown pricing modality over the EDLP in a monopoly setting (e.g., Özer and Zheng 2016). Second, suppose markdown can be shown to be a dominant pricing modality in a competitive setting that assumes consumers do not experience regret at all. One might then argue that the markdown pricing modality generates high-price and availability regret in consumers (as they are well documented in practice). And in contrast, the EDLP pricing modality may ex-ante seem unlikely to generate regret (due to a single-price and no rationing policy). Hence, one could rightfully argue that regret-prone consumers would have favored the EDLP retailer, and EDLP would have been an attractive pricing modality for retailers, if one were to correctly account for and consider regret in his or her analysis of a competitive setting. Hence, in our analysis, we explicitly study the impact of regret on the choice of pricing modality and also consider the regret-free consumer as a special case of our general model. In doing so, our results provide a more complete picture than simply ignoring the effect of regret. In summary, at the current state of the literature on pricing, an analysis of pricing modality in a competitive setting needs to capture and understand the impact of regret on consumers' decisions.

To better understand the implications of these aforementioned issues on a retailer's choice of pricing modality, we consider two retailers in competition, selling perfectly substitutable products. One retailer uses EDLP and the other uses markdown. We consider consumers who, knowing that the markdown retailer will offer a discount on unsold products in a future time period, are strategic and regret-prone. Our goal is to understand how markdown can be explained to be the dominant pricing modality as a defense against potential entry of a competitor. To achieve this goal, we explore a sequential game between an incumbent and an entrant.[1] We consider two scenarios in which the incumbent is either a markdown retailer or an EDLP retailer while the entrant uses the other pricing modality. These two scenarios allow us to understand whether and how the existing pricing modality (e.g., markdown) may or may not protect a retailer against the entry of a competitor with a new pricing modality (e.g., EDLP). To do so, we use a stylized yet parsimonious model which captures the key trade-offs observed when two retailers with different pricing modalities compete in a sequential game in which forward-looking consumers decide whether, when and from which retailer to purchase the product while potentially experiencing regret in their choice.

2. Literature Review

Four streams of research informed and inspired the present paper. We refer the reader to Özer and Phillips (2012) for a comprehensive review of this pricing management literature.

The first stream of research takes the pricing modality as given (i.e., does not consider the role of pricing modality) and studies how a monopolist firm set its price and inventory level (to maximize profits) when consumers are strategic in timing their purchase. Firms often use markdowns to promote the liquidation of excess stock before the end of season. Optimally marking down price helps clear unsold inventory while maximizing profits. Such markdowns however can also encourage some consumers to delay their purchase. Consumers behave strategically, as opposed to myopically, when they learn to anticipate the firm's pricing and inventory strategy and look forward (e.g. anticipate a markdown) when making a purchase decision. What we know from this literature is how a monopolist firm must adjust its pricing and inventory decisions in the presence of strategic consumers (Su 2007; Gallego et al. 2008; Ovchinnikov and Milner 2012; Aviv and Vulcano 2012 and references therein). For example, firms benefit from using markdowns, if this pricing modality is combined with an inventory rationing policy. In this case, consumers who consider delaying their purchase face the risk of not finding the product available later, and thus they would consider purchasing the product immediately at the higher price (Liu and van Ryzin 2008). A firm can also mitigate the adverse effect of strategic consumer behavior by committing to a certain stocking quantity and giving availability guarantees such as consumer compensation in case of a stockout (Su and Zhang 2009).

The second stream of research studies how different pricing modalities affect a monopolist firm's pricing and inventory decisions. Researchers find that markdowns may not be the optimal pricing

[1] Several other researchers have analyzed a sequential game in a competitive market with an incumbent and entrant narrative to understand the reasons behind a certain observed characteristic in a market. For example, Balachander (2001) provides a signalling-based explanation for the empirical observation that products with low quality tend to offer longer warranties. Nalebuff (2004) shows that bundling is an effective tool as an entry barrier. Tyagi (2000) demonstrates that a firm may prefer to defensively position its product away from the most attractive location, in case a competitor with a cost advantage later enters the market. Liu et al. (2006) demonstrate that, by refraining from entering the online market, a brick-and-mortar retailer can deter the online entry of a competing e-tailer.

modality for a monopolist firm, especially when the firm holds high levels of inventory (Aviv and Pazgal 2008). Yet, when the product is perishable and either the demand is uncertain or the consumer's willingness-to-pay is unknown or some consumers are myopic, markdowns are more profitable than a single-price (Gallego et al. 2008). We also know that consumers may regret when they wait for a markdown and do not find the product available or when they pay the high price earlier. Intensity of such regret affects consumers' purchase timing decision and as a result determines when markdown is a better pricing modality than single-price (e.g., EDLP) (Özer and Zheng 2016). In the long run, frequent markdowns may also yield greater profits than a single-price, for example, when consumers experience search costs (Cachon and Feldman 2015). Nevertheless, a monopolist firm may want to avoid committing to a markdown price (or to have no markdown price) especially when inventory is likely to remain unsold (Cachon and Swinney 2009).

The third stream of research studies how competition affects firms' decisions when firms use the exact same pricing modality for strategic consumers who lack any emotional motive (e.g., do not regret at all). This literature shows that competition reduces firms' ability to increase profits from rationing inventory in the first period to counter strategic behavior (Liu and van Ryzin 2008).[2] Firms may also benefit more from limiting the information available to consumers than from responding to fully-informed consumers' strategic behavior (Levin et al. 2009). When firms' products are quality-differentiated, consumer' strategic behavior reduces the low-quality firm's profit more so than the high-quality firm's (Liu and Zhang 2013). Competing firms in these studies use the same pricing modality. In contrast to this literature, in our paper competing firms use different pricing modalities (markdown and EDLP) to sell identical products. This modeling choice helps us understand the effect of the competitive setting on the pricing modality. Also both Levin et al. (2009) and Liu and Zhang (2013) consider situations in which stock levels are fixed and there is no spillover effect among competing firms. In our paper, the firm using the markdown pricing modality also makes a stocking decision, and thereby manages availability and can create scarcity. The stocking decision thus has a major impact on consumer choice. We also allow consumers to spill over to the competitor in case the product is out of stock. Finally, our paper takes into account how regret affects consumers' decision-making process and firms' decisions and profits.

The fourth and final stream of research studies how consumers' emotional motives (such as, regret) affect their purchase decisions and how a monopolist firm responds (i.e., in the absence of competition). Özer and Zheng (2012) provide a comprehensive review of this literature. This line of research studies consumers who are motivated both by monetary and emotional motives in their purchase decisions. For example, consumers may form an internal reference price that they

[2] We remark that Liu and van Ryzin (2008) consider competing firms who use markdown as a pricing modality. They assume that all firms set prices identical to one another in each of the two time periods, and that the consumer chooses randomly from any firm as long as there is available inventory. This assumption allows them to focus their investigation on the firms' stocking decisions.

use for price judgements (Popescu and Wu 2007). Consumers may experience regret when they purchase a product in advance (i.e. prior to the regular sales season) and later find that their valuation of the product to be lower than the price paid (Nasiry and Popescu 2012). Such regret affects consumers' purchase decisions and whether and when firms should advance sell. Similarly, during regular selling seasons consumers may also experience regret when the markdown pricing modality is used (e.g., when a consumer waits for the markdown and finds that the product is no longer available). Intensity of such regret defines when the markdown pricing modality may outperform the EDLP pricing modality and vice versa (Özer and Zheng 2016). A key difference of our work from these papers is that we consider a competitive setting. The presence of a competing alternative firm affects consumers' purchase decisions. Hence, our consumer model also introduces two important distinctions. First, in our model, demand may spill over to the competitor in case of a stockout. Second, regret may be experienced because of comparison of surpluses across competing firms in addition to an inter-temporal comparison of surpluses. Thus, the dynamics driving how and why firms make their pricing and stocking decisions in a competitive setting are fundamentally different from a monopoly setting.

3. The Overall Model

We consider a market in which two retailers, a markdown retailer and an everyday-low-price (EDLP) retailer, compete over two time periods (i.e., Period 1 and Period 2) selling an identical product. In both time periods, the EDLP retailer selects price p_E and does not seek any intertemporal consumer segmentation. Anticipating demand, it stocks enough of the product to incur no stockout (Sullivan and Adcock 2002; Thain and Bradley 2012). Accordingly, part of the EDLP retailer's strategy is to provide a guarantee to consumers that the product will be available. Conversely, the markdown retailer sets a list price (i.e., full price) p_1 for the first time period, and marks the price down in the second time period using a discount factor δ; thus, the product is sold at the markdown (i.e., discounted) price δp_1 in Period 2. The markdown retailer also determines a stocking level K such that consumers who choose to buy the product from the markdown retailer in Period 2 may risk finding the product unavailable; the probability that a consumer will find the product available at the markdown retailer in Period 2 is denoted by q and referred to as the availability probability. When a consumer encounters a stockout at the markdown retailer in the second time period, she has the option to purchase the product from the EDLP retailer.[3] For every

[3] Appendix B (available in the online supplement) discusses the case in which consumers cannot spill over to the EDLP retailer in case of a stockout.

product sold, each retailer incurs a procurement cost c.[4] We assume $c < \bar{v}$, where $\bar{v}$ is the highest consumer reservation price for the product. Otherwise, retailers would have to price the product above the highest consumer reservation price to make a profit, and no consumer would purchase it. We provide a glossary of notations in Appendix A.

The markdown retailer's discount factor $\delta < 1$ is fixed and known to consumers and to the EDLP retailer. Fashion retailers, for one, often use the same limited set of discount rates in clearance seasons (see, for example, Caro and Gallien 2012); for instance, the clothing retailer Gap and its related brands, such as Banana Republic and Old Navy, periodically offer "40% off" sales events. For managerial and marketing reasons, firms often optimize list prices while keeping discount rates fixed. Under this practice, retailers apply the same discount during each markdown period (e.g., semi-annual 50% off sales events) (see Liu and van Ryzin 2008, and Özer and Zheng 2016 for several other industry examples following this pricing modality).

The market includes N consumers. Each consumer is characterized by her reservation price, v, which follows a uniform distribution on $[0, \bar{v}]$. Each consumer chooses whether to purchase the product, and if so, from which retailer to purchase. Consumers make decisions that maximize the utility they gain from a purchase, given that their utility is zero when no purchase is made.[5] Figure 1 illustrates the decision tree and realized utilities faced by a consumer with a reservation price v.

Consider first decisions in the absence of regret. If a consumer decides to visit the markdown retailer, she decides whether to purchase in Period 1 or 2. Purchasing in Period 1 gives her the utility $v - p_1$. Purchasing in Period 2 gives her the utility of $v - \delta p_1$ if the product is not sold out. Otherwise, she can choose either to visit the EDLP retailer and gain utility $v - p_E$ or not and gain zero utility. The consumer can also decide to visit the EDLP retailer instead of the markdown retailer to begin with. In this case, her utility would be $v - p_E$. Alternatively, she may decide not to purchase the product at all and gain zero utility.[6] Consumers, however, are both strategic and regretful; that is, they both anticipate the markdown and also experience high-price and availability regret (Simonson 1992; Zeelenberg 1999; Özer and Zheng 2016). Regret arises when the consumer realizes that a different decision would have yielded a higher surplus. The regret

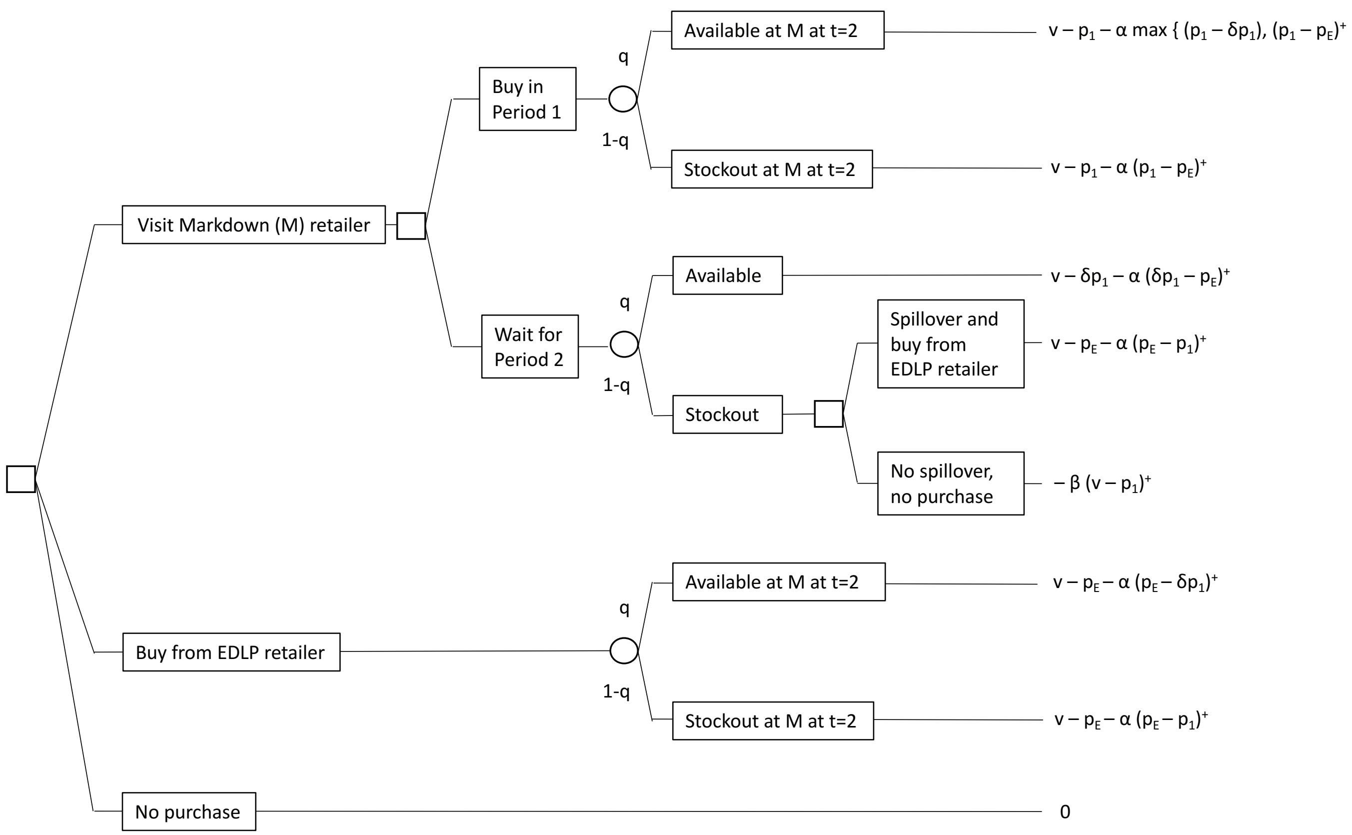
[4] Our goal is to understand how the choice of the pricing modality affects profits while all other things – in particular costs – are equal. Procurement or production costs are primarily affected by the choice of supply chain design (e.g., postponement) and not the pricing modality. Therefore, we focus on the impact of pricing modality by assuming equal procurement costs at each retailer and refer the reader to the online supplement for the differential cost case.

[5] We use the following tie-breaking rules: for the same expected utility, the consumer prefers a purchase over no purchase, prefers the EDLP retailer over the markdown retailer, and prefers the markdown retailer in Period 2 over the markdown retailer in Period 1.

[6] We assume without loss of generality consumers value a purchase the same regardless of the time period the product is purchased. Explicitly modeling the reduction in the value of a second period purchase (e.g., $v - \epsilon$) does not provide new insights to our study, mainly because its effect on a consumer's purchase utility can be considered together with the effect of the second period (or markdown) price (e.g., $v - (\epsilon + \delta p_1)$). Therefore, to keep the discussions simpler, the literature assumes same valuation in both periods (e.g., Liu and van Ryzin 2008; Özer and Zheng 2016).

is evaluated ex-post as the expected value of the forgone surplus once any uncertainty present is resolved. Anticipation of regret affects the consumer's utility and hence her purchase decision.

Figure 1 Decision tree and realized utilities for a consumer with reservation price v



A consumer may experience *high-price regret*, with intensity $\alpha \in [0,1]$, when purchasing at either of the retailers. A decision incurring high-price regret is accompanied by a disutility that is proportional to the highest possible surplus the consumer forgoes when she makes this decision (Bell 1982; Loomes and Sugden 1982; Zeelenberg 1999; Özer and Zheng 2016). A consumer buying from the *markdown* retailer may face high-price regret in three occasions. (i) High-price regret may arise when the consumer buys the product in Period 1 and the product is available (which occurs with probability q) at the markdown price δp_1 in Period 2 or sold at a lower price p_E at the EDLP retailer. The consumer then incurs the disutility of $-\alpha q \max\{(p_1 - \delta p_1), (p_1 - p_E)^+\} - \alpha(1-q)(p_1 - p_E)^+$, where $(x)^+ \equiv \max\{x, 0\}$. (ii) High-price regret may also arise when the consumer buys the product in Period 2 and the product is sold at a lower price at the EDLP retailer. The consumer then experiences a disutility of $-\alpha(\delta p_1 - p_E)^+$. (iii) Finally, high-price regret may arise when the consumer attempts but fails to buy the product in Period 2, chooses to spill over to the EDLP retailer and buys at the EDLP price, while the product was sold at a lower price at the markdown retailer in Period 1. In this case the consumer experiences the disutility of $-\alpha(p_E - p_1)^+$. Similarly, a consumer buying from the *EDLP* retailer may experience high-price regret in two occasions (i) when the product is sold at a lower price at the markdown retailer in Period 1, incurring a forgone surplus of $(p_E - p_1)^+$, or (ii) when it is available at a lower markdown price in Period 2, incurring a (larger) forgone surplus of $(p_E - \delta p_1)^+$. Thus, a consumer who directly purchases from the EDLP retailer experiences the expected disutility of $-\alpha q(p_E - \delta p_1)^+ - \alpha(1-q)(p_E - p_1)^+$.

A consumer buying from the markdown retailer may also experience *availability regret*, with intensity $\beta \in [0,1]$, when she chooses to purchase the product in Period 2 but finds it out of stock and then chooses not to spill over to the EDLP retailer. The surplus utility a consumer would have gained from a guaranteed purchase in Period 1 is $(v - p_1)^+$. Therefore, the consumer experiences availability regret as a disutility of $-\beta(v - p_1)^+$ in this case. The EDLP retailer secures sufficient stock to satisfy its entire demand. Therefore, consumers who visit the EDLP retailer do not experience availability regret. Note that the consumer facing a stockout from the markdown retailer in Period 2 may choose to spill over to the EDLP retailer, depending on whether spilling over would provide her with a greater utility than not doing so. Note also that if $\alpha = \beta = 0$, we revert to a model in which regret is not in effect. The literature considers the availability regret as more salient in practice than the high-price regret, see Özer and Zheng (2016) and references therein. Hence, we assume $\alpha < \beta$. All of our results continue to hold without this assumption except Lemma 1 part (ii).

A consumer with reservation price v would then have the following expected utilities when she purchases from the markdown retailer in Period 1, when she attempts to purchase from the markdown retailer in Period 2, and when she purchases from the EDLP retailer, respectively:

$$\begin{aligned} U_1 &= (v - p_1) - q\alpha \max\{(p_1 - \delta p_1), (p_1 - p_E)^+\} - (1-q)\alpha(p_1 - p_E)^+, \\ U_2 &= q[(v - \delta p_1) - \alpha(\delta p_1 - p_E)^+] + (1-q)\max\{(v - p_E) - \alpha(p_E - p_1)^+,\ -\beta(v - p_1)^+\}, \\ U_E &= (v - p_E) - q\alpha(p_E - \delta p_1)^+ - (1-q)\alpha(p_E - p_1)^+. \end{aligned} \tag{1}$$

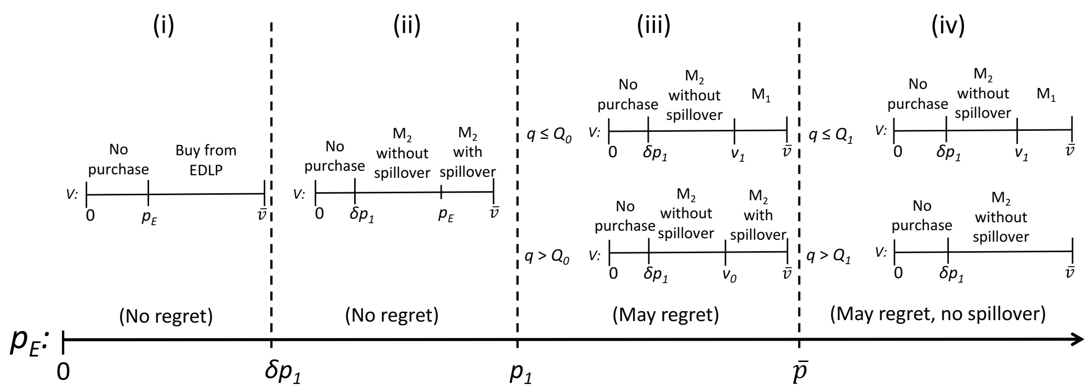
4. The Consumer Purchase Decision

Given each retailer's pricing decision and the markdown retailer's inventory decision (and hence the availability probability q), the consumer decides whether to purchase the product, and if so from which retailer and in which time period to purchase, selecting the decision that provides her with the highest expected utility. We then show how retailers can use price to segment market across consumers with different product valuations. Proposition 1 below summarizes these segments, which we represent as a function of the EDLP retailer's price p_E. This proposition shows, in a transparent way, what the key drivers are and how they (including the regret factors) give rise to these market segments. Once these segments are defined, we then calculate the total number of consumers in each segment to determine the resulting demand at each retailer as shown in Proposition 2. This proposition then helps us determine each retailer's resulting expected profit. All proofs are relegated to online Appendix C.

PROPOSITION 1. *We define thresholds Q_0, Q_1 and cutoff values $v_0, v_1, \bar{p}$ as follows:*

$$Q_0 = \frac{p_E - p_1}{p_E - \delta p_1}, \qquad Q_1 = \frac{(1+\beta)(\bar{v} - p_1)}{\bar{v} - \delta p_1 + \alpha p_1(1-\delta) + \beta(\bar{v} - p_1)},$$
$$v_0 = \frac{p_E + \alpha(p_E - p_1) + \beta p_1}{1+\beta}, \quad v_1 = p_1 \frac{1 + \alpha q(1-\delta) - q\delta + \beta(1-q)}{(1+\beta)(1-q)}, \quad \bar{p} = \frac{\bar{v}(1+\beta) + (\alpha - \beta)p_1}{1+\alpha}.$$

The following figure shows how the retailers' pricing and stocking decisions segment the consumer population among two or three segments (details of which are deferred to Appendix C available in the online supplement) as a function of the EDLP retailer's price p_E.



Notation: 'M_2 without spillover': visit Markdown retailer in Period 2 and buy the product if it is available, otherwise do not spillover to the EDLP retailer (i.e., do not purchase the product); 'M_2 with spillover': visit Markdown retailer in Period 2 and buy the product if it is available, otherwise spill over and purchase from the EDLP retailer; 'M_1': buy from Markdown retailer in Period 1.

We highlight three observations. First, in case (i), consumers do not experience regret because they purchase from the EDLP retailer, without facing the chance of a stockout, and at a price that is below the markdown price. Second, in case (ii) consumers can neither experience availability nor high-price regret. In contrast, in case (iii) consumers may experience either type of regret. As a result, the market segmentation in case (ii) is independent of the value of the regret intensities, but not in case (iii). In other words, if retailers set prices such that the EDLP price is between the markdown price δp_1 and the list price p_1, then consumer regret is eliminated. In this case, no consumer would choose to buy from the markdown retailer in Period 1 because the EDLP retailer offers the product at a cheaper price. Hence, it pays off to wait for the markdown period and attempt to purchase the product then. If the product is not available, the consumer can simply spill over to the EDLP retailer and buy the product at price p_E, which is lower than the markdown retailer's list price p_1. So, in this case, there is no forgone alternative purchase option that would instigate consumer regret. The significance of this distinction between the two cases will be more apparent in Sections 5.1 and 6, in which the markdown retailer is the incumbent. In particular, we will show that in equilibrium a deep discount rate (i.e., $1-\delta$) yields case (ii). In other words, an incumbent markdown retailer, by providing a deep discount, can eliminate both high price and availability regret in the presence of an entrant EDLP retailer. In contrast, a low discount rate yields case (iii) with $q > Q_0$ in equilibrium and regret plays a key role in this case. Finally, market segmentations in cases (iii) and (iv) also differ in an important way. No consumer spills over to the EDLP retailer in case (iv). This case occurs if the EDLP retailer sets a high price. In contrast, spillover may occur in case (iii). Some consumers may choose to spill over in case (iii) because the EDLP price is low enough (or equivalently the markdown price is high enough) that spilling over in case of a stockout provides more utility than forgoing purchase and incurring availability regret. Prices, stocking decision and profits are all different in each of these cases.

Given this market segmentation, we characterize the resulting demand for the markdown retailer in each period (D_1, D_2) as well as for the EDLP retailer (D_E^P for primary demand, D_E^S for spillover demand) in the following proposition. To avoid unnecessary procurement costs, the markdown retailer would never stock more than the maximum possible total demand. However, it may be optimal for the markdown retailer to create scarcity during Period 2. Hence, the optimal stocking decision would satisfy $K \in [D_1, D_1 + D_2]$. The markdown retailer sells $\min\{K - D_1, D_2\} = K - D_1$ during Period 2. Hence, the markdown retailer's stocking decision endogenously determines the availability probability as:

$$q = \frac{K - D_1}{D_2}. \tag{2}$$

The markdown retailer would never consider a markdown price greater than the highest consumer reservation price. Hence, without loss of generality, $\delta p_1 < \bar{v}$.

Proposition 2. *The following table shows demand at each retailer as a function of* p_E*:*

$p_E \in$	(i) $[0, \delta p_1]$	(ii) $(\delta p_1, p_1]$	(iii) $(p_1, \bar{p}]$		(iv) $(\max\{p_1, \bar{p}\}, \infty)$	
			$q \le Q_0$	$q > Q_0$	$q \le Q_1$	$q > Q_1$
D_1	0	0	$\frac{N}{\bar{v}}(\bar{v} - v_1)$	0	$\frac{N}{\bar{v}}(\bar{v} - v_1)$	0
D_2	0	$\frac{N}{\bar{v}}(\bar{v} - \delta p_1)$	$\frac{N}{\bar{v}}(v_1 - \delta p_1)$	$\frac{N}{\bar{v}}(\bar{v} - \delta p_1)$	$\frac{N}{\bar{v}}(v_1 - \delta p_1)$	$\frac{N}{\bar{v}}(\bar{v} - \delta p_1)$
D_E^P	$\frac{N}{\bar{v}}(\bar{v} - p_E)$	0	0	0	0	0
D_E^S	0	$(1-q)\frac{N}{\bar{v}}(\bar{v} - p_E)$	0	$(1-q)\frac{N}{\bar{v}}(\bar{v} - v_0)$	0	0

The above result shows that retailers face one of the four demand scenarios depending on the EDLP retailer's price p_E.[7] In the first scenario (part (i)), i.e., when the EDLP retailer sets a low price, the EDLP retailer captures the demand from all consumers who want to purchase the product while the markdown retailer receives no demand. In the second scenario (part (ii)), i.e., when the EDLP retailer prices moderately, all consumers wait for the markdown period. Hence, neither the markdown retailer nor the EDLP retailer observes demand during Period 1. The EDLP retailer receives some spillover demand, from consumers with a reservation price higher than the EDLP price, if the markdown retailer stocks out during the markdown period. In the third and fourth scenarios (parts (iii) and (iv)), i.e., when the EDLP retailer sets a price higher than the markdown retailer's list price p_1, the EDLP retailer receives no primary demand. Depending on the availability probability, consumers purchase from the markdown retailer in either Period 1 or 2, or attempt to purchase from the markdown retailer only in Period 2. The EDLP retailer may receive some spillover demand when the availability probability at the markdown retailer is large enough, inducing all consumers to wait for markdown period and consider spilling over (if the EDLP retailer's price is not set too high). In other words, the markdown retailer's rationing policy (which affects availability during the markdown period) determines whether the EDLP retailer observes any demand.

Finally, we make a technical observation that enables us to use a change of decision variable for the markdown retailer, simplifying the exposition. We can rewrite the availability probability as

$$q = \begin{cases} \frac{K}{\frac{N}{\bar{v}}(\bar{v}-\delta p_1)} & \text{in scenarios (ii), (iii) with } q > Q_0, \text{ and (iv) with } q > Q_1, \\ \frac{K-\frac{N}{\bar{v}}(\bar{v}-v_1)}{\frac{N}{\bar{v}}(v_1-\delta p_1)} & \text{in scenarios (iii) with } q \le Q_0 \text{ and (iv) with } q \le Q_1. \end{cases}$$

Note that q is always independent of p_E. As a result, regardless of the EDLP retailer decision p_E, there is a one-to-one relationship between (p_1, K) and (p_1, q).

5. The Retailers' Decisions

The aforementioned demand characterization at each retailer yields the following expected profits at the markdown and the EDLP retailer, respectively.

$$\Pi_M = (p_1 - c)D_1 + (\delta p_1 - c)qD_2,$$
$$\Pi_E = (p_E - c)(D_E^P + D_E^S).$$

Our goal is to understand whether and why one pricing modality dominates the other as a defense against the threat of an entrant with a new pricing modality. To this end, we investigate the impact

[7] Case (iii) may only occur when $p_1 < \bar{p}$, that is, when $p_1 < \bar{v}$. Otherwise, the demand has only 3 scenarios: (i), (ii) and (iv), where the threshold between cases (ii) and (iv) is for $p_E = p_1$.

of an entrant on the prevailing (or existing) pricing modality in the market, and the resulting prices and profits. To do so, we consider two scenarios; the prevailing pricing modality in the market is either markdown or EDLP. The incumbent retailer represents the status quo in the market while the entrant retailer represents a firm who enters the market with a new pricing modality. We remark that pricing modality in a market is often stable and does not change from one selling season to another (and it often emerges as an equilibrium in the long-run as discussed in the introduction) while of course prices can be adjusted in each selling season. Therefore, the problem of selecting a pricing modality should not be viewed as a multiple-selling-period problem, in which retailers switch back and forth between the markdown and the EDLP pricing modalities. Structural changes in pricing modality happen over a long horizon. Such a change may start perhaps when a key player (e.g., an entrant) has a reason to believe it can change the entire market dynamics and when others follow in the long term. Our incumbent-entrant narrative helps us understand whether such a structural change may occur and explain why one pricing modality may emerge as an equilibrium.[8]

5.1. The Markdown Retailer as the Incumbent

We start by focusing on the scenario in which the markdown retailer is the incumbent and the EDLP retailer is the entrant. Proceeding by backward induction, we first investigate the EDLP retailer's price response to a given list price p_1 and availability probability q. Then we examine the markdown retailer's optimal first-period pricing and stocking decisions given the EDLP retailer's anticipated price response. Finally, we obtain the ensuing market equilibrium.

From Proposition 2, we know that one of the four types of demand scenarios may occur. In scenario (iv), the EDLP retailer receives no demand and thus no profit. Therefore, the EDLP retailer sets its price such that scenario (iv) is avoided, as the other scenarios yield a non-negative profit. The same is true regarding scenario (iii) with $q \le Q_0$. In other words, the EDLP retailer sets the price below the threshold $\max\{p_1, \bar{p}\}$. Hence, the situation that occurs is of type (i), (ii), or (if $p_1 < \bar{v}$) (iii) with $q > Q_0$ in Proposition 2. The following lemma identifies the EDLP retailer's price response to a given p_1 and q for each of these three scenarios and also helps us examine the role of regret.

Lemma 1. *(i) Given p_1 and q, the EDLP retailer's optimal price response and corresponding profits can be found in closed form and are presented in Appendix C (available in the online supplement).*
(ii) The EDLP retailer's price as a best response to the markdown retailer's pricing and availability decision is increasing in α and decreasing in β in case (iii) of Proposition 2. It is independent of the regret factors in cases (i), (ii) and (iv).

[8] We analyze the Nash game in Appendix B (available in the online supplement), and find that no equilibrium exists.

The lemma and the details provided in Appendix C (available in the online supplement) show in a transparent way (as the best response functions are characterized in closed form) how strategic motives and regret play a key role in retailers' decisions. We highlight two observations. First, both availability and high-price regret affect the EDLP retailer's pricing decision even though the EDLP retailer's core strategy is to stock enough to avoid stockout and to set a constant price for the entire selling season. EDLP pricing modality is often thought to preclude availability and high-price regret phenomena in consumers. However, in the presence of competition with an incumbent markdown retailer, consumer regret has an impact even on the EDLP price. Hence, the EDLP retailer must consider the impact of regret as much as the markdown retailer. Second, the high-price and availability regrets play a complementary role. For example, in case (iii) with $q > Q_0$, a strong availability regret encourages more consumers to spill over in case of a stockout. Hence, a higher availability regret allows the EDLP retailer to price higher while maintaining spillover demand. In contrast, a strong high-price regret discourages spillover purchases at the EDLP price because of the regret of not purchasing at the cheaper first-period list price from the markdown retailer. Hence, a stronger high-price regret applies a downward pressure on the EDLP price.

To obtain the EDLP retailer's *best* price response and resulting highest profit, we first select the price p_E (among those characterized in Lemma 1 part (i)) that yields the highest profit for the EDLP retailer. Then, we choose the price p_E that yields the highest overall profit Π_E for the EDLP retailer.

Anticipating the EDLP retailer's best price response, the markdown retailer chooses a list price p_1 and availability probability q (that is, stocking decision K) to maximize its profit. To do so, the markdown retailer solves the following optimization problem:

$$\max_{p_1, q} \quad (p_1 - c)D_1^*(p_1, q) + (\delta p_1 - c)qD_2^*(p_1, q).$$

As discussed above, either scenario (i), (ii) or (iii) with $q > Q_0$ of Proposition 2 holds and in each of these scenarios, the markdown retailer receives zero demand in Period 1, i.e., $D_1^*(p_1, q) = 0$. $D_2^*(p_1, q)$ can also be evaluated according to Proposition 2, using the EDLP retailer's price response function $p_E^*(p_1, q)$. In scenario (i), the markdown retailer makes zero profit. Thus, in the first stage, the markdown retailer chooses a price and stock level that it anticipates will lead the EDLP retailer to respond by pursuing either scenario (ii) or (iii) with $q > Q_0$. Hence, the availability probability needs to be less than 1 to ensure that the EDLP retailer receives a positive profit in at least one of these scenarios. Otherwise, the EDLP retailer would turn into scenario (i), capturing the entire market and leaving no profit to the markdown retailer. Next, we characterize the retailers' pricing and stocking decisions in equilibrium for all possible intensities of regret $\alpha, \beta \in [0, 1]$, including when consumers do not experience regret.

Proposition 3. *When the markdown retailer is the incumbent and the EDLP retailer is the entrant, in equilibrium,*
(i) either demand scenario (ii) or (iii) with $q > Q_0$ of Proposition 2 is observed; as a result, the markdown retailer sells only in Period 2;
(ii) the EDLP price is higher than the markdown price, i.e., $p_E^* > \delta p_1^*$; the EDLP retailer can set the price to shut down consumer regret or alter its price to take advantage of consumer regret;
(iii) the markdown retailer's optimal stocking decision K^* is such that the resulting availability probability q^* during the markdown period is strictly less than 1. Specifically, if $p_E^* \in (\delta p_1^*, p_1^*]$ then $q^* < 1$; if $p_E^* > p_1^*$ then $q^* \in (Q_0, 1)$;
(iv) the markdown retailer captures consumers with moderate to high reservation price (i.e., $v \in [\delta p_1, \bar{v}]$). The EDLP retailer captures spillover demand from consumers with high reservation prices (i.e., $v \in [p_E^*, \bar{v}]$ if $p_E^* \in (\delta p_1^*, p_1^*]$, and $v \in [v_0, \bar{v}]$ if $p_E^* > p_1^*$) who do not find the product available at the markdown retailer. Consumers with moderate reservation price (i.e., $v \in [\delta p_1^*, p_E^*)$ if $p_E^* \in (\delta p_1^*, p_1^*]$, and $v \in [\delta p_1^*, v_0)$ if $p_E^* > p_1^*$) choose not to spill over, and consumers with low reservation price (i.e., $v \in [0, \delta p_1^*)$) do not attempt to purchase.

Proposition 3 has several important implications. First, an EDLP retailer entering the market to sell identical products results in the markdown retailer selling products only in Period 2 at the markdown price, and not receiving any demand for products at the list price in Period 1. This contrasts with the situation in which the markdown retailer is a monopolist and sells in both Periods 1 and 2 (Özer and Zheng 2016). The distinctions with the monopoly case stem from two reasons. First, in the presence of a competing retailer, demand may spill over to the competitor. Second, consumers' strategic and emotional considerations are not only limited to inter-temporal comparison of utilities but must also include comparison of utilities across retailers. Hence, competition with an entrant EDLP retailer who sells identical products prevents the markdown retailer from selling products at list price. The presence of the EDLP retailer motivates consumers with high reservation price to attempt obtaining the product at the markdown price, knowing that they may spill over to the EDLP retailer should the product be unavailable. Had there been no entrant, these consumers would have been captured by the markdown retailer in Period 1 as they would be unwilling to take the chance of ending up empty-handed. This result is consistent with observed retail practices, especially in the apparel industry. Kapner (2013), for example, notes that "big retailers work backward with their suppliers to set starting prices that, after all the markdowns, will yield the profit margins they want", "list prices [are set] well above where goods are actually expected to sell", and "[the starting price] was designed with the discount built in." The author further points out that before attempting to use the EDLP pricing modality, J.C. Penney was selling fewer than one out of every 500 products at full price, confirming that most, if not all, sales take place in the markdown period in practice. Proposition 3 Part (i) implies that a markdown retailer is even less likely to sell any products at full price when a retailer enters the market using the EDLP pricing modality.

Second, in equilibrium, the retailers could set prices and availability such that they can eliminate the impact of regret factors, resulting in scenario (ii). Thus, when optimal, the EDLP retailer would not allow the markdown retailer to gain any benefit from consumers who anticipate availability regret. However, when the equilibrium corresponds to scenario (iii), both regret factors kick in. We will illustrate in Section 6 when either scenario (ii) or (iii) occurs in equilibrium. Intuitively, a stronger availability regret pushes more consumers to choose to spill over in case of a stockout, improving the EDLP retailer's profit. Hence, the EDLP retailer responds by increasing the EDLP price. In contrast, a stronger high-price regret makes more consumers reluctant to spill over because of the high-price regret caused by the missed opportunity of purchasing at list price p_1^* which is cheaper than p_E^*. Hence, the EDLP retailer responds by decreasing its price to encourage consumers to spill over.

Finally, the markdown retailer rations inventory for the markdown period by intentionally limiting its own sales in Period 2. In a monopoly setting, the markdown retailer rations inventory to incentivize Period 1 full-price sales (Liu and van Ryzin 2008) and regret reduces the need for such rationing (Özer and Zheng 2016). In contrast, in a competitive setting the incumbent markdown retailer rations inventory for a different reason; that is, as a response to an EDLP-retailer entrant. The markdown retailer needs to provide an incentive for the entrant EDLP retailer to keep its price higher than the markdown price. Otherwise, by undercutting the markdown price, the EDLP retailer could capture the entire market. Thus, by limiting its own inventory level and creating scarcity, the markdown retailer ensures that the entrant receives some spillover consumers despite a price disadvantage. High-valuation consumers who are unable to obtain the product at the markdown retailer because of inventory rationing choose to spill over to the EDLP retailer where they are guaranteed to find the product. This observation suggests that competition with an entrant provides a new rationale for inventory rationing. Inventory rationing is usually explained as a strategy to discourage consumers with high valuation from waiting and attempting to purchase the product in the markdown period. This new rationale for rationing can be characterized as *competitive inventory rationing*, a rationing strategy engineered to foster co-existence with the entrant by giving the entrant less reason to cut its price. This finding is in line with other possible rationales behind retailers intentionally creating inventory scarcity to protect their profits. For example, when advertising a discount on a product, a retailer commonly uses disclaimers such as "while supplies last" or "limited quantities only" or "no rainchecks" (Kavilanz 2009). Restricting the quantity of discounted products helps limit the potential profit loss on the sale of these products while attracting consumers drawn to the opportunity of making a purchase at a low price. These consumers may then spill over and purchase other products when visiting the retailer (when/if they find the product unavailable) or visit a nearby retailer that possibly sells identical or similar products.

5.2. The EDLP Retailer as the Incumbent

We now examine the scenario in which the EDLP retailer is the incumbent and the markdown retailer is the entrant. From Proposition 2, we know that one of the four types of demand scenarios may occur. In scenario (i), the markdown retailer receives no demand and thus no profit. Therefore, responding to the EDLP retailer's price selection, the markdown retailer sets its price and availability probability such that scenario (i) is avoided, as the other scenarios yield a non-negative profit. Hence, one of the remaining three demand scenarios of Proposition 2 may be observed. Let's now consider the incumbent EDLP retailer's pricing decision. The EDLP retailer chooses a price p_E to maximize its profit, anticipating the markdown retailer's response. In scenarios (iii) with $q \leq Q_0$ and (iv), the EDLP retailer receives no demand. In the remaining scenarios (ii) and (iii) with $q > Q_0$, the entrant markdown retailer only sells in Period 2. After the EDLP retailer sets its price, as an entrant the markdown retailer maximizes profits by selling as much as possible in Period 2. Thus, the markdown retailer optimally sets the availability level to 100% (i.e., $q = 1$) and does not implement inventory rationing. Therefore, the EDLP retailer receives no demand in these remaining scenarios. In other words, regardless of the price the EDLP retailer selects as an incumbent, after the entrant markdown retailer selects a price and stocking quantity, the EDLP retailer makes zero profit. Hence, we have the following results for any given regret factor $\alpha, \beta \in [0, 1]$, including when consumers do not experience regret.

Proposition 4. *When the EDLP retailer is the incumbent and the markdown retailer is the entrant, in equilibrium either demand scenario (ii) (with $q^* = 1$), (iii) (with $q^* = 1$ or $q^* \leq Q_0$) or (iv) (with $q^* = 1$ or $q^* \leq Q_1$) of Proposition 2 is observed. The EDLP price is higher than the discounted markdown price (i.e., $p_E^* > \delta p_1^*$). All consumers purchase from the markdown retailer. The EDLP retailer makes zero profit.*

This result can be explained as follows. Regardless of the EDLP price set by the incumbent, the markdown retailer – as an entrant – can contingently price low enough, and adjust its stocking level to capture the entire market. The EDLP incumbent does not retain any profit after entry of the markdown retailer because it cannot incentivize the markdown retailer to share demand after the EDLP price is set. Indeed, the markdown retailer chooses not only its price, but also the availability probability, in a way that no consumer needs to, or chooses to spill over to the EDLP retailer. More precisely, when the markdown retailer's decisions lead to scenario (iii) with $q \leq Q_0$ or scenario (iv) of market segmentation, no consumer chooses to spill over to the EDLP retailer even in case of stockout. When the markdown retailer's decisions lead to scenario (ii) or (iii) with $q > Q_0$, the markdown retailer sees no demand in Period 1. Since the EDLP price is fixed, it is optimal for the markdown retailer to satisfy as much of the Period 2 demand as possible, setting the availability probability to 1, and effectively leaving no demand to the EDLP incumbent. Hence, as an entrant the markdown retailer leaves no profit for the incumbent EDLP retailer.

5.3. Summary of Results

We have shown in Proposition 3 that an incumbent who uses the markdown pricing modality can survive the introduction of an entrant who uses the EDLP pricing modality. As shown in Proposition 4, however, the same is not true when the incumbent uses the EDLP pricing modality and the entrant uses the markdown pricing modality. Hence, EDLP is a risky pricing modality, but the markdown pricing modality provides a strong defense against the threat of entry by a competitor. Notably, retailers in the apparel industry employing EDLP are exceedingly rare. Incidentally, the result obtained with our stylized model is consistent with empirical observations: Ellickson et al. (2012) note that EDLP stores were hurt twice as much by the entry of Walmart as stores using the markdown pricing strategy. Thus, the markdown pricing modality proves to be more resilient in the face of a competitor entry.

These results also highlight one factor, namely the choice of pricing modality in a competitive market, that may have contributed to the failure J.C. Penney experienced in 2012. Essentially, J.C. Penney entered the market with the EDLP pricing modality when all competitors (essentially the entire retail industry) were using the markdown pricing modality. This switch might have allowed other competing markdown retailers to survive J.C. Penney's entry to the market as an EDLP retailer. And during the following season, it might have also enabled markdown retailers to set price and availability in a way to capture the market share from J.C. Penney, eventually forcing J.C. Penney to abandon its EDLP pricing modality.

The markdown pricing modality is preferable to the EDLP pricing modality for an incumbent because it provides the retailer with more leverage to segment the market. The markdown retailer gets to offer the product at two distinct prices in two time periods. An incumbent markdown retailer, with the help of two price points combined with the ability to set the stocking level, enjoys leverage and flexibility to use consumer heterogeneity and capture a segment of the market demand. In contrast, an incumbent EDLP retailer cannot appeal to any consumer segment and hence achieves zero profit after entry of a markdown retailer. This poor performance results from the lack of flexibility of EDLP pricing modality. Indeed, even when there is no spillover (so the EDLP retailer cannot be viewed as a backup to the markdown retailer in case of a stockout), markdown remains to be the dominant pricing modality (see Appendix B available in the online supplement for details). Nevertheless, EDLP can be a powerful modality for an entrant facing an incumbent using markdowns. As an entrant, because of its fixed pricing and no-stockout policy, the EDLP can use the credible threat of pricing low to capture all consumers, to force the markdown retailer to price not too low and set the availability probability not too high. As an entrant, the EDLP retailer also benefits from its position as a “backup” to the markdown retailer’s consumers finding a stockout. These consumers cannot go back to Period 1 and purchase the product from the markdown retailer at the original list price p_1. Thus, high-valuation consumers facing a stockout are willing to purchase the product from the EDLP retailer at a price even *above* p_1. However, we have also shown that the EDLP pricing modality is not sustainable enough to change the pricing modality in retail industry. Finally, we have shown that equilibrium prices, stocking decision, resulting availability and profits all depend on high-price regret factor α and availability regret factor β. Next, we quantify the effect of these factors.

6. Quantifying the Role of the Discount and Regret

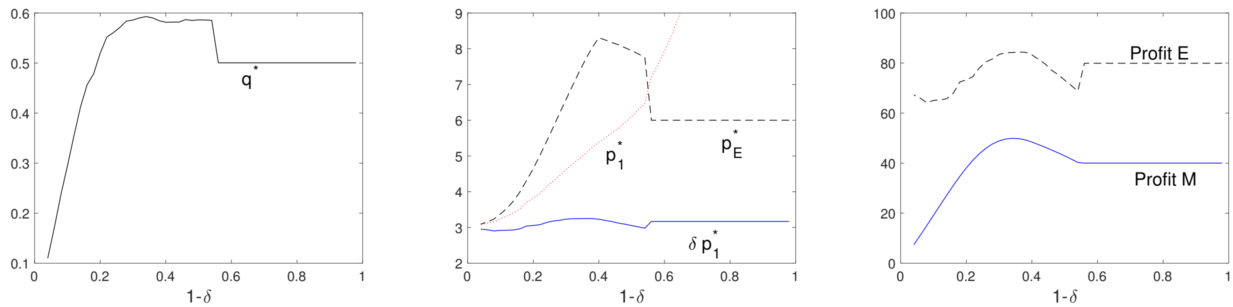
Our goal here is to quantify the role of the discount factor and the regret effects. To do so, we focus on the scenario in which the markdown retailer is the incumbent and the EDLP retailer is the entrant (as both retailers make positive profit in this case). Recall from Proposition 3 part (i), in equilibrium, one observes either demand scenario (ii) or (iii) with $q > Q_0$ of Proposition 2. To calibrate the key input data for the numerical study, we obtained price and discount data from a large department store. We use this data set to represent the distribution of discounts observed in practice. For our base case, we set $\delta = 0.7, c = 2, \bar{v} = 10, N = 100, \alpha = 0$ and $\beta = 1$. To isolate and quantify the impact of the regret factors, we vary each regret factor one at a time within $[0,1]$ as in Özer and Zheng (2016). For ease of exposition, we refer to the discount *rate* as $1-\delta$. The discount rate represents the depth of the discount, that is, the percentage by which the price in the second time period is reduced relative to the list price p_1 (e.g., “30% off”).

6.1. Effect of the Discount Rate

Figure 2 illustrates how the discount rate affects availability probability, prices and resulting profits. We note that the discount rate determines which of the two possible scenarios (i.e., scenario (ii) or scenario (iii) with $q > Q_0$ in Proposition 2) is observed in equilibrium.

We note that when the discount rate is below a certain threshold (e.g., 55% in this case), the discount rate affects even the EDLP retailer’s equilibrium price (in addition to markdown retailer’s list price and availability). In this case, scenario (iii) with $q > Q_0$ in Proposition 2 is observed in equilibrium. Hence, consumers experience availability regret (but not the high-price regret as we set $\alpha = 0$ for this example). In this equilibrium, all purchasing consumers first visit the markdown retailer during the markdown period. Those consumers who do not find the product available, either (1) spill over and purchase at the EDLP price, or (2) decide not to spill over and may experience availability regret (if their valuation is above the list price p_1^*). When the discount rate increases, the markdown retailer increases its list price to maintain the markdown price at a stable

Figure 2 **Effect of discount rate when** $\alpha = 0$ **and** $\beta = 1$



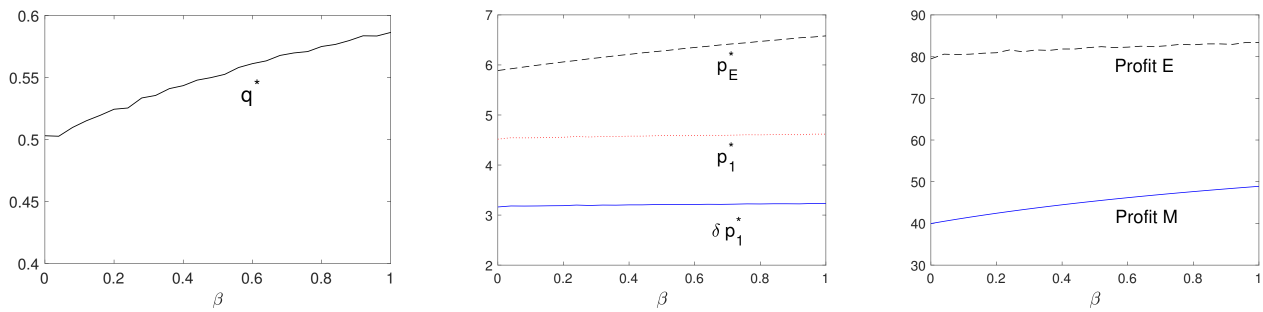
level (despite the increased discount rate), balancing its Period 2 margin (i.e., $\delta p_1^* - c$) with its Period 2 demand (i.e., $(N/\bar{v})(\bar{v} - \delta p_1^*)$). EDLP retailer sets its price so that, for consumers with a high reservation price, the option to wait for a markdown and then spill over is preferred over the option to purchase from the markdown retailer at list price p_1^*. Therefore, when p_1^* increases, the EDLP retailer can increase its price and profit. Since the EDLP retailer's margin improves, it does not require as large a sales volume. Therefore, the markdown retailer can ration less (i.e., stock more, increasing availability of its product), increasing its sales, and thus its own profit, and generating less demand for the EDLP retailer via spillover. As the markdown retailer's list price keeps increasing along with the discount rate, fewer consumers have a valuation higher than the list price, and thus fewer consumers experience availability regret. Therefore, those consumers have less incentives to spill over to the EDLP retailer when they find the product unavailable at the markdown price. Hence, spillover demand at the EDLP retailer shrinks further and when the discount rate exceeds a certain point (e.g., 40% in this case), the EDLP retailer starts to lower its price, and the markdown retailer stops increasing its stocking level (and availability) further, to slow the decline in EDLP demand and regulate the EDLP retailer's incentive to keep its price above the markdown price. When the discount rate exceeds the threshold (e.g., 55% in this case), however, increasing the discount rate no longer affects stocking decision and profits because the equilibrium changes to scenario (ii) of Proposition 2. A deep discount rate essentially shuts down both types of regret (as discussed after Proposition 1) because the EDLP retailer and the markdown retailer set prices such that $p_E^* \in [\delta p_1^*, p_1^*]$. As no consumer experiences regret, an increase in the markdown retailer's list price has no effect on consumers' utility. The markdown retailer keeps the share of consumers who spill over to the EDLP retailer the same by keeping availability and markdown price constant. As a result the EDLP retailer keeps its price p_E^* constant as well.

Second, we observe that the markdown retailer's profit is unimodal across the discount rate range. This property can help the markdown retailer determine its optimal discount rate ahead of the competitive game with the entrant. For instance, in the numerical example considered here, the markdown retailer's profit is highest if it selects a discount rate of $1 - \delta = 33\%$.

6.2. Effect of the Availability Regret

Figure 3 illustrates the effect of varying the intensity of availability regret, β. Recall that availability regret exists if scenario (iii) with $q > Q_0$ of Proposition 2 is observed in equilibrium, and only for consumers who find a stockout at the markdown retailer, choose not to spill over and have a reservation price above the list price. In particular, availability regret is not experienced by consumers purchasing from the EDLP retailer, who holds ample inventory. Yet, as Figure 3 illustrates, even the EDLP retailer is not immune to the effect of availability regret.

Figure 3 **Effect of availability regret when** $\alpha = 0$ **and** $\delta = 0.7$

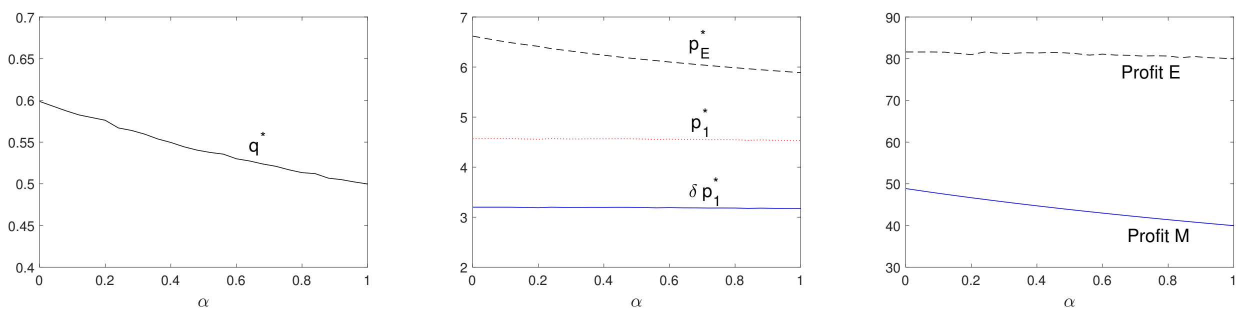


We highlight three observations. First, as the availability regret gets more intense, the markdown retailer optimally increases its stocking decision and hence the availability probability, i.e., it rations less. With a stronger availability regret, consumers who choose not to spill over experience a larger loss of utility due to availability regret. As a result, the option to spill over becomes more appealing for those facing a stockout, which advantages the EDLP retailer. Hence, the markdown retailer does not need to ration as much to regulate the EDLP retailer's incentive to keep its price above the markdown price. Second, the EDLP retailer optimally increases its price slightly to take advantage of the fact that the spillover option is becoming more appealing for consumers who face a stockout. Finally, the EDLP retailer's profit increases due to a higher price, and the markdown retailer's profit increases due to a higher availability probability and thus more sales.

6.3. Effect of the High-Price Regret

Figure 4 illustrates the effect of varying the intensity of high-price regret, α. Recall that high-price regret exists if scenario (iii) with $q > Q_0$ of Proposition 2 is observed in equilibrium, and only for consumers who find a stockout and choose to spill over to the EDLP retailer. Therefore, the intensity of high-price regret may affect the EDLP retailer's price. The EDLP retailer's consumers experience high-price regret due to the missed opportunity of purchasing from the markdown retailer in Period 1 at the list price p_1^*, which is lower than the EDLP price p_E^*. In addition, consumers who purchase from the markdown retailer do not experience high-price regret because they all purchase at the markdown price. Yet, the intensity of high-price regret affects the markdown retailer's stocking strategy and profit.

Figure 4 Effect of high-price regret when $\beta = 1$ and $\delta = 0.7$



We highlight three observations. First, as the high-price regret gets more intense, the markdown retailer optimally decreases its stocking decision and hence the availability probability, i.e., it rations more. With a more intense high-price regret, markdown consumers who face a stockout experience a larger loss of utility if they continue to choose spilling over. As a result, the option to spill over becomes less appealing for those facing a stockout, which disadvantages the EDLP retailer. Hence, the markdown retailer must ration more to increase the volume of consumers facing a stockout and to regulate the EDLP retailer's incentive to keep its price above the markdown price. Second, the EDLP retailer optimally decreases its price to compensate the fact that the spillover option is becoming less appealing for consumers who do face a stockout. Third, the markdown retailer's profit decreases due to a lower availability probability and thus fewer sales.[9]

6.4. Impact of Ignoring Regret

Here we measure the profit loss each retailer incurs when its decisions fail to account for regret effects. Specifically, we determine the prices and stock levels that the markdown retailer and the EDLP retailer set if they assume consumers do not experience regret (i.e., set $\alpha = \beta = 0$). Then, given the actual values of the high-price regret intensity (α) and availability regret intensity (β), we derive consumers' responses to these decisions, namely the actual availability, demand at each retailer, and the retailers' resulting profit. As a benchmark, we also determine each retailer's pricing

[9] We note that the entrant EDLP retailer achieves higher profits than the incumbent markdown retailer in our numerical study. This observation is not surprising because it essentially illustrates that the entrant benefits from observing and optimally responding to the incumbents strategy. However, this observation does not imply that EDLP is a better pricing modality, since an incumbent using EDLP would be left with no profit upon entry of a competitor using the markdown pricing modality. Also note that EDLP is a special case of the markdown pricing modality with $\delta = 1$ and $q = 1$. Hence, an entrant with availability and pricing flexibility may have achieved higher profits by using the markdown pricing modality (a scenario we do not study in this paper).

and stocking decisions, as well as profits when regret intensities are considered accurately. For each retailer, we then calculate the percentage profit loss as the difference between the optimal profit considering regret and the profit under suboptimal decisions (i.e., ignoring regret) divided by the optimal profit. We note that a negative profit loss indicates that the retailer earns more profit when regret is ignored than when regret is considered.

We also calibrate the discount rate in our numerical study using an actual data set. To do so, we obtained price data from a large department store. We used the list price and markdown price offered for each product in a category (namely women's dress), and determined the discounts over 4 years (over 47,000 discount applied). Figure 5 depicts the distribution of the discount rate for this product category.[10] We observe that discount rates typically range from 30% to 70%, with the most frequent discount rates around 35% (that is, a discount factor δ around 65%).

Our literature review reveals that the intensity of regret factors varies depending on the product and the context. For example, in the context of auctions, Engelbrecht-Wiggans and Katok (2008) estimate action regret (which is analogous to high-price regret) at 0.2349 and inaction regret (which is analogous to availability regret) at 0.6371. In a model in which regret intensities are unbounded, Filiz-Ozbay and Ozbay (2007) estimate the intensity of winner regret (action regret) at 2.69 and that of loser regret (inaction regret) at 6.19. Interestingly, for both sets of estimates, inaction regret is approximately 2.5 times higher than that of action regret. Given these observations, we considered the following regret intensities $(\alpha, \beta) \in \{(0,1),(0.1,0.5),(0.3,0.7),(0.5,0.9),(0.24,0.6),(0.32,0.8),(0.4,1)\}$, that is, three instances having a constant gap between the two regret intensities, and three more instances with availability regret factor being 2.5 times higher than that of the high-price regret factor. For each of the seven scenarios of regret intensities, we let δ vary within [0,1] according to the empirical distribution, and calculate the average profit loss for the markdown retailer and the EDLP retailer. When computing the average profit losses, for each discount rate we use the corresponding weight given by the empirically obtained distribution.

We find that ignoring the effect of regret on consumers' decision-making process results in non-negligible losses or gains. Generally, ignoring regret leads the markdown retailer to lose profit (on average from 3 to 9%), and the EDLP retailer to gain profit (on average from 2 to 5%). Figure 6 summarizes our findings. We highlight four observations. First, the markdown retailer incurs a large profit loss when it ignores consumer regret (as high as 20% when $\alpha = 0, \beta = 1$) for discount rates near the most frequently observed value (35%). The markdown retailer sets the list price too high and the stock level too low, resulting in stockouts, fewer sales, and a profit loss. Second, such aggressive rationing results in more consumers spilling over to the EDLP retailer, increasing

[10] For expositional simplicity, we rounded values from 0 to 10% to 5%, values from 10 to 20% to 15%, and so on.

Figure 5 **Empirical distribution of the discount rate**

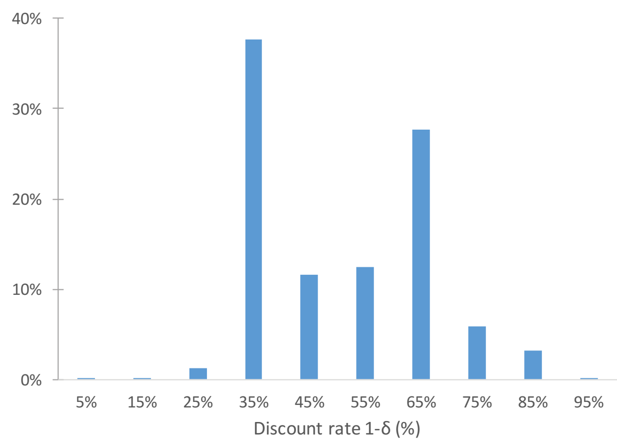
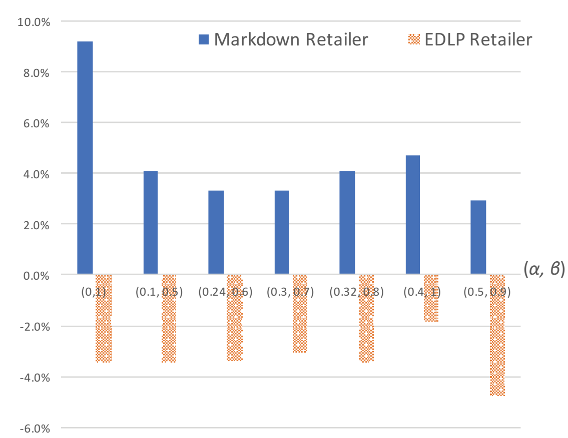


Figure 6 **Average profit loss due to ignoring regret**



its demand. As a result, the EDLP retailer experiences profit gain when both retailers ignore the effect of regret on consumers purchase decisions. Third, neither retailer loses (or gains) profit by ignoring regret when the discount rate is high (i.e., higher than 55%) because regret does not play a role in the resulting equilibrium. As shown in Section 6.1, regret affects pricing and stocking strategies only for lower to moderate values of the discount rate. Finally, ignoring regret yields the opposite effect on the two retailers' profits (while the markdown retailer forgoes profits, the EDLP retailer gains additional profits). As a result, in a competitive market, ignoring regret causes the markdown retailer to leave significant amount of profit on the table and more so than in a monopoly setting (as high as 20% versus 7.7% reported in Özer and Zheng 2016[11]). In addition, the markdown retailer leaves some of that forgone profit to its competitor, the EDLP retailer who may observe a significant profit increase (as high as 38% when the discount rate is 5%).

7. Concluding Remarks

This paper proposes an explanation for why markdown endures as a dominant pricing modality in the presence of a threat of entry by a competitor offering an identical product. Markdowns remain ubiquitous in retail despite the many theoretical advantages the EDLP pricing modality has to offer. We use a stylized model to show that a retailer using the markdown pricing modality is able to maintain profits when an EDLP retailer enters the market. Conversely, an incumbent EDLP retailer will lose all profits if a markdown retailer enters the market. Hence, employing the markdown pricing modality acts as a defense against a possible entry of a competitor. Together with the results obtained in other papers (e.g., Su 2007; Gallego et al. 2008; Cachon and Feldman

[11] Özer and Zheng (2016, Table 1 p. 339) find that in a monopoly setting, a markdown retailer who ignores behavioral factors may be leaving up to 7.7% (and on average, 3.1%) of its potential profits on the table.

2015; Özer and Zheng 2016), our findings suggest that markdowns are here to stay as a retail strategy.

We find that consumers' strategic motives and regret effects, along with the competitive environment, drive the market segmentation, retailers' pricing and stocking decisions, and their resulting profits. Our paper discovers a new type of market segmentation for a markdown retailer. In a monopoly, a markdown retailer implements *intertemporal* price discrimination to split consumers among high-valuation consumers (who purchase in the first period at the list price) and low-valuation consumers (who attempt to purchase in the second period at the markdown price). In contrast, in a sequential game with an entrant EDLP retailer, the markdown retailer implements an intertemporal and *competitive* price discrimination scheme. Such pricing scheme helps split consumers among those who purchase at the markdown retailer in the markdown period and those who purchase from the EDLP retailer after observing a stockout at the markdown retailer. In addition, we find a new rationale for inventory rationing. In a monopoly, a markdown retailer may ration inventory to discourage consumers (who value the product highly) from waiting and attempting to purchase the product at the markdown price. In a competitive market, the markdown retailer rations inventory to allow the entrant EDLP retailer to gain a sufficient market share and earn enough profit so that the EDLP retailer does not undercut the markdown retailer's price and capture the entire market. Hence, *competitive inventory rationing* serves the purpose of stopping a cutthroat competition and bankruptcy.

We also find that both high-price and availability regret play a critical role in (and hence we quantify their impact on) the resulting decisions and profits. When discounts offered by the markdown retailer are not very deep (e.g., less than 55%, which is what most retailers typically implement in practice), consumer-regret affects *both* retailers' decisions and profits. We show that availability and high-price regret affect even the EDLP retailer's strategy and profits, despite the EDLP retailer's policy of procuring ample inventory and maintaining a constant price. In particular, availability regret reduces rationing at the markdown retailer, increases the EDLP price, improves the markdown retailer's profit and reduces the EDLP retailer's profit. High-price regret has the opposite effect on pricing and stocking decisions and reduces the markdown retailer's profit. In addition, ignoring regret causes large losses for the markdown retailer. Using a price data set from a large department store, we show that the markdown retailer could leave up to 20% of its profits on the table (from 3 to 9% on average). These findings also substantiate the conjecture made in Özer and Zheng (2016) that a competitive environment could amplify the markdown retailer's profit loss resulting from a failure to consider regret (up to 7.7% in a monopoly). In addition, in a competitive market, the markdown retailer rations too aggressively when regret is ignored, and as a result leaves some of the forgone profit to its competitor – the EDLP retailer. Retail industry is often characterized by its slim profit margins (e.g., 1% and 8% for the grocery and nonbranded apparel industries, see Johnson 2015; Sable 2015). In such an environment, the possibility of losing large profits while letting a competitor capture this forgone profit as a gain should seriously concern retailers. Hence, these observations also suggest that retailers should invest in developing the capacity to estimate and quantify the role of regret in consumers' purchase decisions.

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Appendix A: Notation

N	Total number of consumers in the market
c	Unit cost for procuring inventory
p_i	Unit price in Period i at the markdown retailer, with $i \in \{1,2\}$
δ	Discount factor at the markdown retailer, $p_2 = \delta p_1$
p_E	Unit price at the EDLP retailer
K	Total inventory of the product at the markdown retailer
q	Probability that the product is available in Period 2 at the markdown retailer
v	A consumer's reservation price for the product
$\bar{v}$	The highest reservation price for the product among all consumers
v_0	Cutoff value of the product reservation price above which spillover occurs in case of a stockout
v_1	Cutoff value of the product reservation price above which markdown consumers choose Period 1 over 2
Q_0	Cutoff value of the availability probability in scenario (iii)
Q_1	Cutoff value of the availability probability in scenario (iv)
$\bar{p}$	Price cutoff value between scenarios (iii) and (iv)
α	Marginal value of high-price regret, $\alpha \in [0,1]$
β	Marginal value of availability regret, $\beta \in [0,1]$
D_i	Demand in Period i at the markdown retailer, with $i \in \{1,2\}$
D_E^P	Primary demand at the EDLP retailer
D_E^S	Spillover demand at the EDLP retailer
U_i	Consumer utility from visiting the markdown retailer in Period i, with $i \in \{1,2\}$
U_E	Consumer utility from initially visiting the EDLP retailer
Π^M	Markdown retailer profit
Π^E	EDLP retailer profit
$p_E^*(p_1,K)$	EDLP retailer's best response price to a given (p_1,K)
$q^*(p_1,K)$	Availability probability when the EDLP retailer chooses its best response price to a given (p_1,K)
$D_1^*(p_1,K)$	Markdown retailer's Period 1 demand when the EDLP retailer chooses its best response price to a given (p_1,K)
$D_2^*(p_1,K)$	Markdown retailer's Period 2 demand when the EDLP retailer chooses its best response price to a given (p_1,K)

Appendix B: Extensions and Discussions

Distribution of consumer valuations. We model possible consumer valuations with a uniform distribution on $[0,\bar{v}]$. Uniform distribution is widely used in the literature because it captures fickle consumers' tastes and also leads to the well-known linear demand function. The market segmentation obtained in Proposition 1 does not depend on this distribution. The form of the distribution plays a role only in the derivation of the aggregate demand at each retailer (Proposition 2). The form of the distribution also affects the profits, and therefore the best response decisions. Let $f(\cdot)$ denote the probability distribution over the possible consumer valuations $[0,\bar{v}]$. Proposition 1 continues to hold as is. The markdown retailer's Period 2 demand is then given by $N\int_0^{\bar{v}} I^M(v)f(v)dv$, where $I^M(v)$ equals to 1 if a consumer with valuation v attempts to purchase from the markdown retailer, and zero otherwise. This function can be obtained from Proposition 1; for instance when p_E is in the range matching case (ii), $I^M(v)=0$ when $v<\delta p_1$, and $I^M(v)=1$ otherwise. Similarly, we determine the spillover demand at the EDLP retailer as $(1-q)N\int_0^{\bar{v}} I^E(v)f(v)dv$, where $I^E(v)$ equals 1 if a consumer with valuation v finding a stockout would decide to spill over to the EDLP retailer, and zero otherwise. For example, when p_E is in the range matching case (ii), $I^E(v)=0$ when $v<p_E$, and $I^E(v)=1$ otherwise. Hence, the distribution of consumer valuation affects the demands shown in Proposition 2, and as

a result it affects the profits. We can obtain closed-form expressions for demand and corresponding profit at each retailer when, for example, the distribution of consumer valuation is uniform, triangular or exponential. In Proposition 2, the non-zero demands depend on the distribution $f(\cdot)$, but the zero demands remain at zero regardless of this distribution. Also, the finding that the markdown retailer makes a positive profit in equilibrium and that the EDLP incumbent makes zero profit in equilibrium rely not on the actual demand and profit values, but on the cases leading to positive or zero demand. Therefore, these results would stand under different distributional assumptions. The closed-form expressions in the detailed Lemma 1 part (i) would change.

Symmetric procurement costs. Here we investigate the scenario in which the EDLP retailer has a lower cost c_E than the markdown retailer's cost c_M. Our results on the market segmentation (Proposition 1) and the aggregate demands (Proposition 2) remain unchanged as they are independent of the procurement costs. However the resulting profit expressions would need updating:

$$\Pi_M = (p_1 - c_M)D_1 + (\delta p_1 - c_M)qD_2,$$
$$\Pi_E = (p_E - c_E)(D_E^P + D_E^S).$$

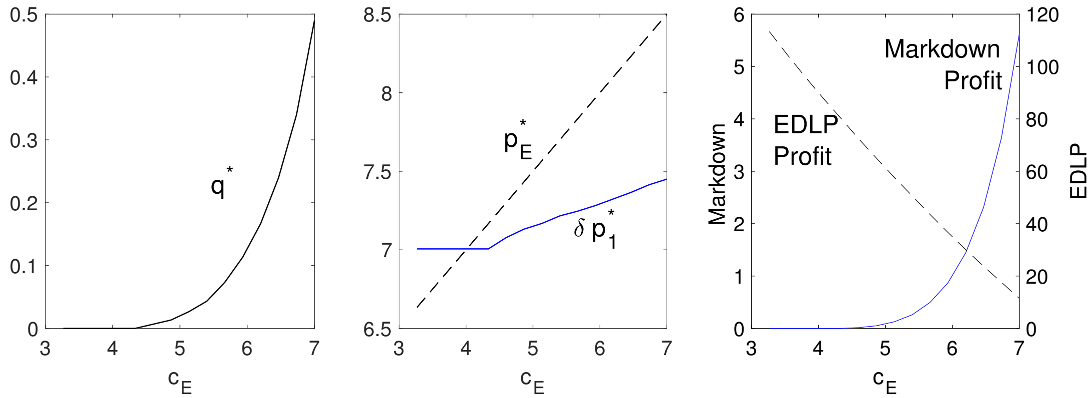
The cost asymmetry affects the profitability of the markdown retailer, and in some cases, the EDLP retailer can exploit the cost differential to price lower and prevent the markdown retailer from earning any profit. Specifically, we obtain the following results.

PROPOSITION 5. *Suppose $c_E < c_M$. When the EDLP retailer is the incumbent and the markdown retailer is the entrant, in equilibrium the markdown retailer chooses not to enter. The EDLP price is higher than the EDLP cost but lower than the markdown cost (i.e., $p_E^* = \min\{c_M, (c_E + \bar{v})/2\} \in (c_E, c_M]$).*

We study numerically the scenario in which the markdown retailer is the incumbent. We find that if the EDLP retailer's cost advantage becomes large, the markdown retailer may no longer be profitable in equilibrium. The markdown retailer must set its markdown price above its cost c_M to make a profit. This may end up being higher than the EDLP price if the EDLP retailer enjoys a large cost advantage. Even if the markdown retailer allows consumers to spill over to the EDLP retailer (by setting a low availability probability) and lowers its markdown price near its cost, the EDLP retailer may still find it profitable to undercut the markdown price and attract a large demand (scenario (i)), rather than price above the markdown price and obtain only spillover demand (scenarios (ii) or (iii)), when the EDLP cost is low. In an extreme case, when the EDLP cost is sufficiently low, the entrant EDLP retailer prefers to undercut the markdown price (by pricing below the markdown retailer's cost), pushing the incumbent markdown retailer out of the market. Such a strategy ensures a large demand and a sufficient profit margin, considering the low EDLP cost. We illustrate this finding by a numerical example, where $\alpha = 0, \beta = 1, \delta = 0.7, c_M = 7$ and c_E varies from 3 to 7. Note from Figure 7 that when the EDLP cost drops below 4.4, the markdown incumbent achieves no profit.

Overall, when the EDLP retailer enjoys a cost advantage over the markdown retailer, the EDLP retailer may be able to dominate the markdown retailer (either by deterring entry, or by pushing the incumbent out

Figure 7 Effect of entrant EDLP retailer's cost on availability, prices and profits



of the market) as long as the EDLP retailer can set its price below the markdown retailer's cost. Perhaps Walmart enjoys a scale matched by no other retailer, allowing it to benefit from economies of scale, advanced supply chain management technology, high bargaining power with suppliers (all of which are supply side advantages and not due to the choice of pricing modality) to keep its costs very low. This cost advantage may be the reason why Walmart can use the EDLP pricing modality and deter a markdown retailer with higher cost from entering the market.

EDLP inventory rationing. Because of its fixed price policy, an EDLP retailer typically enjoys a stable demand, which allows the retailer to avoid stockout. In practice, the EDLP retailer often stocks enough to satisfy all demand, as its strategy is to appeal to consumers by guaranteeing availability. In theory, the EDLP retailer, like the markdown retailer, could intentionally create scarcity (even though it makes little practical sense because there is little reason to induce customers to purchase in an earlier period under fixed price policy). Inventory rationing at the EDLP retailer might have two opposite effects: (i) high-valuation consumers could prefer to purchase from the markdown retailer in the first period to avoid the risk of finding a stockout; (ii) in the second period, some consumers may choose to attempt purchasing from the EDLP retailer rather than the markdown retailer if the EDLP price is low enough and/or the EDLP availability probability is high enough in comparison to the markdown retailer. We conjecture that when the EDLP retailer is the incumbent, an entrant markdown retailer could still capture the entire market demand by setting an availability probability slightly higher, and a markdown price slightly lower than the EDLP retailer, to attract both the low- and high-valuation consumers. The analysis of this scenario requires one to capture in the analysis the two-way demand spillover and two endogenous and inter-related availability probabilities.

Basket shoppers. Our model applies to a single-product case. In some other cases, consumers may select a retail venue for a basket of multiple products. This may provide an advantage to the EDLP retailer who has all the products in the basket in stock (Bell and Lattin 1998), while the markdown retailer may have stocked out for at least some of the products in the basket at the time of the consumer's visit. Our study may be viewed as a good approximation of the case of basket shoppers when the competing retailer offers a substitutable basket. To capture this situation, we may consider the basket as one product and assume that the consumer does not make a partial basket purchase and may spill over if at least one product in the basket is out of stock. The valuation would then be the valuation of the entire basket; the availability probability would be the probability that all the products in the basket are in stock; the discount rate at the markdown retailer would be the rate of discount on the overall basket in the future markdown period (even if not all products individually are discounted at that time).

Product differentiation. A retailer may successfully implement an EDLP pricing modality by differentiating its product from those of its competitor. Such differentiation could protect the retailer against the entry of a competitor, making co-existence possible. For example, Trader Joe's offers products, including a large collection of organic products, that are unavailable at other grocery stores, and it enjoys high consumer loyalty.

Simultaneous move. Here we determine whether a Nash equilibrium exists in pure strategies.

PROPOSITION 6. When the two retailers make decisions simultaneously, the game has no equilibrium.

Without demand spillover. Here, we investigate the restrictive scenario in which spilling over is not an option, i.e., consumers never consider spilling over to the EDLP retailer in case of a stockout at the markdown retailer. A consumer with reservation price v would then have the following expected utilities when she purchases from the markdown retailer in Period 1, when she attempts to purchase from the markdown retailer in Period 2, and when she purchases from the EDLP retailer, respectively:

$$\begin{aligned} U_1 &= (v - p_1) - q\alpha(p_1 - \delta p_1), \\ U_2 &= q(v - \delta p_1) - (1-q)\beta \max\{v - p_1, 0\}, \\ U_E &= v - p_E. \end{aligned}$$

The following proposition characterizes consumers' purchase decisions.

PROPOSITION 7. *We define thresholds Q_2, Q_3, Q_4 and cutoff values v_2, v_3, v_4 as follows:*

$$\begin{aligned} Q_2 &= \frac{\bar{v} - p_E}{\bar{v} - \delta p_1}, & v_2 &= \frac{p_E - q\delta p_1}{1-q}, \\ Q_3 &= \frac{(1+\beta)\bar{v} - p_E - \beta p_1}{(1+\beta)\bar{v} - (\delta+\beta)p_1}, & v_3 &= \frac{p_E + p_1(\beta(1-q) - q\delta)}{(1+\beta)(1-q)}, \\ Q_4 &= \frac{(1+\beta)(\bar{v} - p_1)}{(1+\beta)\bar{v} + (\alpha - \beta - (1+\alpha)\delta)p_1}, & v_4 &= \left(\frac{(1+\alpha)(1-\delta)q}{(1+\beta)(1-q)} + 1\right)p_1. \end{aligned}$$

Then:

(i) When $p_E \in [0, \delta p_1]$, a consumer does not buy if her reservation price $v \in [0, p_E)$, and buys from the EDLP retailer if $v \in [p_E, \bar{v}]$.

(ii) When $p_E \in (\delta p_1, (1 - q(1-\delta))p_1]$,

(a) For any $q \in [0, Q_2]$, a consumer does not buy if her reservation price $v \in [0, \delta p_1)$, buys from the markdown retailer in Period 2 if $v \in [\delta p_1, v_2)$, and buys from the EDLP retailer if $v \in [v_2, \bar{v}]$.

(b) For any $q \in (Q_2, 1]$, a consumer does not buy if $v \in [0, \delta p_1)$ and buys from the markdown retailer in

Period 2 if $v \in [\delta p_1, \bar{v}]$.

(iii) When $p_E \in ((1-q(1-\delta))p_1, (1+\alpha q(1-\delta))p_1]$,

(a) For any $q \in [0, Q_3]$, *a consumer does not buy if her reservation price* $v \in [0, \delta p_1)$, *buys from the markdown retailer in Period 2 if* $v \in [\delta p_1, v_3)$, *and buys from the EDLP retailer if* $v \in [v_3, \bar{v}]$.

(b) For any $q \in (Q_3, 1]$, *a consumer does not buy if* $v \in [0, \delta p_1)$ *and buys from the markdown retailer in Period 2 if* $v \in [\delta p_1, \bar{v}]$.

(iv) When $p_E \in ((1+\alpha q(1-\delta))p_1, \infty)$,

(a) For any $q \in [0, Q_4]$, *a consumer does not buy if her reservation price* $v \in [0, \delta p_1)$, *buys from the markdown retailer in Period 2 if* $v \in [\delta p_1, v_4]$, *and buys from the markdown retailer in Period 1 if* $v \in (v_4, \bar{v}]$.

(b) For any $q \in (Q_4, 1]$, *a consumer does not buy if* $v \in [0, \delta p_1)$ *and buys from the markdown retailer in Period 2 if* $v \in [\delta p_1, \bar{v}]$.

Given this market segmentation, we characterize the resulting demand for the markdown retailer in each period (D_1, D_2) as well as for the EDLP retailer (D_E) as follows.

Table 1 Demand at each retailer

$p_E \in$	(i) $[0, \delta p_1)$	(ii) $(\delta p_1, (1-q(1-\delta))p_1]$		(iii) $((1-q(1-\delta))p_1, (1+\alpha q(1-\delta))p_1]$		(iv) $((1+\alpha q(1-\delta))p_1, \infty)$	
		$q \le Q_2$	$q > Q_2$	$q \le Q_3$	$q > Q_3$	$q \le Q_4$	$q > Q_4$
D_1	0	0	0	0	0	$\frac{N(\bar{v}-v_4)}{\bar{v}}$	0
D_2	0	$\frac{N(v_2-\delta p_1)}{\bar{v}}$	$\frac{N(\bar{v}-\delta p_1)}{\bar{v}}$	$\frac{N(v_3-\delta p_1)}{\bar{v}}$	$\frac{N(\bar{v}-\delta p_1)}{\bar{v}}$	$\frac{N(v_4-\delta p_1)}{\bar{v}}$	$\frac{N(\bar{v}-\delta p_1)}{\bar{v}}$
D_E	$\frac{N(\bar{v}-p_E)}{\bar{v}}$	$\frac{N(\bar{v}-v_2)}{\bar{v}}$	0	$\frac{N(\bar{v}-v_3)}{\bar{v}}$	0	0	0

The aforementioned demand characterization at each retailer yields the following expected profits at the markdown and the EDLP retailer, respectively.

$$\Pi_M = (p_1 - c)D_1 + q(\delta p_1 - c)D_2,$$
$$\Pi_E = (p_E - c)D_E.$$

We obtain the following results. The proofs are similar to those in the main body of the manuscript and are not repeated here for brevity.

PROPOSITION 8. *When the markdown retailer is the incumbent and the EDLP retailer is the entrant, in equilibrium,*

(i) we observe from Table 1 either demand scenario (ii) with $q \le Q_2$ *or (iii) with* $q \le Q_3$ *; as a result, the markdown retailer sells only in Period 2;*

(ii) the EDLP price is higher than the markdown price, i.e., $p_E^* > \delta p_1^*$;

(iii) the markdown retailer's optimal stocking decision K^* *is such that the resulting availability probability* q^* *during the markdown period is strictly less than 1 (that is, the markdown retailer's stock level is lower than the number of consumers attempting to purchase in Period 2). Specifically, in scenario (ii) then* $q^* \le Q_2$; *in scenario (iii) then* $q^* \le Q_3$;

(iv) the markdown retailer captures consumers with moderate reservation price (i.e., $v \in [\delta p_1, v_2)$ *in scenario*

(ii), and $v \in [\delta p_1, v_3)$ in scenario (iii)). The EDLP retailer captures demand from consumers with high reservation prices (i.e., $v \in [v_2, \bar{v}]$ in scenario (ii), and $v \in [v_3, \bar{v}]$ in scenario (iii)). Consumers with low reservation price (i.e., $v \in [0, \delta p_1^*)$) do not attempt to purchase.

PROPOSITION 9. *When the EDLP retailer is the incumbent and the markdown retailer is the entrant, in equilibrium either demand scenario (ii) (with $q^* = 1$), (iii) (with $q^* = 1$) or (iv) (with $q^* = 1$ or $q^* \leq Q_4$) of Table 1 is observed. The EDLP price is higher than the discounted markdown price (i.e., $p_E^* > \delta p_1^*$). All consumers purchase from the markdown retailer. The EDLP retailer makes zero profit.*

Both of these key results are similar to the ones we obtain in the presence of spillover. Numerical study for the scenario in which the markdown retailer is the incumbent shows the following:

1. When the discount rate is low, both the availability probability and the high-price regret intensity affect even the EDLP retailer's price; this dynamic holds despite the fact that no consumer actually experiences high-price regret.
2. When discount rate is low, the rationing effect becomes more intense as the discount rate increases.
3. When the discount rate is moderate or low, the markdown retailer's discount rate affects even the EDLP retailer's pricing decision.
4. When the discount rate is high, the actual extent of the discount does *not* matter.
5. When the discount rate is high, the actual values of the availability and the high-price regret intensity do not matter.
6. The markdown retailer's profits are unimodal across the discount range.
7. An increase in availability regret intensity weakens the markdown retailer's rationing effect, while an increase in high-price regret intensity strengthens it.
8. When regret is ignored, the markdown retailer's potential profit loss is on average 12.5%, and up to 46%. With an average profit gain of 0.2%, the EDLP retailer also stands to lose a significant portion – up to 20% – of its potential profit.

Observations 3, 4, 5, 6 and 7 are similar to the case with spillover. Observation 2 is the opposite effect. Observation 1 holds with spillover with the distinction that some consumers do experience high-price regret. The rates of profit loss mentioned in observation 8 are lower in the presence of spillover. Indeed, the possibility of spilling over is a means to reduce opportunities to experience regret. When there is spillover, fewer consumers are exposed to both high-price and availability regret, hence ignoring regret leads to less forgone profit for the retailers.

Appendix C: Proofs

Detailed Proposition 1

We define thresholds Q_0, Q_1 and cutoff values $v_0, v_1, \bar{p}$ as follows:

$$Q_0 = \frac{p_E - p_1}{p_E - \delta p_1}, \qquad Q_1 = \frac{(1+\beta)(\bar{v} - p_1)}{\bar{v} - \delta p_1 + \alpha p_1(1-\delta) + \beta(\bar{v} - p_1)},$$

$$v_0 = \frac{p_E + \alpha(p_E - p_1) + \beta p_1}{1+\beta}, \quad v_1 = p_1 \frac{1 + \alpha q(1-\delta) - q\delta + \beta(1-q)}{(1+\beta)(1-q)}, \quad \bar{p} = \frac{\bar{v}(1+\beta) + (\alpha - \beta)p_1}{1+\alpha}.$$

Then:

(i) When $p_E \in [0, \delta p_1]$, a consumer does not buy if her reservation price $v \in [0, p_E)$, and buys from the EDLP retailer if $v \in [p_E, \bar{v}]$.

(ii) When $p_E \in (\delta p_1, p_1]$, a consumer does not buy if her reservation price $v \in [0, \delta p_1)$ and attempts to buy from the markdown retailer in Period 2 if $v \in [\delta p_1, \bar{v}]$. In the latter case, in case of stockout, she does not spill over to the EDLP retailer if $v \in [\delta p_1, p_E)$ and spills over if $v \in [p_E, \bar{v}]$.

(iii) When $p_1 < \bar{p}$ and $p_E \in (p_1, \bar{p}]$,

(a) For any $q \in [0, Q_0]$, a consumer does not buy if her reservation price $v \in [0, \delta p_1)$, attempts to buy from the markdown retailer in Period 2 if $v \in [\delta p_1, v_1)$ and, in case of stockout, does not spill over to the EDLP retailer, and buys from the markdown retailer in Period 1 if $v \in [v_1, \bar{v}]$.

(b) For any $q \in (Q_0, 1]$, a consumer does not buy if $v \in [0, \delta p_1)$ and attempts to buy from the markdown retailer in Period 2 if $v \in [\delta p_1, \bar{v}]$. In the latter case, in case of stockout, she does not spill over to the EDLP retailer if $v \in [\delta p_1, v_0)$ and spills over if $v \in [v_0, \bar{v}]$.

(iv) When $p_1 < \bar{p}$ and $p_E \in (\bar{p}, \infty)$ or when $p_1 \geq \bar{p}$ and $p_E \in (p_1, \infty)$,

(a) For any $q \in [0, Q_1]$, a consumer does not buy if her reservation price $v \in [0, \delta p_1)$, attempts to buy from the markdown retailer in Period 2 if $v \in [\delta p_1, v_1]$ and, in case of stockout, does not spill over to the EDLP retailer, and buys from the markdown retailer in Period 1 if $v \in (v_1, \bar{v}]$.

(b) For any $q \in (Q_1, 1]$, a consumer does not buy if $v \in [0, \delta p_1)$ and buys from the markdown retailer in Period 2 if $v \in [\delta p_1, \bar{v}]$ and, in case of stockout, does not spill over to the EDLP retailer.

Proof of Proposition 1 We first provide four results that are useful in proving Proposition 1.

Preliminary Lemma 1: Suppose $p_1 < p_E$. A consumer selecting the markdown retailer in Period 2 spills over to the EDLP retailer in case of stockout iff $v > v_0$. In addition, $v_0 > p_1$. Furthermore, $v_0 \leq \bar{v}$ iff $p_E \leq (\bar{v}(1+\beta) + (\alpha - \beta)p_1)/(1+\alpha)$.

Proof: There is spillover iff $v - p_E - \alpha(p_E - p_1) \geq -\beta(v - p_1)^+$. If $v \leq p_1$, then $v \leq p_1 < p_E < p_E + \alpha(p_E - p_1)$, thus the consumer does not spill over. If $v \geq p_E + \alpha(p_E - p_1)(> p_1)$, then $v - p_E - \alpha(p_E - p_1) \geq 0 \geq -\beta(v - p_1)^+$, thus the consumer spills over. Now suppose $p_1 < v < p_E + \alpha(p_E - p_1)$. There is spillover iff $v - p_E - \alpha(p_E - p_1) \geq -\beta(v - p_1)$, that is, iff $v \geq v_0$. It is straightforward to check that $p_1 < v_0 < p_E + \alpha(p_E - p_1)$, and that $v_0 \leq \bar{v}$ iff $p_E \leq (\bar{v}(1+\beta) + (\alpha - \beta)p_1)/(1+\alpha)$. The result follows.

Preliminary Lemma 2: Suppose $p_1 < p_E$. Then $v - p_1 - q\alpha p_1(1-\delta) \geq q(v - \delta p_1) - (1-q)\beta(v - p_1)$ iff $v > v_1$. Furthermore, $v_1 \geq p_1 + q\alpha p_1(1-\delta)$. In addition, $v_1 \leq v_0$ iff $q \leq Q_0$. Finally, $v_1 \leq \bar{v}$ iff $q \leq Q_1$.

Proof: follows from straightforward algebra.

Preliminary Lemma 3: Suppose $p_1 < p_E$ and $p_1 \leq v < \min\{v_0, v_1\}$. Then $U_2 \geq 0$.

Proof: we have $U_2 \geq 0$ iff $v[q - \beta(1-q)] \geq p_1[q\delta - (1-q)\beta]$. If $q - \beta(1-q) > 0$, $v > p_1$ and $\delta < 1$ imply $v[q - \beta(1-q)] > p_1[q - \beta(1-q)] > p_1[\delta q - \beta(1-q)]$, and thus $U_2 \geq 0$. If $q - \beta(1-q) \leq 0$, that is, if $q < \beta/(1+\beta)$, then $U_2 \geq 0$ iff $v \leq p_1[(1-q)\beta - q\delta]/[(1-q)\beta - q]$. After substituting the definition of v_1 into the inequality and simplifying, we find that $p_1[(1-q)\beta - q\delta]/[(1-q)\beta - q] > v_1$ iff $\alpha(\beta(1-q)-q) < 1$. The latter inequality holds because $\alpha, \beta < 1$. Hence, when $q - \beta(1-q) \le 0$, we have $v < v_1 < p_1[(1-q)\beta - q\delta]$, and thus $U_2 \ge 0$.

Preliminary Lemma 4: Suppose $p_1 < p_E$. Then $v - p_1 - q\alpha p_1(1-\delta) \ge q(v - \delta p_1)$ iff $v \ge p_1[1 + \alpha q(1-\delta) - q\delta]/(1-q)$. In addition, $p_1[1+\alpha q(1-\delta) - q\delta]/(1-q) > p_1$.
Proof: follows from straightforward algebra.

Next, we consider four cases to prove Proposition 1.

case (i): $p_E \le \delta p_1$: then $U_1 = v - p_1 - q\alpha p_1(1-\delta) - (1-q)\alpha(p_1 - p_E) < v - p_1 < v - p_E = U_E$. Also, if $v \ge p_E$, then $v \ge p_E - \beta(v - p_1)^+$ so the consumer spills over in case of stockout, and we have $U_2 = q(v - \delta p_1) - q\alpha(\delta p_1 - p_E) + (1-q)(v - p_E) \le q(v - \delta p_1) + (1-q)(v - p_E) \le v - p_E = U_E$. If $v < p_E$, then $v < p_1$ and the consumer does not spill over in case of stockout, and since $v < p_E \le \delta p_1$, we have $U_2 = q(v - \delta p_1) - q\alpha(\delta p_1 - p_E) \le 0$. Thus the markdown retailer is never the preferred option. Consumer chooses the EDLP retailer iff $U_E = v - p_E \ge 0$.

case (ii): $\delta p_1 < p_E \le p_1$: then $U_1 = v - p_1 - q\alpha p_1(1-\delta) - (1-q)\alpha(p_1 - p_E) \le v - p_1 - q\alpha(p_1 - \delta p_1) \le v - p_E - q\alpha(p_E - \delta p_1) = U_E$ so the markdown retailer in Period 1 is not the preferred option. Also, if $v \ge p_E$, then $v \ge p_E - \beta(v-p_1)^+$ so the consumer spills over in case of stockout, and we have $U_2 = q(v - \delta p_1) + (1-q)(v - p_E) \ge v - p_E \ge U_E$. If $v < p_E$, then $U_E \le v - p_E < 0$. Hence, the consumer prefers either the markdown retailer in Period 2 or no purchase. Thus a consumer purchases from the markdown retailer in Period 2 iff $U_2 \ge 0$. When $v \ge p_E (> \delta p_1)$, then $U_2 = q(v - \delta p_1) + (1-q)(v - p_E) = v - p_E + q(p_E - \delta p_1) \ge 0$. When $v < p_E$, then $v < p_1$ so $U_2 = q(v - \delta p_1)$ so $U_2 \ge 0$ iff $v \ge \delta p_1$ (or $q = 0$, in which case the amount sold is 0). Hence the consumer chooses the markdown retailer in Period 2 iff $v \ge \delta p_1$, and only consumers with $v \ge p_E$ spill over to the EDLP retailer in case of stockout.

case (iii): $p_1 < p_E \le (\bar{v}(1+\beta) + (\alpha - \beta)p_1)/(1+\alpha)$. (The last inequality implies $p_1 < \bar{v}$.) Then we have $p_1 < v_0 \le \bar{v}$, where v_0 is such that a consumer finding a stockout at the markdown retailer spills over to the EDLP retailer iff $v > v_0$ (Preliminary Lemma 1). In this case, $U_1 = v - p_1 - q\alpha p_1(1-\delta)$,

$$U_2 = \begin{cases} q(v-\delta p_1) + (1-q)(v - p_E - \alpha(p_E - p_1)) & \text{if } v \ge v_0, \\ q(v - \delta p_1) - (1-q)\beta(v - p_1) & \text{if } p_1 \le v < v_0, \\ q(v - \delta p_1) & \text{if } v < p_1, \end{cases}$$

and $U_E = v - p_E - q\alpha(p_E - \delta p_1) - (1-q)\alpha(p_E - p_1)$. We observe that $U_E \le v - p_E - q\alpha(p_E - \delta p_1) < v - p_1 - q\alpha(p_1 - \delta p_1) = U_1$, thus the EDLP retailer is never the preferred option. It is straightforward to check that $U_1 \ge q(v - \delta p_1) + (1-q)(v - p_E - \alpha(p_E - p_1))$ iff $q \le Q_0$.

case (iii)a: $q \le Q_0$. If $v_0 \le v \le \bar{v}$, we have $U_1 \ge U_2$, thus the consumer chooses either the markdown retailer in Period 1 or no purchase. We have $U_1 \ge 0$ iff $v \ge p_1 + q\alpha p_1(1-\delta)$. We now show that $p_1 + q\alpha p_1(1-\delta) \le v_0$. We proceed by contradiction. Suppose $p_1 + q\alpha p_1(1-\delta) > v_0$. This inequality simplifies to $q > (p_E - p_1)(1+\alpha)/\alpha p_1(1-\delta)(1+\beta))$. When $q \le Q_0$, this implies $(p_E - p_1)(1+\alpha)/\alpha p_1(1-\delta)(1+\beta)) < Q_0$, which simplifies to $p_E < p_1[\alpha(1+\beta)(1-\delta) + \delta(1+\alpha)]/(1+\alpha)$. After rearranging the terms, we find that $[\alpha(1+\beta)(1-\delta) + \delta(1+\alpha)]/(1+\alpha) < 1$ iff $(1-\delta)(1-\alpha\beta)$, which holds since $\alpha, \beta, \delta < 1$. Hence, the previous inequality implies $p_E < p_1$, yielding a contradiction. It follows that $v_0 < v < \bar{v}$, $U_1 \geq 0$ and so the consumer chooses the markdown retailer in Period 1.

If $p_1 \leq v < v_0$, by Preliminary Lemma 2, $U_1 \geq U_2$ iff $v > v_1$, with $p_1 < v_1 \leq v_0$. Thus we have $U_1 \geq U_2$ for $v_1 < v \leq v_0$ and $U_2 \geq U_1$ for $p_1 < v \leq v_1$. It remains to show that $U_1 \geq 0$ when $v_1 < v \leq v_0$, and $U_2 \geq 0$ for $p_1 < v \leq v_1$. Since $U_1 \geq 0$ iff $v \geq p_1 + q\alpha p_1(1-\delta)$, with $v_1 \geq p_1 + q\alpha p_1(1-\delta)$ (Preliminary Lemma 2), we have $U_1 \geq 0$ when $v_1 < v \leq v_0$, so the consumer chooses the markdown retailer in Period 1. When $p_1 < v \leq v_1$, by Preliminary Lemma 3, we have $U_2 \geq 0$, that is, the consumer selects the markdown retailer in Period 2 and, because $v \leq v_1 \leq v_0$, the consumer does not spill over to the EDLP retailer in case of stockout (Preliminary Lemma 1).

If $\delta p_1 \leq v < p_1$, by Preliminary Lemma 4 we have $v < p_1 < p_1[1 + \alpha q(1-\delta) - q\delta]/(1-q)$, so $U_2 > U_1$. Since $v \geq \delta p_1$, we have $U_2 \geq 0$. Thus the consumer chooses the markdown retailer in Period 2. Also, $v < p_1 < v_0$ ensures that no consumer spills over to the EDLP retailer in case of stockout (Preliminary Lemma 1).

If $v \leq \delta p_1$, by Preliminary Lemma 4 we have $v < p_1 < p_1[1 + \alpha q(1-\delta) - q\delta]/(1-q)$, so $U_2 > U_1$. Furthermore, $U_2 \leq 0$, so the consumer does not purchase.

case (iii)b: $q > Q_0$. If $v_0 \leq v \leq \bar{v}$, we have $U_2 \geq U_1$, thus the consumer chooses either the markdown retailer in Period 2 or no purchase. We have $U_2 \geq 0$ iff $v \geq q\delta p_1 + (1-q)(p_E + \alpha(p_E - p_1))$. We now show that $q\delta p_1 + (1-q)(p_E + \alpha(p_E - p_1)) \leq v_0$. We proceed by contradiction. Suppose $q\delta p_1 + (1-q)(p_E + \alpha(p_E - p_1)) > v_0$. This inequality simplifies to $q < (\beta/(1+\beta) \cdot (p_E - p_1 - \alpha(p_E - p_1))/(p_E - \delta p_1 + \alpha(p_E - p_1))$. When $q \geq Q_0$, this implies $(\beta/(1+\beta) \cdot (p_E - p_1 - \alpha(p_E - p_1))/(p_E - \delta p_1 + \alpha(p_E - p_1)) > Q_0$, which simplifies to $(p_E - \delta p_1)[1 - (1-\alpha)\beta/(1+\beta)] + \alpha(p_E - p_1) < 0$, yielding a contradiction. It follows that for $v_0 < v < \bar{v}$, $U_2 \geq 0$ and so the consumer chooses the markdown retailer in Period 2. In addition, because $v \geq v_0$, in case of stockout the consumer would spill over to the EDLP retailer (Preliminary Lemma 1).

If $p_1 \leq v < v_0$, by Preliminary Lemma 2, $U_1 \geq U_2$ iff $v > v_1$, with $v_1 > v_0$. Thus for $p_1 \leq v < v_0$, we have $v < v_1$ and thus $U_1 < U_2$. By Preliminary Lemma 3, we have $U_2 \geq 0$, that is, the consumer chooses the markdown retailer in Period 2. Furthermore, since $v < v_0$, the consumer does not spill over to the EDLP retailer in case of stockout (Preliminary Lemma 1).

If $\delta p_1 \leq v < p_1$ or if $v \leq \delta p_1$, the reasoning from case (iii)a applies.

case (iv): $(\delta p_1 <) p_1 < p_E$ and $p_E > (\bar{v}(1+\beta) + (\alpha - \beta)p_1)/(1+\alpha)$. Then we have $v_0 > \bar{v}$ (Preliminary Lemma 1), that is, we have $v < v_0$ for all $v \in [0, \bar{v}]$, thus no consumer would spill over to the EDLP retailer if selecting the markdown retailer in Period 2 and finding a stockout.

case (iv)a: $q \leq Q_1$. If $p_1 \leq v \leq \bar{v}$, the reasoning from case (iii)a applies after substituting $\bar{v}$ for v_0.

If $\delta p_1 \leq v < p_1$ or if $v \leq \delta p_1$, the reasoning from case (iii)a applies.

case (iv)b: $q > Q_1$. If $p_1 \leq v \leq \bar{v}$, by Preliminary Lemma 2, $U_1 \geq U_2$ iff $v > v_1$, with $v_1 > \bar{v}$. This implies $v < v_1$ and thus $U_1 < U_2$. By Preliminary Lemma 3, we have $U_2 \geq 0$, that is, the consumer selects the markdown retailer in Period 2 and does not spill over to the EDLP retailer in case of stockout.

If $\delta p_1 \leq v < p_1$ or if $v \leq \delta p_1$, the reasoning from case (iii)a applies. □

Proof of Proposition 2 This result follows from the market segmentation described in Proposition 1 and the assumption that consumers' reservation prices are uniformly distributed on $[0,\bar{v}]$. □

Detailed Lemma 1

Over the region of EDLP price where scenario (i) of Proposition 2 holds, the EDLP retailer's optimal price response and profit are as follows:

$$\begin{array}{lll} p_E = \delta p_1, & \Pi_E = N(\delta p_1 - c)(\bar{v} - \delta p_1)/\bar{v}, & \text{if } p_1 \in [0,(\bar{v}+c)/(2\delta)); \\ p_E = (\bar{v}+c)/2, & \Pi_E = N(\bar{v}-c)^2/(4\bar{v}), & \text{if } p_1 \in [(\bar{v}+c)/(2\delta),\infty). \end{array}$$

Over the region of EDLP price where scenario (ii) of Proposition 2 holds, the EDLP retailer's optimal price response and profit are as follows: if $q=1$*, then* $\Pi_E = 0$ *for all* p_E*; otherwise, that is,* $q<1$*, then:*

$$\begin{array}{lll} p_E = p_1, & \Pi_E = (1-q)N(p_1-c)(\bar{v}-p_1)/\bar{v}, & \text{if } p_1 \in [0,(\bar{v}+c)/2); \\ p_E = (\bar{v}+c)/2, & \Pi_E = (1-q)N(\bar{v}-c)^2/(4\bar{v}), & \text{if } p_1 \in [(\bar{v}+c)/2,(\bar{v}+c)/(2\delta)); \\ p_E = \delta p_1 + \epsilon, & \Pi_E = (1-q)N(\delta p_1 - c)(\bar{v}-\delta p_1)/\bar{v}, & \text{if } p_1 \in [(\bar{v}+c)/(2\delta),\infty), \end{array}$$

where $\epsilon > 0$ *is a small increment*[12] *(such as \$0.01). Over the region of EDLP price where scenario (iii) of Proposition 2 holds, the markdown retailer's price* $p_1 \in [0,\bar{v})$ *and the EDLP retailer's optimal price response and profit are as follows: if* $q=1$*, then* $\Pi_E=0$ *for all* p_E*; otherwise, that is,* $q<1$*, then:*

$p_E =$	$\Pi_E = (1-q)\frac{N}{\bar{v}} \times \ldots$	*if* ...
$p_1\frac{1-\delta q}{1-q} - \epsilon$	$\left(p_1\frac{1-\delta q}{1-q} - c\right)\left(\bar{v} - p_1\frac{1-\delta q+\alpha q(1-\delta)+\beta(1-q)}{(1+\beta)(1-q)}\right)$	$p_1 \in [0,\min\{\bar{v},\ l_1\}) \cap [0,l_3]$
$\frac{\bar{v}(1+\beta)+c(1+\alpha)-p_1(\beta-\alpha)}{2(1+\alpha)}$	$\frac{[\bar{v}(1+\beta)-c(1+\alpha)-p_1(\beta-\alpha)]^2}{4(1+\alpha)(1+\beta)}$	$p_1 \in [0,\min\{\bar{v},\ l_2\}) \cap (l_3,l_4]$[13]
$\frac{\bar{v}(1+\beta)+(\alpha-\beta)p_1}{1+\alpha}$	0	$p_1 \in [l_1,\bar{v}) \cap (l_4,\infty)$[14]
$p_1 + \epsilon$	$(p_1-c)(\bar{v}-p_1)$	$p_1 \in [l_2,\bar{v})$

where $l_1 = \bar{v}\frac{(1+\beta)(1-q)}{1-\delta q+\alpha q(1-\delta)+\beta(1-q)}$, $l_2 = \frac{\bar{v}(1+\beta)+c(1+\alpha)}{2+\alpha+\beta}$, $l_3 = (1-q)\frac{\bar{v}(1+\beta)+c(1+\alpha)}{2(1+\alpha)(1-\delta q)+(1-q)(\beta-\alpha)}$,
$l_4 = \frac{c(1+\alpha)-\bar{v}(1+\beta)}{\alpha-\beta}$, *and* $\epsilon>0$ *is a small increment (such as \$0.01).*

Proof of Lemma 1

Part (i): Under case (i), the EDLP retailer solves the following maximization problem:

$$\max_{0 \le p_E \le \delta p_1} \frac{N}{\bar{v}}(p_E - c)(\bar{v} - p_E).$$

The optimal solution follows from the concavity of the objective and using the first-order conditions.

[12] Technically, when the solution of a constrained continuous optimization problem is on the boundary of the feasible region but the boundary is excluded from the feasible set, the problem has no solution mathematically. We assume here that when such a situation occurs, we can set the optimal solution at the value located a small increment ϵ away from the boundary.

[13] When $\beta<\alpha$ the condition becomes $p_1 \in [0,\min\{\bar{v},\ l_2\}) \cap ((l_3,l_1) \cup [\max\{l_1,l_4\},\infty))$. When $\beta=\alpha$, the condition becomes $p_1 \in (l_3,l_2)$.

[14] When $\beta<\alpha$ the condition becomes $p_1 \in [l_1,\min\{\bar{v},l_4\})$. When $\beta=\alpha$, this case does not occur.

Under case (ii), the EDLP retailer solves the following maximization problem:

$$\max_{\delta p_1 < p_E \le p_1} \quad (1-q)\frac{N}{\bar{v}}(p_E - c)(\bar{v} - p_E).$$

The optimal solution follows from the concavity of the objective and using the first-order conditions.

Under case (iii), the EDLP retailer makes a non-zero profit only when the availability probability exceeds Q_0. Hence, the EDLP retailer solves the following maximization problem (which is feasible only when $p_1 < \bar{v}$):

$$\begin{aligned}
\max_{p_E} \quad & (1-q)\frac{N}{\bar{v}}(p_E - c)(\bar{v} - v_0) \\
\text{s.t.} \quad & p_1 < p_E \le \bar{p} \\
& q > Q_0 \equiv \frac{p_E - p_1}{p_E - \delta p_1} \\
& v_0 = \frac{p_E + \alpha(p_E - p_1) + \beta p_1}{1+\beta}.
\end{aligned}$$

Note that when $q = 1$, the profit is zero for any p_E. When $q < 1$, the problem can be rewritten as follows:

$$\begin{aligned}
\max_{p_E} \quad & (1-q)\,\frac{N}{\bar{v}}(p_E - c)\left(\bar{v} - \frac{p_E + \alpha(p_E - p_1) + \beta p_1}{1+\beta}\right) \\
\text{s.t.} \quad & p_1 < p_E \le \bar{p} \\
& \frac{p_E - p_1}{p_E - \delta p_1} < q.
\end{aligned}$$

We can rewrite the last inequality constraint as $p_E < p_1 \frac{1-\delta q}{1-q}$, where the right-hand side is larger than p_1. Hence, the inequality is compatible with the bounds on p_E. After plugging in the definition of $\bar{p}$ and simplifying th terms, we find that

$$p_1 \frac{1-\delta q}{1-q} < \bar{p} \Leftrightarrow p_1 < \bar{v}\frac{(1+\beta)(1-q)}{1-\delta q + \alpha q(1-\delta) + \beta(1-q)} = l_1,$$

where l_1 can be shown to be lower than $\bar{v}$. Hence, when $q < 1$ and $p_1 < l_1$, the problem can be rewritten as follows:

$$\begin{aligned}
\max_{p_E} \quad & (1-q)\,\frac{N}{\bar{v}}(p_E - c)\left(\bar{v} - \frac{p_E + \alpha(p_E - p_1) + \beta p_1}{1+\beta}\right) \\
\text{s.t.} \quad & p_1 < p_E < p_1 \frac{1-\delta q}{1-q},
\end{aligned}$$

while when $q < 1$ and $l_1 \le p_1 < \bar{v}$, the problem can be rewritten as follows:

$$\begin{aligned}
\max_{p_E} \quad & (1-q)\,\frac{N}{\bar{v}}(p_E - c)\left(\bar{v} - \frac{p_E + \alpha(p_E - p_1) + \beta p_1}{1+\beta}\right) \\
\text{s.t.} \quad & p_1 < p_E \le \bar{p}.
\end{aligned}$$

In either case, this problem can thus be seen as a concave maximization problem over an interval. Using the first-order conditions, it is straightforward that, when $q<1$ and $p_1<l_1$, the optimal solution is

$$p_E=\begin{cases}\frac{\bar v(1+\beta)+c(1+\alpha)-p_1(\beta-\alpha)}{2(1+\alpha)} & \text{if } p_1<\frac{\bar v(1+\beta)+c(1+\alpha)-p_1(\beta-\alpha)}{2(1+\alpha)}<p_1\frac{1-\delta q}{1-q}\\ p_1+\epsilon & \text{if } \frac{\bar v(1+\beta)+c(1+\alpha)-p_1(\beta-\alpha)}{2(1+\alpha)}\le p_1\\ p_1\frac{1-\delta q}{1-q}-\epsilon & \text{if } \frac{\bar v(1+\beta)+c(1+\alpha)-p_1(\beta-\alpha)}{2(1+\alpha)}\ge p_1\frac{1-\delta q}{1-q},\end{cases}$$

that is,

$$p_E=\begin{cases}\frac{\bar v(1+\beta)+c(1+\alpha)-p_1(\beta-\alpha)}{2(1+\alpha)} & \text{if } l_3=(1-q)\frac{\bar v(1+\beta)+c(1+\alpha)}{2(1+\alpha)(1-\delta q)+(1-q)(\beta-\alpha)}<p_1<\frac{\bar v(1+\beta)+c(1+\alpha)}{2+\alpha+\beta}=l_2\\ p_1+\epsilon & \text{if } p_1\ge l_2\\ p_1\frac{1-\delta q}{1-q}-\epsilon & \text{if } p_1\le l_3.\end{cases}$$

The EDLP profit is then

$$\Pi_E=\begin{cases}(1-q)\,\frac{N}{\bar v}\,\frac{[\bar v(1+\beta)-c(1+\alpha)-p_1(\beta-\alpha)]^2}{4(1+\alpha)(1+\beta)} & \text{if } l_3<p_1<l_2\\ (1-q)\,\frac{N}{\bar v}(p_1-c)(\bar v-p_1) & \text{if } p_1\ge l_2\\ (1-q)\,\frac{N}{\bar v}(p_1\frac{1-\delta q}{1-q}-c)\left(\bar v-p_1\frac{1-\delta q+\alpha q(1-\delta)+\beta(1-q)}{(1+\beta)(1-q)}\right) & \text{if } p_1\le l_3,\end{cases}$$

When $q<1$ and $l_1\le p_1<\bar v$, the optimal solution is

$$p_E=\begin{cases}\frac{\bar v(1+\beta)+c(1+\alpha)-p_1(\beta-\alpha)}{2(1+\alpha)} & \text{if } p_1<\frac{\bar v(1+\beta)+c(1+\alpha)-p_1(\beta-\alpha)}{2(1+\alpha)}\le\bar p\\ p_1+\epsilon & \text{if } \frac{\bar v(1+\beta)+c(1+\alpha)-p_1(\beta-\alpha)}{2(1+\alpha)}\le p_1\\ \bar p & \text{if } \frac{\bar v(1+\beta)+c(1+\alpha)-p_1(\beta-\alpha)}{2(1+\alpha)}>\bar p,\end{cases}$$

that is,

$$p_E=\begin{cases}\frac{\bar v(1+\beta)+c(1+\alpha)-p_1(\beta-\alpha)}{2(1+\alpha)} & \text{if } p_1(\alpha-\beta)\ge c(1+\alpha)-\bar v(1+\beta)\equiv l_4' \text{ and } p_1<l_2\\ p_1+\epsilon & \text{if } p_1\ge l_2\\ \bar p & \text{if } p_1(\alpha-\beta)<l_4'.\end{cases}$$

The EDLP profit is then

$$\Pi_E=\begin{cases}(1-q)\,\frac{N}{\bar v}\,\frac{[\bar v(1+\beta)-c(1+\alpha)-p_1(\beta-\alpha)]^2}{4(1+\alpha)(1+\beta)} & \text{if } p_1(\alpha-\beta)\ge l_4' \text{ and } p_1<l_2\\ (1-q)\,\frac{N}{\bar v}(p_1-c)(\bar v-p_1) & \text{if } p_1\ge l_2\\ 0 & \text{if } p_1(\alpha-\beta)<l_4'.\end{cases}$$

Part (ii): In case (i), it follows from the expressions in the Detailed Lemma 1 that the best response decision is independent of the regret factors.

In case (ii), it follows from the expressions in the Detailed Lemma 1 that the best response decision is independent of the regret factors.

In case (iv), the EDLP retailer achieves zero profit regardless of its decision.

In case (iii), it follows from the expressions in the Detailed Lemma 1 that the best response decision is independent of the regret factors when $p_1\in[0,\min\{\bar v,\ l_1\})\cap[0,l_3]$ or when $p_1\in[l_2,\bar v)$. When $p_1\in[0,\min\{\bar v,\ l_2\})\cap(l_3,l_4]$, we have $\partial p_E/\partial\beta=(\bar v-p_1)/(2+2\alpha)>0$, and $\partial p_E/\partial\alpha=(p_1-\bar v)(1+\beta)/[2(1+\alpha)^2]<0$. When $p_1\in[l_1,\bar v)\cap(l_4,\infty)$, we have $\partial p_E/\partial\beta=(\bar v-p_1)/(1+\alpha)>0$, and $\partial p_E/\partial\alpha=(p_1-\bar v)(1+\beta)/(1+\alpha)^2<0$. □

Proof of Proposition 3 (i) and (ii): Immediate from Proposition 2 when cases (ii) or (iii) hold.
(iii) $q < 1$ is necessary to guarantee that $\Pi_E > 0$ so that the EDLP retailer responds by selecting case (ii) or case (iii) with $q > Q_0$.
(iv) Immediate from Proposition 1 when cases (ii) or (iii) with $q > Q_0$ hold. □

Proof of Proposition 4 We proceed by backward induction, considering that p_E is fixed, and we solve for the markdown retailer's best response price p_1 and stock level K. These decisions determine which of scenarios (i), (ii), (iii) and (iv) from Proposition 2 holds, and hence what the demands and profits at each retailer are (according to Proposition 2). At its best response, the markdown retailer would not select a price leading to scenario (i), as in scenario (i) the markdown retailer receives no demand ($D_1 = D_2 = 0$) and hence makes no profit ($\Pi_M = 0$). Thus, we have $\delta p_1 < p_E$. If the markdown retailer selects its price and stock level to be in scenario (iv) or scenario (iii) with $q \le Q_0$, the EDLP retailer receives no demand ($D_E = 0$) and hence makes zero profit ($\Pi_E = 0$). If the markdown retailer selects scenario (ii) or scenario (iii) with $q > Q_0$, it makes all its sales in Period 2 ($D_1 = 0$). Therefore, the markdown retailer's profit is $\Pi_M = (\delta p_1 - c)qD_2 = (\delta p_1 - c)q\frac{N}{\bar{v}}(\bar{v} - \delta p_1)$, a quantity that is increasing in q. Hence, it is optimal for the markdown retailer to select a stock level high enough to satisfy all Period 2 demand, i.e., $q = 1$ (that is, $K = (N/\bar{v})(\bar{v} - \delta p_1)$). It thus follows that the EDLP retailer receives no demand, and thus makes zero profit.□

Proof of Proposition 5 If the EDLP sets its price above c_M, according to Proposition 4, the markdown chooses to enter and sets its price in a away that leaves no profit to the EDLP retailer. This choice of EDLP price is thus not optimal for the EDLP retailer. However, if the EDLP retailer sets its price in $(c_E, c_M]$, the markdown retailer cannot set its discount price below the EDLP price (to ensure that scenario (i) does not occur) without eliminating any profit margin. Meanwhile, because of its cost advantage, the EDLP retailer still maintains a profit margin even at that low price point. Hence, the markdown retailer does not enter, and the EDLP retailer captures all demand and achieves a positive profit. The optimal price is the price that maximizes $(p_E - c_E)(\bar{v} - p_E)$ on $(c_E, c_M]$. □

Proof of Proposition 6 When the EDLP retailer moves first, according to Proposition 4, the markdown retailer's best response pricing and stocking decisions are such that either (a) scenario (ii) with $q = 1$ or scenario (iii) with $q = 1$ of Proposition 2 occur, or (b) scenario (iii) with $q \le Q_0$ or scenario (iv) of Proposition 2 occur. When the markdown retailer moves first, according to Section 5.1, the EDLP retailer's best response price is such that either (c) scenario (i) of Proposition 2 occurs, or, if $q < 1$, (d) scenario (ii) of Proposition 2 occurs, or, if $q < 1$, (d) scenario (iii) with $q > Q_0$ of Proposition 2 occurs. We observe that these best responses have no overlap. As a result, there is no Nash equilibrium. □

Proof of Proposition 7 Case (i): $p_E \le \delta p_1$; i.e., $U_1 \le U_E$, $p_1 \ge v_3$, $p_1 \ge v_2$ and $v_2 \le p_E$. In addition, $v \ge p_1$ implies $v \ge p_E$ on this domain for p_E, hence $U_E \ge 0$. The consumer chooses to purchase from the EDLP retailer. If $v < p_1$, we distinguish two cases: $p_E \le q\delta p_1$ and $p_E > q\delta p_1$. If $p_E \le q\delta p_1$, we have $v_2 \le 0$, so $v \ge v_2$, resulting in $U_E \ge U_2$. The consumer purchases from the EDLP retailer if $U_E \ge 0$ (i.e., $v \ge p_E$) and does not purchase otherwise. If $p_E > q\delta p_1$, $v_2 > 0$ and the inequality $p_E \leq \delta p_1$ implies $v_2 \leq \delta p_1$. Hence, when $v < v_2$, we have $U_E \leq U_2 < 0$ and the consumer chooses not to purchase. When $v_2 \leq v < p_E$, $0 > U_E \geq U_2$, the consumer does not purchase. When $v \geq p_E (\geq v_2)$, then $U_E \geq U_2$ and $U_E \geq 0$, and the consumer purchases from the EDLP retailer.

Case (ii): $\delta p_1 < p_E \leq (1 - q(1-\delta))p_1$; i.e., $U_1 \leq U_E$, $p_1 \geq v_3$, $p_1 \geq v_2$ and $v_2 > p_E$. If $v \geq p_1$, then $v \geq v_3$ so $U_2 \leq U_E$. By the same reasoning as Case (i), if $v \geq p_1$ (which implies $v \geq p_E$), the consumer chooses to purchase from the EDLP retailer. If $v < p_1$, $U_2 > U_E$ when $v < v_2 (\leq p_1)$, and $U_2 \leq U_E$ when $v_2 \leq v \leq \bar{v}$. In addition, if $v < p_1$, $U_2 \geq 0$ iff $v \geq \delta p_1$. Furthermore, because $\delta p_1 < p_E$, we have $v_2 > p_E$, hence $U_E \geq 0$ when $v \geq v_2$. Hence the consumer chooses the markdown retailer in Period 2 if $\delta p_1 \leq v < v_2$ and chooses the EDLP retailer if $v_2 \leq v \leq \bar{v}$. The latter requires $v_2 \leq \bar{v}$, that is, $q \leq Q_2$.

Case (iii): $(1 - q(1-\delta))p_1 < p_E \leq (1 + \alpha q(1-\delta))p_1$; i.e., $U_1 \leq U_E$, $p_1 < v_3$ and $p_1 < v_2$. The consumer decides between purchasing from the markdown retailer in Period 2, purchasing from the EDLP retailer, or not purchasing at all. If $v < p_1$, we have $v < v_2$ so $U_2 = q(v - \delta p_1) > U_E$. Thus the consumer chooses the markdown retailer in Period 2 if $\delta p_1 \leq v < p_1$, and does not purchase if $v < \delta p_1$. If $v \geq p_1$, $U_2 = q(v - \delta p_1) - (1-q)\beta(v - p_1) > U_E$ when $v < v_3$, and $U_2 \leq U_E$ otherwise. In addition, when $v \geq p_1$, from Özer and Zheng (2016, Proposition 1), $U_2 \geq 0$. Hence the consumer chooses the markdown retailer in Period 2 if $p_1 \leq v < v_3$ and chooses the EDLP retailer if $v_3 \leq v \leq \bar{v}$. The latter requires $v_3 \leq \bar{v}$, that is, $q \leq Q_3$.

Case (iv): $p_E > (1 + \alpha q(1-\delta))p_1$; i.e., $U_1 > U_E$. The consumer decides between purchasing from the markdown retailer in Period 1 or in Period 2 or not purchasing at all. The result follows from Özer and Zheng (2016, Proposition 1). □