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We study the effect of anticipated regret on consumer decisions, firm profits and policies, in an advance selling context where buyers have uncertain valuations. Advance purchases trigger action regret if valuations turn out to be lower than the price paid, otherwise delaying purchase causes inaction regret. Emotionally rational consumers act strategically in response to the firm's policies and in anticipation of regret. We characterize a regret threshold above which firms should only spot sell to homogeneous markets, otherwise advance selling is optimal. In heterogeneous markets, the seller offers the product in both periods, using regret as a segmentation mechanism. The effect of regret on profits depends on the type of regret, market structure and the firm's pricing power. Action regret lowers the optimal profits of a price-setting firm in homogeneous markets, while inaction regret has the opposite effect. Overall, regret adversely affects optimal profits whenever actions are regretted more than inactions. Otherwise, firms benefit from regret by creating a buying frenzy, where consumers advance purchase at negative surplus. Action regret can be profitable if high valuation consumers are more regretful, or if the firm is price constrained. Our results provide insights for designing effective campaigns to induce or mitigate regret.

Key words: Dynamic Pricing, Advance Selling, Regret, Behavioral Pricing, Behavioral Consumer Theory

1. Introduction

Until September 7, INFORMS members can preregister for the October 2009 INFORMS Annual Meeting in San Diego and pay $360, instead of the full $410 price after that date. Early September, Professor Regrette is still uncertain about her future preferences and possible conflicts mid-October. As these uncertainties materialize, closer to the conference date, she might regret having committed to attend the conference. Anticipation of this regret *ex-ante* may lead her to forego the early registration. On the other hand, as she stands in line to pay for the registration on-site in San Diego, she might regret having foregone the $50 early bird discount. What is the effect of anticipated

regrets on Professor Regrette's decisions? On INFORMS' profits? How should INFORMS account for regret in its pricing policy and marketing campaign? This paper proposes to answer such questions in a general context.

Consumers often make purchase decisions while uninformed about their true valuations for a product or service. Such decisions have emotional consequences once uncertainties are resolved, and consumers learn if they have made, in hindsight, the wrong choice. A purchase decision leads to action (or purchase) regret if the buyer finds out later than she doesn't need, or doesn't value the product as much. On the other hand, delaying purchase triggers inaction (or non-purchase) regret from missing a discount or limited purchase opportunity. Consumers are aware of these emotional consequences, and anticipate them when making purchase decisions. Our goal in this paper is to develop a behavioral model that incorporates anticipated consumer regret in an advance purchase context, and investigate its effects on consumer behavior and firm profits. Further, we seek to understand the consequences of ignoring regret when setting prices. Finally, our results aim to help firms adjust their pricing and selling policies, as well as their marketing campaigns in response to consumer regret. Our work applies to any advance purchase context, from services to consumer goods, and is particularly relevant for ticket markets, including entertainment, travel or tourism.

A consequence of decision making under uncertainty, regret is a negative, cognitive emotion experienced upon realizing *ex-post* that we would have been better off had we made a different decision, even if *ex-ante* the decision was the right one to make (Zeelenberg 1999). Decision affect theory postulates that consumers anticipate regret, or its counterpart rejoice, and account for it when making decisions: "people anticipate the pleasure or pain of future outcomes, weigh those feelings by chances they will occur, and select the option with greater average pleasure" (Mellers and McGraw 2001). There is ample empirical validation for regret and the effect of its anticipation on individual behavior in diverse contexts (see Zeelenberg 1999). In particular, the relationship between anticipated regret and purchase timing was evidenced, among others, by Simonson (1992), in absence of counterfactual information. Cooke et. al. (2001) find that subjects exposed to post-decision information were more likely to subsequently delay purchase, consistent with action regret.

Organizations are not oblivious of the effect of regret on consumer behavior, and often leverage it in their marketing strategies. Advertising campaigns prime the anticipation of regret with slogans such as Online Lotto's "Miss this... Regret it forever!". A Kodak film campaign prompted anticipated regret by asking consumers to consider how they would feel if they bought cheap film and their pictures didn't turn out. Similarly, AT&T ads aired testimonials of past customers who regretted switching to MCI (Tsiros and Mittal 2000). On the other hand, retailers try to mitigate consumer regret by offering price protection mechanisms, "a sales tactic that can give a buyer peace of mind and entice shoppers to buy immediately instead of looking elsewhere or delaying a purchase. It's a kind of regret insurance" (Chicago Tribune, January 2008). For example, in 1983, the Toro company experienced a brisk increase in sales of snow blowers following the introduction of a snow risk guarantee, essentially a regret mitigating mechanism (Bell 1985). Our research proposes to understand when and how companies should respond to consumer regret.

We propose a model where consumers are strategic and "emotionally rational", in that they time their purchase decisions in response to the firm's pricing policies, and the anticipation of regret. Zeelenberg (1999) provides multiple arguments for the rationality of anticipated regret. Consistent with the argument that rationality applies to "what we do with our regrets, and not to the experience itself" (Zeelenberg 1999, p. 325), we focus on anticipated regret and do not consider here the (observed, yet irrational) effect of experienced regret on decisions.[1]

Our consumer behavior model relies on a formal, established theory of regret in consumer choice, developed by Bell (1982), and Loomes and Sugden (1982). By considering forgone alternatives in the evaluation of choice utilities, regret theory has been shown to improve the descriptive power of expected utility theory. In particular, regret allows to explain various puzzles that expected utility cannot, such as preference reversals,coexistence of insurance and gambling, and loss aversion.

Contributions. Our contributions to the existing literature, detailed below, can be summarized as follows: (1) we provide a stylized model of anticipated regret in a dynamic pricing setting,

[1] For example, the regret experienced upon missing a discount may prevent consumers from purchasing later at full price, even if that is below their valuation. Such behavior has been evidenced, but is not rational. It is however consistent with reference dependence and loss aversion.

grounded in behavioral theory and evidence; (2) we characterize the strategic purchase behavior of emotionally rational consumers in this setting; (3) we investigate the effect of regret on the firm's profits and policies, relative to its pricing power and market structure; and finally (4) our results suggest when it is important for a firm to measure consumer regret, and how marketing policies should respond to it.

If consumers are homogenous in the advance period, a firm with full price flexibility either sells on spot or in advance, depending on the strength of regret. Specifically, we characterize a regret threshold above which the firm only spot sells, and below which it only advance sells. The optimal advance selling price decreases with action regret. When consumers are ex-ante heterogenous, the firm offers the product in both periods, using regret to segment the market.

The effect of regret on profits depends on the type of regret, the firm's pricing power and the structure of the market. Action regret negatively affects the profits of a price-setting firm that optimally responds to regret in a homogeneous market. The result holds regardless of seller credibility, marginal costs, and restrictions on the spot period price (e.g. as a result of competition or fairness constraints). The result also extends for markets where buyers with homogeneous valuations vary in their degree of regret anticipation.

On the other hand, we find that optimal profits can increase with action regret if the firm is a price taker in the advance period, or in heterogeneous markets, if high valuation buyers are more prone to regret. For a price-constrained firm, the effect of regret on profits critically depends on the discount level. Firms practicing deep discounts benefit from action regret.

Inaction regret has the opposite effect on profits that action regret. Overall, regret has a negative effect on profits as long as actions are regretted more than inactions, as widely evidenced by the omission bias in psychology (Gilovic and Medvec 1995, Patrick et. al. 2003). However, inactions can be regretted more than actions in specific contexts (Simonson 1992, Zeelenberg 2002), including long-term regrets (Keinan and Kivetz 2008) and limited purchase opportunities (Abendroth and Diehl 2006, Engelbrecht-Wiggans and Katok 2008). In such cases, we show that firms benefit from

overall consumer regret by creating a buying frenzy, in which consumers advance purchase at a negative surplus to avoid inaction regret.

Our findings suggest that firms can indeed benefit from marketing campaigns that reduce action regret (e.g. by allowing resales) or induce inaction regret (e.g. by emphasizing a foregone discount or a limited offer), as long as they practice profitable discounts. Finally, our results motivate further profitability analysis of regret mitigating strategies, such as offering refunds or price guarantees.

Our insights extend when capacity is limited. Supply constraints trigger a coordination game among consumers, as one consumer's choice creates externalities on other consumers' surplus. Unlike the uncapacitated case, consumers may advance purchase at a premium when supply is limited, in order to avoid being rationed in the spot period. Artificially rationing supply can increase profits for price-constrained firms. Nevertheless, we show that rationing and mark-down policies are not equilibrium outcomes of our model when the seller has full pricing flexibility.

Relation to the Literature. Our paper is among few in the literature to model consumer regret in an operational context, and provide prescriptive insights for a firm's decisions. Irons and Hepburn (2007) model variety regret to explain why consumer utility diminishes when there are too many options to choose from. Syam et al. (2008) model anticipated regret to explain consumer's preference for standardized versus customized products. The effect of regret aversion on consumer behavior has been modeled in other business contexts, including Dodonova and Khoroshilov (2005) on stock returns, Braun and Muermann (2004) on demand for insurance, and Engelbrecht-Wiggans and Katok (2006) on overbidding in auctions. In a similar spirit, our results explain how action and inaction regret affect willingness to pay, and purchase timing decisions. We further embed the resulting consumer behavior model into the profit maximization problem of the firm, to derive the optimal pricing policy in response to a regretful market.

There is a significant body of work that deals with strategic, yet unemotional, consumers in a pricing context, see Shen and Su (2007) for a review. More recent papers include Jerath et al. (2007), Liu and van Ryzin (2008), and Cachon and Swinney (2009). Specifically, our work builds

on a stream of literature on advance selling policies, where strategic consumers are uncertain about their valuation, due to the separation of purchase decisions and consumption.

Advance selling has been widely investigated in the marketing and economics literature. A classic reference is Xie and Shugan (2001), who derive conditions for profitability of advance selling to consumers who are uncertain about their valuations, modeled as a two-point distribution. Consumers arrive in both periods, and aggregate demand in each period is known. Gale and Holmes (1992) show the profitability of advance purchase discounts for a credible seller facing aggregate demand uncertainty. DeGraba (1995) finds that a monopolist can generate higher profits by restricting supply and inducing consumers to advance purchase at a premium, in a so-called buying frenzy. The result is triggered by the sellers' lack of credibility and the specific, discrete valuation distribution, as shown in Courty (2005). Our model adds to this stream by investigating the effect of anticipated regret in advance purchase settings, under general valuation distributions.

Our work interfaces a growing literature on behavioral operations, reviewed by Bendoly et al. (2006), Loch and Wu (2007) and Gino and Pisano (2008), and the pricing and revenue management literature. At this juncture, we contribute to the behavioral pricing stream, which studies how firms should optimally set prices in response to "predictably irrational" consumers. Several papers in this stream study pricing policies when backward-looking loss averse consumers anchor on past prices (e.g. Popescu and Wu 2007, Nasiry and Popescu 2008). Closest to our work, Su (2008) and Liu and Shum (2009) model forward-looking consumers prone to inertia, respectively disappointment.

Su (2008) provides a stylized model of buyer inertia, a tendency to postpone purchase decisions, and shows that its strength adversely affects profits, but a larger proportion of inertial consumers can be beneficial. Inertia can be explained by various behavioral regularities, including anticipated action regret, but also hyperbolic discounting, probability weighting and loss aversion. The paper models inertia holistically, as a constant threshold on consumer surplus. In contrast, we focus on modeling consumers' regret, based on its theoretical foundations; regret translates to a non-constant surplus threshold, leading to different insights.

Liu and Shum (2009) study the optimal pricing and capacity decision of a firm when rationing first period sales causes consumer disappointment. They show that disappointment does not affect the firm's policy if it is uncorrelated with consumer valuation. Otherwise, if the correlation is positive, segmenting the market with a markup policy can maximize profits. In contrast with regret, which is experienced if decisions turn out to be wrong, disappointment occurs when outcomes do not meet expectations; see Zeelenberg et al. (2000) for a review. Both disappointment and regret are examples of reference effects (Bell 1985), and results of counterfactual thinking (Zeelenberg et. al. 2000), but they are distinct psychological phenomena, activating different regions in the brain (Chua et. al. 2009).

Structure. The rest of the paper is organized as follows. Section 2 develops the basic model that incorporates action regret in an advance purchase setting. We characterize the consumer's surplus maximizing purchase timing decision in anticipation of regret, and measure the effect of regret on profitability. We further derive the optimal pricing policy of a price-setting firm in response to regret. Section 3 investigates the robustness of our results in a variety of plausible extensions, including the effect of marginal costs, price restrictions and seller credibility. Section 4 focuses on markets where consumers are heterogeneous in terms of regret and/or valuation. Section 5 incorporates inaction regret in our model, and investigates the effect of its interaction with action regret on firm profits and decisions. Section 6 characterizes consumers' equilibrium purchasing behavior and the firm's optimal pricing policies under capacity constraints. Extensions and future research directions are presented in Section 7. Section 8 concludes the paper.

2. Advance Selling with Action Regret

This section presents our basic model where homogeneous buyers anticipate action regret. The firm sets prices p_1, p_2 for advance, respective spot sales. Consumers have unit demand for the product, and decide whether to purchase in the first period, when their valuation $\mathbf{v}$ is uncertain, or wait for the spot period, when they learn their true valuation v. Consumers' valuation distribution $\mathbf{v}$ has (common knowledge) cumulative distribution $F(\cdot)$ with positive support $[0, v_{max}]$, finite mean

$E[\mathbf{v}] = \mu$, and survival function $\bar{F}(\cdot) = 1 - F(\cdot)$. In absence of capacity constraints (studied in Section 6), we scale the market size to $N = 1$ without loss of generality.

2.1. The Consumer Model with Action Regret

In our model, emotionally rational consumers do not discount utility, and act to maximize expected surplus, net of anticipated regret. Following the standard convention, we assume that if consumers are indifferent between buying or waiting, the firm induces the more profitable choice by offering an infinitesimal incentive.

Consumers regret the decision to advance purchase if their valuation for the product turns out to be less than the price paid. Following Bell (1982) and Looms and Sugden (1982), we posit that consumers' utility, assumed risk-neutral, features a separable regret component. The amount of regret is proportional to the foregone surplus, i.e. the discrepancy between the valuation realization v, and the advance price, p_1, denoted $(v - p_1)^- = \min(0, v - p_1)$. Therefore, the expected, or anticipated action regret is $\rho R(p_1) = \rho E[\mathbf{v} - p_1]^-$, where $\rho \geq 0$ measures the strength of regret. In particular, $\rho = 0$ for unemotional buyers. The following properties of $R(x) = E[\mathbf{v} - x]^-$ will be useful throughout our analysis. All proofs are in the Appendix.

Lemma 1. *(a) $R(x) \leq 0$ is decreasing and concave in x, (b) $x + R(x)$ is increasing and concave in x, and (c) $0 \leq x\bar{F}(x) \leq x + R(x) \leq \mu$, for all $x \geq 0$.*

Regret is reflected in the expected consumer surplus from advance purchasing, S_1, as follows:

$$S_1 = S_1(\rho; p_1) = \mu - p_1 + \rho R(p_1). \tag{1}$$

In absence of a spot market, consumers' maximum willingness to pay (wtp) in advance

$$p_1(\rho) \text{ solves } S_1(\rho; p) = \mu - p + \rho R(p) = 0. \tag{2}$$

In particular, in absence of regret we obtain the classic result $p_1(0) = \mu$.

Consumer's expected surplus from waiting for the spot market, and possibly buying at p_2, is:

$$S_2 = E[\mathbf{v} - p_2]^+ = \mu - p_2 - R(p_2) \geq 0. \tag{3}$$

Given prices (p_1, p_2), consumers buy early whenever the expected surplus from doing so, S_1, exceeds the expected surplus from waiting and (possibly) buying the product in the second period, S_2. The differential expected surplus from an advance purchase is:

$$\Delta S(\rho; p_1, p_2) = S_1 - S_2 = p_2 - p_1 + R(p_2) + \rho R(p_1). \tag{4}$$

Lemma 1 implies that consumers' differential expected surplus from buying early, $\Delta S(\rho; p_1, p_2)$, is decreasing in ρ, and in p_1, and increasing in p_2, all else equal. Let $p_1(\rho; p_2)$ denote consumers' maximum wtp in advance, if the spot price is p_2, and let $p_2(\rho; p_1)$ be the lowest spot price that induces consumers to advance purchase at $p_1 \leq p_1(\rho)$; it follows that

$$p_1(\rho; p_2) \quad \text{solves} \quad \Delta S(\rho; p, p_2) = 0, \tag{5}$$

$$p_2(\rho; p_1) \quad \text{solves} \quad \Delta S(\rho; p_1, p) = 0. \tag{6}$$

When $p_1 > p_1(\rho)$, $S_1 < 0$, so (6) does not have a solution, and consumers always wait. Finally, the regret level at which consumers are indifferent between advance and spot buying is:

$$\rho_0(p_1, p_2) = -\frac{\Delta S(0)}{R(p_1)} = \frac{p_2 - p_1 + R(p_2)}{-R(p_1)}, \tag{7}$$

where $\Delta S(0) = p_2 - p_1 + R(p_2)$ is the differential surplus in absence of regret.

Lemma 2. *(a) Given (p_1, p_2), consumers prefer to advance purchase if and only if any of the following equivalent conditions holds: (i) $\rho \leq \rho_0(p_1, p_2)$; (ii) $p_1 \leq p_1(\rho; p_2)$; (iii) $p_2 \geq p_2(\rho; p_1)$.*

(b) Given a spot price p_2, consumers maximum wtp in advance, $p_1(\rho; p_2) \leq p_2$ is increasing in p_2 and decreasing in ρ. Similarly, $p_2(\rho; p_1) \geq p_1$ is decreasing in p_1 and increasing in ρ.

(c) Consumers' overall maximum wtp in advance, $\sup_{p_2} p_1(\rho; p_2) = p_1(\rho) \leq \mu$, is decreasing in ρ.

The higher the regret factor, the more likely consumers are to delay their purchase decisions, and either buy the product at a higher price or not at all. An implication of Lemma 2 is that any pricing policy that induces advance purchase must offer a discount in the first period, i.e. it should be a markup policy. A necessary condition to induce advance purchase is $p_1 \leq p_2 + R(p_2) \leq p_2$. Otherwise,

if the discount is not steep enough, $p_1 > p_2 + R(p_2)$, then regardless of regret, consumers will always prefer to wait. Higher spot prices increase consumers' wtp in advance (this is not necessarily the case under capacity constraints, as shown in Section 6.1), while action regret decreases it. The maximum wtp that the firm can possibly extract in advance equals the maximum wtp in absence of a spot market, $p_1(\rho)$.

2.2. The Effect of Regret on Profits and Prices

We further investigate the impact of anticipated action regret on the firm's profits and decisions. We begin by studying this in the context of a price taking firm, and then for a firm that has full pricing flexibility. For simplicity, we assume that marginal costs are zero. Section 3.1 extends our results in the presence of marginal costs.

2.2.1. Price Taking Firm. Because valuations are ex-ante homogeneous, for any pricing policy (p_1, p_2), either all consumers advance purchase, or all wait. The firm's expected profit under action regret is given by a step function:

$$\pi(\rho; p_1, p_2) = \begin{cases} p_1, & \text{if } \rho \leq \rho_0(p_1, p_2); \\ p_2 \bar{F}(p_2), & \text{otherwise,} \end{cases} \tag{8}$$

where $\rho_0(p_1, p_2)$ is given by (7), and $\bar{F}(p_2) = P(\mathbf{v} \geq p_2)$. A high regret factor makes consumers delay purchase, which benefits the firm if and only if spot sales are more profitable than advance sales, $p_2 \bar{F}(p_2) \geq p_1$; this implies the next proposition. In particular, it follows that firms who offer relatively steep discounts benefit from consumers' action regret.

Proposition 1. *$\pi(\rho; p_1, p_2)$ is increasing in ρ if $d = \frac{p_1}{p_2} \leq \bar{F}(p_2)$, and decreasing otherwise.*

Going back to the example of Professor Regrette, the above result says that INFORMS benefits from members' anticipated regret if and only if $P(\mathbf{v} \geq 410) \geq \frac{360}{410} = .88$, that is, at least 88% of INFORMS members would be willing to register for the conference at full price (assuming homogeneous valuation distributions). Regret heterogeneity does not change this result (see Section 4), whereas a positive marginal cost can only decrease the 88% figure (Section 3.1).

2.2.2. Full Price Flexibility. We next address the firm's expected profit optimization problem in response to consumer choice.

Consider first a firm who only sells on the spot market. The maximum profit $\bar{p} = \max p\bar{F}(p)$ that the firm can extract on the spot market cannot exceed consumers' average valuation, $\bar{p} \leq \mu$ (from Lemma 1c). Without loss of generality, let $p_0 = \arg\max p\bar{F}(p)$, denote the smallest optimal spot price (i.e. the one that maximizes consumer surplus). The optimal spot price is unique if $p\bar{F}(p)$ is quasi-concave. This holds in particular if $\mathbf{v}$ is IGFR, i.e. the generalized failure rate (GFR) of $\mathbf{v}$, $g(p) = \dfrac{pf(p)}{\bar{F}(p)}$ is increasing in p, in which case $g(p_0) = 1$ (see e.g. Lariviere 2006). IGFR is a relatively mild assumption, satisfied by most distributions of practical interest, including Uniform, Exponential, Erlang, Normal, etc. We only make this assumption as needed.

A price-setting firm that optimally responds to regret solves the following bi-level problem:

$$\max_{p_1, p_2} \pi(\rho; p_1, p_2), \tag{9}$$

where π is given by (8). Because consumers are ex-ante homogeneous, they will all buy in the same period, so the optimal policy is to sell either in advance, or on spot. By Lemma 2c, the most that the firm can extract in advance is consumers' maximum wtp in absence of a spot market, $p_1(\rho)$, defined by (2). If consumers are not too regretful, the firm only advance sells at $p_1(\rho)$, otherwise spot selling at the profit optimizing spot price, p_0, is optimal.

Proposition 2. *(a) The optimal pricing policy is to advance sell at $p_A = p_1(\rho)$, if $\rho \leq \bar{\rho} = \frac{\mu - \bar{p}}{-R(\bar{p})}$, and otherwise to spot sell at $p_S = p_0$.*

(b) The optimal expected profit, $\pi^*(\rho) = \max\{p_1(\rho), \bar{p}\}$, is decreasing in ρ.

The threshold $\bar{\rho}$ defined in Proposition 2 is the regret level for which the firm is indifferent between advance and spot selling, i.e. the profits from the two strategies are equal, $p_1(\bar{\rho}) = \bar{p}$.

Proposition 1 suggested that firms can benefit from regret provided that they charge sufficiently steep discounts. Proposition 2b shows that such discounts are not optimal. Indeed, action regret decreases consumers' maximum wtp in advance, $p_1(\rho)$, and further adversely affects the firm's

optimal profits. So, in a homogeneous market, a price-setting firm cannot leverage action regret to increase profits.

The result also implies that ignoring regret can have considerable profit consequences. Indeed, a firm that ignores consumer regret, sets prices as if $\rho = 0$, i.e. it advance sells at $p_A = p_1(0) = \mu$. Regretful customers do not buy at this price, because $p_1(\rho) < \mu = p_A$ when $\rho > 0$. Because the product is not offered in the second period, the firm makes zero profits.

2.2.3. Examples and Estimation. Our results are robust, in that they hold regardless of the underlying valuation distribution.[2] We next explore how these results specialize to specific valuation distributions. For tractability reasons, the most commonly used valuation distributions are uniforms (e.g. Liu and van Ryzin 2008) and two-point distributions (e.g. DeGraba 1995, Xie and Shugan 2001).

Example 1. If $\mathbf{v}$ is uniformly distributed on $[0, b]$, our results indicate that the firm should advance sell at $p_1(\rho) = \frac{b}{1+\sqrt{1+\rho}}$ if consumers' action regret factor $\rho \leq \bar{\rho} = 8$, and otherwise spot sell at $p_0 = \frac{b}{2}$, with spot profits $\bar{p} = \frac{b}{4}$.

Example 2. If $\mathbf{v}$ is exponentially distributed with mean λ, we obtain $\bar{\rho} \simeq 10.523$, $p_0 = \lambda, \bar{p} = \frac{\lambda}{e}$, and $p_1(\rho)$ solves: $(\lambda - p)(1+\rho) - \rho\lambda e^{-\frac{p}{\lambda}} = 0$.

Example 3. With a two-point valuation distribution $\mathbf{v} = (H, q; L, 1-q)$, we obtain $p_1(\rho) = \frac{\mu+\rho(1-q)L}{1+\rho(1-q)}$, and $\bar{p} = \max\{L, qH\}$. Proposition 2 implies that the firm advance sells as long as $\rho \leq \bar{\rho} = \frac{L}{(qH-L)^+}$, in particular whenever $L \geq qH$, and spot sells at $p_S = H$ otherwise. Interestingly, for $L = 0$, we find that regret does not influence firm profits, and a spot selling only policy is optimal.

The above examples suggest that understanding the type of uncertainty underlying consumers' valuation is a critical step to undertake before measuring regret. There are surprisingly few studies in the literature that attempt to measure regret. In an auction context, Filiz-Ozbay and Ozbay (2007) report a 1.23 (loser) regret coefficient, whereas Engelbrecht-Wiggans and Katok (2008) obtain relative estimates of different types of regret. Bleichrodt et. al. (2008) elicit a linear utility

[2] This is important, because specific distributions may drive insights which fail to hold in general. For example, Courty (2005) shows that DeGraba's (1995) buying frenzies are driven by the two-point valuation distribution.

model with non-linear regret, fitted with a power function of degree around 1.5; this suggests that the marginal effect of regret can be steep. Regret coefficients $\rho > 1$ imply that the marginal psychological disutility (from regret) exceeds, in absolute value, the marginal effect of monetary utility; albeit surprising, this is consistent with empirical estimates of other reference dependent models (e.g. Tversky and Kahneman 1991). Overall, our results motivate the importance of measuring the strength of anticipated regret, ρ, in order to design pricing policies.

3. Extensions and Variations

This section investigates the robustness of our main insights. The results in Section 2 extend when production is costly, the firm is price-constrained in the advance period, or lacks credibility in committing to future prices. However, we find that optimal profits can increase in consumers' regret if the firm is a price-taker in the spot period.

3.1. The Firm Incurs a Marginal Cost of Production

For a firm that incurs a marginal cost of production, $c \geq 0$, define $p_0(c) = \text{argmax}(p-c)\bar{F}(p)$, and $\bar{p}(c) = \max(p-c)\bar{F}(p)$. Clearly, $\bar{p}(c)$ is decreasing in c, and $p_0(c)$ is increasing in c. The results of Section 2 extend under marginal costs as follows:

PROPOSITION 3. *Suppose that the firm incurs a marginal cost $c \geq 0$.*

(a) The expected profit $\pi(\rho; p_1, p_2)$ of a pricing policy (p_1, p_2) is increasing in ρ if $\frac{p_1 - c}{p_2 - c} \leq \bar{F}(p_2)$, and decreasing in ρ otherwise.

(b) If $\rho \leq \bar{\rho}(c) = -\frac{\mu - \bar{p}(c) - c}{R(\bar{p}+c)}$, the optimal pricing policy is to advance sell at $p_A = p_1(\rho)$; otherwise, the optimal policy is to spot sell at $p_S = p_0(c)$. Moreover, $\bar{\rho}(c)$ is decreasing in c.

(c) The optimal expected profit, $\pi^*(\rho; c) = \max\{p_1(\rho) - c, \bar{p}(c)\}$, is decreasing in ρ and c.

From (a), for a given pricing policy, $c < p_1 < p_2$, profits increase in ρ whenever $p_1 \leq p_2\bar{F}(p_2) + cF(p_2)$, in particular if $p_1 \leq p_2\bar{F}(p_2)$. So, relative to the result of Proposition 1, a positive marginal cost expands the range of pricing policies for which profit is increasing in regret. For a price-setting firm, the higher the marginal cost, the less attractive advance selling is (because $\bar{p}(c)$ is decreasing in c). Finally, for a positive marginal cost, the range of regret for which advance selling is optimal is smaller (because $\bar{\rho}(c)$ is decreasing in c).

3.2. The Firm Is Price Constrained in The Spot Period

In many industries, firms do not have the flexibility to charge profit optimizing prices; this can be due to competitive pressure, historic, perception or fairness considerations, or other business operating constraints. For example, for the past 10 years the Roland Garros French tennis open has been selling tickets for the finals for about 70 Euros, significantly below the profit optimizing price (tickets on eBay sell for ten times that). This section considers a firm that acts as a price-taker in the spot period, i.e. p_2 is exogenously fixed.

PROPOSITION 4. *(a) For a firm constrained to spot sells at p_2, advance selling is optimal if and only if $\rho \leq -\dfrac{p_2 F(p_2) + R(p_2)}{R(p_2 \bar{F}(p_2))}$. In this case, the optimal advance price is $p_A = p_1(\rho; p_2)$ which solves (5), and all consumers advance purchase.*

(b) The optimal expected profit, $\pi^*(\rho; p_2) = \max\{p_1(\rho; p_2), p_2 \bar{F}(p_2)\}$, is decreasing in ρ.

Intuitively, if the spot price p_2 is fixed, the firm advance sells at consumers' maximum wtp in advance, $p_1(\rho; p_2)$, whenever this yields higher profits than spot selling. Consumers will advance purchase at this price as long as they are not too regretful. By Lemma 2b, $p_1(\rho; p_2)$ is decreasing in ρ, extending Proposition 2b.

3.3. The Firm Is Price Constrained in The Advance Period

Consider now the case where the advance price p_1 is exogenously constrained. This is the case, for example, in the airline industry, where the advance selling market is highly competitive and carriers typically match each others' discounted prices.

Assume that $p_1 \leq p_1(\rho)$ is fixed; this ensures that $S_1 \geq 0$, i.e. advance selling at p_1 is feasible. Otherwise, all consumers wait, and the optimal policy is to spot sell at p_0 with expected profit $\bar{p}$. By definition (6), any spot price above $p_2(\rho; p_1)$ will induce all consumers to advance purchase. A spot price below $p_2(\rho; p_1)$, on the other hand, induces consumers to wait. The following proposition characterizes the optimal pricing policy of the firm. The IGFR assumption on $\mathbf{v}$ ensures that spot profits are unimodal (see Section 2.2.2).

PROPOSITION 5. *Assume $\mathbf{v}$ is IGFR, and the firm is constrained to advance sell at p_1.*

(a) If $\rho < \frac{p_0 - p_1 + R(p_0)}{-R(p_1)}$*, the firm either induces all consumers to buy on spot at* $p_S = p_2(\rho; p_1)$*, or does not spot sell, whichever is more profitable. Otherwise, the firm either induces all consumers to buy on spot at* $p_S = p_0$*, or does not spot sell, whichever is more profitable.*

(b) The optimal profit $\pi^*(\rho; p_1)$ *is increasing in* ρ*.*

The results is illustrated in Figure 1, for a uniform valuation distribution. The condition $\rho < \frac{p_0 - p_1 + R(p_0)}{-R(p_1)}$ is equivalent to $p_1 < p_1(\rho; p_0)$ (or equivalently $p_0 > p_2(\rho; p_1)$), i.e. at the profit-optimizing spot price, p_0, consumers' max wtp in advance, $p_1(\rho; p_0)$, exceeds the advance price p_1. In this case, the firm cannot extract the highest spot profit $\bar{p}$; so it should either spot sell at $p_2(\rho; p_1)$ or only advance sell at p_1, whichever leads to higher profits (see the blue frontier in Figure 1). A higher regret factor increases the likelihood of consumers waiting for spot sales, when the firm can charge a higher price ($p_2(\rho; p_1)$ is increasing in ρ by Lemma 2b) and, as shown in the appendix, earn more profits. Interestingly, and in contrast with previous results, we obtain that *action regret increases profits* when the advance price is fixed.

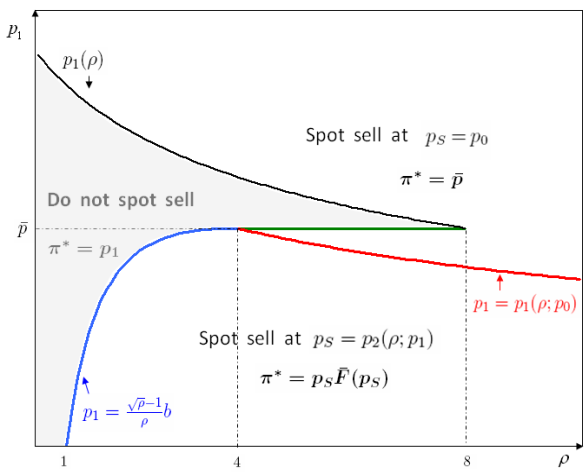

Figure 1 **Optimal policy and profits when the advance price p_1 is exogenously fixed and $\mathbf{v} \sim U[0, b]$;** $p_0 = \frac{b}{2}$, $\bar{p} = \frac{b}{4}$, $p_1(\rho) = \frac{b}{1+\sqrt{1+\rho}}$ **and** $p_1(\rho; p_0) = \frac{3}{2} \frac{b}{2+\sqrt{4+3\rho}}$.

3.4. The Firm Does Not Have Exogenous Credibility

So far, we have assumed that the firm can credibly commit to the prices it announces; this assumption is common in the literature (e.g. Gale and Holmes 1992, Courty 2003, Su 2008, Liu and van

Ryzin 2008). This can be achieved for example by contracting with an intermediary seller, like Ticketmaster in the US, or Sistic in Singapore. Proposition 2 shows that, if the regret factor is low enough, then the firm should only advance sell; spot selling can be ruled out by charging a high spot price ($p_S > v_{max}$). This is possible whenever the firm can credibly commit to a high spot price, i.e. consumers believe that this is not an "empty threat".

When the firm lacks the credibility to enforce the pre-announced prices, consumers form rational expectations about spot prices, i.e. expectations consistent with the firm's incentives to optimize spot profits (e.g. DeGraba 1995, Xie and Shugan 2001, Cachon and Swinney 2009). In our case, consumers anticipate that the firm will rationally charge the profit optimizing spot price, $p_S = p_0$, to whoever happens to wait. At this price consumers prefer to wait, rather than advance purchase at $p_1 = p_1(\rho)$ (because $\Delta S(\rho, p_1(\rho), p_0) < 0$). Seller credibility lowers consumers maximum wtp in advance, $p_1(\rho; p_0) \leq p_1(\rho)$ (by Lemma 2c). The following result characterizes the optimal pricing policy of the firm in absence of credibility.

Proposition 6. *(a) If $\rho \leq -\frac{p_0 + R(p_0) - \bar{p}}{R(\bar{p})}$, the optimal pricing policy of a firm that lacks credibility is $(p_A = p_1(\rho, p_0), p_S = p_0)$, and the firm induces all consumers to buy in advance. Otherwise, the optimal policy is to only spot sell at $p_S = p_0$. (b) Overall, the optimal profits $\pi^*(\rho) = \max\{p_1(\rho; p_0), \bar{p}\}$ decrease with regret, ρ.*

Because $\mu \geq p_0 + R(p_0)$ (by Lemma 1c), a straightforward comparison with Proposition 2 shows that seller credibility makes advance selling more attractive, i.e. advance selling is profitable for a wider range of regret factors. Optimal profits are adversely affected by lack of credibility (because $p_1(\rho) \geq p_1(\rho; p_0)$), and by action regret ($p_1(\rho; p_0)$ is decreasing in ρ by Lemma 2b).

4. Heterogeneous Market

This section investigates the effects of market heterogeneity on pricing policies and optimal profits.

4.1. Regret Heterogeneity

We extend the analysis in Section 2 to a setting where only a share $\alpha \in [0, 1]$ of the market, called segment A, regrets purchase decisions, and the other segment, B, does not anticipate regret.

Consumers have the same valuation distribution $\mathbf{v}$. This is appropriate when regret is idiosyncratic, but valuations are driven by an exogenous factor (such as weather conditions for an open air concert, the qualifying teams for a tournament, or the performing soprana for an opera show).

Type A and B consumers advance purchase if and only if $\Delta S^A(\rho) = p_2 - p_1 + R(p_2) + \rho R(p_1) \geq 0$, respectively $\Delta S^B(0) = p_2 - p_1 + R(p_2) \geq 0$. By Lemma 1a, type B consumers are more likely to advance purchase: $\Delta S^A(\rho) < \Delta S^B(0)$. The firm's expected profit per customer for a given pricing policy (p_1, p_2) is:

$$\pi(\rho; p_1, p_2) = \begin{cases} p_1, & \text{if } \Delta S^A(\rho) \geq 0; \\ (1-\alpha)p_1 + \alpha p_2 \bar{F}(p_2), & \text{if } \Delta S^B(0) \geq 0 > \Delta S^A(\rho); \\ p_2 \bar{F}(p_2), & \text{if } \Delta S^B(0) < 0. \end{cases} \tag{10}$$

Proposition 1 directly extends in this setting.

We further characterize the firm's optimal pricing policy. A policy $(p + R(p), p)$ makes type A consumers wait, whereas technically indifferent type B consumers buy early because it is more profitable for the firm (by Lemma 1c and the standard convention). We argue that the optimal spot price that the firm can charge to segment the market, p_α maximizes $(1-\alpha)(p + R(p)) + \alpha p \bar{F}(p)$. Assuming $\mathbf{v}$ is IGFR, we obtain that

$$p_\alpha \text{ solves } g(p) = \frac{1}{\alpha}. \tag{11}$$

Moreover, p_α is decreasing in α, and in particular $p_\alpha \geq p_0$. So $(p_A = p_\alpha + R(p_\alpha), p_S = p_\alpha)$ is the most profitable policy that segments the market. On the other hand, the policy $(p_A = p_1(\rho), p_S > v_{max})$ induces everyone to buy early. Define ρ_α to be the regret value for which the firm is indifferent between these policies, i.e. the profits of these two pricing policies are equal:

$$\rho_\alpha \text{ solves } (1-\alpha)(p_\alpha + R(p_\alpha)) + \alpha p_\alpha \bar{F}(p_\alpha) = p_1(\rho_\alpha). \tag{12}$$

We are now ready to characterize the firm's optimal pricing policy.

Proposition 7. *Assume that* $\mathbf{v}$ *is IGFR and a fraction* α *of the market regrets.*

(a) The optimal policy is to advance sell only at $p_A = p_1(\rho)$ *if* $\rho \leq \rho_\alpha$*. Otherwise the firm advance sells at* $p_A = p_\alpha + R(p_\alpha)$*, inducing non-regretful consumers to buy early, and spot sells at* $p_S = p_\alpha$ *to regretful buyers. Moreover,* ρ_α *is increasing in* α*.*

(b) The optimal expected profit, $\pi^*(\rho,\alpha) = \max\{p_1(\rho), (1-\alpha)(p_\alpha + R(p_\alpha)) + \alpha p_\alpha \bar{F}(p_\alpha)\}$, *decreases in the strength of regret,* ρ, *and in the share of the regretful market,* α.

When consumers are heterogenous with respect to regret, the firm offers the product for sale in both periods, provided that the regret factor is sufficiently high, or a relatively small fraction of the market regret (because ρ_α is increasing in α). A strong regret factor segments the market so that non-regretful consumers advance purchase and regretful consumers wait.

If the regret factor is relatively low, then advance selling at $p_1(\rho)$ is optimal. Offering this price leaves zero surplus for the regretful segment A, while segment B enjoys a positive surplus of $\mu - p_1(\rho) = -\rho R(p_1(\rho))$, which is increasing in ρ. On the other hand, for a relatively high regret factor, the optimal policy induces the regretful type A consumers to wait while non-regretful type B consumers advance purchase. To induce type B consumers to advance purchase, the advance price must be such that $S_1 \geq S_2 = E[\mathbf{v} - p_\alpha]^+$. Interestingly, advance selling increases firm profits when consumers are heterogeneous, and it is never optimal to only spot sell.

As the proportion of regretful consumers in the market increases, a pure advance selling policy is optimal for a wider range of the regret factor (because ρ_α is increasing in α). In the extreme case when $\alpha = 1$, we recover Proposition 2. Indeed, the policy $(p_0 + R(p_0), p_0)$ suggested in this case by Proposition 7, is effectively a spot-only selling policy because $\Delta S^A(\rho; p_0 + R(p_0), p_0) = \rho R(p_0) < 0$. Finally, optimal profits decrease with the proportion of regretful consumers, α. This result is in contrast with Su (2008), who shows that a larger proportion of inertial consumers may be beneficial for the firm.

4.2. Heterogeneity in Valuation and Regret

The results in Section 2 showed that in a market with ex-ante homogeneous valuations, optimal profits decrease in the action regret factor ρ. This result is robust if consumers have heterogeneous regret factors, as shown in the previous section. The result further extends when high valuation consumers (in the sense of first order dominance) are less regretful; the proof is omitted for conciseness. On the other hand, if high valuation consumers are more prone to regret, this section shows that regret can actually increase optimal profits.

Consider a market with two types of consumers: a high valuation, regretful type, and a low valuation non-regretful type. For simplicity, we assume that a fraction α of the market has a 'high' valuation $(H, q; 0, 1-q)$ and regret factor $\rho_H = \rho > 0$, and a fraction $1-\alpha$ has a 'low' valuation $(L, q; 0, 1-q)$, with $H > L$ and regret factor $\rho_L = 0$. High valuation consumers advance purchase if and only if $\Delta S^H(\rho) = qH - p_1 - \rho(1-q)p_1 - q(H-p_2)^+ \geq 0$ (by Lemma 2). Similarly, low valuation consumers buy early if and only if $\Delta S^L = qL - p_1 - q(L-p_2)^+ \geq 0$.

Proposition 8. *(a) If $\rho > \frac{H-L}{L(1-q)}$, the optimal policy is $(p_A = qL, p_S = H)$ with expected profit $\pi^* = (1-\alpha)qL + \alpha qH$. Otherwise, (i) if $\alpha \leq \frac{L}{H}$, the optimal policy is $(p_A = qL, p_S = H)$, or equivalently $(p_A = qL, p_S = L)$. The optimal expected profit is $\pi^* = qL$. (ii) If $\alpha > \frac{L}{H}$, then the optimal policy is to only spot sell at $p_S = H$, with expected profit $\pi^* = \alpha qH$.*

(b) The optimal expected profit is increasing in the regret factor ρ, and in the proportion of regretful consumers α.

If regret is sufficiently strong ($\rho > \frac{H-L}{L(1-q)}$), the firm profitably segments the market, by selling to low valuation consumers in the advance period, while high valuation consumers wait for the spot period and pay higher prices. If the strength of regret is relatively mild, the firm cannot segment the market. In that case, the firm either spot sells at $p_S = H$ to the high valuation segment, if it has a high market share ($\alpha > \frac{L}{H}$), or else it sells to the entire market at a low price $p_A = qL$.

The positive correlation between valuation and regret creates a mechanism whereby high valuation consumers wait for the spot period, where prices are higher, while low valuation consumers purchase in the advance period at a low price. This segmentation extracts the maximum profit potential from the market. The insights extend for other types of valuation distributions, where the effect of regret on profits is generally non-monotone. Our results suggest that, in order to understand the effect of regret on profitability, it is important for the firm to estimate the correlation between consumer regret and valuation.

5. Action and Inaction Regret

Action regret makes consumers reluctant to advance purchase because their valuation may turn out lower than the price paid for the product. In contrast, a consumer anticipates inaction regret

from foregoing an advance purchase discount below her valuation.

Any valuation realization, v, above the advance period price, p_1, triggers inaction regret for consumers who have not advance purchased under a markup policy $p_1 \le p_2$. In general, inaction regret is a function of the forgone surplus, which equals $(p_2 - p_1)^+$ if $v \ge p_2$, and $(v - p_1)^+$ otherwise. In the first case, the consumer buys the product on spot but regrets missing the discount, whereas in the latter the consumer leaves the market empty-handed, but regrets not buying the product in the first period. The expected (anticipated) inaction regret is $\delta E[\min(\mathbf{v}, p_2) - p_1]^+$, where $\delta \ge 0$ quantifies the strength of inaction regret. With unlimited supply, inaction regret is only relevant under a markup policy, so we assume throughout this section that $p_1 \le p_2$.

Inaction regret does not affect the expected surplus from purchasing in the advance period, S_1, but lowers the expected surplus from waiting: $S_2^{IR} = S_2 - \delta E[\min(\mathbf{v}, p_2) - p_1]^+$. The latter can be negative (and as low as $-\delta E[\mathbf{v} - p_1]^+$) for sufficiently high p_2.

Lemma 3. *Consumers' differential expected surplus from advance purchasing is:*

$$\Delta S(\rho, \delta; p_1, p_2) = S_1 - S_2^{IR} = (1+\delta)(p_2 - p_1 + R(p_2)) + (\rho - \delta)R(p_1), \tag{13}$$

which is decreasing in ρ and p_1, and increasing in δ and p_2.

When action and inaction regret have the same strength, $\rho = \delta$, the differential expected surplus is proportional to that in absence of regret, $\Delta S(\delta, \delta; p_1, p_2) = (1+\delta)\Delta S(0)$ (see (7)), so consumers behave as if they do not anticipate regret.

Inaction regret increases the likelihood of an advance purchase. Consumers buy the product early if and only if $\Delta S(\rho, \delta; p_1, p_2) \ge 0$, i.e. $\frac{\rho - \delta}{1+\delta} \le \rho_0(p_1, p_2)$, given by (7). For a given spot price p_2, the maximum wtp in advance, $p_1(\rho, \delta; p_2)$, solves $\Delta S(\rho, \delta; p_1, p_2) = 0$, and it is decreasing in ρ and increasing in δ and p_2. Consumers' overall maximum wtp in advance is $p_1(\rho, \delta) = \sup_{p_2} p_1(\rho, \delta; p_2)$, where

$$p_1(\rho, \delta) \text{ solves } (1+\delta)(\mu - p) + (\rho - \delta)R(p) = 0. \tag{14}$$

In particular, $p_1(\rho, \delta) \ge p_1(\rho)$, by (2), suggesting that consumers advance purchase at a loss.

Unlike traditional models, our consumers may indeed advance purchase at a negative surplus ($S_1 < 0$), in order to avoid inaction regret (because S_2 can be negative). This is because, in our model, consumers cannot avoid regret (e.g. through self-control). This is consistent with evidence that consumers anticipate regret even in the absence of counterfactual information (e.g. Simonson 1992), and moreover, they search for (practically irrelevant) negative counterfactual information, which triggers regret (Shani et. al. 2008).

The next result shows how action and inaction regret affect the firm's profits and policies, depending on its pricing power.

PROPOSITION 9. *a) For a price taking firm, if* $d = \frac{p_1}{p_2} \leq \bar{F}(p_2)$*, then* $\pi(\rho, \delta; p_1, p_2)$ *is increasing in* ρ *and decreasing in* δ*. Otherwise,* $\pi(\rho, \delta; p_1, p_2)$ *is decreasing in* ρ *and increasing in* δ*.*

b) If $\frac{\rho-\delta}{1+\delta} \leq -\frac{\mu-\bar{p}}{R(\bar{p})}$*, then the optimal policy is to only advance sell at* $p_A = p_1(\rho, \delta)$*, and otherwise, to only spot sell at* $p_S = p_0$*.*

c) For a price setting firm, optimal profits are decreasing in ρ*, and increasing in* δ*. Moreover, optimal expected profit under regret is lower than without regret if and only if* $\rho > \delta$*.*

Inaction regret has the opposite effect on profits than action regret, so firms can always take advantage of regret by priming the appropriate counterfactual thinking. Specifically, part (a) shows that inducing inaction regret and mitigating action regret are profitable marketing strategies as long as the firm offers profitable discounts.

For a price-setting firm, the effect of regret on profits is determined by the relative strength of action and inaction regret. Experimental research is abundant in providing evidence that, on the short term, actions are regretted more than inactions, i.e. $\rho > \delta$, consistent with the omission bias (Kahneman and Tversky 1982, Gilovich and Medvech 1995). In this case, our results imply that regret adversely affects the profits of a price-setting firm that optimally accounts for regret in its pricing policy.

However, a reversal of the omission bias has been evidenced in purchase timing decisions (Simonson 1992), and specifically for long-term regrets (Keinan and Kivetz 2008) and limited purchase

opportunities (Abendroth and Diehl 2006), including auctions (Filiz-Ozbay and Ozbay 2007, Engelbrecht-Wiggans and Katok 2008). [3] For example, consumers are presumably more likely to regret not buying a lottery ticket, a limited edition of Disney DVDs, or tickets for a U2 rock concert or Formula 1 race; and more so when putting these decisions in a long term perspective.

Our results suggest that, in contexts where non-purchases are associated with greater regret than purchases, price-setting firms can benefit from consumer regret, by creating a sort of buying frenzy, in which consumers advance purchase at a net loss in order to avoid inaction regret. Indeed, when $\rho \leq \delta$, Proposition 9b shows that the optimal pricing strategy is to advance sell at $p_1(\rho, \delta) \geq p_1(\rho)$, so consumers buy at negative surplus.

A firm that ignores consumers regret in its pricing decisions, only advance sells at $p_A = \mu$ (Proposition 2b). When actions are regretted more than inactions, consumers do not buy at all because $p_1(\rho, \delta) < \mu$ for $\rho > \delta$ (Proposition 9c). So the firm overprices, and collects zero profits. If, on the other hand, inactions are regretted more than actions, consumers advance purchase because $p_1(\rho, \delta) > \mu$ for $\rho < \delta$, and the firm loses profits by underpricing. We conclude that ignoring regret adversely affects optimal profits, and more so if actions are regretted more than inactions.

Our results motivate the importance of assessing the relative strength of action and inaction regret in the specific context of the firm, and taking these regrets into account when setting prices. Our findings support the common practice of priming inaction regret in advertising campaigns (e.g. by focusing on discounts and framing them as limited opportunities), provided that the firm practices profitable (not too steep) discounts; otherwise, such campaigns can hurt profits.

6. Capacity Constraints and Consumer Regret

This section investigates the effect of capacity constraints on consumer behavior and firm policies. Under capacity constraints, the surplus of any consumer depends on other consumers' choices. This is because each consumer purchasing the product increases the probability of other consumers

[3] Zeelenberg et al. (2002) also find evidence than inactions are regretted more than actions under negative prior outcomes of related experiences. For example, if a consumer is considering to repeat purchase a product or switch to another brand, inactions, i.e. not switching, will be regretted more if the consumer did not like the product before.

being rationed, thus imposing an externality. A consumer's purchase decision is then determined by strategic interaction in response to the firm's pricing policy, and relative to how other consumers behave. We characterize the rational expectations equilibrium, where consumers' expectations of firm behavior, given its credibility, is consistent with the firm incentives to optimize profits.

The firm moves first by announcing the prices for the two periods, p_1, p_2, given the capacity $C < N$, where N is the market size. Consumers then decide to advance purchase or wait. When capacity is insufficient, we assume proportional rationing (i.e. consumers have the same probability of being rationed). We assume the firm does not limit sales if capacity is available (e.g. by setting booking limits, as in Xie and Shugan 2001).

6.1. Consumer Model

Capacity constraints trigger a purchasing game whereby a consumer decides to advance purchase, or wait, in response to what she expects others will do. Because of market homogeneity, it is intuitive to expect that all purchasing equilibria are symmetric, i.e. either all consumers advance purchase, or all wait.

Lemma 4. *Given a pricing policy (p_1, p_2), in equilibrium, either all consumers advance purchase or all wait.*

Lemma 4 shows that no individual consumer has an incentive to unilaterally deviate from what the rest of the market does. The expected surplus of an advance purchase, given that others advance purchase, is $S_1^C = \frac{C}{N} S_1$. On the other hand, a decision to wait, given that all consumers wait, generates a surplus of $S_2^C = q_C(p_2) S_2$, where $q_C(p_2) = \min(1, \dfrac{C}{N\bar{F}(p_2)})$ is the probability of obtaining the product in the spot period, given that all consumers wait.

For a spot price p_2, define $p_1(\rho; p_2, C)$ to solve:

$$\mu - p + \rho R(p) = q_C(p_2) E[\mathbf{v} - p_2]^+. \tag{15}$$

Equation (15) balances, on the right hand side, the expected surplus for waiting given all other consumers wait, S_2^C, with the surplus a consumer obtains by unilaterally deviating and advance

buying, $S_1(p)$. Because $S_1(p)$ is strictly decreasing in p, it follows that for $p_1 \leq p_1(\rho; p_2, C)$, there cannot be an equilibrium in which all consumers wait. Lemma 4 then implies that all consumers advance purchase if $p_1 \leq p_1(\rho; p_2, C)$.

If $p_1(\rho; p_2, C) > p_2$, consumers might advance purchase at a premium in the advance period. This can happen only if the spot price is sufficiently low to create excess demand in the spot period, i.e. $p_2 < \bar{F}^{-1}(\frac{C}{N})$. Otherwise, consumers' maximum wtp in the advance period is always less than the spot price (see (15)), so a markdown policy cannot induce advance purchasing. The next result provides necessary and sufficient conditions for consumers to advance purchase at a premium.

Lemma 5. *a) A necessary condition for a markdown pricing policy $p_1 \geq p_2$ to induce advance purchasing is $p_2 \leq p_2^C$, where p_2^C is the unique solution of $\mu - p + \rho R(p) = \frac{C}{N\bar{F}(p)} E[\mathbf{v} - p]^+$. In particular, $p_2^C \leq p_1(\rho)$.*

b) For any pricing policy (p_1, p_2) such that $p_2 < p_2^C$, and $p_2 < p_1 < p_1(\rho; p_2, C)$ consumers advance purchase at a premium.

Note that (p_2^C, p_2^C) is the unique singe-price policy for which a consumer is indifferent between buying early or waiting, given everyone else waits. The following proposition characterizes consumers' equilibrium purchase behavior.

Proposition 10. *For a given pricing policy (p_1, p_2), a) if $p_1 < p_1(\rho; p_2, C)$, all consumers advance purchase, b) if $p_1 > p_1(\rho)$, all consumers wait, and c) if $p_1 \in [p_1(\rho; p_2, C), p_1(\rho)]$, either all consumers advance purchase or wait.*

Figure 2 illustrates the results of Lemma 5 and Proposition 10 for a uniform valuation distribution. For $p_1 \in [p_1(\rho; p_2, C), p_1(\rho)]$, in absence of a coordination mechanism, our model cannot predict which equilibrium will emerge in the marketplace. From the consumer perspective, the waiting equilibrium generates higher surplus, indicating that consumers would be better off if they could signal their decision to wait. From the firm's perspective, the waiting equilibrium is more profitable whenever the advance purchase discount is sufficiently low, i.e. $p_1 < \min(1, \frac{N}{C}\bar{F}(p_2))p_2$ (see Table 1); this is illustrated by the shaded area H in Figure 2. Our stylized setup does not provide the

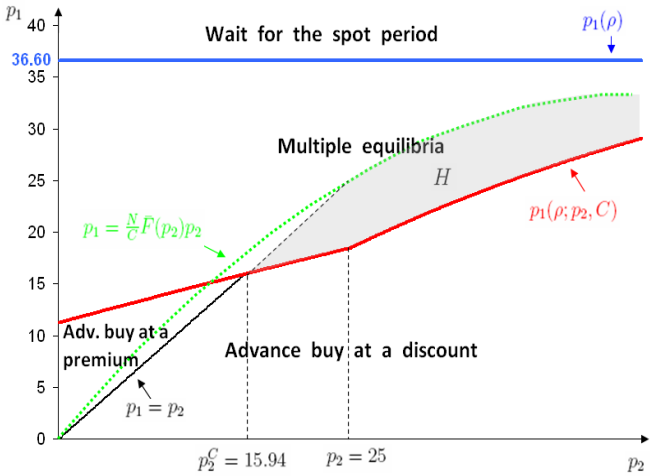

Figure 2 **Purchasing equilibria for** $\mathbf{v} \sim U[0, 100]$**,** $\rho = 2$**,** $C = 750$**, and** $N = 1000$**.**

firm with a mechanism to drive a purchasing equilibrium; the design of such mechanisms is left for future research.

The higher the regret factor, or the larger the capacity, the lower the consumers' wtp in the advance period; this is because $p_1(\rho; p_2, C)$ is decreasing in ρ and C. Specifically, a higher capacity reduces the probability of being rationed in the spot period, and thus reducing the premium consumers are willing to pay to obtain the product in advance. An implication of the coordination game described above is that consumers wtp in advance depends on other consumers' behavior. If all consumers wait, the maximum wtp in advance solves (15), i.e. a consumer will not pay more than $p_1(\rho; p_2, C)$ in advance if all other consumers wait. On the other hand, if all consumers advance purchase, a consumer is willing to pay more (as much as $p_1(\rho)$) to obtain the product in advance.

Interestingly, and in contrast with the results in previous sections, under capacity constraints, a higher spot price does not necessarily increase the wtp in the advance period, i.e. $p_1(\rho; p_2, C)$ may not be monotone in p_2. Monotonicity holds, however, if $\mathbf{v}$ is DMRL (decreasing mean residual life, i.e. $E[\mathbf{v} - p|\mathbf{v} > p]$ is decreasing in p, see Müller and Stoyan 2002), implying that the RHS of equation (15) is decreasing.[4] All IFR distribution are DMRL. Figure 2 illustrates $p_1(\rho; p_2, C)$ for a

[4] For $p_2 \geq \bar{F}^{-1}(\frac{C}{N})$, the RHS equals $E[v - p_2]^+$, which is always decreasing in p_2. Otherwise, $\frac{C}{N\bar{F}(p_2)}E[v - p_2]^+$ is decreasing whenever $\mathbf{v}$ is DMRL (Müller and Stoyan 2002, Theorem 1.8.4).

uniform (DMRL) distribution. If $\mathbf{v}$ is not DMRL, the maximum wtp in the advance period may not be monotone in the spot price as illustrated in Figure 3 for a two-point distribution $\mathbf{v}$.

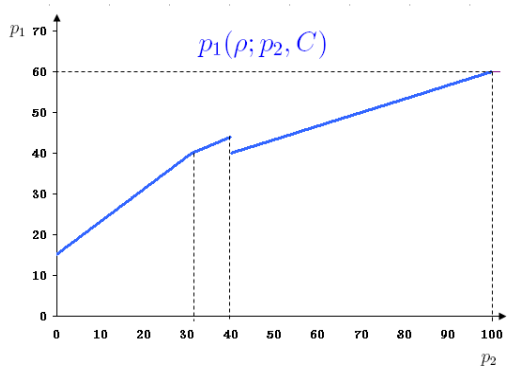

Figure 3 **Maximum wtp $p_1(\rho; p_2, C)$ is non-monotone in the spot price p_2; $\mathbf{v} \sim (100, \frac{3}{5}; 40, \frac{2}{5})$, $\rho = 2$, $\frac{C}{N} = \frac{4}{5}$.**

6.2. Firm Profits and Decisions

Before presenting the optimal equilibrium policy of the firm, we first investigate the effect of capacity constraints and action regret on the profitability of a price-taking firm. Observe that $p_1(\rho; p_2, C) \geq p_1(\rho; p_2)$, i.e. consumers' maximum wtp in advance, for a given spot price, is higher if capacity is limited. This suggests that for a given pricing policy, restricting capacity may be profitable if firms are price constrained. For a given pricing policy, (p_1, p_2), Table 1 compares the firm's expected equilibrium profit, $\pi(\rho; p_1, p_2, C)$, for a fixed capacity C, to the profit without capacity constraints, $\pi(\rho; p_1, p_2)$. In particular, this shows that for prices in the range $p_1(\rho; p_2) < p_1 \leq p_1(\rho; p_2, C)$, expected profits increase by restricting capacity, as long as $C \geq N \frac{p_2}{p_1} \bar{F}(p_2)$. The next section shows that limiting capacity is suboptimal, however, when the firm has full pricing power.

Table 1 **Expected profit for a given pricing policy (p_1, p_2), with and without a capacity constraint C.**

price range	$\pi(\rho; p_1, p_2, C)$	$\pi(\rho; p_1, p_2)$
$p_1 \leq p_1(\rho; p_2)$	Cp_1	Np_1
$p_1(\rho; p_2) < p_1 \leq p_1(\rho; p_2, C)$	Cp_1	$N\bar{F}(p_2)p_2$
$p_1(\rho; p_2, C) < p_1 \leq p_1(\rho)$	Cp_1 or[a] $\min(C, N\bar{F}(p_2))p_2$	$N\bar{F}(p_2)p_2$
$p_1 > p_1(\rho)$	$\min(C, N\bar{F}(p_2))p_2$	$N\bar{F}(p_2)p_2$

[a] Depending on which equilibrium emerges.

For a fixed pricing policy, Table 1 implies that expected equilibrium profits, $\pi(\rho; p_1, p_2, C)$, increase with the regret factor ρ if and only if $d = \frac{p_1}{p_2} \leq \min(1, \frac{N}{C}\bar{F}(p_2))$, in particular if the spot price is low enough to generate excess demand (i.e. $p_1 < p_2 < \bar{F}^{-1}(\frac{C}{N})$), or else if the advance purchase discount is sufficiently steep, or if demand is large enough relative to capacity ($\frac{N}{C} \geq \frac{d}{\bar{F}(p_2)}$).

Based on consumers' equilibrium purchase behavior in response to a given pricing policy, as determined in Section 6.1, we now derive the firms' optimal pricing policy for a fixed capacity C. Assuming that $p\bar{F}(p)$ is unimodal, in particular $\mathbf{v}$ is IGFR (see Section 2.2.2), the optimal spot price under capacity constraints is $\min(p_0, \bar{F}^{-1}(\frac{C}{N}))$. The maximum revenue per unit of capacity in the spot period is:

$$\bar{p}_C = \begin{cases} \frac{N}{C}\bar{p}, & \text{if } p_0 \leq \bar{F}^{-1}(\frac{C}{N}); \\ \bar{F}^{-1}(\frac{C}{N}), & \text{otherwise.} \end{cases}$$

Proposition 11. *Assume* $\mathbf{v}$ *is IGFR, and supply is limited to* C.

(a) If $\rho \leq \bar{\rho}_C = -\frac{\mu - \bar{p}_C}{R(\bar{p}_C)}$, *the optimal policy is to only advance sell at* $p_1(\rho)$, *which solves (2). Otherwise, spot selling at* $\min(p_0, \bar{F}^{-1}(\frac{C}{N}))$ *is optimal.*

(b) The optimal profit $\pi^*(\rho; C) = \max\{Cp_1(\rho), \min\{\bar{p}, C\bar{F}^{-1}(\frac{C}{N})\}\}$ *is decreasing in the regret factor* ρ, *and increasing in capacity* C.

In equilibrium, either all consumers advance purchase or wait. The maximum price to guarantee advance purchasing in equilibrium is $p_1(\rho; C) = \sup_{p_2} p_1(\rho; p_2, C) = p_1(\rho)$ (obtained by setting $p_2 > v_{max}$). By committing to a high spot price, the firm can extract consumers' maximum willingness to pay, $p_1(\rho)$, which is the same as without capacity constraints. So effectively, a capacity constraint only limits the amount of sales, and optimal profits are weakly increasing in capacity. This implies that rationing is not optimal in our setting, i.e. the firm with full pricing power does not have an incentive to artificially limit supply, unlike DeGraba (1995).

Moreover, the smaller the capacity the less attractive it is to advance sell. Technically, this follows because the threshold, $\bar{\rho}_C$, below which advance selling is optimal is decreasing in C. Intuitively, the smaller the capacity, the higher the price the firm can charge in the spot period ($\bar{F}^{-1}(\frac{C}{N})$ is increasing in C), while consumers' maximum wtp in advance, $p_1(\rho)$, is independent of capacity.

6.3. Capacity Constraints and Inaction Regret

Our results in the previous section extend under inaction regret. In particular all purchasing equilibria are symmetric, extending Lemma 4. Capacity constraints affect inaction regret when a consumer wishes to purchase on spot ($v \geq p_2$), but the product is unavailable. This happens with probability $1 - q_C(p_2)$, where $q_C(p_2) = \min(\frac{C}{N\bar{F}(p_2)}, 1)$. In that case, inaction regret is proportional to the foregone surplus $(v - p_1)^+$, as opposed to the lesser $(p_2 - p_1)^+$ in the uncapacitated case.

For a given spot price p_2, denote $p_1(\rho, \delta; p_2, C)$ the maximum advance price for which all consumers advance buy. We show in the Appendix that limited capacity does not affect consumers' maximum wtp in advance, i.e. $\max_{p_2} p_1(\rho, \delta; C, p_2) = p_1(\rho, \delta)$, where $p_1(\rho, \delta)$ is defined in (14). Above this price, all consumers wait in equilibrium. This key result allows us to extend the results in the previous sections (Propositions 9, 10, and 11) under inaction regret, by replacing $p_1(\rho)$ with $p_1(\rho, \delta)$ and $p_1(\rho; p_2, C)$, with $p_1(\rho, \delta; p_2, C)$. Inaction regret increases consumers' wtp in advance, so $p_1(\rho, \delta; p_2, C) \geq p_1(\rho; p_2, C)$ and $p_1(\rho, \delta) \geq p_1(\rho)$. For a given pricing policy, expected profits increase in the strength of inaction regret, δ, if $d = \frac{p_1}{p_2} \geq \min(1, \frac{N}{C}\bar{F}(p_2))$, and decrease otherwise. Combining Proposition 11 and Proposition 9b, the firm advance sells at $p_1(\rho, \delta)$ whenever $\frac{\rho - \delta}{1 + \delta} \leq \bar{\rho}_C$, in particular when $\rho \leq \delta$, in which case consumers advance purchase at negative surplus.

Like in the uncapacitated case, the firm benefits from regret if and only if inactions are regretted more than actions. This is more plausible under limited capacity, as perceptions of scarcity trigger higher non-purchase regret (Abendroth and Diehl 2006). This further suggests that the strength of regrets may be context dependent, and possibly affected by availability. Such effects are not captured by our model, and could potentially affect the optimality of rationing decisions for firms with full pricing power.

7. Extensions and Future Work

Our work motivates several directions for future research on modeling and estimating regret in an advance purchase setting, some of which we outline next.

7.1. Measuring Regret

Our results emphasize the importance of measuring anticipated regret in an advance purchase setting. There is surprisingly little empirical work on measuring regret (Filiz-Ozbay and Ozbay 2007, Engelbrecht-Wiggans and Katok 2008, Bleichrodt et. al. 2008). We hope that our work will motivate companies, as well as researchers to pay more attention to assessing behavioral parameters, in particular, the strength of anticipated action and inaction regret (ρ, δ), as well as its propensity in the market (α).

Our results also underline the importance of assessing the type of uncertainty underlying consumer valuations, which in turn affects the regret thresholds relevant for the firm's decisions. For example, regret is shown not to affect firm profits and decisions if homogeneous consumers face the same type of binary uncertainty, leading either to a high value for the product or no value at all (i.e. a two point distribution with support $L = 0, H$; see Section 2.2.3); however this is not the case with other distributions. In general, once valuation uncertainty ($\mathbf{v}$) is estimated, firms can calculate the threshold $\bar{\rho}$ based on our results, and assess whether consumer's regret ρ falls above or below it. Only if regret is below this threshold does it become relevant to measure it exactly for pricing purposes; above this threshold, the firm can ignore regret, and only spot sell. Finally, our results in Section 4.2 suggest that firms should assess the correlation between regret and valuation, in order to understand the effect of regret on profitability.

7.2. Regret Mitigating Mechanisms and Resales

Our results in this paper suggest that action regret will typically have an adverse effect on firm profits. This raises the question of identifying regret mitigating mechanisms, such as refunds, resales and price protection, and study their impact on profitability. While this investigation is left for future research, we briefly argue here that secondary markets can increase firm profits by mitigating regret. This may explain why entertainment venues such as theaters, concerts, and sporting events allow brokers and scalpers to resell primary tickets; estimates suggest that about 10% of tickets are resold, but the figure can reach 20-30% for top-tiered seats (Happel and Jennings 2002).

Suppose that consumers have the opportunity to resell the product in the second period to a third party broker, for a price $\mathbf{s}$, which is a priori uncertain with distribution $F_{\mathbf{s}}$. Assuming that the broker sells to a different consumer pool than the firm,[5] it is easy to see that the model with resales is equivalent to the basic model in Section 2 with valuation $\mathbf{w} = \max(\mathbf{v}, \mathbf{s})$. It follows that, for a given pricing policy, consumers are more likely to advance purchase, and willing to pay a higher advance price when resale is allowed (because resales provide a protection against action regret). This provides the firm the opportunity to charge higher prices and obtain higher profit in the advance period. Moreover, resales also allow the firm to extract higher spot profits. These results, formalized in the Appendix, together imply that resales improve profitability by mitigating regret. In contrast, Courty (2003) finds no benefit to resales in absence of regret.

7.3. Other Research Directions

To this end, we highlight some limitations of our model, which call for further investigation. (a) We captured regret as a linear function of the utility gap between the actual and forgone outcome. It interesting to study the sensitivity of our results to non-linear functional forms of regret, evidenced in the literature (Bleichrodt et. al. 2008). (b) Rejoice is experienced if a decision proves to be better than the alternative, and evidenced to be a weaker counterpart to regret (hence our focus on regret). A possible extension would integrate both effects and investigate the overall impact on consumer behavior and the firm's policies and profits. (c) While we focused on a monopolistic setup, it would be interesting to study the effect of regret when consumers choose among competing brands.

8. Conclusions

We developed a model where strategic but regretful consumers decide whether to advance purchase while uninformed about their valuations, or wait until they become informed. We showed how anticipated action and inaction regret affects consumer behavior and expected profits for a

[5] For example, until recently, the Roland Garros sold tickets either in advance by mail to French residents, or at the stadium, while secondary markets (e.g. eBay and Razorgator.com) targeted international sales outside France. An alternative assumption is to assume market clearing conditions in the secondary market.

monopolistic firm, prescribing how firms should change their pricing policies in response to consumer regret. The effect of regret on firm profits critically depends on the firm's pricing power, customer heterogeneity and the type of regret. By conditioning and quantifying the relationship between regret and profits, our results provide managerial insights for running effective marketing campaigns, to prime or mitigate regret.

References

[1] Abendroth, L. J., K. Diehl. 2006. Now or never: Effects of limited purchase opportunities on patterns of regret over time. *Journal of Consumer Research* 33(3) 342-351.

[2] Bell, D. E. 1982. Regret in Decision Making under Uncertainty. *Operations Research* 30(5) 961-981.

[3] Bell, D. E. 1985. Putting a premium on regret. *Management Science* 31(1) 117-120.

[4] Bendoly, E., K. Donohue, K. Schultz. 2006. Behavioral Operations Management: Assessing Recent Findings and Revisiting Old Assumptions. *Journal of Operations Management*. 24(6) 737752.

[5] Bleichrodt, H., A. Cillo, E. Diecidue. 2008. A quantitative measurement of regret theory. Working paper.

[6] Braun, M., A. Muermann. 2004. The impact of regret on the demand for insurance. *Journal of Risk and Uncertainty* 71(4) 737-767.

[7] Cachon, G., R. Swinney. 2009. Purchasing, pricing, and quick response in the presence of strategic consumers. *Management Science* 55(3) 497-511.

[8] Chua, H. F., R. Gonzalez, S. F. Taylor, R. C. Welsh, I. Liberzon. 2009. Decision-related loss: Regret and disappointment. *NeuroImage*, 47(4):2031-40.

[9] Courty, P. 2003. Ticket pricing under demand uncertainty. *Journal of Law and Economics* 46(2) 627-652.

[10] Courty, P. 2005. Buying Frenzies. working paper, http://www.eui.eu/Personal/Courty/WkgPp/eb2.pdf

[11] Cooke, A. D. J., T. Meyvis, A. Schwartz. 2001. Avoiding future regret in purchase timing decisions. *Journal of Consumer Research* 27(4) 447-459.

[12] DeGraba, P. 1995. Buying frenzies and seller-induces excess demand. *RAND Journal of Economics* 26(2) 331-342.

[13] Dodonova, A., Y. Khoroshilov. 2005. Applications of regret theory to asset pricing. SSRN working paper.

[14] Engelbrecht-Wiggans, R., E. Katok. 2006. Regret in auctions: Theory and evidence. *Economic Theory* 33(1) 81-101.

[15] Engelbrecht-Wiggans, R., E. Katok. 2008. Regret and feedback information in first-price sealed-bid auctions. *Management Science* 54(4) 818-819.

[16] Filiz-Ozbay, E., E. Y. Ozbay. 2007. Auctions with anticipated regret: Theory and experiment. *American Economic Review* 97(4) 1407-1418.

[17] Gale, I., T. Holmes. 1992. The efficiency of advance purchase discounts in the presence of aggregate demand uncertainty. *International Journal of Industrial Organization* 10(3) 413-437.

[18] Gilovich, T., V. H. Medvec. 1995. The experience of regret: What, when, and why. *Pshychological Review* 102(2) 379-395.

[19] Gino, F., G. P. Pisano. 2008. Toward a theory of behavioral operations. *Manufacturing & Service Operations Management* 10(4) 676-691.

[20] Happel, S. K., M. Jennings. 2002. Creating a futures market for major event tickets: Problems and prospects. *Cato Journal* 21(3) 443-461.

[21] Irons, B., C. Hepburn. Regret theory and the tyranny of choice. *Economic Record* 83(261) 191-203.

[22] Jerath, K., S. Netessine, S. K. Veeraraghavan. 2007. Revenue management with strategic customers: Last minute selling and opaque selling. Working paper.

[23] Kahneman, D., A. Tversky. 1982. The psychology of preferences. *Scientific American* 246(1) 160173.

[24] Keinan, A., R. Kivetz. 2008. Remedying hyperopia: The effects of self-control regret on consumer behavior. *Journal of Marketing Research.* 45(6) 676-689.

[25] Lariviere, M. A. 2006. A Note on probability distributions with increasing generalized failure rates. *Operations Research* 54(3) 602-404.

[26] Liu, Q., G. van Ryzin. 2008. Strategic capacity rationing to induce early purchases. *Management Science* 54(6) 1115-1131.

[27] Liu, Q., S. Shum. 2009. On the value of psychological elation and disappointment effects in capacity and pricing decisions. Working paper.

[28] Loch, C. H., and Y. Wu. 2005. Behavioral operations management. *Foundation and Trends® in Technology and, Information and Operations Management* 1(3) 121-232.

[29] Loomes, G., R. Sugden. 1982. Regret theory: An alternative theory of rational choice under uncertainty. *Economic Journal* 92(368) 805-824.

[30] Mellers, B., A. P. McGraw 2001. Anticipated emotions as guides to choice. *Current Directions in Psychological Science* 10(6) 210-214.

[31] Müller, A., D. Stoyan. 2002. Comparison methods for stochastic models and risks. John Wiley & Sons.

[32] Nasiry, J., I. Popescu. 2008. Dynamic pricing with loss averse consumers and peak-end anchoring. INSEAD/SSRN Working Paper.

[33] Patrick, V. M., M. Lancellotti, G. E. De Mello. 2003. Coping with it: Regret for action vs. inaction in the consumer context. *Advances in Consumer Research* 30(1) 241-248.

[34] Shani, Y., O. Tykocinski, M. Zeelenberg. 2008. When ignorance is not bliss: How feelings of discomfort promote the search for negative information. *Journal of Economic Psychology* 29(5) 643-653.

[35] Shen, Z-J. M., X. Su. 2007. Customer behavior modeling in revenue management and auctions: A review and new research opportunities. *Production and Operations Management* 16(6) 713-729.

[36] Simonson, I. 1992. The influence of anticipating regret and responsibility on purchase decisions. *Journal of Consumer Research* 19(1) 105-118.

[37] Su, X. 2008. A model of consumer inertia with applications to dynamic pricing. Working Paper, University of California, Berkeley, CA.

[38] Syam, N., P. Krishnamurthy, J. D. Hess. 2008. That's what I thought I wanted? Miswanting and regret for a standard good in a mass-customized world. *Marketing Science* 27(3) 379-397.

[39] Tsiros, M., V. Mittal. 2000. Regret: A model of its antecedents and consequences in consumer decision making. *Journal of Consumer Research* 26(4) 401-417.

[40] Tversky, A., D. Kahneman. 1991. Loss aversion in riskless choice: a reference dependent model. *The Quarterly Journal of Economics* 106(4) 1039-1061.

[41] Xie, J., S. M. Shugan. 2001. Electronic tickets, smart cards, and online prepayments: When and how to advance sell. *Marketing Science* 20(3) 219-243.

[42] Zeelenberg, M. 1999. The use of crying over spilled milk: a note on the rationality and functionality of regret. *Philosophical Psychology* 12(3) 325-340.

[43] Zeelenberg, M., K. van den Bos, E. van Dijk, R. Pieters. 2002. The inaction effect in the psychology of regret. *Journal of Personality and Social Psychology* 82(3) 314-327.

[44] Zeelenberg, M., W. W. van Dijk, A. S. R. Manstead, J. van der Pligt. 2000. On bad decisions and disconfirmed expectancies: The psychology of regret and disappointment. *Cognition and Emotion* 14(4) 521-541.

Appendix: Proofs

Proof of Lemma 1: Part (a) follows because $(v-x)^-$ is decreasing and concave in x, and expectation preserves monotonicity and concavity. Parts (b) and (c) follow by writing $x+R(x) = E[\min(\mathbf{v},x)]$, which is increasing and concave in x, and moreover $\mu = E[\mathbf{v}] \geq E[\min(\mathbf{v},x)] = x\bar{F}(x) + E[\mathbf{v}|\mathbf{v}<x]F(x) \geq x\bar{F}(x)$.

Proof of Proposition 2: (a) We verify that the firm does not have any incentive to deviate from this policy. First, assume $\rho \leq \bar{\rho}$; we show that any $p_1 \neq p_1(\rho)$ cannot increase profits above $p_1(\rho)$.

(i) For $p_1 > p_1(\rho)$, no consumer buys in the first period. Rewrite $\rho \leq \bar{\rho} = -\frac{\mu-\bar{p}}{R(\bar{p})}$ as $S_1(\bar{p}) = \mu - \bar{p} + \rho R(\bar{p}) \geq 0 = S_1(p_1(\rho))$. Because $S_1(p)$ is decreasing in p, the maximum expected spot profit, $\bar{p} \leq p_1(\rho)$.

(ii) For $p_1 < p_1(\rho)$, if $\Delta S(\rho) \geq 0$, consumers buy early, and the firm profit is $p_1 < p_1(\rho)$. If $\Delta S(\rho) < 0$, consumers wait, and the maximum expected profit is $\bar{p} \leq p_1(\rho)$ (see above). So the firm cannot do better than advance selling at $p_1(\rho)$.

Second, assume $\rho > \bar{\rho}$, or equivalently $p_1(\rho) < \bar{p}$. A price above $p_1(\rho)$ makes consumers wait, so the maximum profit the firm can earn is $\bar{p}$. For $p_1 \leq p_1(\rho)$, consumers either advance purchase (if $\Delta S(\rho) \geq 0$), leading to inferior profits $p_1 \leq p_1(\rho) < \bar{p}$, or they wait, and the expected profit is $p_2\bar{F}(p_2) \leq \bar{p}$. We conclude that no profitable deviation exists.

(b) The result follows from Part (a) because $p_1(\rho)$ is decreasing in ρ.

Proof of Proposition 3: The proof resembles that of Proposition 2. Homogeneity implies that either all consumers purchase in the first period or wait, so the optimal policy is either to only advance sell or only to spot sell. The maximum expected profit from spot, respectively advance

selling is $\bar{p}(c)$, respectively $p_1(\rho)-c$, where $p_1(\rho)$ is consumers' overall maximum wtp in advance. If $p_1(\rho)-c \geq \bar{p}(c)$, then the optimal strategy is to advance sell at $p_A = p_1(\rho)$, and otherwise spot sell at $p_0(c)$. By definition, $\bar{\rho}(c)$ is the regret level where the profits of the two policies are equal, i.e. $p_1(\rho)-c = \bar{p}(c)$, and

$$\bar{\rho}(c) \text{ solves } \mu - (\bar{p}(c)+c) + \rho R(\bar{p}(c)+c) = 0.$$

To show monotonicity of $\bar{\rho}(c)$, observe that (1) $\rho(x) = \frac{\mu - x}{-R(x)}$ is decreasing in x (it is easy to see this for $1+\rho(x) \geq 0$, using Lemma 1); and (2) $x = \bar{p}(c)+c$ is increasing in c (by the Envelope Theorem), so $\bar{\rho}(c) = \rho(x = \bar{p}(c)+c)$ is decreasing in c.

Proof of Proposition 4: Consumers advance purchase if and only if $\Delta S(\rho) \geq 0$. Given p_2, the maximum price that induces consumers to advance purchase is $p_1(\rho; p_2)$, which solves $\Delta S(\rho; p, p_2) = 0$. Therefore, advance selling is optimal if and only if $p_1(\rho; p_2) \geq p_2 \bar{F}(p_2)$. Because $\Delta S(\rho; p, p_2)$ is decreasing in p, the inequality implies that $\Delta S(\rho; p_2\bar{F}(p_2), p_2) \geq 0$, or $\rho \leq \dfrac{p_2 F(p_2) + R(p_2)}{-R(p_2\bar{F}(p_2))}$.

Proof of Proposition 5: (a) The firm is guaranteed to earn a profit of p_1 by not offering the product in the spot period. Because of valuation homogeneity, consumers either all advance purchase or wait. Therefore, the firm should spot sell if and only if the expected profit of doing so exceeds p_1. The maximum expected from spot selling is:

$$\max \qquad \{p\bar{F}(p) | p + R(p) < p_1 - \rho R(p_1)\}. \tag{16}$$

The inequality ensures that consumers wait for the second period and is equivalent to $p \leq p_2(\rho; p_1)$. We next argue that $p_0 \leq p_2(\rho; p_1)$, implying that (16) is optimized at $p_S = p_0$, and the maximum objective value is $\bar{p}$, so the firm benefits from spot selling iff $p_1 < \bar{p}$. Rewriting $\rho \geq \frac{p_0 - p_1 + R(p_0)}{-R(p_1)}$ as $\Delta S(\rho; p_1, p_0) = p_0 - p_1 + R(p_0) + \rho R(p_1) \leq 0 = \Delta S(\rho; p_1, p_2(\rho; p_1))$, because $\Delta S(\rho; p_1, p)$ is increasing in p (Lemma 1), we conclude that indeed $p_0 \leq p_2(\rho; p_1)$. This proves the first part of the proposition.

Similarly, $\rho < \frac{p_0 - p_1 + R(p_0)}{-R(p_1)}$ is equivalent to $p_0 > p_2(\rho; p_1)$. The maximum profit in the spot period solves (16) and is achieved at $p_2 = p_2(\rho; p_1)$. This is because $p\bar{F}(p)$ is unimodal ($\mathbf{v}$ is IGFR, see Section 2.2.2), so spot profit is increasing to the left of its maximizer p_0. Therefore, the optimal

feasible price $p_2 \le p_2(\rho; p_1)$ is $p_2 = p_2(\rho; p_1)$. It remains to compare p_1 with $p_2(\rho; p_1)\bar{F}(p_2(p_1, \rho))$ to determine the optimal policy, which shows the second part of the proposition.

(b) If $\rho \ge \frac{p_0 - p_1 + R(p_0)}{-R(p_1)}$, the optimal profit is $\pi_1 = \max\{p_1, \bar{p}\}$, and thus independent of ρ (weakly increasing). Otherwise, if $\rho < \frac{p_0 - p_1 + R(p_0)}{-R(p_1)}$, the optimal profit is $\pi_2 = \max\{p_1, p_2(\rho; p_1)\bar{F}(p_2(\rho; p_1))\} \le \pi_1$. It remains to show that $p_2(\rho; p_1)\bar{F}(p_2(\rho; p_1)) \le \bar{p}$ is increasing in ρ. This follows because (i) $p_2(\rho; p_1)$ is increasing in ρ by Lemma 2b, (ii) spot profit $p\bar{F}(p)$ is increasing in p for $p \le p_0$ (because $p\bar{F}(p)$ is unimodal with mode p_0) and (iii) $p_2(\rho; p_1) \le p_0$ whenever $\rho < \frac{p_0 - p_1 + R(p_0)}{-R(p_1)}$.

Proof of Proposition 6: Based on the rational expectations framework, in absence of seller credibility, consumers expect the firm to spot sell at $p_S = p_0$, the profit-optimizing spot price. It follows that consumers advance purchase if and only if $\Delta S(\rho; p_1, p_0) \ge 0$, or equivalently $p_0 + R(p_0) - p_1 + \rho R(p_1) \ge 0$. The maximum price that induces consumers to advance purchase, $p_1(\rho; p_0)$, solves $\Delta S(\rho; p_1(\rho; p_0), p_0) = 0$. Advance selling is optimal if and only if $p_1(\rho; p_0) \ge p_0\bar{F}(p_0) = \bar{p}$. This holds whenever $\Delta S(\rho; \bar{p}, p_0) \ge 0$ (because $\Delta S(\rho; p, p_0)$ is decreasing in p), i.e. $\rho \le -\frac{p_0 + R(p_0) - \bar{p}}{R(\bar{p})}$. Otherwise, spot selling at $p_S = p_0$ is optimal.

Proof of Proposition 7: We optimize the expected profits, given in (10), for each of the three cases, and then compare these to determine the optimal pricing policy.

Case 1: Suppose that prices are such that $\Delta S^A(\rho) \ge 0$. The maximum wtp in advance for type A and B consumers is $p_1(\rho) \le \mu$ (see Lemma 2c, respectively $p_1(0) = \mu$. If $(1-\alpha)\mu \ge p_1(\rho)$, then it is optimal to advance sell at $p_A = \mu$, and only type B buy, with expected profits $(1-\alpha)\mu$; otherwise the firm sells to both types at $p_A = p_1(\rho)$, with expected profit $p_1(\rho)$.

Case 2: When prices are such that $\Delta S^B \ge 0 > \Delta S^A$, type A consumers wait and type B advance purchase; resulting in the following optimization problem:

$$\begin{aligned} \max \quad & (1-\alpha)p_1 + \alpha p_2 \bar{F}(p_2), \\ \text{s.t.} \quad & p_2 - p_1 + R(p_2) + \rho R(p_1) < 0, \\ & p_2 - p_1 + R(p_2) \ge 0. \end{aligned}$$

Relaxing the first constraint, the second must be binding, $p_1 = p_2 + R(p_2)$, because the objective function is increasing in p_1. The relaxed problem reduces to the unconstrained problem:

$$\max_{p_2} \pi_S(\alpha; p_2), \text{ where } \pi_S(\alpha; p) = (1-\alpha)(p + R(p)) + \alpha p \bar{F}(p),$$

the solution of which is, by definition, p_α. The first order condition shows that p_α is the unique solution of $g(p) = \frac{1}{\alpha}$, because $F(v)$ is IGFR. Finally, it is easy to verify that $(p_1 = p_\alpha + R(p_\alpha), p_2 = p_\alpha)$ satisfies the other constraint, so this is indeed the profit maximizing segmentation strategy.

Case 3: Now suppose that prices are such that $\Delta S^B < 0$, so both types wait. The optimal price p_0 solves $g(p) = 1$, and the optimal expected profit is $\bar{p}$.

To specify the optimal pricing policy, we need to compare the optimal profits in the three cases above. First, profits in Case 3 are dominated by those in Case 2, because $(1-\alpha)(p + R(p)) + \alpha p \bar{F}(p) \geq p\bar{F}(p)$, by Lemma 1c. It remains to compare Cases 1 and 2.

(i) If $1 - \alpha \geq \frac{p_1(\rho)}{\mu}$, the optimal policy under Case 1, $(p_A = \mu, p_S > v_{max})$ with expected profits $(1-\alpha)\mu$ is feasible for Case 2, but sub-optimal. So Case 2 dominates, i.e. a combination of advance and spot selling is optimal.

(ii) Now suppose that $1 - \alpha < \frac{p_1(\rho)}{\mu}$. If $\pi_S(\alpha; p) = \pi(\rho; p_\alpha + R(p_\alpha), p_\alpha) \leq p_1(\rho) = \pi(\rho; p_1(\rho), v_{max})$, then advance selling at $p_A = p_1(\rho)$ is optimal. Otherwise, $(p_A = p_\alpha + R(p_\alpha), p_S = p_\alpha)$ is optimal. Because $\pi_S(\alpha; p_\alpha)$ is independent of ρ, and $p_1(\rho)$ is decreasing in ρ, it follows that they single cross at ρ_α, given by (12). Moreover, if $\rho \leq \rho_\alpha$, the optimal policy is to advance sell at $p_A = p_1(\rho)$, otherwise, the optimal policy is $(p_A = p_\alpha + R(p_\alpha), p_S = p_\alpha)$.

Combining the results of (i) and (ii), it follows that advance selling at $p_1(\rho)$ is optimal if $\rho \leq \rho_\alpha$, otherwise the optimal policy is $(p_A = p_\alpha + R(p_\alpha), p_S = p_\alpha)$.

It remains to show that ρ_α increases in α. By definition, ρ_α solves (12), i.e. $p_1(\rho) = \pi_S(\alpha; p_\alpha)$, and $p_1(\rho)$ is decreasing in ρ (Lemma 2c. On the other hand, $\pi_S(\alpha; p_\alpha)$ is decreasing in α (and independent of ρ), because: (i) $\pi_S(\alpha; p)$ is decreasing in α (Lemma 1c); (ii) $\pi_S(\alpha; p) \leq p_0$ is increasing in p for $p \leq p_0$ (because $p\bar{F}(p)$ is unimodal with mode p_0), and (iii) p_α is decreasing in α (because $g(p_\alpha) = 1/\alpha$ and g is increasing). This concludes the proof.

(b) This follows from Part (a) because $\pi^*(\rho,\alpha)=\max\{p_1(\rho),\pi_S(\alpha;p_\alpha)\}$; the first term is decreasing in ρ and independent of α, whereas the second is decreasing in α and independent of ρ.

Proof of Proposition 8: The optimal spot price is $p_2\in\{L,H\}$; it is easy to see that profits in these two cases dominate all other options, including $p_2>H$. For each case, we determine the optimal advance price, and obtainable profits, and compare them to derive the optimal policy.

Case 1: $p_2=L$. The maximum wtp for type A, respectively type B, consumers is $p_1^A(\rho;p_2)=\frac{qL}{1+\rho(1-q)}$, and $p_1^B(\rho=0;p_2)=qL$ (see (5)). Because $p_1^A(\rho;p_2)\le p_1^B(\rho=0;p_2)$, it follows that the optimal advance price is either $p_1=qL$ or $p_1>H$ (i.e. not advance selling). The corresponding profit is $\pi=qL$.

Case 2: $p_2=H$. The maximum wtp for type A, respectively type B, consumers is $p_1^A(\rho;p_2)=\frac{qH}{1+\rho(1-q)}$, and $p_1^B(\rho=0;p_2)=qL$. Thus, the optimal advance price is $p_1\in\{qL,\frac{qH}{1+\rho(1-q)},p_1>H\}$.

(i) If $p_1^A(\rho;p_2)\ge p_1^B(\rho=0,p_2)$, i.e. $\rho\le\frac{H-L}{L(1-q)}$, then $\pi=\max\{qL,\alpha\frac{qH}{1+\rho(1-q)},\alpha qH\}=\max\{qL,\alpha qH\}$. In this case, if $\alpha>\frac{L}{H}$, then the optimal profit is $\pi=\alpha qH$, and otherwise $\pi=qL$.

(ii) Otherwise, $\pi=\max\{(1-\alpha)qL+\alpha qH,\frac{qH}{1+\rho(1-q)},\alpha qH\}=(1-\alpha)qL+\alpha qH$.

The proposition follows by comparing the profits in the above cases .

Proof of Lemma 3: Rewrite $S_2=E[\mathbf{v}-p_2]^+=E[\mathbf{v}]-E[\min(\mathbf{v},p_2)]=\mu-p_2-R(p_2)$. Similarly,

$$\begin{aligned}E[\min(\mathbf{v},p_2)-p_1]^+ &= E[\min(\mathbf{v},p_2)]-E[\min(\mathbf{v},p_2,p_1)]\\ &= E[\min(\mathbf{v},p_2)]-E[\min(\mathbf{v},p_1)]\\ &= R(p_2)-R(p_1)+p_2-p_1.\end{aligned}$$

The result follows by substituting these in $S_2=E[\mathbf{v}-p_2]^+-\delta E[\min(\mathbf{v},p_2)-p_1]^+$.

Proof of Proposition 9: a) Suppose $d=\frac{p_1}{p_2}\le\bar{F}(p_2)$, i.e. $p_1\le p_2\bar{F}(p_2)$. Therefore, the firm obtains higher profits if consumers wait, i.e. $\Delta S(\rho,\delta)<0$, or equivalently $\frac{\rho-\delta}{1+\delta}>-\frac{\Delta S(0)}{R(p_1)}$. The result then follows because $\frac{\rho-\delta}{1+\delta}$ is increasing in ρ, and decreasing is δ. The other part is proved similarly.

b) It suffices to show that the LHS of (14) is decreasing in p, decreasing in ρ and increasing in δ. Indeed, using Lemma 1:

$$\frac{dLHS}{dp}=-\rho F(p)-1-\delta\bar{F}(p)\le 0,\qquad \frac{dLHS}{d\rho}=R(p)\le 0,\quad \frac{dLHS}{d\delta}=\mu-p-R(p)\ge 0.$$

c) Assume $\rho > \delta$. Without regret, the optimal profit is μ (Proposition 2). If $p_1(\rho,\delta) < \bar{p}$, the optimal profit under regret is lower because $\bar{p} \leq \mu$ (Lemma 1c). On the other hand, if $p_1(\rho,\delta) \geq \bar{p}$, then optimal profit under regret is $p_1(\rho,\delta)$, and

$$p_1(\rho,\delta) = \mu + \frac{\rho-\delta}{1+\delta} R(p_1(\rho,\delta)) \leq \mu.$$

The inequality follows because $R(x) \leq 0$ (see Lemma 1a) and $\rho > \delta$. We conclude optimal profits are negatively affected by regret if action regret is stronger than inaction regret. If $\rho \leq \delta$, advance selling at $p_1(\rho,\delta) \geq \mu$ is optimal, so optimal profits under regret are larger than without regret.

Proof of Lemma 4: The proof is by contradiction. Suppose that in equilibrium, $m \in (0,N)$ consumers strictly prefer to advance buy at $p_1 < p_1(\rho)$, and the others weakly prefer to wait. For consumers who advance purchase, it must be that:

$$S_1 = \min(\frac{C}{m},1)(\mu - p_1 + \rho R(p_1)) > S_2 = \min(\max(\frac{C-m+1}{(N-m+1)\bar{F}(p_2)},0),1)E[\mathbf{v}-p_2]^+. \tag{17}$$

Similarly, for a consumer who (weakly) prefers to wait, we have:

$$S_1 = \min(\frac{C}{m+1},1)(\mu - p_1 + \rho R(p_1)) \leq S_2 = \min(\max(\frac{C-m}{(N-m)\bar{F}(p_2)},0),1)E[\mathbf{v}-p_2]^+. \tag{18}$$

For (18) to hold, it must be that $C \geq m$. Upon simplification, 18 becomes:

$$\mu - p_1 + \rho R(p_1) \leq \min(\frac{C-m}{(N-m)\bar{F}(p_2)},1)E[\mathbf{v}-p_2]^+. \tag{19}$$

Further, $C \geq m$ simplifies (17) to: $\mu - p_1 + \rho R(p_1) > \min(\frac{C-m+1}{(N-m+1)\bar{F}(p_2)},1)E[\mathbf{v}-p_2]^+$, and comparing this with (19), we get:

$$\begin{aligned}\mu - p_1 + \rho R(p_1) &\leq \min(\frac{C-m}{(N-m)\bar{F}(p_2)},1)E[\mathbf{v}-p_2]^+ \\ &\leq \min(\frac{C-m+1}{(N-m+1)\bar{F}(p_2)},1)E[\mathbf{v}-p_2]^+ < \mu - p_1 + \rho R(p_1),\end{aligned}$$

which is a contradiction. Similarly, one can rule out the case where some consumers strictly prefer to wait, while others (weakly) prefer to advance purchase. Finally, when all consumers are indifferent between advance buying and waiting, following the standard assumption, the firm induces all

consumers to make the same, more profitable choice, by lowering the corresponding price infinitesimally.

Proof of Lemma 5: Denote $Q(p) = \mu - p + \rho R(p) - \dfrac{C}{N\bar{F}(p)} E[\mathbf{v} - p]^+$. Thus, p_2^C solves $Q(p) = 0$. For part (a), first, observe that the solution must be $p_2^C < \bar{F}^{-1}(\frac{C}{N})$, i.e. $\bar{F}(p_2^C) > \frac{C}{N}$. The uniqueness of p_2^C then follows because:

$$\frac{dQ(p)}{dp} = -\frac{C}{N}\frac{f(p)}{\bar{F}(p_2)^2}(\mu - p - R(p)) - (1 - \frac{C}{N\bar{F}(p)}) - (\rho + \frac{C}{N\bar{F}(p)})F(p) < 0.$$

The first two terms are negative because $\mu - p + \rho R(p) \geq 0$ and $\bar{F}(p) > \dfrac{C}{N}$. Further, $Q(p = 0) > 0$, and $Q(p = p_1(\rho)) < 0$.

Moreover, $\mu - p + \rho R(p)$ is decreasing in p, vanishing at $p_1(\rho)$ (see (2)), and $\frac{C}{N\bar{F}(p)} E[\mathbf{v} - p]^+ \geq 0$ for all $p \geq 0$, so it must be that $p_2^C \leq p_1(\rho)$.

b) For a markdown policy, $p_1 \geq p_2$, to induces advance purchasing, it must be that $p_1(\rho; p_2, C) \geq p_2$, i.e. consumers' maximum wtp in the advance period must exceed that in the spot period. Because $p_1(\rho; p_2, C)$ solves (15), the LHS of which is decreasing in p, we have $Q(p_2) \geq 0$. Because $Q(p)$ is decreasing in p (see proof of part a), we conclude that $p_2 \leq p_2^C$.

Proof of Proposition 10: Consumers always wait if $p_1 > p_1(\rho)$. On the other hand, for a given spot price p_2, consumers always advance purchase if $p_1 \leq p_1(\rho; p_2, C)$. For $p_1 \in [p_1(\rho; p_2, C), p_1(\rho)]$, Lemma 4 rules out the possibility that some consumers advance purchase while others wait. For this range of advance prices, consumers might all advance purchase or wait. Both equilibria are admissible. To see this, assume that all consumers advance purchase. It follows that each consumer's expected surplus is $\frac{C}{N}(\mu - p_1 + \rho R(p_1)) \geq 0$. No consumer has an incentive to unilaterally deviate, which would give 0 surplus. On the other hand, assume that all consumers wait. A consumer's expected surplus is then $q_C(p_2) E[\mathbf{v} - p_2]^+$. Once again no consumer has an incentive to unilaterally deviate, as she would obtain $\mu - p_1 + \rho R(p_1) < q_C(p_2) E[\mathbf{v} - p_2]^+$ because $p_1 \in [p_1(\rho; p_2, C), p_1(\rho)]$.

Proof of Proposition 11: For any pricing policy, consumers either advance purchase, or wait (Lemma 4). The firm can extract the maximum wtp in the advance period, $p_1(\rho)$, by setting a high spot price ($p_2 > v_{max}$)(see (15)). Lemma 5 then implies that consumers purchase in the advance

period at $p_1(\rho)$. On the other hand, by setting an advance price higher than $p_1(\rho)$, the firm can induce the consumers to wait, where the profit maximizing spot price is $\min(p_0, \bar{F}^{-1}(\frac{C}{N}))$ (see Section 3.3).

It remains to compare the profits from advance and spot selling to determine the optimal policy. Assume first that $p_0 \leq \bar{F}^{-1}(\frac{C}{N})$, which implies that the maximum achievable spot profit is $N\bar{p}$. The maximum profit from advance selling is $C\,p_1(\rho)$. Thus, advance selling is optimal if and only if $C\,p_1(\rho) \geq N\bar{p}$, or $p_1(\rho) \geq \frac{N}{C}\bar{p}$, which holds if and only if $\mu - \frac{N}{C}\bar{p} + \rho R(\frac{N}{C}\bar{p}) \leq 0$ (because $p_1(\rho)$ solves equation (2) whose LHS is decreasing in p). Upon simplification, the desired result follows. The other part of the proposition is proven similarly.

Proof of the Results in Section 6.3: We prove that, for a given spot price p_2, consumers maximum wtp in advance $p_1(\rho, \delta; p_2, C)$ solves:

$$\mu - p + \rho R(p) = q_C(p_2)E[\mathbf{v} - p_2]^+ - \delta\Big(E[\mathbf{v} - p]^+ - q_C(p_2)E[\mathbf{v} - \max(p, p_2)]^+\Big), \tag{20}$$

and further, $p_1(\rho, \delta) = \max_{p_2} p_1(\rho, \delta; C, p_2)$.

The expected surplus from advance purchasing, if all consumers advance purchase, is $S_1^{\mathrm{IR},C} = S_1^C$, as in Section 6.1. Denote $S_2^{\mathrm{IR},C}$ as a consumer's expected surplus from waiting, given all others wait. For a given pricing policy (p_1, p_2), we first prove that:

$$S_2^{\mathrm{IR},C} = q_C(p_2)E[\mathbf{v} - p_2]^+ - \delta\Big[E[\mathbf{v} - p_1]^+ - q_C(p_2)E[\mathbf{v} - \max(p_1, p_2)]^+\Big]. \tag{21}$$

With probability $\bar{F}(p_2)$, the consumer is willing to spot purchase, leading to two possible cases:

(i) with probability $q_C(p_2)$, she finds the product available and her material surplus is $E[(\mathbf{v} - p_2)^+ \mid \mathbf{v} \geq p_2]$. She experiences inaction regret if the advance price was lower. The magnitude of regret is then $\delta(p_2 - p_1)^+$. Therefore, the overall expected surplus is: $\bar{F}(p_2)q_C(p_2)\Big(E[(\mathbf{v} - p_2)^+ \mid \mathbf{v} \geq p_2] - \delta(p_2 - p_1)^+\Big) = q_C(p_2)\Big(E[\mathbf{v} - p_2]^+ - \delta(p_2 - p_1)^+\bar{F}(p_2)\Big)$.

(ii) with probability $1 - q_C(p_2)$, she does not find the product available, hence the material surplus is 0, but she regrets not purchasing early if her revealed valuation exceeds the advance price $v \geq p_1$. In this case, the overall expected surplus is: $\bar{F}(p_2)(1 - q_C(p_2))(-\delta E[(\mathbf{v} - p_1)^+ \mid v \geq p_2]) = -\delta(1 - q_C(p_2))E[\mathbf{v} - p_1]^+$.

With probability $F(p_2)$, the consumer is not willing to spot purchase. In this case, her material surplus is 0, but she regrets not buying the product early if $v \geq p_1$. The overall expected surplus is then: $F(p_2)(-\delta E[(\mathbf{v}-p_1)^+ \mid \mathbf{v} \leq p_2]) = -\delta E[\mathbf{v}-p_1]^+$.

The result follows by summing the expected surplus in the above cases.

Uniqueness of $p_1(\rho,\delta;p_2,C)$ follows because the LHS of (20) is strictly decreasing in p, while the RHS is strictly increasing in p. Further, at $p=0$, the LHS attains its maximum, μ, while the RHS attains its minimum, $qE[\mathbf{v}-p_2]^+ \leq \mu$.

To show the last part, first assume that $p \leq p_2$. Thus $p_1(\rho,\delta;p_2,C)$ solves the equation: $\mu - p + \rho R(p) = (1+\delta)q_C(p_2)E[\mathbf{v}-p_2]^+ - \delta E[\mathbf{v}-p]^+$, or equivalently:

$$(1+\delta)(\mu-p)+(\rho-\delta)R(p) = (1+\delta)q_C(p_2)E[\mathbf{v}-p_2]^+. \tag{22}$$

The LHS of (22) is strictly decreasing in p, while the RHS is non-negative, and independent of p. Thus, the maximum value of p that solves (22) is obtained by setting $p_2 > v_{max}$, for which the RHS becomes 0. The result follows because the resulting solution is $p_(\rho,\delta) \leq p_2 > v_{max}$.

Now, consider $p \geq p_2$. Then, $p_1(\rho,\delta;p_2,C)$ solves $\mu - p + \rho R(p) = q_C(p_2)E[\mathbf{v}-p_2]^+ - \delta(1-q_C(p_2))E[\mathbf{v}-p]^+$, or equivalently:

$$(1+\delta)(\mu-p)+(\rho-\delta)R(p) = q_C(p_2)E[\mathbf{v}-p_2]^+ + \delta q_C(p_2)E[\mathbf{v}-p]^+. \tag{23}$$

Regardless of the spot price, the solution of (23) is less than $p_1(\rho,\delta)$. This is because, for any $p > p_1(\rho,\delta)$, the LHS of (23) is negative, while the RHS is positive. This proves the desired result.

Proof of the Results in Section 7.2: Because $\mathbf{w} = \max(\mathbf{v},\mathbf{s})$, it follows that $F_{\mathbf{w}} = F_{\mathbf{s}}F_{\mathbf{v}}$, so $\mathbf{w} \succeq_{SD_1} \mathbf{v}$. This implies that: (i) $\bar{F}_{\mathbf{v}}(p) \leq \bar{F}_{\mathbf{w}}(p)$, (ii) $\mu_{\mathbf{v}} \leq \mu_{\mathbf{w}}$, and (iii) $R_{\mathbf{v}}(p) \leq R_{\mathbf{w}}(p)$. Notation follows that of Section 2, indexed by the corresponding valuation distribution, $\mathbf{v}$ or $\mathbf{w}$. The results stated in the text can be summarized by the following proposition.

Proposition 12. *(a) $\rho_0^{\mathbf{v}}(p_1,p_2) \leq \rho_0^{\mathbf{w}}(p_1,p_2)$, (b) $p_1^{\mathbf{v}}(\rho) \leq p_1^{\mathbf{w}}(\rho)$, (c) $\bar{p}_{\mathbf{v}} \leq \bar{p}_{\mathbf{w}}$, and (d) $\pi^*_{\mathbf{v}} \leq \pi^*_{\mathbf{w}}$.*

For a given pricing policy (p_1,p_2), $\rho_0(p_1,p_2)$ solves $p_2 - p_1 + R(p_2) + \rho R(p_1) = 0$ (see (7)). Part (a) then follows by (iii) above. Parts (b) and (c) are immediate from (i), respectively (iii) above. Finally, (d) follows because $\pi^*_{\mathbf{v}} = \max(p_1^{\mathbf{v}}(\rho),\bar{p}_{\mathbf{v}}) \leq \max(p_1^{\mathbf{w}}(\rho),\bar{p}_{\mathbf{w}}) = \pi^*_{\mathbf{w}}$.

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