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# Advance Selling When Consumers Regret

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We characterize the effect of anticipated regret on consumer decisions and on 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, whereas delaying purchase may cause *inaction regret* from missing a discount or facing a stockout. Consumers whom we describe as *emotionally rational* act strategically in response to the firm's policies and in anticipation of regret. In this context, regret explains two types of behavioral patterns: inertia (delayed purchase) and frenzies (buying early at negative surplus). We show how firms should optimally respond to consumer regret and also characterize a normative regret threshold above which they should not advance sell. Action regret reduces profits as well as the value of advance selling and booking limit policies for price-setting firms; inaction regret has the opposite effects. These effects are diminished by capacity constraints and are reversed for firms facing price pressure in the advance period (owing, e.g., to competition or market heterogeneity). Regret heterogeneity explains premium advance selling for the capacity-constrained firm, which may benefit from larger shares of regretful buyers. Finally, we show how the negative effects of regret on profits can be mitigated by regret-priming marketing campaigns and by offering refunds or options or allowing resales. Our results highlight the importance of assessing the relative strength of regret within and across market segments and of accounting for these factors in pricing and marketing policies.

**Key words:** advance selling; behavioral pricing; consumer regret; refunds; consumer options

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## 1. Introduction

Until October 7, INFORMS members can preregister for the November 2011 INFORMS Annual Meeting in Charlotte and pay only \$410 instead of the full \$480 price after that date. In early October, Professor Regrette is still uncertain about her future preferences and possible conflicts in early November. 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 forgo early registration. On the other hand, as she stands in line to pay for the registration on-site in Charlotte, she might regret having forgone the \$70 early-bird discount. What is the effect of anticipated regret on Professor Regrette's decisions? On INFORMS's profits? How should INFORMS account for regret in its pricing policy and marketing campaign? This paper proposes to answer such questions in a general advance selling context.

Consumers often make purchase decisions while uninformed about their true valuations for a product or service. Such decisions have emotional consequences once uncertainties (about valuation and product availability) are resolved and consumers

learn if they have made, in hindsight, the wrong choice. As consumers reflect on forgone alternatives, wrong decisions trigger emotions of *action regret* or *inaction regret* ("I should have waited" or "I should have bought"). The anticipation of those emotions affects purchase decisions. 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 the decision was, *ex ante*, the correct one (Zeelenberg 1999). There is ample empirical validation for regret and the effect of its anticipation on individual behavior in diverse contexts (Zeelenberg 1999), and in particular for purchase timing decisions (Cooke et al. 2001, Simonson 1992).

Our goals in this paper are to understand, in an analytical framework, the effects of anticipated consumer regret on purchase decisions and firm profits, and to provide prescriptions so firms can better respond to regret in an advance selling context where consumers face valuation uncertainty.

In such a context, we seek to understand: (1) *What is the effect of regret on advance purchase behavior, in particular, what departures from rationality in buy-or-wait decisions are explained by regret?* Consumers often

delay purchase, a behavior known as *buyer inertia*. For example, a significant fraction of regular participants at INFORMS conferences register on site, at a surcharge, or end up having to stay at another hotel. In contrast, consumers rush to buy lottery tickets, limited-edition Nintendo games they have never tried, or tickets to a sports event (before knowing the qualifying teams or even whether they will be able to attend). Our results show that action and inaction regret provide alternative explanations for such behavior.

Consumer regret is a potential concern for companies (e.g., Internet retailers selling to uninformed consumers who may be wary of purchasing products they cannot try) and for providers of opaque services, such as Expedia's undisclosed-name hotel bookings or Lastminute.com's short-lived "surprise destination" holiday campaign. In such circumstances, the benefits of advance selling are in question. However, because consumers may fear a stockout (e.g., not finding tickets for a Broadway show or World Cup match), a company can leverage their inaction regret by selling at high prices in advance. This raises the second question addressed in this research: (2) *What is the effect of consumer regret on profits, and how should firms optimally respond to regret?*

Organizations are certainly aware of regret's effect on consumer behavior, and they often leverage it in their marketing strategies. Advertising campaigns prime the anticipation of regret with slogans such as "Don't miss this..." or "Buy now or regret it later!" Even so, 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" (Karp 2008). For example, General Motors's "May the Best Car Win" campaign aimed to revive sales by guaranteeing buyers that, if they did not like their new car, they would have 60 days to bring it back for a full refund (Chang 2009). This is essentially a regret-mitigating mechanism. Yet not all companies offer refunds. Open-box video games or DVDs cannot be returned, while airline and concert tickets are often nonrefundable. This motivates the third and last question addressed in this research: (3) *When should firms prime or mitigate regret, and what mechanisms should they use to do so?*

To answer these three broad questions, 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) offers a number of arguments for the rationality of anticipated regret.<sup>1</sup>

Our model relies on a formal, axiomatic theory of regret in consumer choice (See Bell 1982, Loomes and Sugden 1982) to characterize: (1) consumer buy-or-wait decisions under anticipated regret in an advance selling context (§3); (2) the effect of regret and its heterogeneity on profits and advance selling policies (§§4 and 6); and (3) mechanisms by which firms can mitigate the negative consequences of consumer regret (§5). Our main findings, summarized in §7, indicate when it is important for a firm to consider consumer regret in an advance selling context and how marketing policies should incorporate that regret. In §2 we present our model and assumptions, and then relate them to the extant literature.

## 2. The Model and Relation to the Literature

A profit-seeking firm with capacity  $C$  sets static prices  $p_1, p_2$  for, respectively, advance and spot-period sales, assuming consumers' best response. Given the firm's policy, strategic consumers with unit demand and uncertain valuation  $\mathbf{v}$  decide whether to purchase in advance, or wait until their valuation is realized. Their emotionally rational choice maximizes the expected surplus *net of anticipated regret*, as detailed in §3. Consumers' valuation  $\mathbf{v}$  has the common-knowledge cumulative distribution  $F(\cdot)$  on  $[0, v_{\max}]$ , finite mean  $E[\mathbf{v}] = \mu$ , and survival function  $\bar{F} = 1 - F$ . For technical convenience, we occasionally assume that the revenue rate  $p\bar{F}(p)$  is unimodal or that  $\mathbf{v}$  follows a two-point distribution, but most of our results hold for general distributions.

We focus on relatively large markets, which motivate a fluid model with infinitesimal consumers, i.e., the decision of one consumer does not affect how other consumers behave and spot demand is proportional to  $\bar{F}(p)$ . Without loss of generality, we normalize market size to 1; hence  $C \in (0, 1]$  is the fraction of the market that can be served. In case of excess demand,  $C < 1$ , all consumers face the same rationing probability on spot  $k$  (proportional rationing) and form rational expectations about it. The firm commits to prices, through mechanisms like Ticketmaster, for example, and optimizes profits assuming consumers' best response. These assumptions, which are relevant mainly when capacity is tight ( $C < 1$ ), are consistent with a large literature on strategic customers and advance selling; examples include Xie and

1999, p. 325), we focus on *anticipated* regret and do not consider here the (observed yet irrational) effect of *experienced* regret on decisions. For example, the regret experienced upon missing a discount may prevent consumers from purchasing later at full price, even if that price is also below their valuation. Such behavior, which is consistent with loss aversion, has been evidenced, but is not (emotionally) rational.

<sup>1</sup> Consistent with the argument that rationality applies to "what we do with our regrets, and not to the experience itself" (Zeelenberg

Shugan (2001), Gallego and Şahin (2010), and Yu et al. (2008). Liu and van Ryzin (2008) provide an excellent review of modeling assumptions.

The literature in marketing, economics, and operations provides abundant reasons that firms should advance sell. Operations literature has largely focused on advance selling in B2B settings, where it has been shown to improve demand information and reduce inventory risk; see e.g., Boyacı and Özer (2010) and the references therein. In contrast, our focus is behavioral aspects emerging from selling directly to consumers when their valuation is uncertain. In this case, advance selling allows firms to extract additional surplus because consumers are (more) homogeneous before their valuation is realized (Xie and Shugan 2001). We explore how these insights are moderated by consumer regret as triggered by valuation uncertainty.

Despite abundant arguments provided by the literature, advance selling is not a universal practice. Capacity constraints can diminish the benefits of advance selling (Xie and Shugan 2001, Yu et al. 2008), as can consumer risk aversion (Che 1996, Prasad et al. 2011). We show that consumer action regret provides an additional reason for firms not to sell in advance. In exploring how to counter this negative effect, we investigate regret-mitigating mechanisms that provide an alternative, psychological argument in favor of returns (Su 2009b), refunds (Che 1996, Liu and Xiao 2008), options (Gallego and Şahin 2010), and resale markets (Calzolari and Pavan 2006).

Capacity constraints make advance sales more appealing to consumers who want to avoid stockouts. This can justify strategically limiting supply (DeGraba 1995, Liu and van Ryzin 2008) or advance selling at a premium (Möller and Watanabe 2010, Nocke and Peitz 2007). We provide two new explanations for why firms can sell at high prices in advance: dominant inaction regret (i.e., commission bias; Kahneman and Tversky 1982) and, if supply is tight, regret heterogeneity.

Our work contributes to a growing literature on behavioral operations (for a review, see e.g., Loch and Wu 2007) that studies how firms should optimally set prices in response to predictably irrational consumers. Closest to our work, Su (2009a) and Liu and Shum (2009) model forward-looking consumers who are prone to inertia and disappointment, respectively.

Liu and Shum (2009) study a model in which rationing first-period sales causes disappointment to consumers with certain valuations. Disappointment and regret both result from counterfactual thinking (Zeelenberg et al. 2000), but differ in the nature of the counterfactual comparison, leading to structurally different models and insights. Intuitively, we *regret* wrong choices (buy or wait), but are disappointed by

poor outcomes (low valuation or stockout) of a given decision.

Su (2009a) provides a stylized model of buyer inertia, the tendency to postpone purchase decisions. He shows that its strength adversely affects firm profits, but that a larger share of inertial consumers can be beneficial. Inertia, modeled holistically as a positive constant threshold on consumer surplus, can be explained by various behavioral regularities that include anticipated action regret in addition to hyperbolic discounting, probability weighting, and loss aversion. In contrast, we focus on modeling consumers' regret in terms of its theoretical foundations. Thus, regret translates into a nonconstant, possibly negative surplus threshold that leads to a richer set of implications for consumers and firms.

Our paper is one of few in the literature to model consumer regret in an operational context *and* provide prescriptive insights for a firm's decisions. Regret has been used to explain market behavior, including why too much choice decreases demand (Irons and Hepburn 2007); preferences for standardized versus customized products (Syam et al. 2008); demand for insurance (Braun and Muermann 2004); and overbidding in auctions (Engelbrecht-Wiggans and Katok 2006). In a similar spirit we show that, in an advance selling context, regret explains not only buyer inertia (delayed purchase), consistent with Su (2009a) and Diecidue et al. (2012), but also frenzies (buying at negative surplus). Unlike these authors, we also use this model to derive optimal policies for a firm responding to regretful markets.

### 3. Consumer Purchase Behavior Under Regret

This section presents our model of how regret-averse consumers behave in an advance selling setting given prices  $p_1$ ,  $p_2$  for advance and spot sales, respectively, and the probability  $k \in [0, 1]$  of finding the product available in the spot period. Emotionally rational consumers do not discount utility, and act to maximize expected surplus net of anticipated regret. An advance purchase triggers action regret from paying above valuation or from missing a subsequent markdown. In contrast, a consumer anticipates inaction regret from forgoing an affordable advance purchase discount or facing a stockout. Following Bell (1982) and Loomes and Sugden (1982), we posit that consumer surplus includes a separable regret component that is proportional to the forgone surplus.

#### 3.1. Consumer Surplus with Action and Inaction Regrets

Faced with an opportunity to advance buy, customers decide whether to do so (or wait) based on rational



expectations about future availability that affect their anticipated regrets. If the product is unavailable in the spot market (because of a stockout or firm policy to sell only in advance), the consumer regrets buying if  $v < p_1$ ; otherwise, she regrets waiting. So the forgone surplus from buying or waiting correspond, respectively, to the negative and positive part of  $v - p_1$ , denoted  $(v - p_1)^-$  and  $(v - p_1)^+$ . Anticipated regret is proportional to their expected values.

If, however, the product is available on the spot (with probability  $k$ ), the spot price  $p_2$  introduces an additional anchor for regret. A consumer who buys early will regret if she realizes a valuation below the price paid (i.e.,  $v < p_1$ ), but may also regret paying a premium in advance if  $v > p_1 > p_2$ . The forgone surplus from an advance purchase is then the larger of the two losses:  $(\min(v, p_2) - p_1)^-$ . On the other hand, a consumer who decides to wait either (a) buys on the spot if  $v \geq p_2$  and regrets missing an advance purchase discount  $(p_2 - p_1)^+$  or (b) cannot afford to purchase if  $v < p_2$  and so leaves the market empty-handed, but regrets not having bought in the first period if  $v \leq p_1$ . Thus, in this case the foregone surplus from waiting is  $(\min(v, p_2) - p_1)^+$ . Figure 1 illustrates customers' choices, as well as the realized surplus and regrets from buying versus waiting, separately for discount and premium advance selling policies.

We can express the total expected surplus from buying and waiting, respectively, as

$$S_1 = S_1(\rho) = \mu - p_1 + \rho((1 - k)E[v - p_1]^- + kE[\min(v, p_2) - p_1]^-), \quad (1)$$

$$S_2 = S_2(\delta) = kE[v - p_2]^+ - \delta((1 - k)E[v - p_1]^+ + kE[\min(v, p_2) - p_1]^+). \quad (2)$$

Here  $\rho, \delta \geq 0$  measure the strength of action and inaction regrets; in particular,  $\rho = \delta = 0$  for unemotional buyers. The first terms,  $S_1(0) = \mu - p_1$  and  $S_2(0) = kE[v - p_2]^+$ , reflect the expected economic surplus from, respectively, buying and waiting in the absence of regret, while the second terms capture the corresponding emotional surplus. Intuitively, the symmetry in emotional surplus is explained by viewing inaction regret as the positive counterpart of action regret; a consumer regrets waiting whenever she would have rejoiced over buying, and vice versa. Our model thus implicitly captures regret's counterpart: rejoice, or the ex post positive emotional surplus from having made the right choice.

### 3.2. A Sufficient Regret Statistic for Consumer Choice

Consumers' differential expected surplus from an advance purchase can be written as

$$\Delta S = S_1 - S_2 = (1 + \delta)\Delta S(0) + (\rho - \delta) \cdot ((1 - k)E[v - p_1]^- + kE[\min(v, p_2) - p_1]^-), \quad (3)$$

where  $\Delta S(0) = S_1(0) - S_2(0) = \mu - p_1 - kE[v - p_2]^+$  is the differential expected surplus without regret. A consumer buys early whenever  $S_1$ , the expected surplus from doing so, exceeds  $S_2$ , the expected surplus from waiting—that is, if  $\Delta S \geq 0$ . We follow the standard assumption that a consumer who is indifferent between buying and waiting will choose to buy. The consumer's decision can be quantified using the expected valuation shortfall, denoted  $R(x) = E[v - x]^-$ , as follows:<sup>2</sup>

LEMMA 1. Consumers advance purchase if and only if

$$\gamma = \frac{\rho - \delta}{1 + \delta} \leq \bar{\gamma}(p_1, p_2, k) = \frac{\mu - p_1 - k(\mu - p_2 - R(p_2))}{-R(p_1) + k(p_1 + R(p_1) - p_2 - R(p_2))^+} \quad (4)$$

and  $\bar{\gamma}(p_1, p_2, k)$  is decreasing in  $k$  and  $p_1$  and is increasing in  $p_2$ . All else equal, consumers are less likely to buy early the more (less) they regret actions,  $\rho$  (inactions,  $\delta$ ).

The second term in the denominator vanishes for markup policies  $p_1 \leq p_2$  because  $x + R(x) = E[\min(v, x)]$  is increasing in  $x$ . The result confirms that, ceteris paribus, lower advance prices  $p_1$ , higher spot prices  $p_2$ , and higher rationing risk (lower  $k$ ) increase the propensity to buy early.

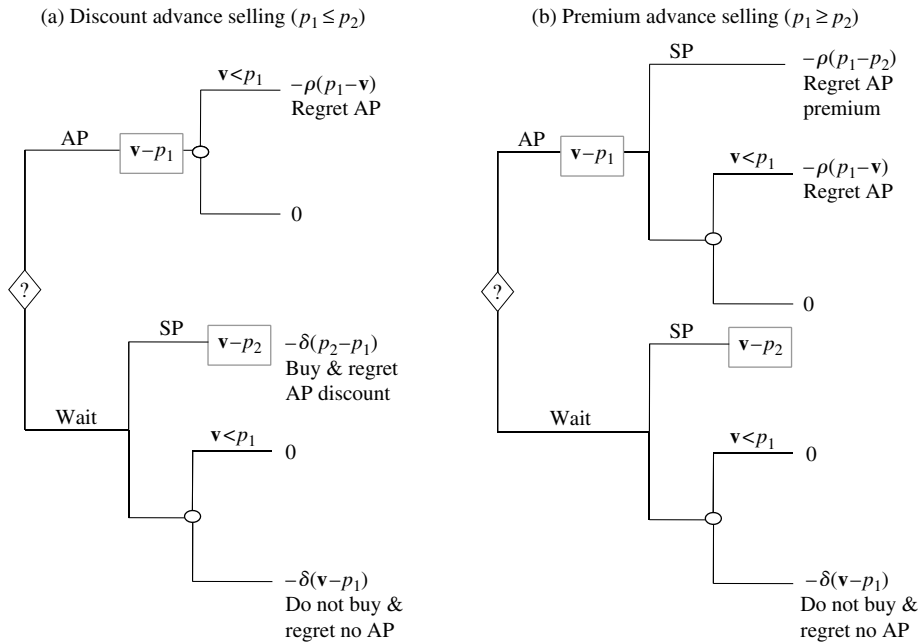
Lemma 1 shows  $\gamma = (\rho - \delta)/(1 + \delta)$  to be a *sufficient regret statistic* for characterizing regret-averse consumer choice in an advance selling setting. In other words,  $(\rho, \delta)$  consumers can be segmented into equivalence classes according to the unique regret parameter  $\gamma = (1 + \rho)/(1 + \delta) - 1 \geq -1$ . Any  $(\rho, \delta)$  consumer makes the same buy-or-wait choices as a  $(\gamma, 0)$  consumer if  $\gamma \geq 0$  or as a  $(0, -\gamma)$  consumer if  $\gamma < 0$ ; hence, for simplicity we refer to her as a  $\gamma$  consumer type. Thus  $\bar{\gamma}(p_1, p_2, k)$  is the highest regret type who is willing to advance purchase given the policy  $(p_1, p_2, k)$ .

In particular, if action and inaction regret have the same strength,  $\rho = \delta$ , then consumers behave as if they do not anticipate regret. Emotional buyers derive additional value from optimally managing their regrets, which magnify differential surplus (3) by a factor of  $1 + \delta$ . Yet this does not change the outcome of their advance purchase decision (4).

### 3.3. On the Relative Strength of Regrets

Lemma 1 implies that regret-averse consumers are less (more) likely to advance purchase than unemotional buyers whenever they regret actions more than inactions, i.e.,  $\gamma > 0$  ( $\gamma < 0$ ). It is therefore important to determine which type of regret is dominant.

<sup>2</sup> We use the terms increasing/decreasing and positive/negative in the weak sense throughout.

**Figure 1** Consumer Buy-or-Wait Decision Tree, Economic Surplus (Boxed) and Regrets

Note. AP, advance purchase; SP,  $v \geq p_2$  and product is available on spot;  $\Pr(\text{SP}) = k\bar{F}(p_2)$

Experimental research suggests that the relative strength of regrets is context dependent. In the short term, actions are typically regretted more than inactions (i.e.,  $\gamma > 0$ ), which is consistent with the omission bias (Kahneman and Tversky 1982) and labeled as “the clearest and most frequently replicated finding in the entire literature on counterfactual thinking” (Gilovich and Medvec 1995).

However, a reversal of the omission bias ( $\gamma < 0$ ) has been evidenced in purchase timing decisions (Simonson 1992), in particular for long-term regrets (Keinan and Kivetz 2008) and limited purchase opportunities (Abendroth and Diehl 2006). For example, consumers are presumably more likely to regret forgoing a limited-time offer (50% off Curves Gym membership for signing up on the day of trial) or not purchasing a special or limited edition (e.g., Omega Moon Watch, 2012 Chevrolet Camaro Transformers, Disney DVD collections), a travel souvenir, or a ticket to a unique event (graduation ball, U2 concert), and to regret having resisted even more when these decisions are viewed from a long-term perspective.

For simplicity of exposition, in the rest of this paper we mostly refer to the cases  $\gamma > 0$  and  $\gamma < 0$  as consumers regretting actions and inactions, respectively, rather than actions being regretted more or less than inactions.

### 3.4. Inertia and Buying Frenzies

Our consumer behavior model (4) explains two types of predictably irrational purchase behaviors: inertia

and frenzies. As consumers regret buying, they are more likely to delay a rational purchase—an observed behavioral pattern known as buyers’ inertia (Su 2009a, Zeelenberg and Pieters 2004). Conversely, the more consumers regret forgoing a purchase opportunity, the more they act myopically and accelerate purchase. In particular, we may observe buying frenzies.

Indeed, unlike traditional economic models, *emotionally rational consumers may advance purchase at a negative economic surplus* ( $S_1 \leq \mu - p_1 < 0$ ) to avoid inaction regret. This is because, unlike in expected utility models, the expected surplus from not buying early (waiting),  $S_2$ , can be negative because of inaction regret. For example, in the absence of spot sales ( $k = 0$ ) and at any price  $p_1$  such that  $0 > S_1(0) = \mu - p_1 > -\delta E[v - p_1]^+$ , a  $\rho = 0$  consumer prefers to advance purchase because doing so causes less (emotional and economic) pain than not buying at all:  $-\delta E[v - p_1]^+ = S_2 < S_1 < 0$ . Yet unemotional consumers in the same situation would not buy at all.

That consumers may buy at negative expected surplus is a distinctive feature of our consumer model, one driven by counterfactual thinking and the assumption that consumers cannot avoid regret (e.g., through self-control) even when they decide not to buy. This assumption has strong empirical support. Indeed, even in the absence of counterfactual information, consumers have been shown to anticipate regret (Simonson 1992) and often search for (costly but economically irrelevant) negative counterfactual information that triggers regret (Shani et al. 2008).

National lotteries are a classical example of consumers purchasing at negative expected surplus. The unusual popularity of the Dutch Postcode Lottery, which splits the jackpot among ticket holders with the winning postcode, has been attributed to the anticipation of inaction regret (Zeelenberg and Pieters 2004).<sup>3</sup> In an experimental setting, Nasiry and Popescu (2010) find that sports' fans are willing to pay above their expected valuation for tickets to a game when these are sold only in advance (i.e., before the qualifying teams are known).

#### 4. The Effect of Regret on Profits and Policies

In this section, we investigate the impact of anticipated regret on the firm's profits and decisions when consumers are ex ante homogeneous. Section 6 explores how our insights extend when consumers are heterogeneous in terms of regret.

##### 4.1. The Uncapacitated Firm

In absence of capacity constraints, we set  $C = k = 1$ . Because consumers are ex ante homogeneous, given a pricing policy  $(p_1, p_2)$ , either all consumers wait and a fraction  $\bar{F}(p_2)$  purchase on the spot, or they all advance purchase if  $\Delta S \geq 0$ . By (3), the latter occurs whenever  $\mu - p_1 - E[v - p_2]^+ \geq \gamma E[\min(v, p_2) - p_1]^-$ . For simplicity, we ignore marginal costs, which actually magnify the effects of regret, and so the profit is

$$\pi(\gamma; p_1, p_2) = \begin{cases} p_1 & \text{if } \gamma \leq \bar{\gamma}(p_1, p_2, k=1) \text{ (see (4))}, \\ p_2 \bar{F}(p_2) & \text{otherwise.} \end{cases} \quad (5)$$

The higher is  $\gamma$ , the more likely consumers are to delay purchase, by Lemma 1. Therefore, higher action regret or lower inaction regret benefits a price-taking firm whenever spot sales are more profitable than advance sales (i.e., when  $p_2 \bar{F}(p_2) \geq p_1$ ). These effects change when the firm can optimize the spot or advance price in (5) in response to regret. Our next result summarizes the effect of regret on the profits of a firm that is constrained in either one or both periods.

**PROPOSITION 1.** (a) *The expected profit of a price-taking firm is increasing in  $\gamma$  if  $p_1/p_2 \leq \bar{F}(p_2)$ ; otherwise, it is decreasing in  $\gamma$ .* (b) *The optimal expected profit of a firm that is a price taker in the advance (spot) period is increasing (decreasing) in  $\gamma$ .*

<sup>3</sup> Unlike regular lotteries, feedback here is almost unavoidable: You do not have to buy a ticket to know your combination (postcode) and will find out from neighbors if you could have won. Given this feedback, regret aversion motivates purchase as a protection against the large regret experienced if you did not buy and your postcode was drawn.

Action regret has negative profit consequences for firms facing spot-price constraints, in particular, those practicing markdowns or lacking credible commitment devices. However, action regret can benefit firms that offer relatively steep advance purchase discounts or face price pressure in the advance period. Incumbent airlines, for example, offer steep advance purchase discounts in response to competitive pressure from low-cost carriers. Sports teams and rock bands may keep advance prices low for image, fairness, or social considerations. Section 6.2 illustrates a setting where market heterogeneity creates pressure on advance prices and so makes action regret beneficial.

A firm with full pricing flexibility optimally responds to regret by solving  $\max_{p_1, p_2} \pi(\gamma; p_1, p_2)$ , as given by (5). Consumers are ex ante homogeneous, so the firm will sell only in one period. On the spot, it obtains at most  $\bar{\pi} = \max p \bar{F}(p)$  by charging  $p_0 = \arg \max p \bar{F}(p)$ , a price that is unique by the unimodality assumption (§2). In advance, the firm extracts at best the consumers' maximum willingness to pay (wtp) in the absence of a spot market,  $p_1 = \bar{w}(\gamma)$ , which by (3) solves

$$\mu - p_1 + \gamma R(p_1) = 0. \quad (6)$$

The left-hand side (LHS) is decreasing in  $p_1$  (because  $\gamma \geq -1$ ), so  $\bar{w}(\gamma)$  is decreasing in  $\gamma$ . In particular,  $\bar{w}(\gamma) \geq \bar{w}(0) = \mu$  whenever consumers regret inactions more than actions ( $\gamma \leq 0$ ); in this case, because  $\bar{\pi} \leq \mu$ , the firm always advance sells. Our next result shows that, nonetheless, advance selling may not be profitable if consumer regret exceeds a positive threshold  $\bar{\gamma}$ .

**PROPOSITION 2.** *A price-setting firm sells only in advance at  $p_1^* = \bar{w}(\gamma)$  if  $\gamma \leq \bar{\gamma} = -(\mu - \bar{\pi})/R(\bar{\pi})$ ; otherwise, it sells only on the spot at  $p_2^* = p_0$ . The optimal profit,  $\pi^*(\gamma) = \max\{\bar{w}(\gamma), \bar{\pi}\}$ , is decreasing in regret,  $\gamma$ . In particular, the firm benefits from consumer regret if and only if inactions are regretted more than actions, i.e.,  $\gamma < 0$ .*

In contrast with the bulk of the advance selling literature (e.g., Nocke et al. 2011, Xie and Shugan 2001), this result provides an argument for why firms might not benefit from advance selling even when capacity is ample and buyers are homogeneous. This would occur if consumers regret purchases beyond a threshold  $\bar{\gamma} > 0$  determined by their valuation uncertainty. In other words, whether a firm can profitably sell to uninformed consumers depends on the relative intensity of their regrets and the uncertainty they face.

On the other hand, in contexts where not buying is associated with greater regret (such as limited purchase opportunities or unique events; see §3.3), advance selling allows firms to create a buying frenzy whereby consumers advance purchase at a net loss to

avoid inaction regret, as discussed in §3.4. Indeed, if  $\gamma < 0$  (e.g., if customers regret inactions only), then Proposition 2 shows that the optimal pricing strategy is to advance sell at  $\bar{w}(\gamma) > \mu$ ; in particular,  $S_2 \leq S_1 < 0$  and so consumers buy at negative expected economic (and emotional) surplus. Our results provide an emotionally rational explanation for how firms can create frenzies not by limiting supply, but rather by selling only in advance. For example, this may explain the high prices fetched by (nominal) tickets to our school's graduation ball, which are sold only in advance despite ample capacity; students anticipate that they would regret missing this once-in-a-lifetime event more than being stuck with an unused ticket.

In short, the effect of regret on the profits of a price-setting firm depends on the type of regret—action regret hurts profits, whereas inaction regret is beneficial—and their relative magnitude  $\gamma$ . This result suggests that firms may benefit from mechanisms that mitigate consumers' action regret, such as refunds or resales (investigated in §5), but less so from price protection or other guarantees mitigating inaction regret. That being said, price-setting firms can benefit from priming inaction regret—for example, through marketing campaigns that trigger appropriate counterfactual thinking (e.g., “buy now or regret later” advertising or framing the offer as a special or limited opportunity; see §3.3).

#### 4.2. Capacity Constraints

This section extends our analysis to the case when the firm faces capacity constraints,  $C < 1$ . The risk of being rationed on the spot interferes with consumer regrets, affecting both economic and emotional surplus. This risk is endogenously determined by consumer response to the firm's policy.

We assume that all consumers are present in the first period and try (but do not commit) to advance purchase.<sup>4</sup> If a customer is rationed in advance, she has no choice but to wait and does not experience regret. Customers who have the opportunity to buy in advance choose either to do so or wait based on rational expectations about the probability of getting the product on the spot. If they all wait, this probability equals  $k = k(p_2) = \min(1, C/\bar{F}(p_2))$ , for a given capacity  $C$  and spot price  $p_2$ . Consumers' ex ante wtp,  $w(\gamma; p_2, C)$ , then solves  $\Delta S(\gamma; w, p_2, k(p_2)) = 0$  and increases with capacity; see (3).

The insights of §4.1 extend under capacity constraints. Here, instead of revenue per customer  $\bar{\pi}$ ,

the relevant unit of analysis is revenue per capacity unit:

$$\bar{\pi}_C = \begin{cases} \bar{\pi}/C & \text{if } C \geq \bar{F}(p_0), \\ \bar{F}^{-1}(C) = \inf\{x; \bar{F}(x) \geq C\} & \text{otherwise.} \end{cases} \quad (7)$$

**PROPOSITION 3.** *A price-setting firm sells in advance at  $\bar{w}(\gamma)$ , solving (6), if  $\gamma \leq \bar{\gamma}(C) = -(\mu - \bar{\pi}_C)/R(\bar{\pi}_C)$ ; otherwise, it spot sells at  $p_0(C) = \max(p_0, \bar{F}^{-1}(C))$ . The optimal profit  $\pi^*(C) = C \max\{\bar{w}(\gamma), \bar{\pi}_C\}$  is decreasing in  $\gamma$  and increasing in  $C$ , and  $\bar{\gamma}(C)$  is increasing in  $C$ .*

This result extends Proposition 2 by characterizing the highest regret type willing to advance purchase,  $\bar{\gamma}(C)$ , as a function of capacity and valuation uncertainty. Alternatively, the result shows that advance selling is optimal above a capacity threshold  $\bar{C}(\gamma)$  given by  $\bar{\gamma}(\bar{C}(\gamma)) = \gamma$  and that this threshold increases with  $\gamma$ . A price-setting firm will not advance sell at a premium to homogeneous buyers, although the latter would pay a premium to avoid a high rationing risk.

Capacity constraints limit the benefit of advance selling for a price-setting firm by lowering the threshold on regret  $\bar{\gamma}(C)$  below which advance selling is optimal. Intuitively, capacity constraints increase the spot period price,  $\bar{F}^{-1}(C)$ , but do not affect customers' maximum wtp in advance,  $\bar{w}(\gamma)$ . Proposition 3 also shows that regret ( $\gamma$ ) is relevant to the firm's policy only if it falls below the threshold  $\bar{\gamma}(C) = -(\mu - \bar{\pi}_C)/R(\bar{\pi}_C) \geq -1$ , which is determined by capacity and valuation. Above this threshold, the firm should spot sell and the spot prices and profits are unaffected by  $\gamma$ .

The regret threshold below which advance selling is optimal is not necessarily positive if capacity is tight:  $\bar{\gamma}(C) < 0$  for  $C < \bar{F}(\mu)$ , meaning that the capacity constrained firm might not advance sell to customers who regret inactions. In contrast, the unconstrained firm always advance sells to consumers who regret inactions, leading to buying frenzies.<sup>5</sup> Thus, by limiting the benefits of advance selling, capacity constraints reduce the prevalence of buying frenzies predicted in §3.4. Overall we conclude that, at optimality, the effects of both action and inaction regret on profits and policies are actually diminished by capacity constraints.

#### 4.3. Limited Advance Sales

We next investigate how limiting advance sales by setting a booking limit,  $B \in (0, C)$  interferes with consumer regret in affecting the optimal policy and profits. The benefits of booking limits are well established theoretically (Xie and Shugan 2001, Yu et al. 2008).

<sup>4</sup> Considering customers' cost-free “try to advance purchase” decision, and associated regrets, before rationing occurs in the advance period leads to the same predictions.

<sup>5</sup> Our inaction regret-driven frenzies are different from DeGraba's (1995) supply-driven frenzies under spot-market price pressure; the latter can also be replicated under regret.



A common practice in airlines, hotels, ticketing, and other capacity-constrained service industries, booking limits allow firms to reserve availability for late-coming, high-paying customers. Note, however, that we do not require second-period arrivals or aggregate demand uncertainty to justify the optimality of booking limits.

Given a pricing and booking limit policy,  $(p_1, p_2, B)$ , customers who have the opportunity to buy in advance choose either to do so or wait based on rational expectations about the probability of getting the product on the spot. This probability amounts to  $k = k(p_2, B) = \min(1, (C - B)/((1 - B)\bar{F}(p_2)))$  unless everyone prefers to wait. Customers who are rationed out by the booking limit do not face a buy-or-wait decision and hence do not anticipate regret. An optimal policy makes an infinitesimal customer who has the opportunity to advance purchase indifferent between doing so and waiting; hence it satisfies  $\Delta S(p_1, p_2, k(p_2, B)) = 0$  (see (3)).

**PROPOSITION 4.** *Suppose that the firm can limit advance sales and that  $\mathbf{v}$  has either log-concave density or a two-point distribution. Then the firm's optimal policy is to advance sell at a discount with a positive booking limit if  $\gamma \leq \bar{\gamma}_B(C)$ , where  $\bar{\gamma}_B(C) \geq \bar{\gamma}(C)$ ; otherwise, spot selling is optimal. Moreover, the optimal prices, booking limit, and profits, all decrease with  $\gamma$ .*

Papers that use incentive compatible, fluid pricing models to characterize booking limits without regret make similar distributional assumptions (e.g., two-point support in Möller and Watanabe 2010; continuous in Yu et al. 2008). A wide range of parametric families have log-concave density, including the uniform, exponential, normal, and logistic (Bagnoli and Bergstrom 2005).

Booking limits are suboptimal in uncapped settings and increase the prevalence of discount advance selling; premium advance selling remains suboptimal with booking limits. Effectively, booking limits enable the firm to sell to some high-valuation consumers in the spot period while clearing the remaining capacity at a discount in advance. Booking limits also increase the regret threshold above which spot selling is optimal. The profitability and magnitude of booking limits is diminished by action regret. On the other hand, the more consumers regret forgoing the discount or potentially being stocked out, the more relevant booking limits are.

A robust result of our analysis so far is that firms that set prices optimally are hurt by action regret, but benefit from inaction regret. This motivates us to study, in the next section, mechanisms aimed at mitigating action regret. Yet limited purchase opportunities and the perception of scarcity have been shown (Abendroth and Diehl 2006, Simonson 1992)

to increase inaction regret, triggering a reversal of the omission bias (so that  $\gamma < 0$ ); see §3.3. In such cases, our results suggest that firms with limited availability will benefit from consumer regret. Psychological effects of capacity on the relative scale of regret (such as  $\gamma$  increasing in  $C$  or  $B$ ) are not captured by our model, but they offer an interesting departure for further empirical and analytical investigation.

## 5. Regret-Mitigating Mechanisms

Action regret adversely affects profits for price-setting firms. Therefore, in this section we propose three mechanisms to help mitigate action regret—refunds, options, and resales—and study their impact on consumer behavior and on firm decisions and profits. Because we are interested in mitigating action regret, we assume that  $\gamma \geq 0$  throughout this section.

### 5.1. Refunds

Refund policies, such as GM's 60-day money-back offer (see §1), provide a means to stimulate demand and profits by insuring consumers against the downside of their decisions. Similarly, by allowing returns, Internet retailers can induce consumers to buy an item without first trying it, as Amazon.com did for the Kindle. Not all companies offer full refunds; for instance, Best Buy deducts restocking fees for returned items. We investigate the effectiveness and design of optimal refund policies to mitigate consumer regret. We assume that the firm considers two selling strategies: either advance selling with refund or spot selling. Our analysis shows that this simplification is without loss of generality because neither pure advance selling nor refund menus are optimal in homogeneous markets.

**5.1.1. Consumer Behavior.** Upon an advance purchase, a customer returns the product for a refund  $r$  whenever her valuation turns out to be lower than the refund (i.e., if  $v < r$ ). The refund reduces then her foregone surplus, and action regret by  $v - r$ . Thus, the customer who buys the refundable product expects to gain back her valuation shortfall below  $r$  (i.e.,  $-R(r)$ ) in both economic and emotional surplus. So the total expected surplus from an advance purchase (1) increases by  $-(1 + \rho)R(r)$ . In effect, the refund policy shifts the valuation of consumers who advance purchase from  $\mathbf{v}$  to  $\max(\mathbf{v}, r)$ , insuring them against downside valuation risk. Refunds do not affect expected surplus from waiting (2). In particular, inaction regret is triggered only when  $v > p_1$ , in which case refunds are irrelevant. In sum, the consumer decision tree in Figure 1 remains the same, except for an additional refund and regret branch when the consumer advance purchases and  $v < r$ . The customer buys in advance whenever

the expected surplus from doing so is positive, equivalently  $\Delta S'/(1 + \delta) = \Delta S/(1 + \delta) - (1 + \gamma) \cdot R(r) \geq 0$ . By (3), it follows that, with refunds as well,  $\gamma$  remains a sufficient regret statistic for customer choice.

**5.1.2. Profits.** GM resells returned cars as used and at a lower price. Assume for simplicity that the firm salvages items that are returned or unsold at  $s \geq 0$  (see Su 2009b).<sup>6</sup> The firm maximizes incremental profit on top of the salvage value, which can be written as

$$\pi_s(\gamma; p_1, p_2, r) = \begin{cases} \min(C, 1)(p_1 - s - (r - s)F(r)) & \text{if all consumers buy early,} \\ \min(C, \bar{F}(p_2))(p_2 - s) & \text{if all consumers buy on the spot.} \end{cases} \quad (8)$$

From the consumer's perspective, buying on the spot at  $p_2$  is equivalent to buying in advance with a full refund,  $r = p_2 = p_1$ . This policy also yields the same profits for a firm with excess supply,  $C = 1$ , by (8). Such firms can therefore focus on advance selling with refunds.

We first analyze the uncapacitated case and then argue that the main insights extend when capacity is limited. For a given refund  $r$ , consumers' maximum wtp,  $\bar{w}(\gamma; r)$ , solves  $\mu - p + \gamma R(p) = (1 + \gamma)R(r)$ . In particular,  $\bar{w}(\gamma; r)$  is increasing in  $r$  and decreasing in  $\gamma$  (see the appendix).

**PROPOSITION 5.** *The optimal policy is to offer partial refunds,  $0 < r^* < p^* = \bar{w}(\gamma; r^*)$ , that solves*

$$1 + \gamma F(p^*) = (1 + \gamma) \frac{F(r^*)}{F(r^*) + (r^* - s)f(r^*)}. \quad (9)$$

*The optimal refund  $r^* = r^*(\gamma)$  is increasing in  $\gamma$ , and  $r^*(0) = s$ ; optimal profits  $\pi_s^*(\gamma)$  decrease in  $\gamma$ .*

Refunds increase consumers' wtp in advance by insuring them against wrong purchase decisions. Such guarantees command a premium and so the firm charges a higher price when it offers refunds than when it does not:  $p^* = \bar{w}(\gamma; r^*) \geq \bar{w}(\gamma; 0) = \bar{w}(\gamma)$ , as defined in (6). For unemotional buyers, the firm refunds the salvage value  $r^*(0) = s$ ; thus,  $r^*(\gamma) - s$  reflects the positive refund for regret.

We find it interesting that, *with refunds, the firm may actually charge higher prices to consumers who regret purchases more*. In other words, above a certain threshold,

the optimal advance price  $p^*(\gamma) = \bar{w}(\gamma; r^*)$  is increasing in  $\gamma$ , as illustrated in Figure 1(a). This is in sharp contrast with our results in previous sections, where the optimal advance selling price,  $\bar{w}(\gamma)$ , was always decreasing in  $\gamma$ . Intuitively, as regret becomes a bigger issue for consumers, the positive effect of a higher refund on wtp outweighs the negative effect of action regret.

A full-refund policy (such as GM's) eliminates action regret by providing full insurance against wrong advance purchase decisions. However, Proposition 5 shows that full-refund policies are suboptimal,  $r^* < p^*$ ; this explains, for example, Best Buy's partial refund policy. In contrast with Proposition 2, spot selling is suboptimal regardless of regrets if uncapacitated firms can offer refunds. Although they are dominated by partial refunds, *full refunds dominate no refunds* for sufficiently high salvage value  $s$  (regardless of regret) or if customers are sufficiently regret averse.<sup>7</sup>

A common finding in the literature is that the profitability of refunds in homogeneous markets is determined by supply-side variables—for example, marginal cost of production or salvage value (Liu and Xiao 2008, Su 2009b). In the absence of such variables, refunds have been shown to be suboptimal in homogeneous markets even when capacity is constrained (Liu and Xiao 2008). Our results add a new dimension to this literature by showing that demand-side effects, such as anticipated regret, can trigger the profitability of refunds. As illustrated in Figure 1(a), refunds can be profitable in our model even if  $s = 0$ , provided that consumers are sufficiently regret averse.

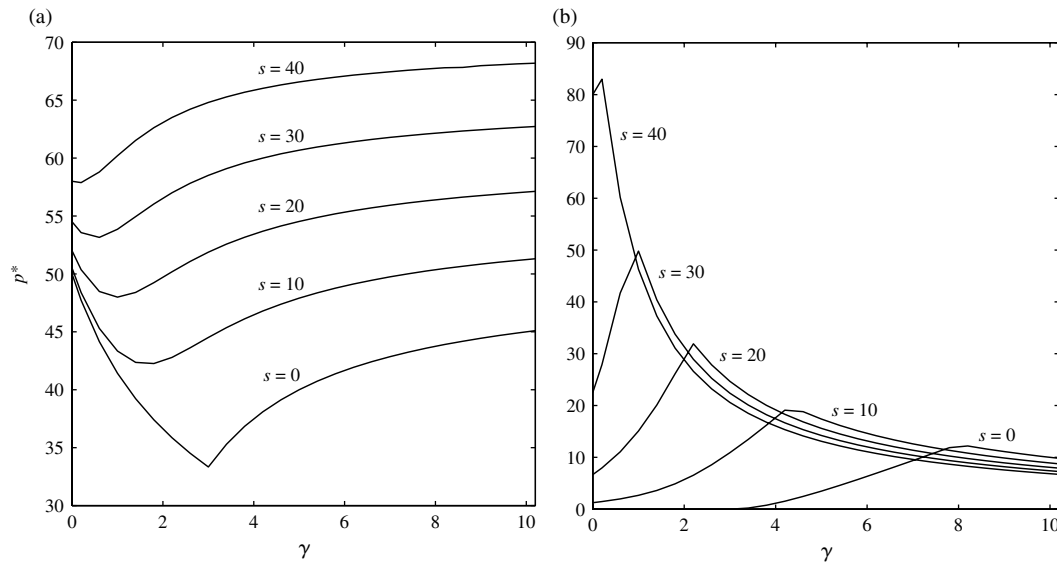
Figure 2 indicates that the relative incremental profit gains from offering refunds can be significant. It is interesting that the value of offering refunds depends nonmonotonically on regret. Refunds are increasingly beneficial up to a regret threshold, after which their relative benefits diminish; the reason is, without refunds, the firm spot sells to sufficiently regretful buyers and spot profits do not depend on regret. Short of this threshold, profits with and without refunds decrease with regret, but refunds recapture a larger share of the revenues lost to regret.

**5.1.3. Capacity Constraints.** With capacity constraints,  $C < 1$ , the firm either advance sells with the partial refund policy (given in Proposition 5) or sells only on the spot if capacity is sufficiently tight; spot prices and profits are independent of regret. All other insights from this section remain valid under capacity constraints, although they diminish the negative

<sup>6</sup> An alternative setup whereby returned items are put back into circulation at full price is considered in the next section. All results extend for a marginal cost of production  $c = s$ .

<sup>7</sup> See the appendix. Similarly, Che (1996) shows that full refunds are more profitable than no refunds if the firm faces high marginal cost or if (CARA) consumers are sufficiently risk averse; he does not study partial refunds.

**Figure 2** (a) Optimal Price  $p^*(\gamma)$  as a Function of Regret  $\gamma$ ; (b) Relative Increase in Profits Due to Refunds,  $(\pi_s^* - \pi^*(r=0))/\pi^*(r=0)$



Note. In both figures,  $v \sim U[0, 100]$ .

effects of regret on profits and hence the prevalence of advance selling with refunds. We omit the analysis for conciseness.

## 5.2. Options

Suppose that consumers can purchase, at a price  $x$ , the right to buy the product on the spot at an exercise price of  $r$ . A consumer exercises the option whenever  $v \geq r$  and so, for her, this option is technically equivalent to a partial refund policy ( $p = x + r, r$ ). Options are different from refunds, however, and firms may offer both. For example, a car dealer might sell options (framed as nonrefundable deposits) on, say, a Chevy Volt before it is available. Once the car is on the lot, the consumer can buy it upon paying in full (i.e., by exercising the option). Unlike GM's refund policy, whereby a purchased car can be returned after two months, a capacitated firm can sell more options than capacity because only a fraction of them will actually be exercised.<sup>8</sup> Thus options allow for better capacity use than refunds. Options are equivalent to a full-recirculation refund model in which returned products are put back on the market at no loss of margin. This is appropriate for services (e.g., travel) with delayed consumption.

Our setup in this section follows that in Gallego and Şahin (2010), who show that options considerably improve profits for capacity-constrained firms and that the fluid model (used here) is asymptotically optimal. The optimal policy is derived in the appendix.

<sup>8</sup> In practice, selling options beyond capacity may cause loss of goodwill if customers are denied service, but this will not occur in our fluid model.

**PROPOSITION 6.** *The optimal profit and option price  $x^*(\gamma) > 0$  are decreasing in  $\gamma$ , and the optimal exercise price  $r^*(\gamma)$  is increasing in  $\gamma$ . Moreover,  $r^*(\gamma) > 0$  for  $C < 1$  or for  $\gamma$  above a positive threshold.*

To mitigate regret, firms offer lower option prices to regretful buyers, but then charge them higher exercise prices. If capacity is limited or if consumers are sufficiently regret averse, options dominate pure advance selling (i.e.,  $r^* > 0$ ). Unlike the case with refunds, spot selling, i.e., offering free options  $x = 0$ , is suboptimal even if capacity is tight, supporting the practice of nonrefundable deposits used by hotels and car dealers. In an experimental setting, Sainam et al. (2010) show that offering options on tickets for sporting events increases customers' wtp and seller profits. Our results suggest that an alternative explanation for this effect is that options mitigate regret.

## 5.3. Resales

We briefly argue that secondary markets can increase profits by mitigating action regret. This may explain why entertainment venues such as theaters, concerts, and sporting events allow reselling of the primary tickets. Estimates suggest that roughly 10% of tickets for shows and sporting events are resold, a figure that reaches 20%–30% for top-tiered seats (Happel and Jennings 2002).

Suppose customers have the opportunity to resell in the spot period to a third-party broker for a price  $s$ , which is, a priori, uncertain with known distribution  $F_s$ . For simplicity, we assume that the broker sells to a different customer pool than the firm (as in Calzolari and Pavan 2006). Cars, books, and appliances are typical items for which primary and resale

(secondary) markets are largely disjoint. Our results extend as long as cannibalization between the two markets is limited.

Our model with resales is equivalent to the basic model in §2 with a shifted valuation distribution,  $\mathbf{w} = \max(\mathbf{v}, \mathbf{s})$ . This implies that, for a given pricing policy, customers are more likely to advance purchase, and are also willing to pay a higher advance price when resale is allowed because resales provide a protection against action regret. Resales thus provide the firm the opportunity to charge higher prices and obtain higher profit in the advance period. In addition, resales allow the firm to extract higher spot profits. These results, formalized in Proposition 7, imply that allowing resales can be profitable as a means of mitigating action regret. The notation follows that in previous sections, indexed here by the corresponding valuation distribution ( $\mathbf{w}$  or  $\mathbf{v}$ ).

**PROPOSITION 7.** (a)  $\bar{w}_v(\gamma) \leq \bar{w}_w(\gamma)$ ; (b)  $\bar{\pi}_v \leq \bar{\pi}_w$ ; and (c)  $\pi_v^*(\gamma) \leq \pi_w^*(\gamma)$ .

Benefits of secondary markets in the absence of regret are identified in Su (2010). When it comes to regret, however, secondary markets can be a double-edged sword if brokers can also sell to the primary market. In that case, the possibility of buying later from the secondary market mitigates consumers' inaction regret, thereby reducing advance sales and firm profits. This may explain why firms seek to limit brokers' access to the primary market (Courty 2003).

## 6. Regret Heterogeneity

In this section we illustrate how regret heterogeneity affects our insights. Not everybody regrets, at least not to the same extent. Unlike Professor Regrette, her colleague, Ilia Piaf [pseudo.], prides himself on making rational decisions. He has no regrets for being wrong, ex post, provided he can rationalize his choices, ex ante. So emotions do not influence his decisions. In this case, we show that a capacitated firm may sell to Ilia (and others like him) in advance at a premium and benefit from a larger share of consumers like Professor Regrette. On the other hand, if she has higher valuation than he does, the firm may be able to benefit from her regrets by selling to her at a premium on the spot.

To illustrate these insights, we assume for simplicity that consumers have two-point valuation distributions and a fraction,  $\alpha$ , of the market anticipates regret ( $\gamma > 0$ ) whereas the rest does not ( $\gamma = 0$ ). Our insights extend provided one segment regrets more than the other, as measured by  $\gamma$ .

### 6.1. Premium Advance Selling

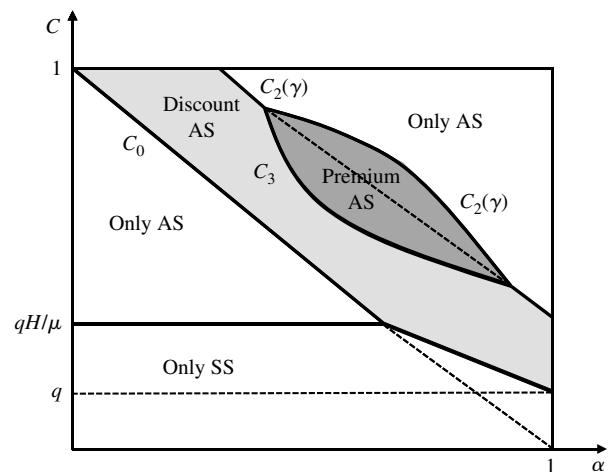
Premium advance selling, or last minute sales, is a common practice not only for music and sporting events (Broadway shows, La Scala in Milan, Duke's basketball games), but also for travel and tourism. The next result provides an alternative explanation for premium advance selling when consumers are heterogeneous in their regrets and face the same uncertainty  $\mathbf{v} = (H, q; L, 1 - q)$ .

**PROPOSITION 8.** The firm's optimal pricing policy is as depicted in Figure 3. In particular, premium advance selling can be optimal in mixed markets (intermediate values of  $\alpha$ ), and becomes more prevalent as  $\gamma$  increases. The optimal profit  $\pi^*(\gamma, \alpha, C)$  is increasing in  $C$ , decreasing in  $\gamma$ , and generally nonmonotonic in  $\alpha$ .

There are five possible policies at optimality, depending on capacity and market mix: (1) spot sell at  $H$  (for very tight capacity); (2) advance sell at  $\mu$  to nonregretful buyers only (if they can clear capacity); (3) implement a markup policy that sells to nonregretful buyers in advance at a discount  $\mu$  and to regretful buyers on the spot at  $H$  (when capacity is not cleared by the nonregretful buyers in advance); (4) implement a markdown policy that offers the product on the spot at  $L$  and charges a premium in advance to nonregretful buyers (when capacity is moderately large, but still tight enough to ration spot demand at low prices); (5) advance sell to the entire market at  $\bar{w}(\gamma)$ , the wtp of regretful buyers (when capacity is ample).

Without capacity constraints ( $C = 1$ ) or if the optimal policy does not clear capacity, we show in the appendix that profits decrease in the fraction of regretful consumers,  $\alpha$ . This is not necessarily true when capacity is tight. Indeed, when discount

**Figure 3** Optimal Policy in Markets Where a Fraction  $\alpha$  of Customers Regret,  $q \leq L/H$ , and  $\gamma \leq \bar{\gamma}(L, H, q)$



*Note.* The premium advance selling area grows with  $\gamma$  because  $C_i(\gamma)$  are increasing in  $\gamma$  for  $i = 1, 2$  and are independent of  $\gamma$  otherwise. See the appendix for boundary equations. AS, advance selling; SS, spot selling.



advance selling clears capacity, more customers buy on spot as  $\alpha$  increases, which results in higher profits. Profits decrease in  $\alpha$  under premium advance selling, but they do not depend on  $\alpha$  when the firm sells in one period. These results quantify and condition the intuition presented in Su (2009a) about the breadth of inertia.

Proposition 8 shows that, unlike the case of homogeneous markets, a firm with intermediate levels of capacity will segment the market in terms of regret and offer the product in both periods. In this case, the pricing policy induces regretful customers to wait while nonregretful customers buy in advance. When available capacity cannot be cleared at high spot prices, the firm may be better off advance selling at a premium and then clearing the remaining capacity at low spot prices. Unemotional customers pay a premium in advance to avoid being rationed on the spot because of competition with regretful buyers. As  $\gamma$  increases, premium advance selling policies become more prevalent. In other words, the corresponding area in Figure 3 becomes larger.

Limiting advance sales does not change our insights except that profits decrease in  $\alpha$  whereas the booking limit is nonmonotonic in  $\alpha$ . The regions that depict spot selling and premium advance selling shrink in Figure 3, and pure advance selling is sub-optimal. Thus, booking limits increase the prevalence of discount advance selling policies, thereby enabling the firm to clear capacity more often. However, the benefit and magnitude of booking limits are diminished by regret, which confirms the insights of §4.3.

In sum, the results of this section suggest that regret heterogeneity is an alternative explanation for premium advance selling. Note that we obtain this result without assuming aggregate demand uncertainty (Nocke and Peitz 2007), heterogeneity in arrivals (Su 2007), or in valuation distributions (Möller and Watanabe 2010).

## 6.2. Action Regret May Benefit the Firm

So far we have demonstrated that price-setting firms see diminished profits if homogeneous consumers regret purchase decisions. This result extends to markets in which consumers are heterogeneous with respect to valuations and regrets *unless* high-valuation buyers regret their purchases more than low-valuation buyers. In such settings only (and contrary to our previous findings) firms can actually benefit from action regret. Our goal in this section is to illustrate this effect. Suppose, for example, that notwithstanding her regrets, Professor Regrette has a higher value for attending the INFORMS conference than her überational colleague Ilia. How can INFORMS leverage this situation when targeting both consumers?

**Table 1** Effect of Regret on Profits in Heterogeneous Markets, Where One Segment Does Not Regret ( $\gamma = 0$ )

Regretful segment	High valuation ( $\mathbf{v}_H$ )	Low valuation ( $\mathbf{v}_L$ )
Regret actions ( $\gamma > 0$ )	(1) $\pi^*$ increasing in $\gamma$	(2) $\pi^*$ independent of $\gamma$
Regret inactions ( $\gamma < 0$ )	(3) $\pi^*$ decreasing in $\gamma$	(4) $\pi^*$ decreasing in $\gamma$

Consider for simplicity a heterogeneous market, a fraction  $\alpha$  of which have valuation  $\mathbf{v}_H = (H, q; 0, 1 - q)$ , the others have a lower valuation  $\mathbf{v}_L = (L, q; 0, 1 - q)$ ,  $H > L$ , and where only one of the segments anticipates regret.

**PROPOSITION 9.** *The effect of regret on optimal profits in heterogeneous markets depends on whether the regretful segment has higher or lower valuation, and regrets actions ( $\gamma > 0$ ) or inactions ( $\gamma < 0$ ), as summarized in Table 1.*

Table 1 shows that action regret can actually benefit the firm, if high-valuation customers regret their purchase decisions (case 1). In this case, our results show that the optimal policy segments the market by selling in advance, at  $p_1 = qL$ , to low-valuation consumers and spot selling at  $p_2 = H$  to high-valuation consumers, provided the latter are sufficiently regretful ( $\gamma > (H - L)/(L(1 - q))$ ). Otherwise, the firm sells only in one period. Higher regret increases the prevalence of the more profitable, separating equilibrium, resulting in higher profits for the firm.<sup>9</sup>

In absence of regret, Nocke et al. (2011) show that firms sell in advance at a discount to high-valuation customers and to low-valuation customers on the spot. Regret reinforces this equilibrium in cases 2 and 3, but affects profit only in the latter by decreasing advance wtp. In case 1, however, action regret makes high-valuation customers wait, so the firm sells to them at higher prices on the spot, while low-valuation buyers get a discount in advance. This separating equilibrium extracts the maximum profit potential from the market because it makes high-valuation customers pay more by delaying purchase, here, because they regret buying.<sup>10</sup> This segmentation can also emerge if low-valuation customers regret inactions (case 4), but then a higher  $\gamma < 0$  hurts the firm because it *reduces* differentiation between segments and hence the prevalence of this more profitable, separating equilibrium.

These results suggest that it is important for firms to understand how regret varies across market segments to manage its effect on profits. Organizations such as INFORMS, airlines, and tour operators

<sup>9</sup> The firm also benefits from a larger share  $\alpha$  of regretful customers because they have higher valuation.

<sup>10</sup> This segmentation occurs also in the absence of regret, e.g., if low-valuation customers are myopic (see Su 2007).

may actually benefit from consumers' regret if high-valuation buyers regret more. In these settings, firms are advised not to offer such regret-mitigating mechanisms as refunds, options, or allowing resale markets.

## 7. Conclusions

In this paper we developed a model in which strategic customers anticipate regret when deciding whether to advance purchase while uncertain about their true valuations. Our results provided answers to the three questions raised in the Introduction, as follows:

(1) We showed that the purchase behavior of regret-averse consumers with uncertain valuations is characterized by a single regret parameter,  $\gamma$ , which measures the relative strength of action and inaction regrets. Our model explains two behavioral regularities observed in buy-or-wait contexts: inertia (delayed purchase) and frenzies (buying in advance at negative surplus).

(2) We characterized the effect of regret on the firm's policies and profits and identified a normative threshold above which regret changes the structure of optimal sales policies. In general, we found that action regret reduces the benefits and prevalence of advance selling and booking limit policies, which leads to lower advance prices, booking limits, and profits for a price-setting firm. Inaction regret has the opposite effect. When it is dominant, firms can create frenzies by advance selling at high prices even in the absence of capacity constraints. These effects are diminished by capacity constraints, and can be reversed if the firm faces price pressure in the advance period or if regretful buyers have higher valuations. Differences in regret trigger premium advance selling by capacitated firms, which may actually benefit from larger shares of regretful buyers.

(3) Finally, we showed when and how firms should leverage or mitigate regrets. Our results explain the profitability of marketing campaigns that induce inaction regret (e.g., advertising of the "buy now or regret later" type, emphasizing a potentially forgone discount or a limited offer) for firms with full price flexibility. Such practices may not be beneficial for firms such as airlines, which face price pressure in advance, or if high-valuation buyers regret more. On the other hand, we showed how firms can recover a large fraction of the profit lost to action regret by selling in advance with partial refunds, offering options, or allowing resales. Our results offer a new explanation for the profitability of these practices: They mitigate regret. Finally, our results underline the importance of understanding the relative strength of anticipated regrets,  $\gamma$ , within and across market segments as well as the type of uncertainty underlying customer valuations.

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## Appendix. Proofs

The following properties of  $R(x) \triangleq E[\mathbf{v} - x]^-$  will be useful throughout our analysis.

LEMMA 2. (a)  $R(x) \leq 0$  is decreasing concave in  $x$ ; in particular, if  $F$  is continuous then  $R'(x) = -F(x)$ . (b)  $x + R(x)$  is increasing concave in  $x$ . (c)  $0 \leq x\bar{F}(x) \leq x + R(x) \leq \mu$  for all  $x \geq 0$ .

PROOF. Part (a) follows because  $(v - x)^-$  is decreasing and concave in  $x$ , and expectation preserves monotonicity and concavity. The derivative follows from Leibniz's rule. Parts (b) and (c) follow by writing  $x + R(x) = E[\min(\mathbf{v}, x)]$ , which is increasing and concave in  $x$ , and moreover  $\mu = E[\mathbf{v}] \geq E[\min(\mathbf{v}, x)] = x\bar{F}(x) + E[\mathbf{v} | \mathbf{v} < x]F(x) \geq x\bar{F}(x)$ .  $\square$

PROOF OF LEMMA 1. By (3) we can write

$$\bar{\gamma}(p_1, p_2, k) = -\frac{\mu - p_1 - kE[\mathbf{v} - p_2]^+}{E[\mathbf{v} - p_1]^- + k(E[\min(\mathbf{v}, p_2) - p_1]^- - E[\mathbf{v} - p_1]^-)}.$$

Writing  $E[\mathbf{v} - p_2]^+ = E[\mathbf{v}] - E[\min(\mathbf{v}, p_2)] = \mu - p_2 - R(p_2)$  gives the numerator in (4). We can then use  $E[\min(\mathbf{v}, p_2) - p_1]^- = E[\min(\mathbf{v}, p_2, p_1)] - p_1$  to write  $E[\mathbf{v} - p_1]^- - E[\min(\mathbf{v}, p_2) - p_1]^- = E[\min(\mathbf{v}, p_1)] - E[\min(\mathbf{v}, p_2, p_1)] = p_1 + R(p_1) - (p_2 + R(p_2))$  if  $p_1 > p_2$  (and equals zero otherwise). Because  $x + R(x)$  is increasing by Lemma 2(b), this gives the desired expression for the denominator. To show monotonicity, after some algebra we can write

$$\bar{\gamma}(p_1, p_2, k) = \frac{(1-k)E[\mathbf{v} - p_1]^+ + kE[\min(\mathbf{v}, p_2) - p_1]^+}{-(1-k)E[\mathbf{v} - p_1]^- - kE[\min(\mathbf{v}, p_2) - p_1]^-} - 1.$$

It is easy to see that both numerator and denominator are positive. The numerator is decreasing in  $k$  and  $p_1$  and increasing in  $p_2$ , and vice versa for the denominator. This gives the desired result.  $\square$

PROOF OF PROPOSITION 1.

(a) Suppose  $d = p_1/p_2 \leq \bar{F}(p_2)$  (i.e.,  $p_1 \leq p_2\bar{F}(p_2)$ ). Then the firm obtains higher profits if customers wait. In other words,  $\Delta S < 0$  or, equivalently,  $\gamma > -\Delta S(0; p_1, p_2)/R(p_1)$ . The result then follows because  $\gamma$  is increasing in  $\rho$  and decreasing in  $\delta$ . The other part is proved similarly.

(b) Suppose the spot price  $p_2$  is fixed. The maximum price that induces consumers to advance purchase is  $w(\gamma; p_2)$ , which solves  $\Delta S = 0$  and hence is decreasing in  $\gamma$  (see (3)). Therefore, so is the optimal profit  $\pi^*(\gamma; p_2) = \max\{w(\gamma; p_2), p_2\bar{F}(p_2)\}$ .

Consider now the case where the advance price  $p_1$  is exogenously fixed. Assume that  $p_1 \leq \bar{w}(\gamma)$ , for otherwise advance selling at  $p_1$  is not feasible (all consumers wait, and the firm spot sells at  $p_0$  with profit,  $\bar{\pi}$ , independent of  $\gamma$ ).

The spot price that makes customers indifferent between buying early and waiting,  $p_2(\gamma)$ , solves (4) and by Lemma 1 increases in  $\gamma$ . The optimal spot selling profit is  $\bar{\pi}$  if  $p_0 \leq p_2(\gamma)$  and is  $p_2(\gamma)\bar{F}(p_2(\gamma))$  otherwise. Alternatively, advance selling fetches profit  $p_1$ . If  $p_0 \leq p_2(\gamma)$ , optimal profit is  $\pi^* = \max(p_1, \bar{\pi})$ , independent of  $\gamma$ . On the other hand, if  $p_0 > p_2(\gamma)$ , optimal profit is  $\pi^* = \max(p_1, p_2(\gamma)\bar{F}(p_2(\gamma)))$ . This increases in  $\gamma$  because  $p\bar{F}(p)$  is unimodal, and so it increases to the left of  $p_0$ .  $\square$

**PROOF OF PROPOSITION 2.** The proof follows the logic in the text and is omitted for conciseness.  $\square$

**PROOF OF PROPOSITION 3.** We first show that the firm cannot extract more than  $\bar{w}(\gamma)$  in advance by exploiting consumer regret and the threat of rationing risk. Given a spot price  $p_2$ , consumers' ex ante wtp,  $w(\gamma; p_2, C)$ , solves  $\Delta S = 0$  (Equation (3)) and it is unique because  $\Delta S$  is strictly decreasing in  $p_1$ , nonnegative at  $p_1 = 0$  (because  $\mu - kE[\mathbf{v} - p_2]^+ \geq 0$ ), and negative at sufficiently high  $p_1$ . Consider first the case  $w = w(\gamma; p_2, C) \leq p_2$ . Then, by (3),  $w = p_1$  solves  $\mu - p_1 + \gamma E[\mathbf{v} - p_1] = kE[\mathbf{v} - p_2]^+$ . The LHS is strictly decreasing in  $p_1$ , so  $w$  is maximized by setting  $p_2 > v_{\max}$ ; this yields  $w = \bar{w}(\gamma)$ . It remains to show that the firm cannot extract more than  $\bar{w}(\gamma)$  by advance selling at a premium (i.e., if  $w \geq p_2$ ). In this case, by (3)  $w$  solves  $\mu - p_1 + \gamma E[\mathbf{v} - p_1] = kE[\mathbf{v} - p_2]^+ + \gamma kE[\min(\mathbf{v}, p_1) - p_2]^+$ , whose solution cannot exceed  $\bar{w}(\gamma)$  because the RHS is always positive. We conclude that  $\max_{p_2} w(\gamma; p_2, C) = \bar{w}(\gamma)$ .

For any pricing policy, all customers either advance purchase or wait. By selling exclusively in advance at  $\bar{w}(\gamma)$ , the firm obtains  $\pi = C\bar{w}(\gamma)$ . The optimal spot selling strategy solves  $\max\{p\bar{F}(p); \bar{F}(p) \leq C\}$ . Because  $p\bar{F}(p)$  is unimodal, it follows that the profit-maximizing spot price is  $\max(p_0, \bar{F}^{-1}(C))$  and the optimal profit is  $C\bar{\pi}_C$ . The optimal policy follows by comparing optimal advance and spot selling profits;  $\bar{\gamma}(C)$  is the regret threshold that makes the firm indifferent between the two, solving  $\bar{w}(\gamma) = \bar{\pi}_C$  (i.e.,  $\mu - \bar{\pi}_C + \gamma R(\bar{\pi}_C) = 0$ ), which gives the desired result.

The optimal profit  $\pi^*(C) = \max(C\bar{w}(\gamma), C\bar{\pi}_C)$  increases in  $C$  because  $C\bar{w}(\gamma)$  and  $C\bar{\pi}_C$  both increase in  $C$ . The latter follows because, for  $C > \bar{F}(p_0)$ ,  $C\bar{\pi}_C = \bar{\pi}$  is independent of  $C$  and otherwise  $C\bar{\pi}_C = C\bar{F}^{-1}(C)$ , which is increasing in  $C$  because, by the unimodality assumption,  $p\bar{F}(p)$  is increasing to the left of  $p_0$ . Finally, because  $\bar{\pi}_C$  is decreasing in  $C$  and  $R(x)$  is negative and decreasing in  $x$  (Lemma 2), it follows that  $\bar{\gamma}(C) = (\mu - \bar{\pi}_C)/R(\bar{\pi}_C)$  is increasing in  $C$ .  $\square$

**PROOF OF PROPOSITION 4.** We first characterize the policy for a two-point distribution and then for the continuous distribution case.

**LEMMA 3.** Suppose that  $\mathbf{v} = (H, q; L, 1 - q)$ . If  $C \leq q$  or if  $C > q$  and  $\gamma > L/(Hq - L) > 0$ , then the firm only spot sells at  $p_2 = H$ . Otherwise, the optimal policy is to sell in advance at  $p_1 = \bar{w}(\gamma)$  with a booking limit  $B = (C - q)/(1 - q)$  and on the spot at  $p_2 = H$ .

**PROOF OF LEMMA 3.** For a given policy  $(p_1, p_2)$ , customers' wtp in advance,  $w(\gamma; p_2, k(p_2, B))$ , solves (3) with  $k = k(p_2, B)$ . For  $p_2 = H$ , (3) gives  $w(\gamma; H, k(H, B)) = \bar{w}(\gamma) = L + q(H - L)/(1 + \gamma(1 - q))$ . For  $p_2 = L$ , (3) simplifies to  $\mu - p -$

$kE[\mathbf{v} - L]^+ + \gamma((1 - k)E[\mathbf{v} - p]^- + k(L - p)^-) = 0$ . Solving this expression for  $p$  gives  $w(\gamma; L, k(L, B)) = L + q(1 - k)(H - L)/(1 + \gamma(1 - q(1 - k))) \leq \bar{w}(\gamma)$ . So, for a booking limit  $B$ , the maximum price to induce advance purchasing is  $\bar{w}(\gamma) = L + q(H - L)/(1 + \gamma(1 - q))$ , which corresponds to  $p_2 = H$ . In particular, premium advance selling (PAS) is dominated by advance selling only (AS) at  $\bar{w}(\gamma)$ , which yields  $\pi_{AS} = C\bar{w}(\gamma)$ . In contrast, pure spot selling (SS) at  $p_2 = H$  or  $p_2 = L$  yields  $\pi_{SS} = \max(qH, CL)$ .

Obviously, if  $C \leq q$ , the firm sells only on the spot at  $p_2 = H$ , which yields  $\pi^* = CH$ . For  $C > q$ , discount advance selling (DAS) with booking limits can be optimal. In this case,  $p_2 = H$  and  $p_1 = w(\gamma; H, k(H, B)) = \bar{w}(\gamma)$ . The profit is then  $\pi_B = B\bar{w}(\gamma) + \min(C - B, (1 - B)q)H$ . It is now easy to verify that, if  $\gamma > L/(Hq - L) > 0$ , then  $B = 0$  and  $\pi_B = qH$  (i.e., SS at  $p_2 = H$ ); otherwise,  $B = (C - q)/(1 - q)$  and  $\pi_B = ((C - q)/(1 - q))\bar{w}(\gamma) + q(1 - C)/(1 - q)H$ . The result follows by comparing profits case by case.  $\square$

We proceed to prove the result for log-concave distributions. Similar to our approach for two-point distributions, we show that PAS policies are suboptimal and so the optimal policy is spot sell or DAS. Advance selling is a special case of DAS with  $B = C$ .

To implement a PAS policy, there must be a positive rationing probability on the spot; that is,  $k(p_2, B) = (C - B)/((1 - B)\bar{F}(p_2)) < 1$ . Otherwise, customers facing a markdown policy will wait. Hence, from (3) we obtain

$$\mu - p_1 - kE[\mathbf{v} - p_2]^+ - \frac{\gamma}{1 + \gamma}(1 - k)E[\mathbf{v} - p_1]^+ = 0. \quad (10)$$

The profit under a PAS policy is  $\pi = p_1B + (C - B)p_2$ , which means that such a policy clears the capacity over two periods. We next show that  $\pi$  is increasing in  $B$  and hence  $B = C$  at optimality, implying that AS is more profitable. Indeed, for a given  $p_2$ , because  $p_1 > p_2$  implicit differentiation on (10) gives

$$\frac{\partial p_1}{\partial B} = \frac{1 - C}{(1 - B)^2\bar{F}(p_2)} \frac{(1 + \gamma)E[\mathbf{v} - p_2]^+ - \gamma E[\mathbf{v} - p_1]^+}{1 + \gamma + \gamma(1 - k)\bar{F}(p_1)} > 0.$$

Therefore,  $\pi$  increases in  $B$  and  $B = C$  at optimality. Substituting  $k = 0$  into (10), the optimal advance price solves  $\mu - p_1 - (\gamma/(1 + \gamma))E[\mathbf{v} - p_1]^+ = 0$ , or  $p_1 = \bar{w}(\gamma)$ . The optimal profit is  $\pi = C\bar{w}(\gamma)$ .

Next, we investigate DAS policies (i.e.,  $p_1 < p_2$ ). Under an optimal DAS policy the firm must clear the capacity over two periods, i.e.,  $k \leq 1$  or  $C - B \leq (1 - B)\bar{F}(p_2)$ . To see this, assume the contrary. The profit function is then  $\pi = p_1B + (1 - B)\bar{F}(p_2)p_2$ . It follows that  $p_1 = p_2\bar{F}(p_2)$  at optimality, for otherwise the firm could do better by adjusting the booking limit without violating the constraint. For  $p_1 = p_2\bar{F}(p_2)$  the objective function becomes  $\pi = p_2\bar{F}(p_2)$ , which must be optimized subject to  $\Delta S = 0$  or  $\mu - p_1 + \gamma R(p_1) = E[\mathbf{v} - p_2]^+$ . The solution to this problem is always dominated by an SS policy.

When  $k \leq 1$ , the profit function is  $\pi = p_1B + (C - B)p_2$  and the optimal DAS policy solves

$$\max_{p_1, p_2, B} \pi = p_1B + (C - B)p_2, \quad (11)$$

$$C - B \leq (1 - B)\bar{F}(p_2), \quad (12)$$

$$\mu - p_1 + \gamma R(p_1) = \frac{C - B}{(1 - B)\bar{F}(p_2)} E[\mathbf{v} - p_2]^+. \quad (13)$$



Because  $\mathbf{v}$  is log-concave,  $E[\mathbf{v} - p_2]^+ / \bar{F}(p_2)$  is decreasing (see Lemma 2 in Bagnoli and Bergstrom 2005). It follows that, at optimality, equality holds in (12), i.e.,  $B = (C - \bar{F}(p_2)) / F(p_2)$  or  $k = 1$ . Otherwise, the firm could achieve higher profit for the same  $B$  by increasing  $p_2$ , which would result in a higher value of  $p_1$  because the LHS of (13) is decreasing in  $p_1$ , which is a contradiction.

From (13) we have  $p_1 = w(\gamma; p_2)$ . We can therefore simplify the optimization problem (11) to the following unconstrained optimization problem:  $\max_{p_2} \pi = (w(\gamma; p_2) - p_2) \cdot (C - \bar{F}(p_2)) / F(p_2) + Cp_2$ . To show that the optimal booking limit decreases in  $\gamma$ , it suffices to show that  $\pi$  is submodular in  $(\gamma, p_2)$ . This is indeed the case because  $\partial B / \partial p_2 = (1 - C)(f(p_2) / [F(p_2)]^2) > 0$ ,  $\partial p_1 / \partial p_2 = \bar{F}(p_2) / (1 + \gamma F(p_1)) > 0$ , and

$$\begin{aligned} \frac{\partial^2 \pi}{\partial \gamma \partial p_2} &= \frac{\partial}{\partial p_2} \frac{\partial p_1}{\partial \gamma} B + \frac{\partial p_1}{\partial \gamma} \frac{\partial B}{\partial p_2} \\ &= \frac{\partial p_1 - F(p_1)(1 + \gamma F(p_1)) - \gamma R(p_1)f(p_1)}{\partial p_2 (1 + \gamma F(p_1))^2} B \\ &\quad + (1 - C) \frac{R(p_1)}{1 + \gamma F(p_1)} \frac{f(p_2)}{[F(p_2)]^2} < 0. \end{aligned}$$

This always holds for  $\gamma < 0$ . On the other hand, because  $f$  is log-concave, so is  $-R(p_1) = \int_0^{p_1} F(t) dt$  (Bagnoli and Bergstrom 2005); that is,  $\partial \log(-R(p_1)) / \partial p_1 = F(p_1) / (-R(p_1))$  is decreasing or  $F^2(p_1) + f(p_1)R(p_1) > 0$ . Hence the first term is negative for  $\gamma \geq 0$  and so the optimal  $B, p_1, p_2$  all decrease in  $\gamma$ . This implies the existence of the threshold  $\bar{\gamma}_B(C)$  that exceeds  $\bar{\gamma}(C)$ . Indeed, if it is optimal to spot sell when booking limits are allowed then it is also optimal to do so when they are not allowed.  $\square$

**PROOF OF PROPOSITION 5.** We first show that  $\bar{w}(\gamma; r)$  is increasing in  $r$  and decreasing in  $\gamma$ . These claims follow by differentiating the characteristic equation of  $\bar{w}(\gamma; r)$ ,

$$\mu - p + \gamma R(p) = (1 + \gamma)R(r), \quad (14)$$

and using  $R'(x) = -F(x)$ , from Lemma 2(a), as follows:

$$\frac{\partial}{\partial r} \bar{w}(\gamma; r) = \frac{(1 + \gamma)F(r)}{1 + \gamma F(\bar{w}(\gamma; r))} \geq 0; \quad (15)$$

$$\frac{\partial}{\partial \gamma} \bar{w}(\gamma; r) = \frac{R(\bar{w}(\gamma; r)) - R(r)}{1 + \gamma F(\bar{w}(\gamma; r))} \leq 0. \quad (16)$$

The last inequality holds because  $\bar{w}(\gamma; r) \geq r$  and  $R$  is decreasing.

The optimal solution, if it is interior, satisfies the first-order condition with respect to  $r$  on  $\pi_s(\gamma; r) = \bar{w}(\gamma; r) - (r - s)F(r)$ ; this gives precisely (9). Note that the optimal solution  $(r^*, p^*)$  may not be unique, but this does not affect our insights. For valuation distributions of practical interest, such as uniforms and exponentials, one can show that  $\pi_s(\gamma; r)$  is unimodal, implying uniqueness.

To rule out boundary solutions, we first argue that full refunds are not optimal (i.e.,  $r^* < p^*$ ). Indeed, if  $r^* = p^*$ , substituting into (14) yields  $\mu - r^* \bar{F}(r^*) = E[\mathbf{v} - r^*]^+ = 0$ , implying that  $r^* = p^* = v_{\max}$ . This policy yields zero profit and so cannot be optimal. Furthermore,  $r^* > 0$  because  $\pi_s(\gamma; r = 0) = \bar{w}(\gamma) < \pi_s(\gamma; r = s) = \bar{w}(\gamma; s)$ . The inequality holds because  $\bar{w}(\gamma; s)$  solves (14), the LHS of which is decreasing in  $p$ .

To show that  $r^*(\gamma)$  is increasing in  $\gamma$ , it suffices to show that  $\pi(\gamma, r) = \bar{w}(\gamma; r) - (r - s)F(r)$  is supermodular in  $(\gamma, r)$ . This follows from (15) once we write

$$\begin{aligned} \frac{\partial \pi^2}{\partial r \partial \gamma} &= \frac{\partial}{\partial \gamma} \frac{\partial \bar{w}(\gamma; r)}{\partial r} = \frac{F(r)}{(1 + \gamma F(\bar{w}))^2} \\ &\quad \cdot \left( 1 - F(\bar{w}) - (1 + \gamma) \gamma f(\bar{w}) \frac{\partial \bar{w}(\gamma; r)}{\partial \gamma} \right) \geq 0 \end{aligned} \quad (17)$$

for all  $\gamma \geq 0$ , because  $p(\gamma; r)$  is decreasing in  $\gamma$  by (16).

Writing (9) as  $(r - s)f(r)/F(r) = \gamma \bar{F}(\bar{w}) / (1 + \gamma F(\bar{w}))$  shows that  $r^*(\gamma = 0) = s$  and that  $r^*(\gamma) > s$  for  $\gamma > 0$ .

Finally, because  $\bar{w}(\gamma; r)$  is decreasing in  $\gamma$ , so is  $\pi^*(\gamma) = \max_r \bar{w}(\gamma; r) - (r - s)F(r)$ . The reason is that the maximum of decreasing functions is decreasing.  $\square$

**Full Refunds vs. No Refunds.** For a full-refund policy, the objective function is  $\pi(r; s) = (r - s)\bar{F}(r)$  (see (8)), which is the profit from a pure spot selling policy. The optimal profit is then  $\pi^*(s) = (r^*(s) - s)\bar{F}(r^*(s))$ . The optimal profit *without* a refund policy is  $\bar{w}(\gamma) - s$ , where  $\bar{w}(\gamma)$  is as defined in (6). Full refunds dominate no refunds whenever  $\pi^*(s) \geq \bar{w}(\gamma) - s$ . In particular, this is true if  $\pi^*(s) - s \geq \mu$  because  $\bar{w}(\gamma) \leq \mu$ . Note that the function  $s + \pi^*(s)$  is increasing in  $s$  because its derivative is  $F(r^*(s))$ . We can therefore uniquely define  $\bar{s}$  such that  $\bar{s} + \pi^*(\bar{s}) = \mu$  and  $s + \pi^*(s) \geq \mu \geq \bar{w}(\gamma)$  for all  $s \geq \bar{s}$ . In this case, full refunds dominate no refunds irrespective of regret. Otherwise, for any  $s \leq \bar{s}$ , the expression  $\pi^*(s) + s = \bar{w}(\gamma)$  defines the threshold on  $\gamma$  above which full refunds dominate.

**PROOF OF PROPOSITION 6.** The firm optimizes the option price  $x$ , exercise price  $r$ , and number of options to sell  $X$  by solving

$$\begin{aligned} \max_{X, x, r} \quad & X(x + r\bar{F}(r)) \\ \text{s.t.} \quad & X \leq 1, \\ & X\bar{F}(r) \leq C, \\ & \mu - (x + r) + \gamma R(x + r) - (1 + \gamma)R(r) = 0. \end{aligned} \quad (18)$$

Define  $x(\gamma; r)$  to solve the last equation, so that  $x(\gamma; r) = \bar{w}(\gamma; r) - r$  (where  $\bar{w}(\gamma; r)$  solves (14)). From (15) and (16) it now follows that  $x(\gamma; r)$  is decreasing in  $r$  and  $\gamma$ .

Clearly, at optimality we have  $X = \min(1, C/\bar{F}(r))$ . If  $r \leq r(C) = \min\{r \geq 0: \bar{F}(r) \leq C\}$ , the objective is  $\pi_C(r) = C(x(\gamma; r)/\bar{F}(r) + r)$ . This is increasing and so, over  $r \leq r(C)$ , this objective is maximized at  $r(C)$  because

$$\begin{aligned} \pi'_C(r) &= 1 + \frac{1}{\bar{F}(r)} \frac{\partial x}{\partial r} + \frac{xf(r)}{(\bar{F}(r))^2} \\ &= \frac{F(r)}{\bar{F}(r)} \frac{\gamma \bar{F}(x + r)}{1 + \gamma F(x + r)} + \frac{xf(r)}{(\bar{F}(r))^2} \geq 0. \end{aligned}$$

Therefore, at optimality,  $X = 1$  and the problem reduces to  $\max\{\pi(r) = x(\gamma; r) + r\bar{F}(r); r \geq r(C)\}$ . The optimal profit decreases in  $\gamma$  because  $x(r; \gamma)$  does.

For  $C < 1$ , we have  $r(C) > 0$  and so the optimal solution is  $r^*(\gamma) > 0$ . For  $C = 1$ , we have  $r(C) = 0$ , so the problem is unconstrained. Observe that  $\pi(r)$  is decreasing in  $r$  for  $\gamma \leq 0$



because  $\pi'(r) = \gamma \bar{F}(x(\gamma; r) + r)F(r)/(1 + \gamma F(x(\gamma; r) + r)) - rf(r)$ ; hence  $r^*(\gamma) = 0$ . So, in the absence of capacity constraints, the firm only advance sells to consumers who regret inactions (more than actions). For sufficiently large  $\gamma > 0$  such that  $\gamma(1 - 2F(\bar{w}(\gamma))) > 1$ , the second-order condition at zero ensures that  $r = 0$  is suboptimal and so  $r^*(\gamma) > 0$ .

To show that  $r^*(\gamma)$  increases in  $\gamma$ , it suffices to show that  $\pi(r)$  is supermodular in  $(\gamma, r)$ . Indeed, using  $(\partial/\partial r)x(\gamma; r) = (1 + \gamma)F(r)/(1 + \gamma F(x + r)) - 1 \leq 0$  and because  $R(x)$  decreases in  $x$ , we have

$$\frac{\partial^2}{\partial \gamma \partial r}(x(\gamma; r) - r\bar{F}(r)) = F(r)\bar{F}(x + r) - \gamma(R(x + r) - R(r)) \cdot f(x + r) \left(1 + \frac{\partial x}{\partial r}\right) > 0.$$

Finally, we argue that  $x(\gamma; r^*) > 0$ , in other words, that spot selling is suboptimal. For this it suffices to show that  $\bar{w}(\gamma; r) > r$  at  $r^*$ . Because the LHS of (14) is decreasing, this inequality amounts to  $\mu - r + \gamma R(r) > (1 + \gamma)R(r)$  or, equivalently,  $\mu > E[\min(v, r)]$ , which holds whenever  $r < v_{\max}$ . But  $x^* = 0$ ,  $r^* = v_{\max}$  cannot be optimal, which concludes the proof.  $\square$

**PROOF OF PROPOSITION 7.** Because  $\mathbf{w} = \max(\mathbf{v}, \mathbf{s})$ , it follows that  $F_{\mathbf{w}} = F_{\mathbf{s}}F_{\mathbf{v}}$  and 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)  $R_{\mathbf{v}}(p) \leq R_{\mathbf{w}}(p)$ . Parts (a) and (b) are immediate from (i) and (iii), respectively. Part (c) follows because  $\pi_{\mathbf{v}}^*(\gamma) = \max(\bar{w}_{\mathbf{v}}(\gamma), \bar{\pi}_{\mathbf{v}}(\gamma)) \leq \max(\bar{w}_{\mathbf{w}}(\gamma), \bar{\pi}_{\mathbf{w}}(\gamma)) = \pi_{\mathbf{w}}^*(\gamma)$ .  $\square$

**PROOF OF PROPOSITION 8.** Define  $C_0 = 1 - \alpha$ . For  $C \leq C_0$ , sales can occur in only one period. The optimal policy in this case is: (1) if  $C \leq q$ , spot selling at  $p_2 = H$  and  $\pi = CH$ ; (2) if  $q < C \leq q(H/\mu)$ , spot selling at  $p_2 = H$  and  $\pi = qH$ ; or (3) if  $C > q(H/\mu)$ , advance selling at  $p_1 = \mu$  and  $\pi = C\mu$ .

If  $C > C_0$ , the firm can implement one of the following four strategies:

**Pure advance selling (AS).** The firm can offer the product at  $p_1 = \bar{w}(\gamma) = (\mu + \gamma(1 - q)L)/(1 + \gamma(1 - q))$  at which all customers are willing to buy and thus earn a profit of  $\pi_{AS} \triangleq C(\mu + \gamma(1 - q)L)/(1 + \gamma(1 - q))$ . Alternatively, the firm can charge  $p_1 = \mu$ , a price at which only nonregretful customers buy for a profit of  $\pi = (1 - \alpha)\mu$ . We will show that this is never optimal, however.

**Pure spot selling (SS).** It is straightforward to verify that (1) if  $C \leq q$ , then  $p_2 = H$  and  $\pi = CH$ ; (2) if  $q < C \leq q(H/L)$ , then  $p_2 = H$  and  $\pi = qH$ ; and (3) if  $C > q(H/L)$ , then  $p_2 = L$  and  $\pi = CL$ .

**Premium advance selling (PAS).** This policy is implementable only if  $C > C_0$ , so that sales can happen in both periods. In this case,  $p_2 = L$  and  $p_1 = w(p_2 = L, \gamma = 0, k = (C - (1 - \alpha))/\alpha)$ ; that is,  $\mu - p_1 = ((C - (1 - \alpha))/\alpha)(\mu - L)$  or  $p_1 = L + (\mu - L)((1 - C)/\alpha)$ . The profit is then  $\pi_{PAS} \triangleq ((1 - \alpha)/\alpha)(\mu - L)(1 - C) + CL$ .

**Discount advance selling (DAS).** This policy, too, is implementable only if  $C > C_0$ , so that sales can happen in both periods. In this case, however, the optimal prices are  $p_2 = H$  and  $p_1 = \mu$  and the profit is  $\pi = \mu(1 - \alpha) + H \min(C - (1 - \alpha), \alpha q)$ .

In sum, the optimal policy (for  $C > C_0$ ) follows by comparing the optimal profits from the policies just described.

First, if  $C_0 < C \leq (1 - \alpha) + \alpha q = C_5$  then DAS yields  $\pi = \mu(1 - \alpha) + H(C - (1 - \alpha))$ , which dominates AS and PAS. Therefore, the optimal policy is SS at  $p_2 = H$  if  $C < C_4 = q + (1 - \alpha)(H - \mu)/H$  and is DAS otherwise. Second, if  $C > C_5 = (1 - \alpha) + \alpha q$  DAS yields  $\pi_{DAS} \triangleq \mu(1 - \alpha) + qH\alpha = \mu - \alpha(1 - q)L$ . This dominates SS at  $p_2 = H$  and AS at  $\mu$ , which yields  $\pi = (1 - \alpha)\mu$ . Therefore, we need only compare AS at  $\bar{w}(\gamma)$ , DAS, and PAS (note that SS at  $p_2 = L$  is dominated by AS at  $\bar{w}(\gamma)$ ). The following thresholds emerge from comparing the corresponding profits  $\pi_{AS}$ ,  $\pi_{DAS}$ , and  $\pi_{PAS}$ :

- $C_1(\gamma) = (\mu - L)(1 - \alpha)/(\mu - L + \alpha(\bar{w}(\gamma) - \mu)) = 1 - \alpha/(1 + \gamma(1 - \alpha)(1 - q))$  results from  $\pi_{AS} = \pi_{PAS}$ . In particular,  $C_1$  is decreasing in  $\alpha$  and increasing in  $\gamma$ . The points where  $C_1$  crosses the box boundaries in the figure are  $C_1(\alpha = 1) = 0$  and  $C_1(\alpha = 0) = 1$ .

- $C_2(\gamma) = \mu - \alpha(1 - q)L/\bar{w}(\gamma) = (1 + \gamma(1 - q))(\mu - \alpha(1 - q)L/(\mu + \gamma(1 - q)L))$ , follows from  $\pi_{DAS} = \pi_{AS}$ . In particular,  $C_2$  is increasing in  $\gamma$ ,  $C_2(\alpha = 1) = qH/\bar{w}(\gamma)$ , and  $C_2 = 1$  for  $\bar{\alpha}_2 = (\gamma/(1 + \gamma(1 - q)))(\mu/L - 1)$ .

- $C_3 = 1 - \alpha + \alpha^2 qH/(L - (1 - \alpha)\mu) = 1 - \alpha(L + \alpha(1 - q)L - \mu)/(L - (1 - \alpha)\mu)$  by setting  $\pi_{PAS} = \pi_{DAS}$ . This equation has no solution for  $\alpha = 1 - L/\mu$ , but this is not relevant for  $\alpha < 1 - L/\mu$  because  $C_3 \leq C_5$  (with equality at  $\alpha = 0$  and  $\alpha = -q/(1 - q) < 0$ ). For  $\alpha > 1 - L/\mu$  we have  $C_3 > C_5$ ; in particular,  $C_3 = 1$  for  $\bar{\alpha}_3 = (\mu/L - 1)/(1 - q) > \bar{\alpha}_2$  and  $C_3 = qH/L > C_2$  at  $\alpha = 1$ .

By definition, if  $C_1(\gamma)$ ,  $C_2(\gamma)$ , and  $C_3$  intersect then they do so at the same two points that satisfy  $\pi_{AS} = \pi_{DAS} = \pi_{PAS}$ ; these points identify the area for premium advance selling. Because both  $C_1$  and  $C_2$  are increasing in  $\gamma$ , this area (if it exists) expands with  $\gamma$ . PAS is optimal for  $\alpha \in [\alpha_1, \alpha_2]$ , where  $\alpha_{1,2}$  solve  $C_1(\gamma) = C_2(\gamma)$  or, equivalently,

$$L(1 - q)(\mu - \bar{w}(\gamma))\alpha^2 - [(2\mu - L)(\mu - \bar{w}(\gamma)) - (\mu - (1 - q)L)(\mu - L)]\alpha + (\mu - \bar{w}(\gamma))(\mu - L) = 0.$$

For  $\gamma = 0$ , this expression implies that  $\alpha = 0$ . Otherwise, we can use  $\mu - \bar{w}(\gamma) = (\mu - L)/(1 + 1/(\gamma(1 - q)))$  to rewrite it as

$$L(1 - q)\alpha^2 - \left(\mu - qL - \frac{\mu - (1 - q)L}{\gamma(1 - q)}\right)\alpha + \mu - L = 0. \quad (19)$$

A necessary and sufficient condition for PAS is that (19) admit solutions in  $[0, 1]$ . A necessary condition is that  $\alpha_1\alpha_2 = (\mu - L)/(L(1 - q)) \in [0, 1]$ , or  $qH \leq L$ . Furthermore, both roots must be positive, i.e.,  $\alpha_1 + \alpha_2 \geq 0$  or, equivalently,  $\gamma \geq (\mu - (1 - q)L)/((1 - q)(\mu - qL))$ . Because  $(1 - \alpha_1)(1 - \alpha_2) = qH/(\gamma(1 - q)^2L) > 0$ , the preceding conditions guarantee that, if (19) has real roots, then both are in  $[0, 1]$ .

It remains to determine the conditions under which (19) has real roots. The discriminant can be written as  $[\mu - qL - (\mu - (1 - q)L)/\gamma(1 - q)]^2 - 4(\mu - L)(1 - q)L$ . This is nonnegative for  $\gamma \geq (\mu - (1 - q)L)/((1 - q)(\mu - qL))$  if and only if  $\mu - qL - (\mu - (1 - q)L)/\gamma(1 - q) \geq 2\sqrt{(\mu - L)(1 - q)L}$ , i.e., whenever  $\gamma \geq (\mu - (1 - q)L)/[(1 - q) \cdot (\mu - qL - 2\sqrt{(\mu - L)(1 - q)L})] \triangleq \tilde{\gamma}(L, H, q)$ . This expression identifies the bound on  $\gamma$  in the proposition, which together with  $qH \leq L$  ensures that PAS occurs for  $\alpha$  in between  $\alpha_{1,2}(\gamma)$  that solve (19).

The optimal profit is decreasing in  $\gamma$  because it is the maximum of functions that are decreasing in  $\gamma$ ; likewise, it is increasing in  $C$ . We have argued in the text why the optimal profit is nonmonotonic in  $\alpha$  when  $C < 1$ ; indeed,  $\pi = CH - (1 - \alpha)(H - \mu)$  is increasing in  $\alpha$  for  $C_4 < C < C_5$  (DAS).

This concludes the proof of the proposition. We now prove the statements following Proposition 8 that concern the uncapacitated case  $C = 1$  and the effect of booking limits.  $\square$

**Uncapacitated Case.** For  $C = 1$ , the optimal policy is either DAS ( $p_1 = \mu$  and  $p_2 = H$ ) or exclusively advance sell at  $\bar{w}(\gamma)$ , and the optimal profit is  $\max(\bar{w}(\gamma), (1 - \alpha)\mu + \alpha qH)$ . Therefore, profits are decreasing in  $\gamma$  and in the share of the regretful customers  $\alpha$ . In Figure 3,  $C_2(\gamma)$  intersects with  $C = 1$  at  $\alpha = (\mu - \bar{w}(\gamma))/(\mu - qH)$ , which is decreasing in  $\gamma$ . Therefore, above a threshold, the firm segments the market based on regret: selling to nonregretful buyers in advance and to regretful ones on the spot.

**Booking Limits.** We finally discuss the effect of booking limits on the optimal policy in heterogeneous markets. It is easy to observe that booking limits affect only optimal DAS policies. Sales can occur in two periods under a DAS policy: at  $(p_1 = \mu, p_2 = H)$  and, unlike the case without booking limits, also at  $(p_1 = \bar{w}(\gamma), p_2 = H)$ . The profit under these conditions is  $\pi = \min(B, 1 - \alpha)\mu + \min(C - B, (1 - \min(B, 1 - \alpha))q)H$  and  $\pi = B\bar{w}(\gamma) + \min(C - B, (1 - B)q)H$ , respectively. Under pricing policy  $(p_1 = \bar{w}(\gamma), p_2 = H)$ , the optimal booking limit is  $B = (C - q)/(1 - q)$  and the optimal profit is  $\pi_{DAS}^{(2)} = ((C - q)/(1 - q))\bar{w}(\gamma) + (q(1 - C)/(1 - q))H$ . To derive the optimal DAS policy under pricing policy  $(p_1 = \mu, p_2 = H)$ , observe that for  $p_2 = H$  the customers' maximum ex ante wtp is independent of  $B$ . We must therefore have  $\min(B, 1 - \alpha) = B$ , otherwise the firm could do better by lowering  $B$  to make more capacity available on the spot without any effect on advance sales. Therefore, the profit function simplifies to  $\pi = B\mu + \min(C - B, (1 - B)q)H$ . Upon optimizing subject to  $B \leq (1 - \alpha)$ , we find that: (1) if  $C \leq C_5$ , then  $B = (C - q)/(1 - q)$  and  $\pi_{DAS}^{(3)} = ((C - q)/(1 - q))\mu + (q(1 - C)/(1 - q))H$ ; and (2) if  $C > C_5$ , then  $B = (1 - \alpha)$  and  $\pi_{DAS} = (1 - \alpha)\mu + \alpha qH$ .

Define  $C_3(\gamma)$  to solve  $\pi_{DAS} = \pi_{DAS}^{(2)}$ . The optimal DAS policy is then as follows: (1) if  $C \leq C_5$ , then  $(p_1 = \mu, p_2 = H)$ ,  $B = (C - q)/(1 - q)$ , and the optimal profit is  $\pi_{DAS}^{(3)}$ ; (2) if  $C_5 < C \leq C_3(\gamma)$ , then  $(p_1 = \mu, p_2 = H)$ ,  $B = 1 - \alpha$ , and the optimal profit is  $\pi_{DAS}$ ; and (3) if  $C > C_3(\gamma)$ , then  $(p_1 = \bar{w}(\gamma), p_2 = H)$ ,  $B = (C - q)/(1 - q)$ , and the optimal profit is  $\pi_{DAS}^{(2)}$ .

The optimal policy then follows by comparing the profits obtainable under optimal DAS, PAS, SS, and AS. We omit the details for conciseness and conclude with the following insights

1. Given  $C < 1$ , an exclusive AS policy is never optimal. Such a policy generates  $\pi = \max(C\bar{w}(\gamma), (1 - \alpha)\mu)$ . The DAS policy  $(p_1 = \bar{w}(\gamma), p_2 = \mu)$  and  $B = (C - q)/(1 - q) < C$  generates  $\pi_{DAS}^{(2)} > C\bar{w}(\gamma)$ . On the other hand, if the optimal AS policy does not clear the capacity (i.e.,  $\pi = (1 - \alpha)\mu$ ), a DAS policy  $(p_1 = \mu, p_2 = H)$  generates  $\pi = (1 - \alpha)\mu + \min(C - (1 - \alpha), qH\alpha)$  which better uses the capacity and yields higher profits.

2. The optimal profit is decreasing in  $\alpha$ , the fraction of regretful customers. This is because profit depends on regret

only when the firm cannot clear the capacity through a DAS policy, i.e.,  $(p_1 = \mu, p_2 = H)$  with profits  $\pi_{DAS}$ , or implements a PAS policy with profits  $\pi_{PAS}$ . In both cases, profits are decreasing in  $\alpha$ .

3. The optimal booking limit is decreasing in  $\gamma$  and nonmonotonic in  $\alpha$ . The former claim follows because the boundaries  $C_i(\gamma)$  are either increasing in  $\gamma$  or else constant. The latter follows because the optimal booking limit for a capacity level  $C > q$  is  $(C - q)/(1 - q)$  (and independent of  $\alpha$ ) if  $\alpha$  is sufficiently large or small and is  $1 - \alpha$  for intermediate  $\alpha$ , which is decreasing in  $\alpha$ .  $\square$

**PROOF OF PROPOSITION 9.** We focus here on case 1 in Table 1 because it leads to different insights. The proofs for the other cases, omitted for conciseness, are similar, and available from the authors on request.

The optimal spot price can be either  $p_2 = L$  or  $p_2 = H$ . We next determine the corresponding optimal advance price and profits for each case.

**Case (i):  $p_2 = L$ .** The maximum wtp for type A (high-valuation regretful) and type B (low-valuation nonregretful) customers is, respectively,  $w^A(\gamma; p_2) = qL/(1 + \gamma(1 - q))$  and  $w^B(\gamma = 0; p_2) = qL$  (see (6)). Because  $w^A(\gamma; p_2) \leq w^B(\gamma = 0; p_2)$ , it follows that the optimal advance price is either  $p_1 = qL$  or  $p_1 > H$  (i.e., no advance sales). The optimal profit in this case is  $\pi = qL$ .

**Case (ii):  $p_2 = H$ .** The maximum wtp for type A and type B customers is, respectively,  $w^A(\gamma; p_2) = qH/(1 + \gamma(1 - q))$  and  $w^B(\gamma = 0; p_2) = qL$ . Thus, the optimal advance price is  $p_1 \in \{qL, qH/(1 + \gamma(1 - q)), p_1 > H\}$ . If  $w^A(\gamma; p_2) \geq w^B(\gamma = 0, p_2)$ , i.e., if  $\gamma \leq (H - L)/(L(1 - q))$ , then  $\pi = \max\{qL, \alpha qH/(1 + \gamma(1 - q)), \alpha qH\} = \max\{qL, \alpha qH\}$ . On the other hand, if  $\gamma > (H - L)/(L(1 - q))$ , then  $\pi = \max\{(1 - \alpha)qL + \alpha qH, qH/(1 + \gamma(1 - q)), \alpha qH\} = (1 - \alpha)qL + \alpha qH \geq qL$ . So  $p_2 = H$  yields higher profits than  $p_2 = L$ .

If  $\gamma > (H - L)/(L(1 - q))$  the optimal policy sells to type A on the spot at  $H$  and to type B in advance at  $qL$ . Otherwise the firm sells only on the spot, either to the whole market at  $L$ , if  $\alpha < L/H$ , or only to type A at  $H$ . As  $\gamma$  increases, the more profitable, separating equilibrium prevails.  $\square$

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