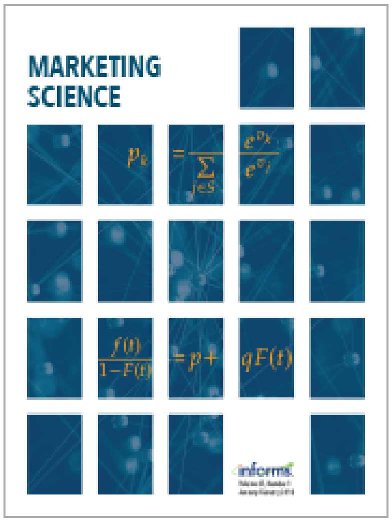

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Service Cancellation and Competitive Refund Policy

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Although previous research demonstrates the profitability of partial refund policies in a monopoly setting, there is a certain lack of ubiquity in practice about these refunds in competitive service markets. This raises the question of how a partial refund policy may work and whether it is even sustainable in a competitive environment. This study investigates how competition may influence the profitability and the equilibrium choice of refund policies. It is shown that partial refunds may endogenously change the nature of strategic interaction between service providers from local monopolies into a competition regime, which moderates the gains from exploiting the efficiency-enhancing effect of partial refunds. A whole range of pure-strategy equilibria can be obtained as a result of the interplay between the efficiency-improving and the competition-intensifying effects. When the capacity is small (large) such that the efficiency-improving (the competition-intensifying) effect is dominant, both firms in equilibrium follow identical partial (zero) refund policies. Moreover, interestingly, the symmetric firms may end up in an asymmetric equilibrium in which one firm follows a partial refund policy and the other adopts a zero refund policy.

Key words: advance selling; cancellations; capacity constraint; competition; contingent contracts; refunds; reservations; services; uncertainty; yield management
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1. Introduction

Advance selling is widespread in many service industries that appear to be highly competitive. Consumers are increasingly permitted to purchase services in advance in a wide array of businesses such as airlines, car rentals, concerts, health clubs, hotels, professional sports, and theaters (Gale and Holmes 1993, Dana 1998, Xie and Shugan 2001, Shugan and Xie 2005). Service providers commonly practice advance selling by charging buyers a prepayment in exchange for a certified entitlement (e.g., a ticket) to consume the service in a future time interval (i.e., the spot period). Interestingly, advance selling in some occasions may involve a buy-back clause under which consumers can cancel the advance transaction prior to a particular deadline by paying a penalty (Xie and Gerstner 2007). That is, consumers can choose to give up their consumption entitlement in exchange for a refund before the service is actually delivered. For example, airlines and hotels usually exercise a partial refund policy by allowing consumers to terminate prepurchased services with a cancellation fee while crediting back the remaining advance payment. In this paper, I focus on competing service providers' incentives to adopt or abandon partial refund policies. There are two central issues to investigate: (1) How would a partial refund policy influence the firms' strategic interaction, and (2) how sustainable are partial refund policies in a competitive environment? I address these questions by analyzing a model of competitive refund policy and examining how competition may influence the equilibrium choice of refund policies.

This first question is motivated by Xie and Gerstner (2007), who demonstrate the profitability of a partial refund policy for monopoly service providers. They show that offering refunds for service cancellations can be beneficial under a set of unrestrictive conditions. In their model, a firm can sell its service to an advance or a late-arriving consumer. Following the advance purchase, the advance buyer has a stochastic opportunity to obtain a better alternative. By offering a partial refund to cover the hassle cost of cancellation, the seller encourages the advance buyer to give up the presold service if the better alternative is secured. Such cancellations can be profitable because the firm can then sell the service twice, to the advance and the late-arriving buyers, respectively, which is otherwise impossible without the partial refund policy. Their analysis suggests that partial refunds can serve as a Pareto-improving mechanism that allows the seller to accrue more profits, when capacity is limited and there may exist ex post consumption inefficiency. Note that when the advance buyer finds a better option, it is socially efficient to reallocate the consumption of the presold service to the late-arriving consumer. However, it is not a priori clear how a partial refund policy works in a competitive market. How would competing firms interact in the advance period when they offer partial refunds for service cancellations in the spot period? What is the strategic consequence of the firms selling their services multiple times under partial refund policies? In this paper, I extend the work of Xie and Gerstner (2007) to a competitive setting and investigate the effects of partial refund policies under alternative demand and market structure.

The second question seems more puzzling. Following Xie and Gerstner (2007), one should expect to observe the provision of partial refund clauses for prepurchased services, where sellers are capacity constrained and buyers are uncertain at the time of advance purchase about future preferences. However, anecdotal evidence suggests that the practice of offering refunds varies significantly across service providers that are generally believed to be characterized by limited capacity and buyer uncertainty. For example, although many travel-related services (e.g., airline, car rental, hotel) usually provide partial or even full refunds, sellers in such service industries as athletic facilities, concerts, health clubs, professional sports, and theaters are normally resistant to refunding postpurchase cancellations. There also seem to be significant variations across travel agents in their refund policies for different routes, packages, seasons, etc. Even firms in the same service business differ considerably in their practice of and attitude to offering refunds. Although most airlines offer generous refund policies and seek to reduce refund hassles, the tickets issued by United Airlines are mainly nonrefundable. Why, then, do some service providers offer refunds whereas others do not? Why do competing firms in the same service follow nonidentical refund policies?

To address these questions, I develop a model of refund policy choice for two competing service providers. There are two types of consumers with exogenously determined arrival time: low-valuation advance shoppers and high-valuation spot shoppers. Consumers have uncertain preferences over the two firms: in the spot period they may turn out to prefer one firm over the other. In this way, consumer uncertainty about the availability of a better outside option as in Xie and Gerstner (2007) becomes endogenous: the potentially attractive alternative is now offered by the competing firm. The firms are ex ante identical and may choose whether to offer refunds for cancelling advance purchases during the spot period. There is marketwide capacity constraint such that not all consumers can be served.

Under this basic setup, there exists an ex post opportunity to improve consumption efficiency by cancelling and reselling the reserved service units of those advance buyers who find the rival firm to be more attractive. Therefore, similar to Xie and Gerstner (2007), an efficiency-improving effect of partial refund policies may arise. To extract the surplus from exploiting the improved efficiency, a firm desires to sell more units in the advance period anticipating that some presold units would be cancelled and resold to the high-valuation late-arriving consumers. Interestingly, I show that this incentive to increase advance sales may endogenously change the nature of strategic interaction between the service providers in the advance period. In the absence of partial refunds, the firms are de facto local monopolies thanks to their limited capacity. However, when a partial refund policy is adopted, competition may occur as the firms' total desirable advance sales exceed the demand in the advance period. In response to this, the firms in equilibrium offer price promotions to compete for advance reservations. The firms' equilibrium payoffs decrease as the competition becomes more intense. It is also shown that the competition-intensifying effect of a partial refund policy is asymmetric, exerting a stronger influence on the rival firm.

The firms' equilibrium choice of refund policies hinges on the relative importance of the efficiency-enhancing versus the competition-intensifying effect. It is shown that the equilibrium number of firms adopting a partial refund policy decreases as the competition becomes more intense. The net benefit of adopting a partial refund policy first increases and then decreases with the firms' overall capacity. When the capacity is small, the competition regime does not endogenously arise such that equilibrium advance sales increase with capacity. In contrast, when the capacity becomes sufficiently large, the firms are involved in intense competition, in which case a firm's equilibrium expected payoff is negatively related to the rival's capacity. Therefore, when the capacity is small (large) such that the efficiency-improving (competition-intensifying) effect is dominant, both firms in equilibrium follow identical partial (zero) refund policies. Moreover, interestingly, there may exist an asymmetric equilibrium in which one firm follows a partial refund policy and the other adopts zero refund. This occurs when neither the efficiency-improving nor the competition-intensifying effect is dominant. In this case, it is profitable to exploit the efficiency-improving effect, but only when the rival is not following suit, because otherwise competition would be too intense with both firms pursuing the partial refund policy. This result is interesting because it could explain why symmetric firms may end up in equilibrium choosing asymmetric refund policies.

There is a recent literature on advance selling. Gale and Holmes (1993) and Dana (1998) investigate the role of advance selling as a price discrimination mechanism. Xie and Shugan (2001) examine a monopoly service provider's incentive to circumvent its ex post information disadvantage by selling in the advance period. They show that advance selling can improve profitability by increasing sales in the advance period when consumers and firms are equally uncertain about the consumers' future valuation. Shugan and Xie (2005) consider the impact of competition on advance-selling incentives. They show that competing firms' incentive for price cutting can be softened when the firms smooth their sales between the advance and the spot period. Similarly, in this paper I show that when the firms are motivated to sell more advance units under partial refund policies, the competition may become more intense.

This paper is related to the studies that provide a variety of explanations for the provision of money-back guarantees. Offering refunds for product returns can be used as costly signals for product quality (Moorthy and Srinivasan 1995, Shieh 1996). Consumer concerns about uncertainty can be insured through the provision of refunds for either products or services (Mann and Wissink 1988, Png 1989, Fruchter and Gerstner 1999). Other researchers investigate the trade-off, through offering partial refunds, between helping consumers hedge against uncertainty concerns and preventing opportunistic product returns (Davis et al. 1995, Chu et al. 1998). These studies differ in the underlying economic mechanisms from Xie and Gerstner (2007), which is the first to show that partial refund policies can deal with ex post consumption inefficiency caused by limited capacity and buyer uncertainty. This paper follows Xie and Gerstner (2007) in considering the impact of limited capacity and buyer uncertainty on the profitability of partial refund policies.

Refund clauses can be viewed as a special form of contingent contracts (Bazerman and Gillespie 1999), where the execution of the presold service contracts is conditional on the buyers' ex post decision not to cancel the service. Such clauses can be used to improve ex post efficiency in incomplete contracts. Note that in the spot period the advance consumers have better information about their realized preferences, and thus about the socially optimal consumption allocation, than the firms do. As a result, refund clauses can be used to delegate to consumers the ex post decision right on consumption allocation. Such delegation can be profitable even for service providers that have market power, because the party who has more information should be given more decision rights (Grossman and Hart 1986). Biyalogorsky et al. (1999) and Biyalogorsky and Gerstner (2004) follow the same reasoning. In these two studies, although consumers are certain about their preferences, the seller is uncertain about the arrival of high-valuation consumers in the spot period. As a result, it is the seller who has more information in the spot period about the optimal consumption allocation. The seller can therefore profit from imposing a contingent clause that gives itself the right to buy back the presold service contracts.

The issues investigated in this paper are similar to those in the literature on yield management (e.g., Weatherford and Bodily 1992, Desiraju and Shugan 1999, McGill and van Ryzin 1999). In particular, the current model considers how to allocate capacity between low-valuation advance shoppers and high-valuation spot shoppers when there may be "no shows" from advance shoppers. However, service cancellations are exogenous in the yield management literature but can be managed in this paper through the provision of partial refunds. In addition, this paper focuses on how optimal capacity allocation should respond to different refund policies and, more important, how this influences the strategic interaction between competing firms.

The rest of this paper is organized as follows. The next section describes the basic model. Section 3 presents the analysis and results, highlighting the effects of refund policies on yield management and price competition. Model extensions are discussed in §4. Section 5 discusses managerial implications, identifies potential directions for future research, and concludes the paper.

2. The Model

Consider a duopoly market with two service-selling firms, $j \in \{A, B\}$. The market also consists of M consumers. Following the advance-selling literature (e.g., Xie and Shugan 2001), the consumers arrive at the market in either the advance or the spot period, which is denoted as $t = 1$ or $t = 2$, respectively. The fraction of consumers entering in the advance or the spot period is α or $1 - \alpha$, labelled as the "early arrivals" or the "late arrivals," respectively. The late arrivals can purchase only in the spot period, but the early arrivals can choose to buy in the advance period or wait until the spot period. For example, the early arrivals can represent leisure travellers who come to the market earlier than business travellers do. Each consumer has a demand for one service unit. No additional utility can be accomplished from consuming more than one unit of service, and the utility of choosing the outside option (e.g., no consumption) is normalized to zero. Consumption of the service can occur only in the spot period for both early and late arrivals. The firms and consumers are risk neutral and maximize wealth-equivalent expected payoffs.[1]

[1] I deliberately assume that consumers are risk neutral to rule out the possibility that a firm's incentive to offer refunds is driven by consumer risk aversion. When consumers are risk averse, partial refunds can be used as an insurance device against consumer uncertainty (e.g., Png 1989).

The gross utility of a consumer who arrives in the period $t \in \{1, 2\}$ for firm j is given by

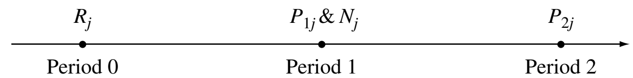
$$U_{tj} = V_t f_j, \tag{1}$$

where $V_t > 0$ captures the consumer's valuation for the service, and $f_j \in \{1, 0\}$ is a dummy indicator representing the fit between the consumer's need and the service provided by firm j. Consistent with the literature on yield management (e.g., Weatherford and Bodily 1992, McGill and van Ryzin 1999), I assume that the late arrivals have sufficiently higher valuation than the early arrivals, i.e., $V_2/V_1 > 1/(1-\alpha)$. For instance, late-arriving business travellers are normally time constrained and willing to pay a much higher price than early-arriving leisure travellers who can plan their schedule ahead of time (Desiraju and Shugan 1999, Biyalogorsky et al. 2005).

Consumers in the advance period are uncertain about their consumption utility in the spot period. For expositional ease, I use a Bernoulli distribution that has been used in the literature to capture consumer valuation uncertainty under competition (e.g., Mayzlin 2006). In particular, it is assumed that there exist two consumption states of nature, with equal probability. In one consumption state, firm A's service provision fits consumers' consumption need/circumstances in the spot period, whereas firm B's does not, i.e., $f_A = 1$ and $f_B = 0$. The reverse is true in the other consumption state, i.e., $f_A = 0$ and $f_B = 1$. Moreover, it is assumed that the realization of consumption states is independent across consumers. As in Shugan and Xie (2005), here consumption uncertainty is caused by personal factors such as health, mood, family, and travelling schedule, which tend to be independent across consumers and unobservable to the service providers.[2]

Each firm is endowed with N service units. The firms provide services to the market at constant marginal costs, which, without loss of generality, are normalized to zero. To capture marketwide limited capacity, it is assumed that $N < M/2$. As a result, the firms taken together cannot serve all consumers. This reflects the practice in a variety of service industries in which service capacity is fixed in the short term and cannot satisfy all potential demand. More important, this assumption is deliberately made such that, as will be shown, in the absence of refunds the service providers in equilibrium are de facto local monopolies and their profits increase with larger service capacity. This provides a sharp context for us to investigate how offering refunds can endogenously give rise to and intensify competition between the service providers as service capacity increases.

Figure 1 **Timing of Firm Decisions**



I consider a three-period game. The sequence of moves is shown in Figure 1 and elaborated as follows. In period $t = 0$, the firms simultaneously decide whether to offer refunds and how much to offer. This will become common knowledge, and the firms commit to their refund policies. Let us denote a firm's refund policy as $R_j \geq 0$, $j = A, B$. Next, in the advance period ($t = 1$), the firms simultaneously make two decisions, the advance price P_{1j} and the service units N_j that can be reserved by consumers. The early arrivals enter the market in the advance period when their consumption utility U_{1j} is uncertain. They make a service reservation in the advance period from firm A or firm B, or they may postpone their purchase to the spot period, depending on the expected surplus of each of these options. If they are indifferent between the service providers, they randomly choose one firm to make the reservation. If the advance consumers are rationed by their preferred firm in making reservations, they may turn to the other firm if that alternative leads to a higher expected surplus than waiting until the spot period. It is also assumed that consumers cannot make reservations from both service providers, possibly because of budget/cost considerations in making/cancelling multiple purchases.

Note that the firms do not need to physically allocate any service unit to the advance period because no reserved service is to be consumed in that period. Let us denote the service units that are actually reserved as N_j', $j = A, B$. It is not a constraint in the current setup that $N_j' \leq N$; the constraint on service reservation is, instead, $N_j' \leq \min\{N_j, \alpha M\}$. In other words, strategic overselling is feasible, which constitutes a major departure of service reservations from product orderings (Iyer and Villas-Boas 2003). Nevertheless, overselling is feasible only when sufficient refund is offered to induce consumers to notify the cancellation of oversold service units, because opportunistic cancellations initiated by service providers (Biyalogorsky et al. 1999) are not considered. This also implies that the current setup is more applicable to identity based service reservations (e.g., airlines).[3]

The spot period ($t = 2$) represents the last period of the game when the value of service fit, f_j,

[2] In contrast, consumption uncertainty caused by external factors (e.g., weather) may lead to correlation across consumers in the realization of consumption states and may allow the service providers to adjust their strategies (e.g., pricing) according to the realized consumption state.

[3] For services that are not identity based (e.g., parks), the service providers can oversell even with zero refund because some consumers may prefer not to show up if their realized utility for the reserved service is sufficiently low.

becomes known to the consumers. The events and actions in this period are as follows. First, the service providers simultaneously charge their spot prices, P_{2j}, $j = A, B$. Depending on how consumption uncertainty is resolved, an early-arriving consumer may cancel her service reservation. In making a cancellation, consumers obtain the refund R_j while incurring a hassle cost H of notifying the service provider.[4] For example, if a consumer who reserved firm A's service finds out later that firm A's service does not, whereas firm B's does, fit her need in the spot period (i.e., $f_A = 0$ and $f_B = 1$), she may cancel the service if and only if $R_A \geq H$. Let us denote the service units cancelled for a service provider as N_j'', $j = A, B$. The maximum service units a service provider can sell at the spot price P_{2j} are its overall capacity N, minus the reserved units N_j' and plus the cancelled units N_j''. All consumers, both early and late arrivals, may also decide whether to make a spot purchase and from which service provider, depending on their realized consumption utilities U_{tj} and the spot prices P_{2j}. Finally, transactions are cleared and consumptions take place.

3. Analysis and Results

In solving the game, backward induction is used to ensure subgame perfection. Note first that to induce an advance shopper for whom a firm's service fit turns out to be unfavorable (i.e., $f_j = 0$) to cancel her reservation and to notify the firm, the refund has to be sufficiently large to cover the hassle cost, i.e., $R_j \geq H$.[5] Nevertheless, given that both the firms and the consumers are risk neutral, for $R_j \in [H, V_1 + H]$, any change in the expected refund payment for each unit of advance sales will lead to an equivalent change in the consumers' willingness to pay for the firm's service in the advance period, cancelling each other out in influencing the firm's advance pricing decision.[6] As a result, as shown in the Technical Appendix, which can be found at http://mktsci.pubs.informs.org, a firm's equilibrium advance price will be boosted in proportion to the increase in its refund R_j, whereas the profit margin will remain unchanged. This implies that the refund policies $R_j \in [H, V_1 + H]$ are payoff equivalent. Therefore, without any loss of conceptual generality, we can focus on $R_j = 0$ and $R_j = H$, which are referred to as the "zero refund policy" and the "partial refund policy," respectively.

This leads us to consider only three possible scenarios following the firms' decisions in period $t = 0$: both firms adopt the zero refund policy, both firms adopt the partial refund policy, and one firm adopts the partial refund policy, whereas the other adopts the zero refund policy. In §3.1, I examine the firms' equilibrium behavior following each of these possible scenarios, highlighting the role of partial refund policies in the firms' strategic interaction. The equilibrium profit and welfare implications are investigated in §3.2. Following this, in §3.3, I determine if and when each of these scenarios would arise as the firms' equilibrium choice in period $t = 0$.

3.1. Equilibrium Behavior

Let us start with analyzing the interaction between the service providers under the alternative refund policies. Note first that, in the current setup, the firms are de facto local monopolies in the spot period. A fraction (1/2) of the consumers, either early or late arrivals, find that firm A's service fits their needs (i.e., $U_{tA} = V_t > 0$), whereas firm B's does not (i.e., $U_{tB} = 0$). The other half of consumers have reverse preferences: they turn out to have zero consumption utility for firm A, whereas they have positive consumption utility for firm B. Note that this split of the spot market is independent of the firms' refund policies. In other words, the choice of refund policies exerts no influence on the nature of interaction between the service providers in the spot period. In contrast, refund policies may affect how the service providers interact in the advance period.

3.1.1. Both Firms Offer Zero Refund. Given the symmetry of the problem, we can without loss of generality focus on a representative firm $j \in \{A, B\}$. In the spot period, as discussed above, the consumers are split into two segments of equal size, each having a higher consumption utility for one firm than for the other firm. In particular, $\alpha M/2$ early arrivals strictly prefer firm j, among whom $N_j'/2$ reserved firm j's service in the advance period. As a result, $(\alpha M - N_j')/2$ early-arriving consumers may consider buying firm j's service in the spot period. Similarly, the size of late-arriving consumers who may consider purchasing firm j's service is given by $(1-\alpha)M/2$. The size of all potential consumers for firm j in the spot period is then $(\alpha M - N_j')/2 + (1-\alpha)M/2 = (M - N_j')/2$.

Because no refund is offered, all reservations made in the advance period have to be retained and cannot be resold. This implies that the residual capacity that the firm can sell in the spot period is $N - N_j'$. It follows immediately that the capacity is binding and the firm cannot sell to all potential demand in the spot period, because $N - N_j' < (M - N_j')/2$ for all $N_j' \geq 0$. This also suggests that the firm's spot-period profit is given by $\Pi_{2j} = V_1(N - N_j')$ if it charges a spot price

[4] To facilitate analytical tractability, the hassle cost H is assumed to be positive, but sufficiently small.

[5] It does not make sense to induce an advance shopper for whom the firm's service fit turns out to be favorable (i.e., $f_j = 1$) to cancel her service reservation. Doing so (i.e., offering $R_j > V_1 + H$) will lead to a net loss of at least H for each unit sale in the advance period, which is hence strictly dominated by offering $R_j = 0$.

[6] I thank an anonymous reviewer for pointing this out.

$P_{2j} = V_1$. If the spot price is instead $P_{2j} = V_2$, then only the late-arriving consumers would buy and the firm's spot-period profit is $\Pi_{2j} = V_2 \min\{(1-\alpha)M/2, N - N_j'\}$. Noticing that $V_2/V_1 > 1/(1-\alpha)$, one can obtain that in equilibrium the spot price is $P_{2j}^* = V_2$ and the spot profit is

$$\Pi_{2j}^* = \begin{cases} (1-\alpha)MV_2/2, & \text{if } N_j' \le N - (1-\alpha)M/2; \\ (N - N_j')V_2, & \text{otherwise.} \end{cases} \tag{2}$$

Turning back to the advance period, the early-arriving consumers' expected surplus of waiting until the spot period is zero. Therefore, they would make a reservation if and only if their expected surplus of advance purchase is nonnegative. Note that all early-arriving consumers are equally uncertain about their future consumption and hence have a homogeneous expected consumption utility $V_1/2$. The firm's overall expected profit is given by $\Pi_j = \Pi_{1j} + \Pi_{2j}^* = P_{1j}N_j' + \Pi_{2j}^*$, where Π_{1j} is the expected profit gained from reservations and $P_{1j} \le V_1/2$. We have

$$\frac{\partial \Pi_j}{\partial N_j'} = \begin{cases} P_{1j} > 0, & \text{if } N_j' \le N - (1-\alpha)M/2; \\ P_{1j} - V_2 < 0, & \text{otherwise.} \end{cases} \tag{3}$$

Lemma 1. *When both firms offer zero refund, the optimal reservation limit for either firm is given by* $N_j^* = \max\{N - (1-\alpha)M/2, 0\}$, $j = A, B$.

The optimal reservation limit has to ensure that there are enough service units left to cover the potential sales from late arrivals in the spot period. As long as the spot-period sales can be completely fulfilled, the service provider wants to advance-sell as many service units as possible. This is because it is more profitable to sell a service unit to the high-valuation late-arriving consumers than to the early-arriving consumers. Note that when the overall capacity is sufficiently small (i.e., $N < (1-\alpha)M/2$), no advance selling would occur in equilibrium.[7]

Noticing that $2[N - (1-\alpha)M/2] < \alpha M$, one can see that when no refund is offered by either firm, in equilibrium the advance consumers are not fully served and the service providers are local monopolies in the advance period. This also implies that in equilibrium we have $P_{1j}^* = V_1/2$ and $N_j'^* = N_j^*$, $j = A, B$. The firms' equilibrium expected payoffs are given by

$$\Pi_A^* = \Pi_B^* = \begin{cases} NV_2, & \text{if } N \le (1-\alpha)M/2; \\ (N - (1-\alpha)M/2)V_1/2 + (1-\alpha)MV_2/2, & \text{otherwise.} \end{cases} \tag{4}$$

[7] This implies that the firms are better off in comparison to a benchmark model in which advance selling is infeasible, if and only if $N > (1-\alpha)M/2$. This is also the case when partial refund is offered.

3.1.2. Both Firms Offer Partial Refund. In this case, each service provider follows the partial refund policy, allowing consumers to receive a refund if they cancel their reservations and notify the service provider in the spot period. Among the advance buyers who reserved a firm's service, one-half have zero consumption utility for the firm and thus would cancel the service and inform the firm, given that the hassle cost is covered by the refund. That is, $N_j'/2$ service units that are reserved in the advance period will be cancelled and can be resold in the spot period. This suggests that the firm's residual service units are now $N - N_j'/2$, which are $N_j'/2$ higher than those in the case when no refund is offered. Nevertheless, like the case with zero refund, the firm remains a local monopoly in the spot period, with $(\alpha M - N_j')/2$ early-arriving and $(1-\alpha)M/2$ late-arriving consumers considering its service. As a result, similar to the zero refund case, one can obtain that charging $P_{2j} = V_2$ is dominant in the spot period.[8] This leads to the following equilibrium spot-period payoff in the case with a partial refund:

$$\Pi_{2j}^{**} = \begin{cases} (1-\alpha)MV_2/2 - HN_j'/2, \\ \qquad\qquad \text{if } N_j' \le 2N - (1-\alpha)M; \\ (N - N_j'/2)V_2 - HN_j'/2, \quad \text{otherwise.} \end{cases} \tag{5}$$

In comparison to Π_{2j}^*, offering partial refund can result in a higher spot-period payoff if and only if service reservations in the advance period are sufficiently high. When there are not many reservations, the capacity constraint in the spot period is not binding even without the cancelled service units, but the firm has to incur the cost $HN_j'/2$ of fulfilling cancellations. When there are enough reservations, the cancelled service units under the partial refund policy allow the firm to overcome the capacity limit and sell more units to the late-arriving consumers at a higher per-unit price $P_{2j} = V_2$ than the expected cost of fulfilling each cancelled reservation.

Similarly, one can examine how the change in reservations may influence the firm's overall expected profit, $\Pi_j = \Pi_{1j} + \Pi_{2j}^{**} = P_{1j}N_j' + \Pi_{2j}^{**}$, in the case with a partial refund:

$$\frac{\partial \Pi_j}{\partial N_j'} = \begin{cases} P_{1j} - H/2 > 0, & \text{if } N_j' \le 2N - (1-\alpha)M; \\ P_{1j} - (V_2 + H)/2 < 0, & \text{otherwise.} \end{cases} \tag{6}$$

[8] Note that, in the spot-period equilibrium, those advance consumers who choose to cancel their reservations, even though they can, do not purchase from the other firm; i.e., they select the outside option (e.g., no consumption). This equilibrium outcome seems to be consistent with the anecdotal evidence in a variety of service industries. I thank the AE for this observation.

LEMMA 2. *When both firms offer partial refund, the optimal reservation limit for either firm is given by* $N_j^{**} = \max\{2N - (1-\alpha)M, 0\}$, $j = A, B$.

This lemma reveals how the partial refund policy may influence the firm's optimal advance-selling strategy on yield management. Comparing N_j^{**} with N_j^*, one can see that adopting the partial-refund policy leads to a higher optimal limit on the reservations that consumers can make. The intuition is as follows. In deciding on the reservation limit, as discussed earlier, the firm reconciles two objectives. On the one hand, enough service units are needed to serve the high-valuation late-arriving consumers. On the other hand, it is unprofitable to have unsold capacity at the end of the spot period. Balancing these incentives suggests that the optimal reservation limit is such that the expected service units available for sale in the spot period are equal to half of the late-arriving consumers. In the presence of a partial refund, those consumers who made reservations in the advance period and later have zero consumption utility will cancel their reservations. This induces the firm to allocate more service units for reservations, in the hope that some consumers may cancel their booked service, which can be resold in the spot period.

Because the service providers set higher reservation limits than those when both firms offer zero refund, they may no longer remain as local monopolies in the advance period. If they still do, as in the case with zero refund, the optimal advance-pricing strategy is straightforward and given by $P_{1A}^{**} = P_{1B}^{**} = V_1/2$. However, competition would arise when the total units that the firms want to be reserved, $2N_j^{**}$, exceeds the number of advance shoppers, αM. It is straightforward that this would occur when $N > (2-\alpha)M/4$, in which case the firms have to compete for the advance shoppers to reserve their service. To understand the nature of competition, note that the consumers in the advance period have equal expected utility for the service providers. As a result, each firm would like to undercut its rival to be able to obtain its desirable N_j^{**} units of reservations. Nevertheless, the firm charging a lower advance price does not sell to all advance consumers, because $N_j^{**} < \alpha M$. This implies that a firm can still have positive advance sales, which are given by $\alpha M - N_j^{**} = M - 2N$, even if its advance price is higher than its rival's. This discussion suggests that the firms' interaction in the advance period is a Bertrand price competition with limited capacity.

To proceed, note that there exists no pure-strategy equilibrium in the advance-pricing subgame when $N > (2-\alpha)M/4$. The reasoning is as in Varian (1980) and Narasimhan (1988). Suppose that, for example, firm B charges a price P_{1B} that is not too low. Then firm A is willing to undercut just below P_{1B} to obtain the desirable N_A^{**} units of reservations. Suppose, otherwise, that P_{1B} is too low. Then firm A wants to deviate to a higher price while still selling to the advance consumers who remain unserved by firm B. To characterize the mixed-strategy equilibrium, let us define the cumulative distribution for the advance price as $F_j(P) \equiv \Pr(P_{1j} < P)$, $j = A, B$.

PROPOSITION 1. *When both firms offer partial refund*:
(i) *For* $N \le (2-\alpha)M/4$, *the equilibrium advance-pricing strategy is given by* $P_{1A}^{**} = P_{1B}^{**} = V_1/2$;
(ii) *For* $(2-\alpha)M/4 < N < M/2$, *the equilibrium advance-pricing strategy is mixed. The support for the advance price is continuous*: $P_{1j}^{**} \in [\underline{P}^{**}, V_1/2]$, $j = A, B$, *where*

$$\underline{P}^{**} = \frac{H}{2} + \frac{(M-2N)(V_1-H)/2}{2N-(1-\alpha)M}.$$

The cumulative distribution for the advance price is

$$F_j^{**}(P) = \frac{2N-(1-\alpha)M}{4N-(2-\alpha)M} - \frac{(M-2N)(V_1-H)/2}{[4N-(2-\alpha)M](P-H/2)}, \quad j=A,B.$$

This proposition lays out one major result of the paper. That is, a partial refund policy may induce a firm to advance-sell more service units, which may in turn intensify the price competition in the advance period. Recall that in the case when both firms offer zero refund, they are local monopolies and do not offer price cuts. However, when both firms adopt the partial refund policy, they may in equilibrium offer price promotions to the advance shoppers.

This result also suggests that the competition regime is more likely to arise with larger service capacity (i.e., $N > (2-\alpha)M/4$). Moreover, the promotion depth, measured by $V_1/2 - \underline{P}^{**}$, increases with N, whereas it decreases with M. This is because a larger service capacity leads to an increasing incentive to advance-sell without sacrificing spot sales, and a smaller total consumer size implies lower secured sales when a firm charges a higher advance price than its rival does, both inducing the firms to offer deeper promotions to win the pricing race. Similarly, as the fraction of advance shoppers increases, the firms in equilibrium offer deeper price cuts, i.e., $\partial\underline{P}^{**}/\partial\alpha < 0$. The intuition is that a larger number of advance shoppers implies more gains from undercutting the rival, resulting in an increasing incentive to offer promotions. In contrast, a higher hassle cost is associated with a lower level of equilibrium promotion depth, i.e., $\partial\underline{P}^{**}/\partial H > 0$. As the hassle cost increases, the firms incur a higher expected refund payment for the cancelled reservations. This dampens the firms' incentive to compete for more reservations in the advance period.

The firms' equilibrium expected payoffs in the case when both offer partial refund are

$$\Pi_A^{**} = \Pi_B^{**} = \begin{cases} NV_2, & \text{if } N \le (1-\alpha)M/2; \\ (2N-(1-\alpha)M)(V_1-H)/2 \\ \quad +(1-\alpha)MV_2/2, \\ \quad \text{if } (1-\alpha)M/2 < N \le (2-\alpha)M/4; \\ (M-2N)(V_1-H)/2+(1-\alpha)MV_2/2, \\ \quad \text{otherwise.} \end{cases} \tag{7}$$

3.1.3. Asymmetric Refund Policies. Let us then examine the asymmetric case when one firm adopts the partial refund policy and the other firm follows the zero refund policy. Without loss of generality, suppose that firm A offers partial refund ($R_A = H$), whereas firm B chooses zero refund ($R_B = 0$). In this case, it is obvious that firm A's and firm B's equilibrium behavior and payoffs in the spot period exactly follow those laid out in §§3.1.2 and 3.1.1, respectively. Moreover, the impacts of the change in advance reservations on a firm's overall expected payoff mirror those in the previous sections, respectively. That is, firm A desires to increase advance reservations up to $N_A^o = \max\{2N-(1-\alpha)M, 0\}$, whereas firm B's optimal reservation limit is $N_B^o = \max\{N-(1-\alpha)M/2, 0\}$.

Similar to the case when both firms offer partial refund, now the firms may offer price promotions to compete for service reservations, which occurs when $N_A^o + N_B^o > \alpha M$ (i.e., $N > (3-\alpha)M/6$). In the competition regime, firm A can sell N_A^o service units in the advance period if it charges a lower price than firm B does and only $\alpha M - N_B^o = (1+\alpha)M/2 - N$ units otherwise. Similarly, firm B's reservations will be N_B^o units if its advance price is lower than firm A's and only $\alpha M - N_A^o = M - 2N$ units otherwise. The following proposition characterizes the firms' equilibrium advance-pricing strategies in the asymmetric refund case.

Proposition 2. *When firm A offers partial refund and firm B offers zero refund*:

(i) *For* $N \le (3-\alpha)M/6$, *the equilibrium advance-pricing strategy is given by* $P_{1A}^{**} = P_{1B}^{**} = V_1/2$;

(ii) *For* $(3-\alpha)M/6 < N < M/2$, *the equilibrium advance-pricing strategy is mixed and asymmetric. The supports for the firms' advance prices are continuous with* $P_{1A}^o \in [\underline{P}^o, V_1/2]$ *and* $P_{1B}^o \in [\underline{P}^o, V_1/2)$, *where*

$$\underline{P}^o = \frac{H}{2} + \frac{[(1+\alpha)M/2 - N](V_1-H)/2}{2N-(1-\alpha)M}.$$

The cumulative distribution for firm A's advance price is

$$F_A^o(P) = \frac{2N-(1-\alpha)M}{6N-(3-\alpha)M} - \frac{H}{4P} - \frac{[(1+\alpha)M-2N]V_1}{4[6N-(3-\alpha)M]P}.$$

The cumulative distribution for firm B's advance price is

$$F_B^o(P) = \frac{4N-2(1-\alpha)M}{6N-(3-\alpha)M} - \frac{[(1+\alpha)M-2N](V_1-H)/2}{[6N-(3-\alpha)M](P-H/2)}.$$

As in the case when both firms offer partial refund, here there may exist a unique mixed-strategy equilibrium in which the firms compete for reservations. This competition regime is less likely to arise in the asymmetric case than when partial refunds are offered by both firms, i.e., $(3-\alpha)M/6 > (2-\alpha)M/4$. This is because now only one firm offers partial refund and is induced to increase reservations in the advance period. Only when the firms have sufficiently large capacity to sell would they be involved in the competition region in the advance period.

Note that the firms' equilibrium advance-pricing strategies are asymmetric in the mixed-strategy equilibrium when only one firm offers partial refund. Let us now compare this asymmetric equilibrium with that when both firms offer partial refund. We have the following results:

Lemma 3. *When the advance-pricing equilibrium is mixed for both the symmetric and the asymmetric partial refund cases, i.e.,* $N > (3-\alpha)M/6$: (i) $\underline{P}^o > \underline{P}^{**}$; (ii) $F_A^o(V_1/2) = (V-H)/(2V) < 1 = F_B^o(V_1/2) = F_A^{**}(V_1/2) = F_B^{**}(V_1/2)$; (iii) $F_A^o(P) < F_B^o(P)$ *for all* $P \in (\underline{P}^o, V_1/2)$, *and* $F_B^o(P) < F_A^{**}(P) = F_B^{**}(P)$ *for all* $P \in (\underline{P}^{**}, V_1/2)$; (iv) $E^o(P_{1A}) > E^o(P_{1B}) > E^{**}(P_{1A}) = E^{**}(P_{1B})$, *where* $E^{**}(P_{1j})$ *and* $E^o(P_{1j})$, $j = A, B$, *are the equilibrium average prices in the symmetric and the asymmetric partial refund cases, respectively.*

A few interesting features are exhibited in this lemma on the firms' asymmetric advance-pricing strategies. First, the firms offer smaller price cuts when only one of them provides partial refund. Second, the frequency by which a firm offers promotions is lower when it is the only firm that offers partial refund, than when either it is the only firm that does not offer partial refund or when both firms offer partial refund. In particular, a firm cuts its advance price below $V_1/2$ with a probability less than one when it offers partial refund and its rival offers zero refund. In contrast, a firm offers promotions with probability one if and only if its rival adopts the partial refund policy, irrespective of its own refund policy. Third, firm A's equilibrium advance price is first-degree stochastic dominant over that of firm B in the asymmetric refund case, which in turn exhibits first-degree stochastic dominance over that in the symmetric partial refund case. Fourth, although the firms on average charge higher prices when only one of them offers partial refund than when they both offer partial refund, the average advance price is higher for the firm that is the only one offering partial refund than for the firm that is the only one offering zero refund.

The central message emerging from the above results is that offering partial refund intensifies the firms' price competition in the advance period, and it does so more for the rival firm. The competition-intensifying effect is asymmetric: it is weaker for the firm that adopts the partial refund policy. In other words, the *cross effect* of the partial refund policy is stronger than the *own effect*. To understand the asymmetry in the competition-intensifying effect of the partial refund policy, it is important to investigate the differences between the firms regarding the gains from undercutting prices relative to the secured payoffs when the rival has a lower price. In terms of the incentive to cut prices, the firm undercutting below its rival's price can sell more reservations when it offers partial refund than when it does not, i.e., $N_A^o > N_B^o$. On the other hand, the firm charging a higher price than its rival can secure more residual reservations in the asymmetric refund case when it adopts the partial refund policy (i.e., $\alpha M - N_B^o$) than when only its rival offers partial refund (i.e., $\alpha M - N_A^o$). It turns out the latter force dominates the former one, making the firm that is the only one offering partial refund less aggressive in pricing in comparison to its rival.[9]

In this asymmetric scenario, the firms' equilibrium expected payoffs are, respectively,

$$\Pi_A^o = \begin{cases} NV_2, \quad \text{if } N \le (1-\alpha)M/2; \\[4pt] (2N-(1-\alpha)M)(V_1-H)/2 \\ \quad +(1-\alpha)MV_2/2, \\ \quad \text{if } (1-\alpha)M/2 < N \le (3-\alpha)M/6; \\[4pt] ((1+\alpha)M/2-N)(V_1-H)/2 \\ \quad +(1-\alpha)MV_2/2, \quad \text{otherwise}; \end{cases} \tag{8}$$

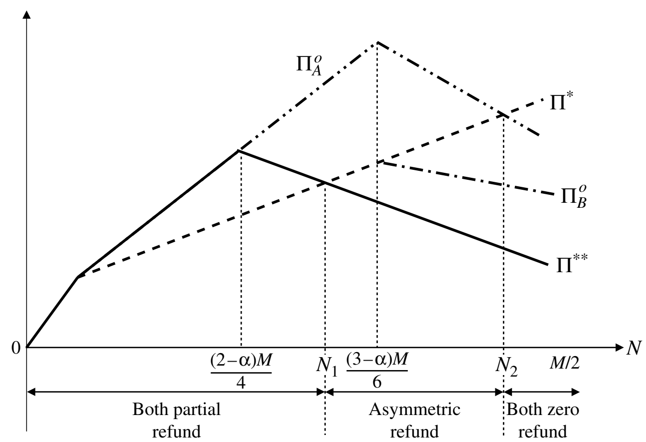
and

$$\Pi_B^o = \begin{cases} NV_2, \quad \text{if } N \le (1-\alpha)M/2; \\[4pt] (N-(1-\alpha)M/2)V_1/2+(1-\alpha)MV_2/2, \\ \quad \text{if } (1-\alpha)M/2 < N \le (3-\alpha)M/6; \\[4pt] ((1+\alpha)M-2N)V_1/8 \\ \quad +[6N-(3-\alpha)M]H/8+(1-\alpha)MV_2/2, \\ \quad \text{otherwise.} \end{cases} \tag{9}$$

3.2. Profit and Welfare Implications

In this section, I investigate the profit and welfare implications of competitive refund policies. To this end, note first that when $N < (1-\alpha)M/2$, the firms' equilibrium expected payoffs remain unchanged for the different refunding strategies: when the firms' overall capacity is sufficiently small, irrespective of the firms' refund policies, they prefer to sell all the capacity in the spot period. As a result, I shall focus on the interesting parameter range, i.e., $(1-\alpha)M/2 < N < M/2$. To facilitate the discussion, the firms' equilibrium expected profits are displayed in Figure 2.

Figure 2 Firms' Expected Profits and Equilibrium Refund Policies



I start the investigation with the comparative statics of the equilibrium expected profits. There are two noteworthy results. First, as the firms' overall capacity N increases, their equilibrium expected payoffs increase unambiguously when neither of them offers a refund but may decrease when at least one of them offers partial refund. The negative effect of service capacity occurs in the competition regime when the capacity is sufficiently large. Intuitively, in the mixed-strategy equilibrium, when the firms compete for the advance consumers' reservations, a firm's equilibrium expected payoff is determined by the residual demand uncovered by the rival firm, which decreases with the rival's capacity. Second, how should the hassle cost H influence the firms' equilibrium payoffs? As in Xie and Gerstner (2007), reducing the hassle cost increases the equilibrium payoff for the firm that offers partial refund. This is because fulfilling service cancellations is less costly when it is easier for consumers to claim a refund. However, a firm may benefit from an increasing hassle cost when only its rival offers partial refund (i.e., $\partial\Pi_B^o/\partial H > 0$ when $N > (3-\alpha)M/6$). This is similar to the result on product returns (e.g., Davis et al. 1995), but for a different reason. In the case of product returns, opportunistically returned products cannot be resold and therefore may hurt the firm, which can otherwise be alleviated with an increasing hassle cost. In contrast, in the asymmetric refund case investigated in this paper, a higher hassle cost makes the firm offering partial refund less aggressive in pricing, benefiting the rival firm that offers zero refund.

[9] There is another force that discourages price cuts, i.e., the refund payment to fulfill cancellations. This effect explains why the frequency of offering promotions, $F_A^o(V_1/2) = (V_1 - H)/(2V_1)$, decreases with the hassle cost H.

Next, I am interested in comparing the firms' (symmetric) equilibrium payoffs when they follow identical—either partial or zero—refund policies. This leads to the following proposition:

PROPOSITION 3. (i) *If $(1-\alpha)M/2 < N < N_1$, the firms earn higher profits with symmetric partial refund policies than they do with symmetric zero refund policies;*

(ii) *If $N_1 < N < M/2$, the firms earn lower profits with symmetric partial refund policies than they do with symmetric zero refund policies, where*

$$N_1 = \frac{[(3-\alpha)V_1 - 2H]M}{6V_1 - 4H}.$$

The relative profitability of the partial versus the zero refund policy when both firms adopt identical policies depends on the firms' overall capacity. Both firms would be better off offering partial refunds when N is low and would be worse off when N is high. To understand this result, note that adopting the partial refund policy has two effects. First, there is an efficiency-improving effect of diverting the rights to consume the service in the spot period to the consumers who happen to value the service more (Xie and Gerstner 2007). In the spot period, half of the early-arriving consumers turn out to have zero consumption utility for their reservations, and it is efficient to transfer their reserved service to the late-arriving consumers. A partial refund policy makes this possible and increases the firms' payoffs through accruing the surplus of improving the consumption efficiency. However, partial refund policies may increase the firms' optimal amount of reservations and thus intensify the competition between them. When consumers can ex post cancel their reservations, the firms desire to advance-sell more units and thus place a higher reservation limit. The increasing desire for advance sales, as shown earlier, can convert the firms from local monopolies into a regime where they compete for consumer reservations. In other words, the partial refund policy can endogenously change the nature of interaction between the firms.

The relative strength of the efficiency-enhancing versus the strategic effect of partial refund policies hinges on the expected advance sales the firms can obtain in equilibrium. As the equilibrium advance sales increase, the expected cancellations loom larger, leading to an increasing gain from improving the consumption efficiency. As a result, when the capacity is not very large, partial refund policies unambiguously increase the firms' equilibrium reservations and thus improve their profitability. However, the pro-efficiency effect can be dominated by the strategic effect that endogenously arises when the capacity becomes sufficiently large. Note that in the competition regime, a firm's secured advance sales are negatively influenced by the rival's optimal reservation limit, which in turn increases with the overall capacity. This explains why the firms can be worse off offering identical partial refund policies when N is high enough.

The above discussion also suggests that partial refund policies can unambiguously enhance social welfare. In the absence of a partial refund, consumers would not cancel their reservations, and as a result, the reserved service units that happen to misfit the consumers' needs would remain unconsumed in the spot period. In contrast, the firms' capacity that would be ex post consumed can be increased in equilibrium when a partial refund is present. Nevertheless, the first-best social optimum cannot be achieved unless all the capacity $2N$ is ex post consumed, which occurs only when in equilibrium the firms are de facto local monopolies in the advance period.

3.3. Equilibrium Refund Policies

In the above section, I analyze the relative profitability of the refund policies when both firms follow identical policies. Although insights are provided into when partial refund is more profitable in a market where both firms follow the same strategy, the issue of whether partial or zero refund policies would be observed in equilibrium remains unaddressed. In particular, an equilibrium in which both firms choosing the partial refund policy or both adopt the zero refund policy can be sustained only when neither firm gains from unilaterally deviating to the alternative policy. I now investigate the firms' incentives for unilateral deviations, and the conditions under which different equilibria arise.

PROPOSITION 4. (i) *A unilateral adoption of zero refund is beneficial if and only if $N > N_1$;*

(ii) *A unilateral adoption of partial refund is (weakly) beneficial if and only if $N < N_2$, where*

$$N_2 = \frac{[2V_1 - (1+\alpha)H]M}{4V_1 - 2H};$$

(iii) *A firm is always (weakly) hurt by its rival's adoption of the partial refund policy.*

Consider the situation when both firms have partial refund policies. We have seen that when the capacity is sufficiently large (i.e., $N > N_1$), the firms would be better off when they both adopt the alternative zero refund policy. Then would a firm unilaterally make the deviation? This proposition suggests that the answer is yes. Intuitively, when the competition-intensifying effect of the partial refund policy becomes so strong as to outweigh the efficiency-improving effect, it is beneficial for a firm to avoid (or at least soften) the competition by switching to the zero refund policy, irrespective of whether the rival firm is following suit. In other words, a unilateral deviation to the zero refund policy is a desirable firm strategy for $N > N_1$.

Now consider the situation when both firms adopt zero refund, and firm A is contemplating the partial refund policy as a unilateral choice. When would such a move makes firm A better off? It is proposed that a unilateral choice of partial refund can be beneficial if and only if the firms' capacity is not sufficiently large (i.e., $N < N_2$). This result is similar to that in the case with bilateral deviations to the partial refund policy, but with some difference. In comparison to that case, now firm A can secure the same gains from the efficiency-improving effect, but the competition-intensifying effect is weaker because only one firm offers partial refund. This implies that the net benefit of the partial refund policy can be higher with a unilateral adoption than with bilateral adoptions. Indeed, firm A's guaranteed advance sales are higher for all $N < M/2$ with the unilateral deviation but may be lower with bilateral deviations to the partial refund policy. Nevertheless, to cover the consumers' hassle cost of cancellation, unilaterally adopting the partial refund policy can decrease firm A's profitability when N is sufficiently high.

The "spillover" effect of adopting the partial refund policy on the rival's profitability is less ambiguous. This proposition shows that when a firm deviates to the partial refund policy, its rival's equilibrium expected payoff can be hurt but never improved, irrespective of the rival's own choice of refund policy. For example, as shown in Figure 2, when firm A switches from the zero to the partial refund policy, firm B's equilibrium expected profit may decrease from Π^* to Π_B^o if firm B chooses zero refund, or from Π_A^o to Π^{**} if firm B offers partial refund. This result is related to the asymmetric competition-intensifying effect of the partial refund policy. As shown earlier, the adoption of the partial refund policy may make the rival firm more aggressive in pricing without improving the consumption efficiency of the rival's service. As a result, a firm can undoubtedly become worse off when the other firm chooses the partial refund policy.

Proposition 5. *The firms' equilibrium refund policies are given by*

(i) *For* $N < N_1$, *both firms adopt partial refund;*

(ii) *For* $N_1 < N < N_2$, *one firm adopts partial refund and the other firm adopts zero refund;*

(iii) *For* $N_2 < N < M/2$, *both firms adopt zero refund.*

This proposition summarizes the service providers' equilibrium refund decisions. As the firms' capacity increases, the number of firms that in equilibrium adopt the partial refund policy decreases. In particular, when N is sufficiently low, both firms in equilibrium pursue the partial refund strategy, whereas they may both embrace the alternative zero refund policy when N is sufficiently high. Interestingly, for intermediate N, there exists an equilibrium in which one firm adopts partial refund, whereas the other firm chooses zero refund. Thus, even with two symmetric service providers, we may have an asymmetric equilibrium on the firms' choice of refund policies.

To understand this result, note that the relative importance of the efficiency-improving versus the competition-intensifying effect of the partial refund policy first increases and then decreases with the firms' capacity N, depending on whether the competition regime is endogenously raised. When the efficiency-enhancing effect is dominant (i.e., N is low enough), both firms pursue the partial refund policy. Conversely, when the competition becomes sufficiently intense (i.e., N is high enough), it is dominant for both firms to give up the partial refund policy. Nevertheless, the asymmetric equilibrium reflects an interesting trade-off between the efficiency-improving and the competition-intensifying effects when neither of them is dominant. As shown earlier, a unilateral adoption of partial (zero) refund is profitable if $N < N_2$ ($N > N_1$). As a result, in the range $N_1 < N < N_2$, it is desirable to choose the partial refund policy, but only when the rival is not pursuing the same strategy. If the firms chose identical partial or zero refund strategies, excessively intense competition would arise or too much consumption efficiency would be lost, respectively. The symmetric firms then end up in an asymmetric equilibrium. Finally, note that in comparison to the case when both firms offer zero refund, the symmetric partial refund equilibrium is a "win-win," whereas the asymmetric equilibrium is a "win-lose" outcome for the firms.

4. Extensions

In this section, I briefly discuss some extensions to the basic model, including alternative setups for consumption uncertainty, stochastic demand, and endogenizing consumer arrival and market size.

4.1. Consumption Uncertainty

The basic model assumes that the consumers' utility U_{tj} is perfectly negatively correlated across firms. That is, if firm A's service fits a consumer's consumption need, then firm B's will necessarily be a misfit, and vice versa. Let us now consider an alternative setup for consumption fit uncertainty where $f_j \in \{1, 0\}$ is independently distributed across firms. As a result, in the spot period there are four segments of consumers whose consumption utilities are given by $(U_{tA}, U_{tB}) \in \{(V_t, V_t), (V_t, 0), (0, V_t), (0, 0)\}$, for $t \in \{1, 2\}$. Let us also define $\Pr(f_j = 1) \equiv \beta$ and $\Pr(f_j = 0) \equiv 1 - \beta$ for each firm $j = A, B$, where $\beta \in (0, 1)$.[10]

[10] In the case when $f_j \in \{1, \gamma\}$, where $\gamma \in (0, 1)$, the same equilibrium will be obtained if γ is sufficiently small or β is sufficiently large, because it would be dominated for a firm j to serve the consumers with $f_j = \gamma$.

As shown in the appendix, there exists an equilibrium in which the firms' optimal reservation limit is given by $N_j^* = \max\{N - (1-\alpha)\beta(2-\beta)M/2, 0\}$ if following the zero refund policy, and by $N_j^{**} = \max\{N/\beta - (1-\alpha)(2-\beta)M/2, 0\}$ if partial refund is adopted, $j = A, B$. It is then evident that $N_j^{**} = N_j^*/\beta > N_j^*$. This indicates that this alternative setup does not change the manner in which the partial refund policy influences the firms' strategic decision making. Similar to the basic case, offering partial refund allows a firm to resell some prereserved service units, which in turn increases the firm's optimal reservation limit without necessarily decreasing the effective residual capacity in the spot period. As a result, one can expect that adopting the partial refund policy will similarly lead to the efficiency-enhancing as well as the competition-intensifying effects. The qualitative results in the basic model for the firms' equilibrium choice of the partial versus the zero refund policy will then be maintained.

4.2. Stochastic Demand

Let us then modify the basic model to consider stochastic demand. Suppose that the size of the advance consumers is deterministic and given by M_1. However, consistent with the yield management literature (e.g., Weatherford and Bodily 1992, Desiraju and Shugan 1999, McGill and van Ryzin 1999), let us assume that the number of late-arriving consumers, $M_2 \in [0, \bar{M}]$, is continuous and stochastic with cumulative distribution $G(m) \equiv \Pr(M_2 \le m)$, where $G(0) = 0$, $G(\bar{M}) = 1$, and $\bar{M}$ is sufficiently large. Given this modified setup, it is shown in the appendix that when firm A adopts the zero refund policy, the interior optimal reservation limit N_A^* is obtained by solving $P_{1A} + [G(2(N - N_A)) - 1]V_2 = 0$. Similarly, the interior optimal reservation limit N_A^{**} when firm A adopts the partial refund policy is implicitly determined by $P_{1A} - H/2 + [G(2N - N_A) - 1]V_2/2 = 0$. Therefore, similar to the basic case, we can obtain the following insights on the effects of adopting the partial refund policy. First, conditional on the advance price P_{1j}, the interior solution N_A^{**} is larger than N_A^*. This implies that the firms have an incentive to allocate more service units to the advance period when the partial refund policy is adopted than when it is not. This is due to the efficiency-improving effect suggested by Xie and Gerstner (2007), which can increase capacity utilization and firm payoff. Second, as a result of the firms' increasing incentive to sell more units in the advance period, the competition regime $N_A + N_B > M_1$ is more likely to arise, i.e., the competition-intensifying effect.[11] We can then expect that the main implications derived from the basic model can be extended to the case with stochastic spot demand.

4.3. Endogenous Arrival and Market Size

In the basic model, the consumers' arrival time is exogenously determined and so is the market size, whereas the early-arriving consumers are permitted to be strategic in that they can choose to buy in the advance period or the spot period. This is the standard assumption made in the literature on advance selling and yield management (e.g., Weatherford and Bodily 1992, McGill and van Ryzin 1999, Xie and Shugan 2001). Nevertheless, consumers could also be strategic in deciding whether and when to enter the market, which to my best knowledge has not been addressed in previous studies. This will be a relevant issue if consumers have to incur a nonnegative search/entry cost to become informed of the firms' service offerings (e.g., prices) before they can choose among the firms' offerings and the outside option. If it is costly for consumers to decide whether and when to make a purchase decision, consumers' arrival time and hence the effective market size will become endogenous, which could be potentially influenced by the firms' long-term strategies (e.g., refund policy) that are known at the time when the consumers make market entry decisions.

Consider the following modified model.[12] At the beginning of the advance period ($t = 1$), some consumers know that they will have a one-unit demand in the spot period with probability one, whereas other consumers have a probability λ (or $1 - \lambda$) that they will demand one (or zero) unit of service in the spot period, where $\lambda \in (0, 1)$ is sufficiently small. Similar to the basic model, one can think of these different consumers as representing leisure and business travellers, with size M_1 and M_2 and valuation V_1 and V_2, respectively. To facilitate exposition, I will label these two consumer types as "early consumers" and "late consumers," respectively. All consumers are informed of the firms' refund policies, which were determined in period $t = 0$, but no consumer is ex ante informed of the firms' prices. A fraction δ of consumers has a negligible cost of price searching, whereas the other fraction $1 - \delta$ of consumers has to invest a search cost $k > 0$ to find out the firms' prices. This search cost will become sunk once it is incurred. A consumer can decide whether or not, and whether in the advance

[11] Unfortunately, the firms' equilibrium advance-pricing strategies become intractable in the competition regime when $N_A + N_B > M_1$. This is because the firms' advance prices will be in mixed strategies in the competition regime, and, in contrast to the basic model, a firm's optimal reservation limit in the stochastic-demand case is influenced by the charged advance price. Note that this intractability issue is immaterial in the yield management literature, which usually focuses on monopolistic settings and/or exogenous prices.

[12] I thank the editor, Eric Bradlow, for inspiring this investigation.

period or the spot period, to invest the search cost to enter the market. Consumers' heterogeneity along the search-cost dimension is independent of their difference in the uncertainty about positive demand (i.e., early versus late consumers). All the other assumptions in the basic model are similarly made.

None of the late consumers will enter in the advance period because λ is sufficiently small, i.e., the chance is sufficiently slim that they will have a demand at all. They will enter in the spot period if and only if the demand is realized and the search cost is negligible; those late consumers with positive search cost will not enter at all, because otherwise their expected surplus of entry will be strictly negative since $P_{2j} = V_2$ will arise in equilibrium. Moreover, the early consumers with negligible search cost will enter the market in the advance period. What remains to be determined is the entry decision of the early consumers with positive search cost: they will not enter in the spot period for sure, because the firms will never charge a spot price below V_1; they will enter in the advance period if and only if the firms' expected equilibrium advance prices are sufficiently low such that the sunk search cost k can be recovered. Finally, note that a consumer deciding not to enter will not make any purchase, because otherwise the firms will charge a prohibitively high price. This implies that the equilibrium spot sales for each of the firms will be $\lambda\delta M_2/2$, and that the total market demand in the advance period can be either δM_1 or M_1, depending on whether the early consumers with positive search cost decide to enter in the advance period.

It follows readily that the firms' equilibrium strategies on spot-period pricing (P_{2j}) and optimal reservation limit (N_j) are similar to those in the basic model. In addition, the efficiency-improving and the competition-intensifying effects can arise when the firms increase their optimal reservation limit under the partial refund policy. However, interestingly, the competition-intensifying effect can be buffered in comparison to the basic model. This is because the effective market demand can be endogenously expanded with the entry of the early consumers with positive search cost, if and only if the firms are expected to interact in equilibrium in the competition regime in the advance period and thus sufficiently cut their advance prices. This *market expansion* effect can then mitigate the competition between the firms which can in turn lead to a higher incentive for the firms to pursue the partial refund policy. As a result, the parameter range under which the partial refund policy is adopted in equilibrium can be expanded. Nevertheless, the competition-intensifying effect cannot be completely removed, and therefore there can still exist equilibria in which the firms embrace zero/asymmetric refund policies.

5. Concluding Remarks

5.1. Implications

This study is motivated by previous analytical research that demonstrates the profitability of partial refund policies for monopolistic service-selling firms and by a certain lack of ubiquity in practice about these refunds in competitive markets. Xie and Gerstner (2007) show that a firm offering partial refund for service cancellations is generally better off when there is limited capacity and buyer uncertainty about future preferences. However, anecdotal evidence suggests that some firms offer refunds and others do not, and even firms in the same service industry differ significantly in their refund policies. To understand this disparity, in this paper I develop a parsimonious model to investigate how competition may influence the profitability as well as the equilibrium choice of refund policies. It is shown that partial refund policies may endogenously change the nature of firm interaction from local monopolies into a competition regime, moderating the gains from exploiting the efficiency-enhancing effect of offering partial refunds. The interplay of the efficiency-improving and the competition-intensifying effects allows us to derive a whole range of pure-strategy equilibria on refund policy choice. In particular, as the competition becomes more intense, one can have equilibria ranging from both firms choosing partial refund, to one firm adopting partial refund and the other pursuing zero refund, and then to both firms adopting zero refund.

The analysis and results in this paper could explain why the insights on the profitability of partial refunds in a monopoly setting may not necessarily transfer over to a competitive environment.[13] This explanation highlights the role of competition, which can be endogenously intensified by a partial refund clause, in decreasing firms' incentive to offer partial refunds for service cancellations. For example, one may conjecture that the differences in the practice of refund policies between travel-related and other services can be attributed to the notion that there are more price-insensitive buyers in the former services. Service providers in airline, car rental, and hotel markets may face less competition than firms in other services do (say, professional sports), because consumers in the former cases may have fewer substitutes than in the

[13] Nevertheless, it is an empirical issue about the extent to which the variations in refund policies across industries, firms, and/or time are actually driven by the economic mechanism proposed in this paper. It is by all means a highly complicated research problem because there are a variety of alternative incentives underlying a firm's provision of refunds (e.g., Png 1989, Moorthy and Srinivasan 1995, Shieh 1996, Chu et al. 1998, Fruchter and Gerstner 1999). It may be difficult, if not impossible, to empirically disentangle these alternative mechanisms. Moreover, the measurement of competition and ex post consumption inefficiency can be difficult.

latter situations—a traveller may have to take a particular flight at a particular time, whereas one can spend her Friday night either at an NBA game or on a variety of other options (e.g., concert, theater, sleeping). This may be why we observe more refunds provided by firms in travel industries. A similar argument could also be applied to explain the apparent asymmetry among the airlines in the number of nonrefundable tickets issued. In the airline industry, there may exist some room to exploit the efficiency-increasing effect of partial refunds, but the competition would be too intense to sustain all firms to do so. Recall that there would be an asymmetric equilibrium on refund policy choice, as predicted in this paper, when neither the efficiency-improving nor the competition-intensifying effect is dominant.

Service managers can benefit from the analysis in this paper. The central insight is that firms should recognize that offering partial refund can be a "double-edged sword." On the positive side, it could encourage consumers to cancel their unused reservations and allow more efficient utilization of limited service capacity. However, adopting a partial refund policy may also intensify competition among the service providers and hence completely nullify the efficiency gain. Therefore, in designing refund policies for service offerings, managers should invest more scrutiny to investigate the consequent impact on the strategic interaction among rival firms.

5.2. Discussions and Future Research

One potential caveat in the current analysis is the multiplicity of equilibrium partial refund.[14] Xie and Gerstner (2007) address this issue by assuming that the firms can commit ex ante whether to offer refunds for consumer cancellation, but the exact refund amount is ex post determined after the advance period. Another way to obtain unique solution is to assume that consumers are risk averse. This equilibrium multiplicity is not a problem in the current study though, because it occurs only in the first stage of the game and the multiple equilibria involve the same payoffs.

The advance-period equilibrium can be mixed, which is caused by the nature of Bertrand price competition. However, this is not necessary for us to obtain the insights in this paper. For example, in a Cournot setup where the firms decide only on the reservation limit and the market price is determined by the total supply, one would obtain similar insights in pure strategies.

The current setup deliberately concentrates on symmetric firms. This allows us to derive the interesting result that an asymmetric equilibrium may arise from the interplay of the two counteracting economic effects of partial refund. Nevertheless, one can extend the analysis to explore whether and how firm asymmetry (e.g., consumer composition, quality, cost, etc.) may result in differential incentives for the adoption of partial refund.

One can think of a partial refund as an effective discrimination mechanism to separate early-buying consumers who have different realized utility in the spot period. This may remind the reader of the well-known result that second-degree price discrimination can intensify competition. However, the underlying economic forces are significantly different. Recall that the firms in equilibrium remain as local monopolies and do not compete for the consumers at all in the spot period. Instead, partial refund works to intensify competition through the feedback effect on the advance-period interaction. Nevertheless, to incorporate second-degree price discrimination into the current analysis, one can employ alternative model setup in which, for example, consumers are ex ante different in their willingness to pay for quantity/quality. One may start with a monopoly setting and then extend the analysis to investigate the role of competition.

This study identifies some directions for future research. A complementary analysis to the current study is to investigate contingent contracts in competitive service markets that are characterized by seller uncertainty. Biyalogorsky et al. (1999) and Biyalogorsky and Gerstner (2004) demonstrate that monopoly firms can profit from buy-back clauses that allow the firms to cancel presold services. One may ask, as in this paper, whether the firms' incentive to impose the buy-back clauses can be softened in a competitive environment. Relatedly, firms can offer flexible/adaptive refunds whereby the effective refund gets to be determined in the spot period and can be conditional on the observed advance demand. One may expect that such flexibility will induce the firms to advance sell more units, which, following the same reasoning as in this paper, can result in more intense competition and hence may not be as attractive as it would be for a monopoly.

Future research may also consider the role of refunds in the strategic interaction between firms in distribution channels. Other related issues involve alternative vehicles that can make consumers escape from unfavorable prepurchased services, i.e., resale to third parties or brokers, or the extension of the consumption entitlement to a future time (e.g., changeable tickets). It would be interesting to investigate how these alternative arrangements may influence ex post consumption efficiency, strategic interaction, and firm profitability. Another interesting direction for future research is to extend the current model to allow for multiple reservations from different

[14] I am grateful to the review team for their insights, which led to some of the following discussions in this section.

service providers (Walsh 1995, Guo 2006). Additional issues may arise under this extension when consumers are induced to advance purchase multiple services and capacity is limited, regarding the optimal rationing rule for firms as well as the optimal search/reservation strategy for consumers. I hope that this paper will inspire future interests in this line of research.

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Appendix
Proof of Proposition 1. Note that $N_j^{**} \le \alpha M/2$ if and only if $N \le (2-\alpha)M/4$. Part (i) of the proposition follows immediately. I then show that there exists no pure-strategy equilibrium when $(2-\alpha)M/4 < N < M/2$. To see this, note first that there is no pure-strategy equilibrium such that $P_{1A} = P_{1B}$. Firm A's expected profit is $\Pi_A = (P_{1A} - H/2)\alpha M/2 + (1-\alpha)MV_2/2$ when $P_{1A} = P_{1B}$. However, if it cuts the price by ϵ, its expected profit will be $\Pi'_A = (P_{1A} - \epsilon - H/2)[2N - (1-\alpha)M] + (1-\alpha)MV_2/2$. The deviating profit is higher when ϵ is small enough, because $N > (2-\alpha)M/4$ implies $2N - (1-\alpha)M > \alpha M/2$. Note also that $P_{1A} < P_{1B}$ cannot be an equilibrium either, because firm A can always increase P_{1A} by a sufficiently small amount without decreasing its reservations.

When a firm's advance price turns out to be higher than its rival's, it is optimal to sell the residual amount $N - N_j^{**} = M - 2N$ in the advance period. This is because $\partial \Pi_j/\partial N_j' > 0$ when $N_j' \le 2N - (1-\alpha)M$ for any $P_{1j} > H/2$.[15] Note that the equilibrium expected profit derived from the late-arriving consumers is $(1-\alpha)MV_2/2$, which is independent of the advance price. Summarizing the above discussion, similar to Narasimhan (1988), one can obtain that the equilibrium price support for both firms is continuous on $[\underline{P}, V_1/2]$, where $\underline{P}$ can be derived as follows:

$$(\underline{P} - H/2)[2N - (1-\alpha)M] = (M-2N)(V_1 - H)/2$$
$$\Longrightarrow \quad \underline{P}^{**} = \frac{H}{2} + \frac{(M-2N)(V_1-H)/2}{2N-(1-\alpha)M}.$$

In the above derivation, $(M-2N)(V_1-H)/2$ is the firm's guaranteed expected payoff from the advance consumers when it charges $P_{1j} = V_1/2$. In a mixed-strategy equilibrium, a firm's expected payoff is the same for any price charged in the support $[\underline{P}^{**}, V_1/2]$:

$$(P - H/2)\{F_j(P)(M-2N) + [1-F_j(P)][2N-(1-\alpha)M]\}$$
$$= (M-2N)(V_1-H)/2, \quad \forall P \in [\underline{P}^{**}, V_1/2].$$

This gives rise to the cumulative distribution function for the mixed strategy:

$$F_j^{**}(P) = \frac{2N-(1-\alpha)M}{4N-(2-\alpha)M} - \frac{(M-2N)(V_1-H)/2}{[4N-(2-\alpha)M](P-H/2)}. \quad \text{Q.E.D.}$$

[15] This also suggests that the equilibrium reservation limit N_j^{**} is indeed optimal even in alternative setups where advance prices and reservation limits are sequentially determined.

Proof of Proposition 2. Note that $N_A^o + N_B^o \le \alpha M$ if and only if $N \le (3-\alpha)M/6$. This proves part (i) of the proposition. Following the proof of Proposition 1, one can easily show that there exists no pure-strategy equilibrium when $(3-\alpha)M/6 < N < M/2$. In this case, when firm A's advance price turns out to be higher than firm B's, it is optimal to sell the residual amount $\alpha M - N_B^o = (1+\alpha)M/2 - N$ in the advance period. Similarly, firm B would like to sell the residual units $\alpha M - N_A^o = M - 2N$ when its advance price is higher than firm A's.

Following Narasimhan (1988), the supports for the firms' advance prices must be continuous, the sets of advance prices charged by both firms are identical and between $\underline{P}$ and $V_1/2$, and there can be at most one mass point at $V_1/2$ for at most one firm. Let us then derive the lower bound $\underline{P}$ of the price support and show that there is exactly one mass point for firm A at $V_1/2$. Suppose instead that there is no mass point for either firm. This implies that firm A and firm B would earn a guaranteed expected advance-period payoff of $\Pi_{1A} = [(1+\alpha)M/2 - N](V_1 - H)/2$ and $\Pi_{1B} = (M-2N)V_1/2$, respectively. This further suggests that the lower bound of the price support must be given by $\underline{P}_A = H/2 + ([(1+\alpha)M/2 - N](V_1-H)/2)/(2N-(1-\alpha)M)$ and $\underline{P}_B = ((M-2N)V_1/2)/(N-(1-\alpha)M/2)$ for firm A and firm B, respectively. However, $\underline{P}_A > \underline{P}_B$ since $N > (3-\alpha)M/6$, which cannot be sustained in equilibrium. Then one firm must have a mass point at $V_1/2$. This cannot be firm B, because otherwise firm B can move its probability mass to $\underline{P}_A$ and earn a higher expected payoff (i.e., $\underline{P}_A[N-(1-\alpha)M/2]$) than that when it charges $V_1/2$ (i.e., $(M-2N)V_1/2$). Therefore, the supports for the firms' advance prices are continuous: $P_{1A}^o \in [\underline{P}^o, V_1/2]$ and $P_{1B}^o \in [\underline{P}^o, V_1/2)$, where $\underline{P}^o = \underline{P}_A = H/2 + ([(1+\alpha)M/2 - N](V_1-H)/2)/(2N-(1-\alpha)M)$.

From the above, we can also see that the firms' equilibrium expected advance-period payoffs are given by

$$\Pi_{1A}^o = [(1+\alpha)M/2 - N](V_1-H)/2$$

and

$$\Pi_{1B}^o = \underline{P}^o[N-(1-\alpha)M/2]$$
$$= [(1+\alpha)M - 2N]V_1/8 + [6N-(3-\alpha)M]H/8.$$

To derive the equilibrium cumulative distribution functions for the firms, note that in a mixed-strategy equilibrium, a firm's expected payoff is the same for any price charged in the support. That is,

$$(P-H/2)\{F_B(P)[(1+\alpha)M/2-N] + [1-F_B(P)][2N-(1-\alpha)M]\}$$
$$= [(1+\alpha)M/2 - N](V_1-H)/2,$$

and

$$P\{F_A(P)(M-2N) + [1-F_A(P)][N-(1-\alpha)M/2]\}$$
$$= \underline{P}^o[N-(1-\alpha)M/2].$$

These then yield the cumulative distribution functions as given in the proposition:

$$F_A^o(P) = \frac{2N-(1-\alpha)M}{6N-(3-\alpha)M} - \frac{H}{4P} - \frac{[(1+\alpha)M-2N]V_1}{4[6N-(3-\alpha)M]P}$$

and

$$F_B^o(P) = \frac{4N-2(1-\alpha)M}{6N-(3-\alpha)M} - \frac{[(1+\alpha)M-2N](V_1-H)/2}{[6N-(3-\alpha)M](P-H/2)}. \quad \text{Q.E.D.}$$

Proof of Lemma 3. Parts (i), (ii), and (iii) of the proposition follow readily from an examination of the respective cumulative distribution functions. To prove part (iv), one can follow the definitions of average prices:

$$E^o(P_{1A}) = \int_{\underline{P}^o}^{V_1/2}[1-F_A^o(P)]\,dP + \underline{P}^o > \int_{\underline{P}^o}^{V_1/2}[1-F_B^o(P)]\,dP + \underline{P}^o = E^o(P_{1B}),$$

where the inequality is obtained by noting that $F_A^o(P) < F_B^o(P)$ for all $P \in (\underline{P}^o, V_1/2)$, and

$$E^o(P_{1B}) = V_1/2 - \int_{\underline{P}^o}^{V_1/2} F_B^o(P)\,dP > V_1/2 - \int_{\underline{P}^{**}}^{V_1/2} F_j^{**}(P)\,dP = E^{**}(P_{1j}), \quad j = A, B,$$

where the inequality is obtained by noting that $\int_{\underline{P}^o}^{V_1/2} F_B^o(P)\,dP = \int_{\underline{P}^{**}}^{V_1/2} F_B^o(P)\,dP$, and $F_B^o(P) < F_j^{**}(P)$ for all $P \in (\underline{P}^{**}, V_1/2)$. This completes the proof. Q.E.D.

Consumption Uncertainty

Let us show that there exists an equilibrium in which the firms' optimal reservation limit is given by $N_j^* = \max\{N-(1-\alpha)\beta(2-\beta)M/2, 0\}$ if following the zero refund policy, and by $N_j^{**} = \max\{N/\beta - (1-\alpha)(2-\beta)M/2, 0\}$ if partial refund is adopted, $j = A, B$.

Consider first the zero-refund case and take firm A as example. Suppose that the firms set their reservation limit as $N_A = N_B = \max\{N - (1-\alpha)\beta(2-\beta)M/2, 0\}$. Note that given this alternative setup on consumption uncertainty, firm A has a demand $(1-\alpha)\beta(1-\beta)M$ from the late-arriving consumers whose realized utility is $(U_{2A}, U_{2B}) = (V_2, 0)$ and competes with firm B for the demand $(1-\alpha)\beta^2 M$ from the late-arriving consumers whose realized utility is $(U_{2A}, U_{2B}) = (V_2, V_2)$. It is straightforward that the total demand from the late-arriving consumers is given by $(1-\alpha)\beta(2-\beta)M$. It is then obvious that increasing the reservation limit leads to a lower expected payoff, because that may sacrifice the spot-period sales that cannot be equally compensated by the increase in the expected advance-period sales. Also, decreasing the reservation limit below N_A cannot increase firm A's expected spot-period payoff, which is determined by the residual demand uncovered by firm B.

Consider, then, the case when both firms adopt partial refund. Suppose that both firms set $N_A = N_B = \max\{N/\beta-(1-\alpha)(2-\beta)M/2, 0\}$. Note that a fraction $1-\beta$ of firm A's reservations will be cancelled and added into its sellable capacity in the spot period. As a result, firm A's residual capacity is at least

$$N - \beta N_A = \min\{(1-\alpha)\beta(2-\beta)M/2, N\},$$

which is sufficient to cover the residual demand in the spot period. As a result, similar to the above case with zero refund, neither decreasing or increasing the reservation limit leads to a higher expected payoff. This verifies the existence of the proposed equilibrium.

Stochastic Demand

Let us start with zero refund. Take firm A as an example. Consider first the scenario $N_A + N_B \le M_1$. Firm A's overall expected payoff, conditional on P_{1A} and reservation limit N_A, is given by $\Pi_A = \Pi_{1A} + \Pi_{2A}^* = N_A P_{1A} + [\int_0^{2(N-N_A)} x/2\,dG(x) + \int_{2(N-N_A)}^{\bar{M}} N - N_A\,dG(x)]V_2$. To understand this, note that in the spot period the firm's demand is $M_2/2$, residual capacity is $N-N_A$, and the optimal price is $P_{2A}^* = V_2$. Therefore, the spot sales are given by $M_2/2$ if $M_2 < 2(N-N_A)$, and by $N-N_A$ if the capacity constraint is binding (i.e., $M_2 > 2(N-N_A)$).

Consider, then, the scenario $N_A + N_B > M_1$, where the advance-period equilibrium is mixed. Denote the cumulative distribution for firm B's advance price as $F_B(P) \equiv \Pr(P_{1B} < P)$. Then, with probability $F_B(P_{1A})$, firm A's advance sales are $M_1 - N_B$, leading to a residual capacity $N - M_1 + N_B$ in the spot period. This in turn implies that the spot sales are $M_2/2$ if $M_2 < 2(N - M_1 + N_B)$, and $N - M_1 + N_B$ if $M_2 > 2(N - M_1 + N_B)$. Moreover, with the complementary probability $1 - F_B(P_{1A})$, firm A can advance-sell all of its reservation limit N_A, and the expected spot sales are hence the same as those in the scenario $N_A + N_B \le M_1$. In summary, firm A's overall expected payoff is given by

$$\begin{aligned}\Pi_A = F_B(P_{1A})\Bigg\{(M_1-N_B)P_{1A} + \bigg[\int_0^{2(N-M_1+N_B)} x/2dG(x) + \int_{2(N-M_1+N_B)}^{\bar{M}} N-M_1+N_B dG(x)\bigg]V_2\Bigg\} \\ + [1-F_B(P_{1A})]\Bigg\{N_A P_{1A} + \bigg[\int_0^{2(N-N_A)} x/2dG(x) + \int_{2(N-N_A)}^{\bar{M}} N-N_A dG(x)\bigg]V_2\Bigg\}.\end{aligned}$$

In either of these scenarios, the first-order condition of firm A's profit function with respect to N_A is

$$P_{1A} + [G(2(N-N_A)) - 1]V_2 = 0,$$

which determines the interior solution $N_A^*(P_{1A}) \in (0, M_1)$.

Let us then address the case with partial refund. One can readily follow the zero refund case to derive the firm's overall expected payoff function, with the following necessary modifications: (1) there is an expected refund payment $H/2$ for each unit of the advance sales, and (2) the firm's expected residual capacity in the spot period becomes $N-(M_1-N_B)/2$ with a probability $F_B(P_{1A})$, and $N-N_A/2$ with a probability $1-F_B(P_{1A})$. As a result,

$$\begin{aligned}\Pi_A = F_B(P_{1A})\Bigg\{(M_1-N_B)(P_{1A}-H/2) + \bigg[\int_0^{2N-M_1+N_B} x/2dG(x) + \int_{2N-M_1+N_B}^{\bar{M}} N-(M_1+N_B)/2dG(x)\bigg]V_2\Bigg\} \\ + [1-F_B(P_{1A})]\Bigg\{N_A(P_{1A}-H/2) + \bigg[\int_0^{2N-N_A} x/2dG(x) + \int_{2N-N_A}^{\bar{M}} N-N_A/2dG(x)\bigg]V_2\Bigg\},\end{aligned}$$

where $F_B(P) = 0$ when $N_A + N_B \le M_1$. The first-order condition without respect to N_A is then $P_{1A} - H/2 + [G(2N-N_A)-1]V_2/2 = 0$, which defines the interior solution

$N_A^{**}(P_{1A}) \in (0, M_1)$. It follows immediately that, conditional on P_{1j}, we have $N_A^{**} > N_A^*$ given that H is sufficiently small.

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