Search Deterrence

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Abstract

A seller wishes to prevent the discovery of rival offers by its prospective customers. We study sales techniques which serve this purpose by making it harder for a customer to return to buy later after a search for alternatives. These include making an exploding offer, offering a "buy-now" discount, or requiring payment of a deposit in order to buy later. It is unilaterally profitable for a seller to deter search under mild conditions, but sellers can suffer when all do so. In a monopoly setting where the buyer has an uncertain outside option, the optimal selling mechanism features both buy-now discounts and deposit contracts. When a seller cannot commit to its policy, it exploits the inference that those consumers who try to buy later have no good alternative. In many cases the outcome then involves exploding offers, so that no consumers return to buy after search.

Keywords: Consumer search, sales techniques, price discrimination, sequential screening.

1 Introduction

A seller would usually like to discourage the investigation of rival offers by its prospective customers, in case a better deal is discovered elsewhere. This paper examines one way a seller may be able to do this, which is to make it harder or more costly for a customer to return to buy later, after a search for alternative offers. When post-search purchase is made artificially difficult, this reduces a consumer's payoff from searching, and thereby

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encourages immediate purchase. A seller can make it harder for a customer to buy later by making an exploding offer, where a customer will not be served if she does not buy during the initial sales encounter, by offering a "buy-now" discount, where a customer is offered a discount only if she buys on her first encounter, or by requiring the customer to pay a deposit to be able to buy later.

Anecdotes. Because inducements for quick decisions may be offered casually during the course of a one-to-one sales encounter, it is hard to obtain empirical evidence about their use. In his account of sales practices, Cialdini (2001, page 208) provides examples of exploding offers: "A prospective health-club member or automobile buyer might learn that the deal offered by the salesperson is good for that one time only; should the customer leave the premises the deal is off. [...] A door-to-door magazine solicitor might say that salespeople are in the customer's area for just a day; after that, they, and the customer's chance to buy their magazine package, will be long gone.[1] A home vacuum cleaner operation I infiltrated instructed its sales trainees to claim that, 'I have so many other people to see that I have the time to visit a family only once. It's company policy that even if you decide later that you want this machine, I can't come back and sell it to you'." In a labor market context, Roth and Xing (1994, page 1001) discuss high-pressure job offers. For instance, judges use exploding offers for clerkships which would be withdrawn if not accepted in some very short time, sometimes during the telephone call itself.

The sociologist John Bone infiltrated two direct selling organizations and documents their sales tactics. Bone (2006, pages 71–73) describes how a home improvement company offers its potential customers a regular price for the agreed service, together with a discounted price—termed a "first call discount"—if the customer signs the contract immediately. On page 89 he records how a kitchen installation company asks for a £50 deposit "to hold the price" if the consumer does not sign the contract immediately but wishes to keep the option open.

Robinson (1995) discusses other examples of buy-now discounts, such as a prospective tenant who is offered an apartment for \$900 per month but to whom the landlord offers \$850 if she agrees immediately, or a car dealer trying to close a deal who offers a further

[1] This tactic is echoed in David Mamet's 1983 play, *Glengarry Glen Ross*, where the salesmen frequently claim to be in the area only for that day. (Mamet once worked in a real estate office in Chicago.)

$500 off the price if the buyer accepts now, so (as he claims) he can then make his sales quota for that month. A recent report on the UK cosmetic surgery market "was concerned about reports of patients being offered discounts for surgery if they sign a binding contract at the end of the first consultation".[2]

To implement these search deterrence strategies a seller needs to be able to recognize customers, in the sense that it can distinguish potential customers it meets for the first time from those who have returned after a previous encounter. In most markets this is simply not possible. (A supermarket, for instance, keeps no track of a consumer's entry and exit from the store.) Nevertheless, in many markets—especially those that depend on personal interaction between buyers and sellers—customer recognition is feasible. A sales assistant might discern from a potential customer's questions or demeanor that this is her first visit to the store for the relevant product. A telephone or doorstep seller can be confident when the first encounter with a prospective customer occurs. Sometimes—as with job offers, automobile sales, housing rentals, tailored consumer financial products, medical or life insurance, cosmetic surgery, or home improvements—a consumer needs to interact with a seller to discuss specific requirements, and this process reveals the consumer's identity. In online markets, a retailer using tracking software may be able to tell if a visitor using the same computer has visited the site before.[3]

Plan of the paper. Our basic model is presented in section 2. There, we assume there is a single seller attempting to sell to a rational customer who has an uncertain outside option (which might be an alternative offer from a non-strategic rival) which she can discover only after leaving the seller for the first time.[4] During her initial encounter with the seller, the buyer discovers her idiosyncratic valuation for the seller's product and decides between immediate purchase or investigation of the outside option. If her outside option is disappointing the buyer may return to purchase from the seller, although at potentially

[2] See paragraph 5.8 of *Review of the Regulation of Cosmetic Interventions (Final Report)*, Department of Health (UK), April 2013.

[3] De los Santos (2008) presents an empirical study of search behaviour using data from online book purchases, and finds that of those consumers who searched at least twice, approximately two-thirds buy from the final firm searched and one-third return to a firm searched earlier.

[4] There are many other methods to induce sales which rely on more psychological factors. Bone (page 90) describes the use of an extreme tactic: the sales woman "burst into tears" when the sale appeared to be in difficulty, claiming she would be in trouble with her boss if she didn't make the sale.

disadvantageous terms. In the benchmark setting of free recall (section 2.1), the seller offers the same price regardless of when the purchase is made. Using this basic model, we go on to analyze the incentive to deter search, under the twin assumptions that the seller can recognize customers and can commit to its selling mechanism.

In section 2.2 we discuss the profitability of simple sales techniques—exploding offers, buy-now discounts and deposits—which are easy to communicate and rationalize to buyers.[5] Making it hard to buy the product later induces more consumers to buy immediately, but it also restricts their ability to buy later after discovering an unfavorable outside option. We show that when the relevant demand curve is log-concave, it is profitable to offer a buy-now discount to a first-time visitor or require her to pay a deposit if she wants to be able to buy later. Making an exploding offer is profitable in the more restrictive case where demand is concave. In section 2.3 we derive the *optimal* way to sell in this environment. This consists of allowing the buyer to buy immediately at a low price, to return later to buy at a high price, together with a menu of deposit contracts. This optimal sales mechanism involves search deterrence, in the sense that more buyers purchase without discovering the outside option than would be the case with free recall.

In section 3, we extend this framework in two directions. In section 3.1 we discuss the seller's equilibrium policy when it cannot commit to the price it offers consumers who wish to buy after search. In the basic model, the seller has two broad reasons to discriminate against consumers who buy later: a *strategic* reason, to commit to make it hard to buy later in order to discourage the investigation of rival offers by its prospective customers, and an *informational* reason, which reflects the fact that the demand from those consumers who buy after search is typically less elastic than the demand of those who buy without search. When the seller cannot commit to its offers to consumers who buy later, the strategic motive cannot operate, but the informational motive remains. A customer who returns to buy later reveals she has found no attractive alternative, and the seller therefore often has an incentive to inflict an unannounced price hike on this customer. When buyers incur no intrinsic costs when returning to the seller after search, we show

[5] For example Bone (page 71) writes that to justify the company's "first call discount" customers were told "the company had so many appointments that it was difficult for our salespeople to cover them all ... if we went back to everyone twice we wouldn't see nearly as many people and would generate a lot less business."

that the seller may still offer a buy-now discount even if it cannot commit to its buy-later price. When buyers incur intrinsic costs of returning, however, an argument similar to Diamond's (1971) paradox shows that the only rational expectations equilibrium involves no consumer returning to the seller after search, and the outcome is as if an exploding offer is made.

Second, in section 3.2 we replace the exogenous outside option with a second strategic seller. As in the monopoly analysis, for strategic or informational reasons either seller has a unilateral incentive to engage in search deterrence. When both do this, however, industry profits may fall relative to the free-recall regime. We study the case with linear demand, where search deterrence not only leads to a less efficient match between buyers and products, but induces sellers to set higher prices. Market performance when these sales techniques are employed is poor: sellers are usually worse off relative to free recall, and buyers obtain a less suitable product for a higher price.

Related literature. The basic mechanism in our model, that a higher cost of returning to buy later makes agents less inclined to search, has been studied before. For instance, Karni and Schwartz (1977) and Janssen and Parakhonyak (2012) show that an agent will cease her search sooner than she would with free recall if returning to a previous option is uncertain or costly. The uncertainty or cost of recall is exogenous in these papers, rather than determined by a seller's choice of sales tactics.

Few previous papers relate directly to strategic search deterrence. One that does is Ellison and Wolitzky (2012), who offer a model in which a seller deters search by making onward search more costly, rather than by making it more costly to buy later. They suppose that a consumer's incremental search cost increases with her cumulative search effort. If a firm increases its in-store search cost (say, by making its tariff harder to comprehend), this will make further search less attractive. They show that if the exogenous component of search costs falls, firms unilaterally increase their endogenous element of search costs, with the result that equilibrium prices are unchanged. Though otherwise very different, our model and theirs both study how search frictions are determined endogenously: even if intrinsic search frictions are negligible, a market may suffer from substantial search frictions—and high prices—in equilibrium.[6]

In our model, a seller attempts to sell to a buyer before the buyer discovers her outside option, i.e., before she knows her net valuation for the product. Other papers examine similar issues in different settings. For instance, Lewis and Sappington (1994) discuss a situation where a buyer has an idiosyncratic valuation for the seller's product, and the seller can control how much the buyer knows about her valuation before purchase. One selling strategy allows the buyer to discover her valuation before agreeing to buy, in which case she purchases when the price is below the valuation. A second strategy, akin to an exploding offer in our framework, forces the buyer to buy without knowing anything about her valuation. The second strategy is more profitable when the production cost is small. In situations where the seller prefers to sell before consumers know their valuation, DeGraba (1995) shows how it can do this by artificially restricting supply: doing so can induce a buying "frenzy", where buyers buy early (before they know their value) so as to have a better chance of obtaining the item.

Aghion and Bolton (1986) investigate an entry deterrence scenario in which one seller considers selling to a buyer before a second seller enters the market. The two sellers offer a homogenous product, and the production cost of the potential entrant is uncertain. If the buyer waits for the entry decision to be made, she benefits from a lower price in the event that the entrant has a lower cost. In other words, the entrant provides an uncertain outside option for the buyer. For the buyer to agree to buy early, she must be offered a price low enough to compensate her for foregoing this option. The authors show that the incumbent has no incentive to induce the buyer to purchase early by means of a low price.[7] However, it does have an incentive to offer a *penalty* contract: before the entry decision is made the buyer agrees to buy from the incumbent at a specified price, but she is able to renege and buy from the entrant provided she pays a specified penalty to the incumbent.

[6] The model presented in section 3 of Armstrong and Chen (2013) describes a scenario where a seller attempts to deter search by revealing that its *earlier* price was high. The fact that a product with limited stock remains available after being offered for some time suggests to potential customers that few early consumers were willing to buy, for the reason that they found a better-value option elsewhere. This makes a consumer inclined to search elsewhere. However, this effect is dampened when the earlier price was high.

[7] An attempt to secure early purchase with a low price is not an exploding offer in our sense, since if the buyer rejects the initial offer, she has the ability to return to buy from the incumbent once the entry decision is made.

This penalty contract is similar to the deposit contracts discussed in this paper.[8]

Our paper (especially the analysis of optimal selling in section 2.3) is related to the literature on sequential screening. An early contribution to the sequential screening literature which in some ways is close to our approach is Courty and Li (2000). They analyze a model with a single seller, where a buyer initially has private information about the distribution of her eventual valuation for the product (say, an air ticket), but only learns her actual valuation when she needs to fly. The airline can offer tickets for sale at the time of flying when travellers know their valuations. Alternatively, akin to an exploding offer, they might only sell advance tickets before buyers know their valuation. However, the airline can do better than either policy by offering a menu of "refund" contracts, where a more expensive ticket comes with a more generous refund if it turns out the buyer does not need the ticket.

Our model differs from Courty and Li (2000) in a number of ways. In the earlier paper, the buyer's information evolves exogenously over time, while in our model the buyer only discovers her net valuation if she chooses to search.[9] We analyze additional settings, such as when the seller cannot commit to buy-later prices or when the outside option is provided by a second strategic seller. We study the welfare effects of sequential screening tactics, which in our framework seem often to be negative, while Courty and Li's analysis is concerned with the seller's perspective. Our focus is more on casual sales encounters, where a salesman attempts to deter a buyer from investigating a rival seller, rather than the publicly announced tariff policies of airlines. Because of this last point, we discuss *ad hoc* but simple sales techniques alongside the optimal way to sell.

Finally, our analysis of search deterrence without commitment (section 3.1) relates to the literature on durable good pricing initiated by Coase (1972). In Coase's problem, when a consumer does not buy quickly, she reveals she has a relatively low valuation for

[8] Diamond and Maskin (1979) study the impact of different types of penalty contracts in a two-sided search market with uncertain match quality. In their model, two parties form a relationship first and then consider whether to search for better partners. Search deterrence happens in their model because the compensation paid to the abandoned party makes search and breach less attractive.

[9] In this respect our analysis is closer to Krahmer and Strausz (2011). They consider a procurement setting where the agent can choose to invest costly effort to discover the actual cost of implementing a project after signing the contract. As in our paper, they find that the optimal mechanism features a fixed price and a menu of option contracts, and it not only aims to screen agents with different *ex ante* private information but also takes into account the incentive for agents to acquire information.

the product. Because of this adverse selection, the seller has an incentive to reduce its price to consumers who buy later. In our model, by contrast, if a consumer tries to buy later, she reveals that she searched and found her outside option was disappointing. Due to this *advantageous* selection, our seller often wishes to set a higher price to these consumers.[10]

2 A Basic Model

This section studies a seller's incentive to deter consumer search in a setting with a single seller and an uncertain outside option. The seller offers a product with constant marginal cost which we normalize to zero. The product yields random utility $u \geq 0$ to a risk-neutral buyer. This utility u is observed by the buyer when she first encounters the seller, and is unchanged over time, but is not observed by the seller. The distribution of u is continuous with support $[0, u_{\max}]$, and has distribution function $F(\cdot)$ and density function $f(\cdot)$ which is continuous on its support. There is an outside option (e.g., an alternative offer from a non-strategic competitor), which yields uncertain net surplus $v \geq 0$ to the buyer. For simplicity, v is assumed to be independently distributed from u.[11] The distribution of v has support $[0, v_{\max}]$, and has distribution function $G(\cdot)$ and has a continuous density function $g(v)$ on $(0, v_{\max}]$. (We allow the distribution for v to have an "atom" at $v = 0$, reflecting the possibility that the buyer has no useful outside option.) The buyer does not know the realization of v when she first encounters the seller, and she needs to incur a search cost $s \geq 0$—and to leave the seller—in order to reach the outside option and discover its value. The seller never observes the realization of v. For simplicity, we assume for now that the buyer incurs no further search costs if she comes back and buys from the seller after investigating the outside option.[12]

[10] Zhu (2012) presents a related model which examines equilibrium pricing in a market for over-the-counter financial securities. His model has a single seller who searches sequentially for a high price offer among a number of potential buyers. A buyer's price is valid only for the initial contact, and if the seller rejects the initial offer and contacts that buyer a second time, the buyer suggests a new price. Zhu shows that a buyer lowers the offered price if the seller makes a second approach, since the buyer infers the seller did not find an attractive price quote from other buyers.

[11] Correlation between u and v might induce a complex non-monotonic stopping rule for the buyer. Uncertainty in v might be due to a rival's uncertain costs or capacities which induce an uncertain price, or as in section 3.2 a rival might supply a differentiated product with uncertain match utility.

[12] In most cases, consumers do face an intrinsic cost of returning to a previously visited firm. In most of our analysis, introducing a small intrinsic returning cost does not affect results qualitatively, but compli-

If the consumer neither buys the firm's product nor the outside option, her payoff is zero. However, this is irrelevant if we assume that the search cost satisfies

$$s < \bar{v} \ , \tag{1}$$

where $\bar{v}$ is the expected value of the outside option v. Condition (1) ensures that the consumer prefers investigating the outside option to buying nothing. The buyer gains no extra utility if she consumes *both* the product and the outside option, i.e., her gross utility with both items is $\max\{u, v\}$.

Let $Q(p) \equiv 1 - F(p)$ denote the demand curve faced by the firm in the hypothetical case when the outside option is zero (i.e., $v \equiv 0$). We make the following assumption:

$$\log Q(p) \text{ is strictly concave when } Q(p) > 0 \ . \tag{2}$$

This assumption implies that a profit function of the form $pQ(p + k)$ is single-peaked in price p, and this optimal price strictly decreases with k. That is to say, if a buyer needs to achieve net surplus k in order to buy the product, the firm optimally chooses a lower price when this required surplus is higher.

2.1 The free-recall benchmark

In most markets, a seller's price does not depend (in the short term) on when the buyer decides to purchase, so that the buyer has "free recall" of the seller's offer. In this section, we analyze this uniform pricing benchmark.

Suppose the firm offers price P to the buyer, regardless of when the buyer decides to purchase. Given P, when will the buyer choose to search? If she discovers utility u at the firm, her net surplus if she buys immediately is $u - P$, while her expected net surplus if she investigates the outside option is $\mathbb{E}_v[\max\{u - P, v\}] - s$. (Here, $\mathbb{E}_v[.]$ denotes taking expectations with respect to v. If she investigates the outside option she incurs the search cost s, but then has the ability to consume the better of the two options.)

Write $S(x) \equiv \mathbb{E}_v[\max\{v, x\}] - x$ for the expected benefit of search when the buyer has

cates the analysis, and we assume it away. However, when we discuss the situation without commitment in section 3.1, whether or not there is an intrinsic return cost will make an important difference.

free recall of payoff x at the seller. This can also be written as

$$S(x) \equiv \mathbb{E}_v[\max\{v, x\}] - x = \int_x^{v_{\max}} (1 - G(v))dv \ . \tag{3}$$

In words, $S(x)$ measures how much the buyer would be willing to pay to be able to search when she has access to the sure payoff x from the seller. Note that $S(x) = \bar{v} - x$ if $x \leq 0$, and $S(\cdot)$ is decreasing and convex. Using this notation, with free recall the buyer will buy the seller's product without search whenever $u - P \geq \mathbb{E}_v[\max\{u - P, v\}] - s = u - P + S(u - P) - s$, i.e., if $u \geq P + S^{-1}(s)$. For convenience in the following, write

$$a = S^{-1}(s) \ .$$

(From (1), such an a exists, and it is unique and positive.) The parameter a, which depends only on the distribution of the outside option and the cost of its discovery, represents the net surplus the buyer needs to be offered by the seller in order to forgo search. Thus, the fraction of consumers who buy without search at price P is $Q(P + a)$.

A useful observation is that

$$\mathbb{E}_v[\min\{v, a\}] = \mathbb{E}_v[v - \max\{0, v - a\}] = \bar{v} - S(a) = \bar{v} - s \ . \tag{4}$$

Note that if the outside option is so attractive relative to the seller's product that $a > u_{\max}$, then the buyer chooses to search even if she has the highest possible valuation $u_{\max}$ and the seller charges the lowest possible price of zero. To rule out this uninteresting case, we make the following assumption:

$$u_{\max} \geq a \ . \tag{5}$$

If the buyer investigates the outside option, she will return to buy from the seller when $v < u - P$, i.e., when the outside option turns out to be worse than the seller's offer. The buyer's purchase decision for the various realizations of (u, v) is summarized in Figure 1. Given this pattern of consumption, the firm's total demand when it sets price P is

$$q_F(P) = \mathbb{E}_v[Q(P + \min\{v, a\})] \ . \tag{6}$$

For given P this demand increases with s, and the seller is better off in a market with greater search frictions.

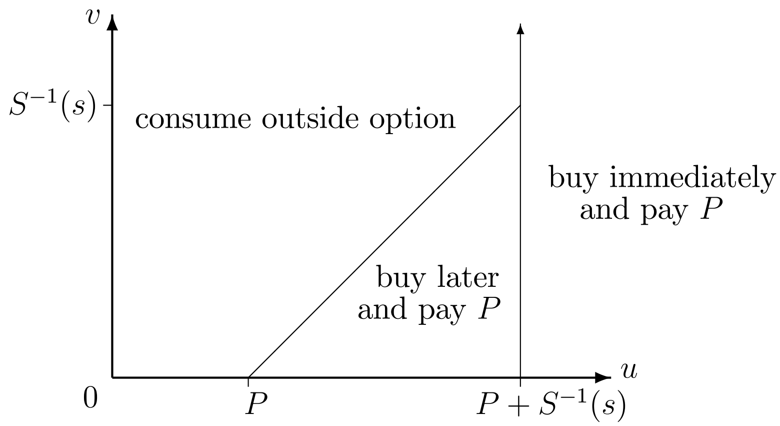


Figure 1: Demand with free recall

The seller's demand q_F can be divided into two components: the "buy-now" demand from those consumers who buy without search and which is equal to $Q(P+a)$, and the "buy-later" demand from those consumers who return to buy after search and which is equal to the measure of the triangle on the figure. It is clear that $Q(P+a) \leq q_F(P) \leq Q(P)$, so that the firm's total demand is greater than its buy-now demand but lower than its hypothetical demand $Q(P)$ if consumers had no outside option. As is proved in the next result, assumption (2) implies that the respective elasticities are inversely related to the scale of demand, so that the seller's demand $q_F(P)$ is more elastic than $Q(P)$ but less elastic than $Q(P+a)$. (Omitted proofs are found in the appendix.)

Lemma 1 *Let $P_F > 0$ be the optimal price in the free-recall regime. Then*
(i) $P_F < p_M$, where p_M maximizes $pQ(p)$ and so is the monopoly price if there were no outside option;
(ii) $P_F > \hat{p}$, where $\hat{p}$ maximizes $pQ(p+a)$ and so is the monopoly price if there were a deterministic outside option a.

The observation that the seller's total demand is less elastic than its buy-now demand implies that buy-later demand is less elastic than buy-now demand. In fact, buy-later demand can *increase* with price in the free-recall regime: from Figure 1 an increase in P shifts the region of buy-later demand uniformly to the right, and so this demand increases with P whenever the density $f(u)$ increases with u, i.e., when $Q(\cdot)$ is concave. The fact that buy-later demand is less elastic than buy-now demand explains in part why the seller wishes to discriminate against those consumers who choose to buy later, as we will see in the next sections.

If there were an intrinsic cost of returning to the seller after search, say r, one can adapt the above discussion to calculate the seller's demand for a given free-recall price P. It is possible that the seller's demand increases with r. Indeed, by making use of the Slutsky symmetry of cross-price effects, one can show that demand increases with r if and only if buy-later demand increases with P. As observed above, a sufficient condition for this to hold is that demand Q be concave, while if Q is convex a greater return cost will reduce demand. When it is more costly to return to the seller after search, this induces more consumers with relatively high u to buy without search, but reduces the number (with relatively low u) who come back to buy later. When the density for u increases, i.e., when Q is concave, the former effect outweighs the latter.

2.2 Two simple ways to deter search

In this section we examine the profitability of two simple selling procedures which act to deter search.

Buy-now discounts. Consider first the situation where the seller can engage in price discrimination, and is able to charge the buyer different prices depending on whether she buys immediately or later. Specifically, suppose that the seller offers two prices: a regular (buy-later) price p which applies if the consumer decides to buy after investigating the outside option, and a discounted buy-now price $p - \tau$ if she buys at the first opportunity. Thus, the buy-now discount is $\tau \geq 0$, and if $\tau = 0$ we return to the free-recall regime.

If the buyer values the product at u, she prefers to buy without search if $u - (p - \tau) \geq \mathbb{E}_v[\max\{u - p, v\}] - s = u - p - s + S(u - p)$, i.e., if $u \geq p + S^{-1}(s + \tau)$. If she does search, she will return to buy later if $u - p \geq v$, and this pattern of demand is depicted in Figure 2.[13] The figure depicts the situation with some buy-later demand, which is the case if the

[13] The buyer may have a third option when faced with a buy-now discount, which is to buy the product immediately at the discounted rate *and* continue to search for the outside option. When the price of the product is high (e.g., due to a high production cost), when the cost of carrying the product as the buyer continues searching is high, or when buying both the product and the outside option is unrealistic (e.g., it is rarely possible for someone to accept two distinct jobs simultaneously), this "buy and search" option is not relevant. We have analyzed the model taking account of this "buy and search" option, and our main results do not change qualitatively though the analysis can be much more involved. For clarity we do not

buy-now discount satisfies $S^{-1}(s+\tau) > 0$, i.e., if $\tau + s < \bar{v}$.

For a given buy-later price p, by comparing Figures 1 and 2 we see that the impact of introducing a buy-now discount τ on total demand is precisely as if the exogenous search cost increased from s to $s+\tau$ in the free-recall regime. In particular, for a given buy-later price introducing a buy-now discount will boost the firm's demand. Thus, the firm is able endogenously to increase search frictions via τ, but at the revenue cost of offering a buy-now discount to its buyers.

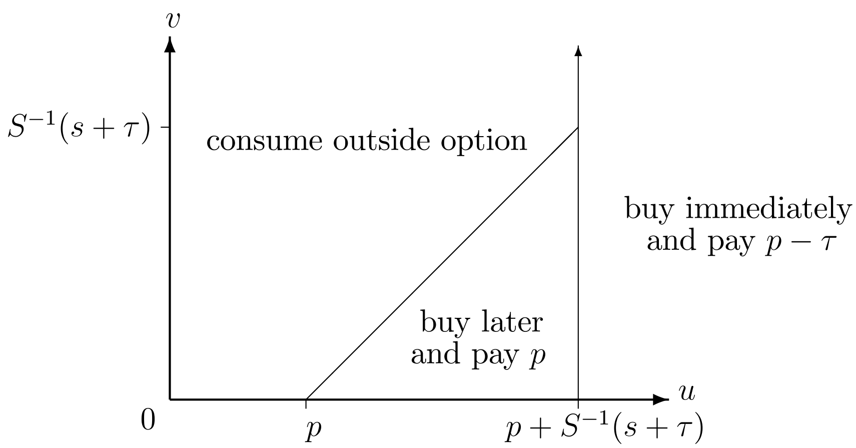


Figure 2: Demand with a buy-now discount

As with (6), the seller's total demand with buy-later price p and buy-now discount τ is

$$q_{BN}(p,\tau) = \mathbb{E}_v[Q(p + \min\{v, S^{-1}(s+\tau)\})] \ . \tag{7}$$

Since

$$\frac{d}{dx}S^{-1}(x) = -\frac{1}{1-G(S^{-1}(x))} \ ,$$

it follows that

$$\frac{\partial}{\partial\tau}q_{BN}(p,\tau) = -Q'(p+S^{-1}(s+\tau)) > 0$$

and

$$\left.\frac{\partial}{\partial\tau}q_{BN}(p,\tau)\right|_{\tau=0} = -Q'(p+a) \ . \tag{8}$$

consider this option further. In addition, in the deposit regime and the optimal mechanism discussed later, or in the regime with a "small" buy-now discount, this third "buy and search" strategy is never optimal for a buyer.

Since buy-now demand receives discount τ, the seller's profit is

$$\pi_{BN}(p,\tau) = pq_{BN}(p,\tau) - \tau Q(p + S^{-1}(s+\tau)) \ ,$$

and from (8) we see that

$$\left.\frac{\partial}{\partial\tau}\pi_{BN}(p,\tau)\right|_{\tau=0} = -pQ'(p+a) - Q(p+a) \ . \tag{9}$$

Part (ii) of Lemma 1 implies that this expression is strictly positive when $p = P_F$, the most profitable free-recall price.[14] In sum, we deduce:

Proposition 1 *Offering a buy-now discount is more profitable than allowing free recall.*

Proposition 1 demonstrates that, for a given buy-later price, the demand expansion effect of offering a buy-now discount outweighs the revenue loss from the discount given to those consumers who buy without search. Equivalently, any demand reduction caused by imposed a buy-later *premium* is outweighed by the revenue gain from charging the premium to those consumers who buy later. In some cases, charging a buy-later premium actually boosts the seller's demand. For a given buy-now price P, introducing a buy-later premium τ causes a buyer to face a cost of returning to the seller, and as discussed in section 2.1, this boosts or reduces total demand according to whether the demand curve Q is concave or convex.

This can be seen most transparently if we compare demand with free recall to demand with an exploding offer (which is the limit of the situation with a large buy-later premium). Suppose the seller makes an exploding offer, i.e., it forces the buyer to decide whether to buy its product before she is able to discover the outside option. If the seller's price is P and the buyer values the seller's product at u, then her net surplus will be $u - P$ if she buys the product. If she does not buy the product but chooses to investigate the outside option, her expected net surplus will be $\bar{v} - s$. Therefore, the buyer will buy the product immediately if and only if $u \geq P + \bar{v} - s$, and the seller's demand with an exploding offer at price P is

$$q_E(P) = Q(P + \bar{v} - s) \ . \tag{10}$$

[14] This argument has assumed that there is buy-now demand in the free-recall regime. If there is no buy-now demand in the free-recall regime (for instance, if $s = 0$), under condition (5) a modified argument shows that the seller has an incentive to introduce a buy-now discount such that there is positive buy-now demand.

If $Q(\cdot)$ is convex, Jensen's Inequality implies that

$$q_F(P) = \mathbb{E}_v[Q(P + \min\{v, a\})] \geq Q(P + \mathbb{E}_v[\min\{v, a\}]) = Q(P + \bar{v} - s) = q_E(P) \ ,$$

where the second equality follows from (4). Therefore, when Q is convex making an exploding offer can only reduce the seller's demand. The reverse argument can be made when Q is concave, provided we take care that demand is always positive. (The function $Q(\cdot)$ cannot be globally concave since it is either zero for large p if $u_{\max}$ is finite, or it approaches zero asymptotically.) Specifically, suppose that at the free-recall price P_F there is positive buy-now demand, i.e., $Q(P_F + a) > 0$. Then the seller's demand $Q(P_F + \min\{v, a\})$ is positive for all v. A parallel argument implies that making an exploding offer at the free-recall price P_F will boost the seller's demand and profits when $Q(\cdot)$ is concave (whenever Q is positive).

This discussion is summarized in the following result:

Proposition 2
(i) If $Q(\cdot)$ is convex, allowing free recall is (weakly) more profitable than making an exploding offer;
(ii) If $Q(\cdot)$ is concave whenever $Q > 0$ and there is positive buy-now demand with free recall, making an exploding offer is (weakly) more profitable than allowing free recall.

To illustrate the analysis so far, consider an example where both u and v are uniformly distributed on $[0, 1]$ and the search cost is $s = \frac{1}{18}$. It follows that $Q(P) = 1 - P$ and $S^{-1}(x) = 1 - \sqrt{2x}$ (for $0 \leq x \leq \frac{1}{2}$). Figure 1 implies that free-recall demand at price P is $q_F(P) = \frac{5}{9} - P$. The optimal free-recall price is therefore $\frac{5}{18}$, which also equals total demand. Of this demand, a fraction 20% comes from consumers who buy without search and the remaining 80% consists of those consumers who search and then return to buy. The seller's profit with free recall is $(\frac{5}{18})^2 \approx 0.077$ while aggregate consumer surplus can be calculated to be about 0.511.

Suppose instead that the seller offers a buy-now discount scheme, where P is its price for immediate purchase and $P + \tau$ is its price for purchase after search. As discussed above, since $Q(\cdot)$ is linear, a buy-later premium does not affect the seller's total demand, which is therefore just equal to $q_F = \frac{5}{9} - P$. The seller's profit is therefore

$$\pi_{BN} = P\left(\tfrac{5}{9} - P\right) + (\tau \times \text{buy-later demand})\ .$$

Buy-later demand is the area of the triangle in Figure 2, which is $\frac{1}{2}(S^{-1}(s+\tau))^2$. Thus, the seller's profit is additively separable in its buy-now price P and its buy-later premium τ. As such, the optimal buy-now price is again $P = \frac{5}{18}$, while the optimal buy-later premium can be calculated to be $\tau \approx 0.121$, which is about 43% of the buy-now price. Note that when the seller engages in this form of price discrimination, in this example *both* its prices weakly increase, which contrasts with the usual case in monopoly third-degree price discrimination where the optimal uniform price typically lies between the discriminatory prices. In this regime, about 70% of the seller's customers buy without search while only 30% buy later, which is approximately the opposite pattern to that with free recall and so this sales tactic significantly deters search. Consumers in this regime are worse off relative to free recall since the price for buying later rises and the buy-now price is unchanged. The seller's profit with a buy-now discount is about 13% higher than it would be with free recall, while consumer surplus is 2% lower.

Finally, suppose the seller makes an exploding offer at price P. A type-u buyer will buy if and only if $u - P \geq \bar{v} - s = \frac{4}{9}$. Therefore, the seller's demand with an exploding offer at price P is exactly the same as with free recall, and so the optimal price with an exploding offer is also $P = \frac{5}{18}$ and the seller makes the same profit using the two sales techniques. However, now all of the consumers who buy do so immediately. Consumers are now about 6% worse off relative to free recall.

Deposit requirements. A second way to deter search is to require the buyer to pay a non-refundable deposit if she wishes to be able to buy later. Specifically, suppose the seller offers two options: a buyer can buy immediately at price P, or in return for paying a deposit $D \leq P$ she can buy later at the incremental price $P - D$. (More general deposit contracts are analyzed in the next section.) If the buyer does not pay the deposit, the seller does not serve her if she returns later. With this selling scheme, if the buyer buys the item, she pays P regardless of when she does so; but if she retains the right to buy later but ends up finding a superior outside option, she still pays the seller D. Thus in contrast to the buy-now discount setting, where the seller penalizes the buyer who chooses to buy later, here the seller penalizes some buyers who choose not to buy later. An exploding offer is a special case of this procedure when $D = P$, while free recall corresponds to $D = 0$.[15]

Faced with this sales procedure, a buyer has three options. If she buys immediately, the type-u buyer's surplus is $u - P$. If she chooses the deposit contract, and hence goes on to search, her expected surplus is

$$\mathbb{E}_v[\max\{u - p, v\}] - s - D = u - P - s + S(u - p) \ , \tag{11}$$

where we have written $p = P - D$ for the "buy-later" price in this selling scheme. The buyer prefers the first strategy to the second whenever $u \geq p + a$. Finally, the buyer can also choose not to pay the deposit, in which case she gives up the seller's product and her expected surplus is $\bar{v} - s$.

In a similar manner to the function $S(\cdot)$ in (3), define $R(x) \equiv \mathbb{E}_v[\max\{v, x\} - v]$ to be the consumer's expected benefit from being able to return to obtain surplus x from the seller after search rather than consuming the outside option for sure. This can be written alternatively as

$$R(x) \equiv \mathbb{E}_v[\max\{v, x\} - v] = S(x) + x - \bar{v} = \int_0^x G(v)dv \ . \tag{12}$$

In words, $R(x)$ measures how much the consumer who searches would be willing to pay for the ability to return to obtain surplus x from the seller after search. Clearly, $R(x) = 0$ if $x \leq 0$, and R is convex and increasing. Using this notation, the surplus from paying the deposit in (11) is

$$R(u - p) - D + \bar{v} - s \ , \tag{13}$$

and so the buyer is indifferent between paying the deposit and abandoning the seller altogether if $R(u - p) = D$. Therefore, the consumer prefers paying the deposit to leaving the firm irrevocably if $u \geq p + R^{-1}(D)$.

On the assumption that the deposit is small enough that $R^{-1}(D) \leq a = S^{-1}(s)$, the pattern of demand is as shown on Figure 3. Note that setting $D = 0$ implies that consumer behaviour is as in the free-recall regime shown in Figure 1.

[15]Note also that a deposit requirement is equivalent to the refund contract analyzed by Courty and Li (2000), since it is as if the buyer can purchase the item for price P on her first visit (but not subsequently), and she has the right to return it (say, if she discovers a superior outside option) for a refund equal to $P - D$.

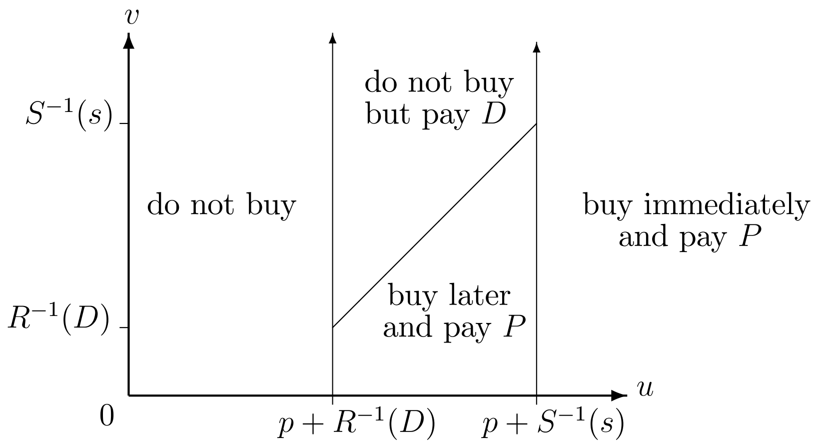


Figure 3: Demand with a deposit contract

Keeping the total price fixed at P, we see that a buyer is more likely to buy immediately with a deposit $D > 0$ (i.e., with a smaller buy-later price p) than with free recall, and so requiring a deposit acts to deter search.

We argue that the seller can boost profits relative to free recall by requiring a positive deposit to secure the product. Write $q_D(p, D)$ for the seller's total demand in terms of the deposit D and buy-later price p. From Figure 3 the seller's profit is

$$\pi_D(p, D) = pq_D(p, D) + DQ(p + R^{-1}(D)) \ .$$

When $D > 0$ it follows from (12) that

$$\frac{d}{dD}R^{-1}(D) = \frac{1}{R'(R^{-1}(D))} = \frac{1}{G(R^{-1}(D))} \ .$$

Using this, one sees from Figure 3 that

$$\frac{\partial}{\partial D}q_D(p, D) = Q'(p + R^{-1}(D)) \ ,$$

and so taking the limit as $D \to 0$ we have

$$\left.\frac{\partial}{\partial D}q_D(p, D)\right|_{D=0} = Q'(p) \ .$$

Moreover,

$$\left.\frac{\partial}{\partial D}DQ(p + R^{-1}(D))\right|_{D=0} = \lim_{D\to 0}\frac{DQ(p + R^{-1}(D))}{D} = \lim_{D\to 0}Q(p + R^{-1}(D)) = Q(p) \ .$$

Putting these two effects together implies that

$$\left.\frac{\partial}{\partial D}\pi_D(p,D)\right|_{D=0} = pQ'(p) + Q(p) \ .$$

Part (i) of Lemma 1 shows that the optimal free recall price P_F is below the monopoly price p_M, and so the above expression is positive when $p = P_F$. We deduce that starting from the most-profitable free recall price, the seller can boost profits by requiring a positive deposit if the consumer wishes to return to buy later. In sum:

Proposition 3 *Requiring potential customers to pay a deposit if they wish to be able to return to buy later is strictly more profitable than allowing free recall.*

For a given price P, introducing a deposit requirement D will boost or contract the seller's total demand according to whether Q is concave or convex. In particular, if Q is linear then requiring a deposit leaves the seller's demand unchanged, and so clearly raises profit since some people then pay D while with free recall they paid nothing. In the same example where u and v are uniformly distributed on $[0,1]$ and $s = \frac{1}{18}$, we have $R^{-1}(x) = \sqrt{2x}$ and total demand with price P and deposit D is again $q_F = \frac{5}{9} - P$. The seller's profit is therefore

$$\pi_D = P\left(\tfrac{5}{9} - P\right) + (D \times [\text{fraction who pay deposit but do not buy}])$$

The fraction who pay the deposit but do not end up buying is $\frac{1}{2}(\frac{2}{3} - \sqrt{2D})(\frac{4}{3} - \sqrt{2D})$. The optimal total price is therefore again $P = \frac{5}{18}$, and the optimal deposit can be calculated to be $D \approx 0.083$, which is about 30% of the price. Here, about half of those who buy the product do so without search, while the other half pay the deposit and buy later. In this example, although not in general, this sales strategy yields precisely the same profit as the buy-now discount regime. However, consumers fare less well in the deposit regime, and their loss is about twice as great relative to free recall as was the case in the buy-now discount regime.

In this section we have discussed two natural, but perhaps *ad hoc*, selling procedures and found mild conditions which ensure they generate higher profits than free recall. These procedures are easy to communicate and rationalize to buyers, and so merit analysis in their own right. However, while it was straightforward to demonstrate the seller's incentive to depart from uniform pricing, the *ad hoc* nature of these procedures makes it hard to obtain attractive results about the most profitable version of either tactic. For instance, it is unclear whether in general the optimal buy-now discount tariff induces a greater fraction of consumers to buy without search than would be the case with free recall. In the next section we derive the optimal selling mechanism for the seller. As well as being a useful benchmark with which to compare profits in the *ad hoc* schemes, the description of the optimal way to sell is relatively transparent in terms of the primitives of the model.[16]

2.3 The optimal way to sell

In this section we derive the seller's optimal selling procedure. As will be seen, the optimal mechanism incorporates both buy-now discounts and deposit contracts. Specifically, a consumer has the option either to buy the product immediately at a relatively low price, P, or return to buy later at a relatively high price (in fact, at the monopoly price p_M which maximizes $pQ(p)$). In addition to this pair of options, a consumer is able to choose from a menu of deposit contracts, whereby by paying a deposit on her first visit she obtains the right to return to buy later at a specified price. Faced with these options, a consumer with high u will choose to buy immediately without search, a consumer with low u will not pay a deposit and not purchase the item, while a consumer with an intermediate u will search but pay a deposit for the right to return later if the outside option is poor.

In the following discussion we derive the seller's optimal choice of procedure within a restricted class of mechanisms, namely a buy-now price together with a menu of deposit contracts. In the appendix, we demonstrate that this selling mechanism is the most profitable among all feasible mechanisms by using the Revelation Principle. (For instance, the seller might ask the buyer to report the realization of the outside option after search, or the seller might commit to sell the product only with some specified probability if the buyer returns later.) In more detail, suppose the seller offers its product for immediate sale at

[16] Another advantage of analyzing these simple selling strategies is that our results about their use will often be robust to natural extensions of the basic framework. For instance, if the search cost s varied across consumers (and was uncorrelated with u and v), our results about the incentive to offer a buy-now discount or to require a deposit remain valid. However, it would not be possible to derive the optimal selling mechanism in this extension, as buyers have two-dimensional private information about s and u.

price P, and also allows the buyer to choose from a menu of deposit contracts of the form whereby to be able to buy later at price p the buyer must pay deposit $D(p)$. If the buyer chooses none of these options, the seller commits not to serve her if she tries to return to buy later. (In the optimal scheme, though, we will see that one of the deposit contracts involves $D = 0$, and a buyer is free to return to buy later at the monopoly price p_M.)

A buyer with match utility u, buy-later price p and deposit D obtains expected surplus from search equal to (13). Given the seller's menu of buy-later options $\{p, D(p)\}$, if the buyer decides to pay a deposit she will choose the best contract from the deposit menu, and her resulting surplus is

$$\phi(u) \equiv \max_p : \{R(u-p) - D(p) + \bar{v} - s\} \ .$$

Since the function $R(\cdot)$ is increasing and convex, $\phi(\cdot)$ is also increasing and convex and hence differentiable almost everywhere. Let $p(u)$ be the optimal choice of buy-later price for the type-u buyer (which is uniquely determined almost everywhere). Since $R(\cdot)$ is convex, a simple revealed preference argument shows $p(u)$ must weakly decrease with u. The reason that a buyer with a higher u will choose a contract specifying a lower buy-later price is because she anticipates she is more likely to buy later, and hence she has more at stake in securing a low buy-later price. The envelope theorem implies that

$$\phi'(u) = R'(u - p(u)) = G(u - p(u)) \ , \tag{14}$$

and the deposit payment associated with the buy-later price $p(u)$ is

$$D(p(u)) = R(u - p(u)) + \bar{v} - s - \phi(u) \ . \tag{15}$$

Expression (14) implies that the surplus from choosing a deposit contract is increasing with u but with slope less than 1. By contrast, the surplus from leaving the firm altogether, $\bar{v} - s$, does not depend on u, and the surplus from immediate purchase, $u - P$, increases with slope 1. Thus, we expect that for small u, say for $u < \check{u}$, the consumer leaves the seller immediately, for intermediate u, say $\check{u} \leq u \leq \hat{u}$, the consumer chooses one of the deposit contracts, and for $u > \hat{u}$ the consumer buys immediately without search.[17] For the

[17] By choosing $\check{u}$ and $\hat{u}$ appropriately one can allow only a subset of the three strategies to be made available. For instance, setting $\check{u} = \hat{u}$ means that no option to buy later is made available and the seller makes an exploding offer.

buyer to be indifferent between the relevant options at the points $\check{u}$ and $\hat{u}$, we require

$$\phi(\check{u}) = \bar{v} - s \ ; \ \phi(\hat{u}) = \hat{u} - P \ . \tag{16}$$

If the type-u buyer chooses a deposit contract with buy-later price p, she will return to buy later when $v \leq u - p$, i.e., with probability $G(u - p)$. Therefore, the seller's profit from this scheme is

$$\begin{aligned} \pi &= P(1 - F(\hat{u})) + \int_{\check{u}}^{\hat{u}} \{D(p(u)) + p(u)G(u - p(u))\} \, dF(u) \\ &= P(1 - F(\hat{u})) + \int_{\check{u}}^{\hat{u}} \{R(u - p(u)) + \bar{v} - s - \phi(u) + p(u)G(u - p(u))\} \, dF(u) \ , \end{aligned}$$

where the second equality follows from (15). Integrating by parts and using (14) yields

$$\int_{\check{u}}^{\hat{u}} \phi(u) dF(u) = \phi(\check{u})(1 - F(\check{u})) - \phi(\hat{u})(1 - F(\hat{u})) + \int_{\check{u}}^{\hat{u}} G(u - p(u))(1 - F(u)) du \ .$$

Substituting this into the expression for profit, and using (16), we see that the seller's profit is

$$(\hat{u} - (\bar{v} - s))(1 - F(\hat{u})) + \int_{\check{u}}^{\hat{u}} \left\{ R(u - p(u)) + \left[p(u) - \frac{1 - F(u)}{f(u)} \right] G(u - p(u)) \right\} dF(u) \ . \tag{17}$$

We need to choose $p(\cdot)$ to maximize the integrand $\{\cdot\}$ in (17). Note first that setting $p(u) \geq u$ implies that the integrand $\{\cdot\}$ is equal to zero. Define

$$\lambda(u) \equiv u - \frac{1 - F(u)}{f(u)} \tag{18}$$

for the agent's "virtual surplus", which is strictly increasing given assumption (2). Consider first the case where u is small enough that $\lambda(u) \leq 0$. (Since the monopoly price p_M which maximizes $pQ(p)$ satisfies $\lambda(p_M) = 0$, this is the situation where $u \leq p_M$.) Then one can check that the integrand is increasing in p for $p < u$, and flat (and equal to zero) for $p \geq 0$. Thus, the integrand $\{\cdot\}$ is maximized by choosing any $p \geq u$ and it equals zero. Second, consider the case where $\lambda(u) > 0$ (i.e., $u > p_M$). In this case, the integrand $\{\cdot\}$ is single-peaked in p, and reaches its maximum $R(\lambda(u)) > 0$ at $p(u) = \frac{1-F(u)}{f(u)}$. This pair of observations also implies that profit strictly decreases with $\check{u}$ when $\check{u} > p_M$, and does not depend on $\check{u}$ when $\check{u} \leq p_M$. Thus, it is optimal to choose any $\check{u} \leq p_M$, and for simplicity we choose $\check{u} = p_M$.[18]

Substituting $p(u) = \frac{1-F(u)}{f(u)}$ and $\check{u} = p_M$ into the profit expression (17) yields

$$\pi = (\hat{u} - (\bar{v} - s))(1 - F(\hat{u})) + \int_{p_M}^{\hat{u}} R(\lambda(u))dF(u) \ . \tag{19}$$

Using the fact from (12) that $R(x) = S(x) + x - \bar{v}$, one can check that the derivative of (19) with respect to the upper threshold $\hat{u}$ is $f(\hat{u})[S(\lambda(\hat{u})) - s]$. Therefore, profit is single-peaked in $\hat{u}$ and maximized when $\lambda(\hat{u}) = S^{-1}(s) = a$. Note that the price $\hat{p}$ which maximizes $pQ(p+a)$ satisfies $\lambda(a+\hat{p}) = a$, and so $\hat{u} = a+\hat{p}$. Since λ is a strictly increasing function, it follows that $\hat{u} > p_M$. In addition, condition (5) and the fact $\lambda(u_{\max}) = u_{\max}$ imply that $\hat{u} \leq u_{\max}$, so that there is some buy-now demand at the optimum.

Since (14) implies that $\phi'(u) = G(\lambda(u))$ for $p_M \leq u \leq \hat{u}$, it follows that in this range the buyer's surplus is given by

$$\phi(u) = \bar{v} - s + \int_{p_M}^{u} G(\lambda(\tilde{u}))d\tilde{u} \tag{20}$$

and so (15) implies that the deposit associated with buy-later price $p(u)$ is as reported in (21) below. Setting $u = \hat{u}$ in (20) and using (16) implies that the buy-now price P is as given in (23) below. Since $R(\cdot)$ is a convex function and the optimal buy-later price $p(u)$ is decreasing in u, standard arguments show that when the deposit schedule D is given by (21) and the buy-now price P is given by (23), a buyer will choose the correct contract.

Therefore, in the optimal selling mechanism, a buyer with $u \geq \hat{u}$ buys the product immediately, a buyer with intermediate $u \in (p_M, \hat{u})$ pays a deposit $D(u)$, investigates the outside option and returns to buy later if $v \leq \lambda(u)$, while a buyer with $u \leq p_M$ consumes the outside option. This pattern of demand is illustrated in Figure 4. To summarize, the optimal procedure within the restricted class of mechanisms—consisting of a buy-now price together with a menu of deposit contracts—is as described in the following result. We show further in the appendix that this procedure is also optimal within the general class of incentive-compatible selling mechanisms.

[18] The reason there is some indeterminacy in $\check{u}$ is because there is no difference for the seller or buyer between (i) the type-u buyer choosing not to participate and (ii) the type-u buyer participating but choosing a deposit contract with buy-later price $p(u) = u$ and deposit $D(u) = 0$. Of course, in (ii) the buyer buys nothing and pays nothing, but formally the buyer "participates" in the seller's scheme.

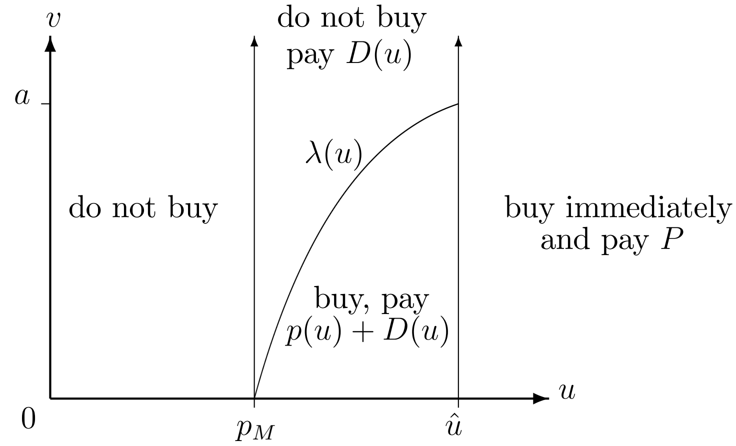


Figure 4: Demand in the optimal mechanism

Proposition 4 *Let $\lambda(\cdot)$ be given in (18), and let p_M satisfy $\lambda(p_M) = 0$ and $\hat{u}$ satisfy $\lambda(\hat{u}) = a$. The optimal selling procedure is given by:*

(i) if $u \leq p_M$ the type-u buyer consumes the outside option for sure;

(ii) if $p_M \leq u < \hat{u}$, the type-u buyer pays the seller a deposit

$$D(u) = R(\lambda(u)) - \int_{p_M}^{u} G(\lambda(\tilde{u}))d\tilde{u} \ , \tag{21}$$

investigates the outside option, and returns to buy the seller's product later if $v < \lambda(u)$ at the incremental price

$$p(u) = u - \lambda(u) \ ; \tag{22}$$

(iii) if $u \geq \hat{u}$, the type-u buyer consumes the seller's product without search at price

$$P = D(\hat{u}) + \hat{u} - a \ . \tag{23}$$

In this optimal scheme, in the intermediate range where the buyer pays a deposit we see that $D(u)$ increases with u while $p(u)$ decreases with u. In particular, when $u = p_M$, $D(u) = 0$, i.e., a buyer has the right to return to buy at the monopoly price, p_M, without paying a deposit. One can also check that the total charge $p(u) + D(u)$ decreases with u in this range, and $p(\hat{u}) + D(\hat{u}) = P$. This implies that the buy-now price P is below the total charge $p(u) + D(u)$ if the buyer searches and returns to buy later. This last point implies that the seller deters search, in the sense that the consumer buys immediately more often than she would in a free-recall regime. In the free-recall regime, the buyer buys immediately when $u \geq a + P_F$, where P_F is the equilibrium free-recall price. In this optimal scheme, the buyer buys immediately when $u \geq \hat{u} = a + \hat{p}$, where $\hat{p}$ maximizes $pQ(p+a)$. However, Lemma 1 shows that $P_F > \hat{p}$, and so the seller does indeed encourage immediate purchase in this optimal mechanism. In sum:

Corollary 1 *In the optimal selling mechanism: (i) it is cheaper for the consumer to buy immediately than to buy after search (i.e., $P < p(u) + D(u)$), and (ii) more consumers buy without search than would be the case with free recall.*

Returning to our example where u and v were uniformly distributed on $[0,1]$ and $s = \frac{1}{18}$, one can check that the buy-now threshold in the optimal mechanism is $\hat{u} = \frac{5}{6}$. From (23) the buy-now price is $P = \frac{5}{18}$ and total output is also $\frac{5}{18}$, just as with all the earlier *ad hoc* schemes. Of the consumers who buy from the seller, exactly 60% do so without searching. From (19), the seller's profit from the optimal mechanism is about 0.09. This is 16% greater than the profits with free recall, but only 3% more than the profits generated with either of the simple schemes with buy-now discounts or deposits. Aggregate consumer surplus here is similar to that with the simple deposit scheme, about 4% below that obtained with free recall. Although total output is identical in all five regimes—that is, in free recall, buy-now discounts, exploding offers, deposits and the optimal mechanism—the pattern of consumption in (u, v)-space is different in each case. Since the buy-now price is the same in all regimes, in this example consumers are best off with free recall (as that regime has least restrictive buy-later policy) and worst off with an exploding offer (as that entirely removes the ability to buy later).

3 Extensions

3.1 Search deterrence without commitment

In the basic model we assumed that the seller can commit to its buy-later policy at the time of the buyer's initial visit. We discuss in this section what happens if we relax this assumption. Suppose that the seller sets a price when the buyer first visits and then sets a second price if the buyer returns to try to buy after discovering the outside option. We assume the seller can make no commitment about the buy-later price when the buyer first visits, and the actual buy-later price can be discovered only after she returns to the seller. We assume that buyers are rational, and foresee the seller's equilibrium price if they return later.[19] (At the end of this section we also discuss how lack of commitment affects the seller's ability to use other selling methods such as deposit contracts.)

Here, unlike the rest of the paper, it makes a crucial difference whether or not the buyer faces an intrinsic returning cost when she goes back to a previously-visited option (either the seller, or the outside option). We consider the two cases in turn.

No intrinsic cost of return: Let P denote the buy-now price and p the buy-later price. Given that a buyer incurs no further search frictions once she has discovered the outside option, we suppose that once she has left the seller to search, she then discovers both her outside option v and the seller's actual buy-later price p. However, the buyer's decision to search can depend only on the anticipated buy-later price, say p^e, not the actual buy-later price, and the seller's choice of buy-later price maximizes its profit given the pool of consumers who search in equilibrium.

A detailed analysis of this problem would be complex, and for simplicity we focus on the previous example where u and v are uniformly distributed on $[0, 1]$ and the search cost is $s = \frac{1}{18}$.[20] The procedure used to solve the seller's problem without commitment is essentially the same as that used to solve a two-period version of Coase's (1972) dynamic pricing problem, and the details of the calculation are presented in the appendix. In this example, the seller's most profitable strategy is to offer the buy-now price $P \approx 0.251$, which induces the subgame-perfect buy-later price $p \approx 0.286$. A substantial (14%) buy-later premium is implemented, therefore, even though the seller cannot commit to its buy-later price.

[19] It is plausible, especially in settings where there is face-to-face interaction between a savvy seller and an inexperienced buyer, that a proportion of buyers are gullible rather than rational, and believe the seller's claims. In this case, it is likely that the seller can affect the propensity to buy by making claims which are not credible. To illustrate, consider the situation where the seller claims that the buyer must decide immediately whether or not to buy, whereas in fact any buyer who did return later would be offered the product on the same terms. If a fraction of buyers believed that they could not return later, the claim makes these buyers more likely to buy immediately than if the claim was not made. Then by the same argument as used for Proposition 2, falsely claiming that the offer is exploding will often be profitable for the seller when $Q(\cdot)$ is concave.

[20] One reason for the difficulty is that the required analysis is "non-local", and we cannot examine local departures from the free-recall regime in the way that is done elsewhere in the paper.

The seller's profit from following this strategy is higher than its free-recall profits, obtained when it could commit to sell at a uniform price to consumers. Note that P is lower, and p is higher, than the most profitable uniform price of $\frac{5}{18} \approx 0.278$ with free recall. Another relevant benchmark is to the optimal buy-now discount tariff with commitment, as analyzed in section 2.2. There, we showed the optimal prices are $P \approx 0.278$ and $p \approx 0.399$ in this example, which are both higher than the corresponding prices without commitment.[21] Thus, there is some similarity to Coasian price dynamics, where a seller's inability to commit to its future prices implies all prices fall relative to the commitment case. However, there is also an important difference, in that in our setting the seller's price *rises* if a buyer does not buy immediately, whereas in Coase's setting prices are lower for those consumers who buy later. In Coase's setting, consumers who wish to buy later have lower valuations than those who buy early, and this adverse selection induces the seller to reduce its price. In our setting there are two effects at play. First, the fact that a consumer defers purchase implies (like Coase) that her valuation is not too high, for otherwise she would have purchased immediately. The second effect, however, goes in the opposite direction: a consumer who wishes to buy later reveals that her outside option is poor. Thus, there is a mixture of adverse and advantageous selection in the pool of consumers who buy later. In the specific example presented here, the second effect outweighs the former, and the price is higher for later purchase.[22]

Positive intrinsic cost of return: Here we consider the situation in which there is a positive return cost, so that a buyer incurs an exogenous cost $r > 0$ to return to the seller after search. The analysis of this case is simpler and more general than the previous case with $r = 0$, and we need make no assumptions about the distribution of u and v. (In fact, we need not assume that Q is logconcave, nor that u and v are independently distributed.)

The main observation is that with an intrinsic returning cost $r > 0$, no matter how

[21] Consumer surplus here is higher than in any of the commitment regimes considered in section 2, very slightly above that obtained with free recall.

[22] In examples with a higher search cost, more consumers buy immediately and those who search have lower valuations for the seller's product. This induces the seller to set a lower buy-later price, and the buy-later price p might be below the buy-now price P. In such cases, it seems plausible, though not inevitable, that the buyer could pretend to search (without incurring the cost s) merely by stepping out of the seller's door and back in again. Whether this form of consumer arbitrage is possible will affect the equilibrium outcome.

small, there is no equilibrium with positive buy-later demand. Suppose, in contrast, that such an equilibrium exists. Consider a buyer who does not accept the initial price but returns to try to buy from the seller after investigating the outside option. By revealed preference, such a buyer must have taste parameters (u, v) and have anticipated a buy-later price p^e and such that

$$u - p^e - r > v \ . \tag{24}$$

(Note that the buyer must incur the extra cost r to return to the seller.) Suppose the seller actually sets a slightly higher buy-later price, say $p^e + \varepsilon$. The buyer, though surprised by this unanticipated offer, is willing to accept it if $\varepsilon < r$. In essence, the seller's buy-later demand is perfectly inelastic around the anticipated price p^e. Therefore, the seller has an incentive to raise its buy-later price above p^e, which contradicts the buyer's belief, and there can be no equilibrium in which the buyer returns to buy later if she does not accept the initial price. This argument is analogous to the hold-up problem in Diamond's (1971) paradox, where a small search cost causes a market to shut down.

As a result, any equilibrium, if one exists, involves a consumer either buying immediately at the initial price, or searching but never returning. This is because the only rational belief buyers can hold is that the seller's buy-later price is so high that a costly return visit is not worthwhile. Hence, the only equilibrium outcome in this setting is as if the seller is forced to make an exploding offer.[23] The seller will choose its initial price to maximize its profit, given that no buyer will ever return.

We summarize the above discussion in the following:

Proposition 5 *Suppose a buyer incurs a positive cost of returning to the seller after discovering her outside option. Suppose the seller sets an initial price on a buyer's first visit, but is unable to make any commitment about the price it will offer if the buyer decides to search and return later. Then the unique equilibrium outcome is as if the seller must make an exploding offer.*

[23] To ensure that an exploding offer is an equilibrium, we need to specify what the seller believes off the equilibrium path when a buyer *does* return to buy later. If the seller believes that such a consumer has taste parameters $u = u_{\max}$ and $v = 0$, it would charge $p = u_{\max}$. Anticipating this, no consumer would ever incur the cost r to return to the seller.

When the seller could commit to its sales strategy, the extreme tactic of making an exploding offer was never optimal. (For instance, it is always dominated by the more flexible buy-now discount scheme). Thus, Proposition 5 implies that the inability to commit at all to future interactions with a potential buyer actually *amplifies* the seller's incentive to discriminate against those buyers who wish to buy later. The fact that a buyer chooses to return to buy after search implies that she values the seller's product, net of her anticipated buy-later price, above her outside option, and this gives the seller an incentive to raise its price above the anticipated price on the buyer's return.

Of course, in practice sellers can usually find ways to commit, at least partially, to future prices if the buyer returns later. For example, suppose the seller is able to commit to any *upper bound* on its buy-later price when a buyer first visits. (In a store, this upper bound might be price label on the product, and a sales assistant has no authority to raise the price above this displayed price.) Then, using the same argument as for Proposition 5, the only equilibrium outcome is for the seller charge a buy-later price equal to this upper bound if the buyer does not accept its initial offer. If the seller can commit to an upper bound on its buy-later price, the buy-now discount regime analyzed in section 2.2 can therefore be implemented.

Likewise, if the buyer pays a deposit the seller may be legally obliged to sell to the buyer later at the specified price. Suppose, though, that a buyer did not pay the required deposit on her first visit, so that the seller has made no commitment to the price she will be offered if she attempts to buy later. By the same argument as in Proposition 5, the only equilibrium is that the seller's price for this returning buyer is so disadvantageous that it is not worthwhile for the buyer to return. Thus, the deposit regime studied in section 2.2 and the optimal mechanism studied in section 2.3 remain credible even if the seller cannot commit to not to serve a buyer who did not pay the deposit for the right to buy later.

3.2 Search deterrence in duopoly

In the basic model in section 2, the buyer's outside option was exogenously given. This simple setting allowed us to investigate when a seller has an incentive to deter consumer search in various ways, and the simplicity of the framework also enabled us to calculate the optimal way to sell. However, the most natural interpretation of the outside option is that it is an offer made by a rival seller. As such, it is worthwhile to see how the previous analysis extends to an oligopoly market with several strategic competitors, each of which considers the use of search deterring strategies. As we will see, firms may end up in a Prisoner's Dilemma: as with monopoly, each seller has a unilateral incentive to deter search, but when all sellers do this industry profits may fall. This extension also allows us to consider the welfare effects of these sales tactics. (In the monopoly model, we could not calculate welfare when the buyer consumes the outside option, as the profit of the supplier of the outside option was not specified.)

Suppose there are two sellers, 1 and 2, which are *ex ante* symmetric, and a consumer's gross valuation of each seller's product is an independent random draw from a common distribution with distribution function $F(u)$. As before, let $Q(p) \equiv 1 - F(p)$ and suppose that (2) holds. We consider a game where firms first choose their selling procedures and prices, and then consumers search sequentially. A buyer discovers her initial seller's match utility, initial price and "buy-later" policy for free, but needs to incur the search cost s to travel to the second seller and discover that seller's match utility and sales policy. Unless stated otherwise, we assume there is no intrinsic cost to return to a previously visited seller and that a seller can commit to its selling policy.

We analyze the Perfect Bayesian Equilibrium in this market. Consumers do not observe a firm's actual choice of price and sales policy before they start searching, but hold rational expectations of firms' strategies.[24] Information unfolds as the search process goes on, but consumers' beliefs about the offer made by the unsampled firm is unchanged, even if they observe off-equilibrium offers from the first firm. We focus on symmetric pure-strategy equilibria in which firms choose the same selling strategy and consumers visit them in a random order (with half the consumers meeting seller 1 first, and the remainder meeting seller 2 first).

This duopoly model has two main differences with the monopoly setting with an exogenous outside option. First, a seller here has buyers who meet it first and buyers who have first encountered the rival and so already know their outside option. Second, although

[24] In a competitive environment sellers have no incentive to announce publicly that they engage in search deterrence, and so it is natural to suppose that the choice of sales technique is discovered only when a consumer visits a seller.

we can regard a buyer's surplus from the second seller as the outside option when she is visiting the first seller, this outside option now depends on the rival's price and so is endogenous. However, as we will argue below these differences do not substantially change a seller's unilateral incentive to adopt these sales techniques.

Free-recall benchmark. If both firms allow free recall, the situation is a duopoly version of Wolinsky (1986). Similarly to the function $S(\cdot)$ in the monopoly setting, define

$$V(p) \equiv \mathbb{E}_u[\max\{0, u-p\}] = \int_p^{u_{\max}} Q(u)du \ , \tag{25}$$

so that $V(p) - s$ is the expected net benefit of incurring search cost s to visit a monopolist who charges p for its product. Similarly to (1), we assume that

$$V(p_M) > s \ , \tag{26}$$

where, as before, p_M is the monopoly price which maximizes $pQ(p)$. Condition (26) implies that a buyer is willing to incur the search cost s to visit a seller charging the monopoly price. In the uniform case with $Q(p) = 1 - p$, the condition requires $s < \frac{1}{8}$.

Let P_F be the symmetric equilibrium price in the free-recall regime, if a symmetric equilibrium exists. Suppose for now that this equilibrium price is below the monopoly price p_M, and so a consumer is willing to investigate the rival seller if her initial seller's offer was disappointing. To derive the equilibrium price P_F, we need to calculate a seller's demand if it sets a different price. Therefore, suppose seller i sets price P while seller j sets the equilibrium price P_F. Consider a buyer who visits seller i first and finds out match utility u_i. If the buyer purchases immediately, her net surplus is $u_i - P$, while if she chooses to search and visit seller j, her expected net surplus given the anticipated price P_F at seller j is

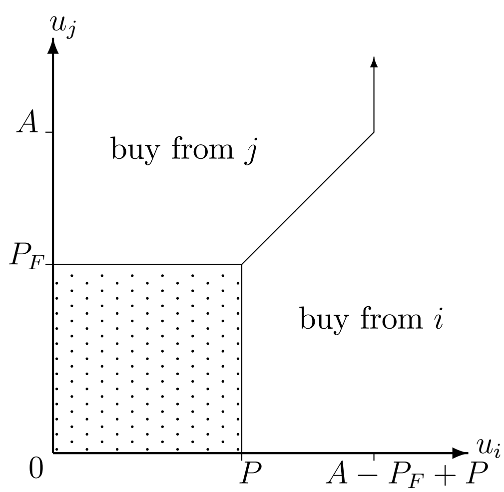
$$\mathbb{E}_{u_j}[\max\{u_i - P, u_j - P_F\}] - s = u_i - P + V(u_i + P_F - P) - s \ .$$

If we define A by

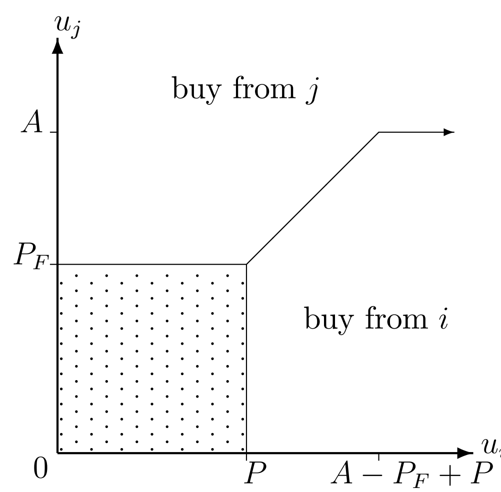
$$A = V^{-1}(s) \ , \tag{27}$$

then the buyer will buy immediately from seller i if and only if $u_i \geq A + P - P_F$. Here, A is the threshold match utility which induces immediate purchase when the two sellers offer the same price.[25] If the buyer chooses to investigate the second seller, she will buy from the seller with the greater net surplus, provided that surplus is non-negative. This pattern of demand is depicted on Figure 5a below. Note that, unlike the monopoly setting, here there is always some buy-now demand in symmetric equilibrium (provided $s > 0$), i.e., $A < u_{\max}$, since if a buyer finds the highest possible match utility at the first seller, she cannot do better at the rival and so will not search.

On the other hand, if a buyer first visits the rival firm j, this buyer anticipates that seller i will be offering the equilibrium price P_F and so she buys immediately from j if $u_j \geq A$, and otherwise she investigates i and then chooses the superior option (if that net surplus is positive). This case is depicted on Figure 5b. As in the situation with a single seller, with assumption (2) a seller's buy-now demand—that is, the demand from those consumers who buy on their first visit to the seller (which includes those consumers who first visited the rival and decided to search)—is more elastic than its buy-later demand.



a: seller i visited first



b: seller j visited first

Figure 5: Demand in duopoly with free recall

Given the pattern of demand in Figure 5, it is straightforward to derive the first-order condition for the symmetric equilibrium price P_F. However, unlike the monopoly setting, in general it is hard to ensure the existence of a symmetric equilibrium in the oligopoly case

[25] Since $V(\cdot)$ is a decreasing function, (26) and (27) imply that A is uniquely determined and $A > p_M$.

with free recall (let alone with more intricate selling strategies).[26] For this reason, we often focus in the following on the particular case of a uniform distribution, where equilibrium exists in all regimes considered.

By examining Figure 5, one can derive the first-order condition for the equilibrium free-recall price P_F in the example with $Q(p) = 1 - p$ as follows. In the symmetric equilibrium where each seller sets price P_F, each firm has total demand $\frac{1}{2}(1 - P_F^2)$ since a fraction P_F^2 of consumers buy from neither seller. If firm i cuts its price by infinitessimal ε, all consumers who buy from it pay less, so it loses $\frac{\varepsilon}{2}(1 - P_F^2)$. On the other hand, its demand increases by $\frac{1}{2}\varepsilon$ on Figure 5a and by $\frac{1}{2}A\varepsilon$ on Figure 5b (here $\frac{1}{2}$ is because half of the consumers visit firm i first and the other half visit firm j first), and it gains revenue P_F from each new consumer. Thus, the first-order condition for P_F is

$$1 - P_F^2 = (1 + A)P_F \ . \tag{28}$$

Provided that $A \geq p_M = \frac{1}{2}$, as required by (26), the solution to (28) is below p_M, and the equilibrium price falls with A (and so rises with the search cost s). This price is shown as the dashed line on Figure 6a below.

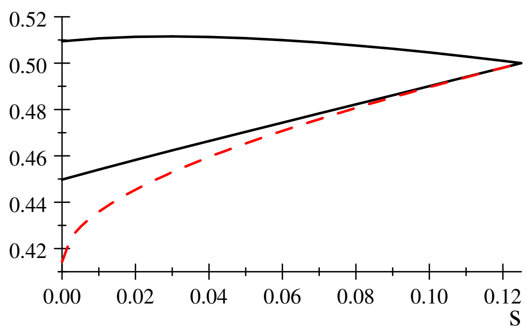
Unilateral incentives to deter search. Starting from the free-recall equilibrium, each seller's incentive to introduce a buy-now discount or to require a deposit is as in the monopoly setting from section 2.2. Consider seller i, say. Suppose it maintains the buy-now price P_F, but unilaterally introduces a buy-later premium τ or requires deposit D. This will not affect the behavior of those consumers who first meet seller j since they believe that firm i is offering the free-recall price P_F. So we need only consider those buyers who first meet seller i. When they first encounter i, their outside option is the random variable $v = \max\{0, u_j - P_F\}$. Since our argument in the monopoly setting did not rely on the form of the distribution for v, the same results hold in the duopoly model.[27] That is, with condition (2), starting from the free-recall equilibrium each firm has a unilateral incentive to impose a buy-later premium on consumers who return to buy later (or equivalently, offer

[26] One can show that a symmetric equilibrium exists in the free-recall regime, and the first-order condition defines the equilibrium price, if $pQ(p)$ is a concave function.

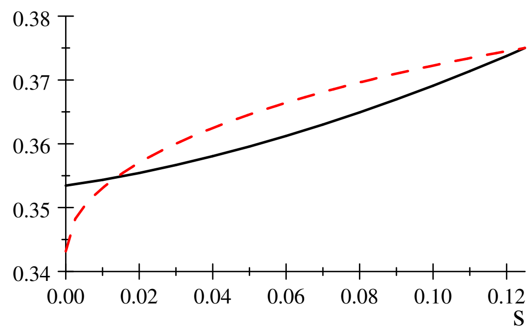
[27] The proofs will be slightly different because the outside option now depends on the benchmark equilibrium price P_F, but the logic is the same.

a buy-now discount to consumers who buy at their first visit), or require consumers to pay a deposit to retain the right to buy later. If the stronger condition that Q is concave for $Q > 0$ is satisfied, each firm also has a unilateral incentive to make an exploding offer.

Equilibrium search-deterring strategies. In general it appears to be hard to investigate the existence of a symmetric equilibrium with both firms offering a buy-now discount or a deposit contract, and to compare the market performance with the free-recall regime. To make progress, we specialize to the case of linear demand $Q(p) = 1 - p$.



a: Prices



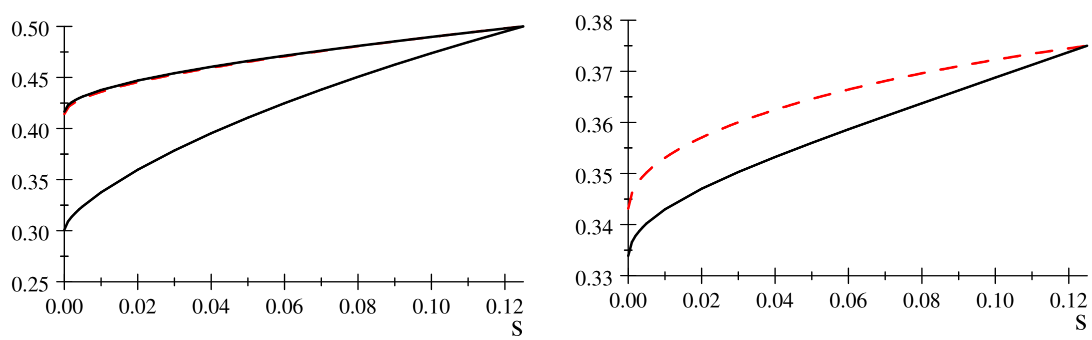
b: Industry profit

Figure 6: Equilibrium buy-now discounts in duopoly

Consider first the regime where sellers offer buy-now discounts. Figure 6 depicts the equilibrium outcome as a function of the search cost s. (The details of these derivations are provided in the appendix.) As shown in Figure 6a below, the use of buy-now discounts leads to higher prices (the middle solid curve is the buy-now price and the upper solid curve is the buy-later price). That is, even the discounted buy-now price is higher than the uniform price, and the ability to offer buy-now customers a discount drives up both prices. (We saw that a similar phenomenon could also arise in the monopoly context.) The intuition is that the buy-now discount adds to the intrinsic search frictions in the market, and this allows firms to charge a higher price. For instance, when $s = 0$ (i.e., when the market has no intrinsic search frictions), firms generate endogenous search frictions via their buy-now discount, which in this case is about 12% of the buy-later price. When the search cost approaches its maximum level which allows search to occur, buy-later demand becomes negligible even with free recall, and all prices converge to the monopoly price $p_M = \frac{1}{2}$.

Whether the use of buy-now discounts leads to higher profit depends on the magnitude of the search cost. Figure 6b shows how industry profits with uniform pricing (the dashed curve) and with buy-now discounts (the solid curve) vary with the search cost s. Price discrimination leads to higher profit only if the search cost is small, and for higher search costs price discrimination leads to high prices which exclude too many consumers. In such cases, sellers are engaged in a Prisoner's Dilemma: an individual seller wishes to offer a buy-now discount, but when both do so industry profits fall. Finally, because of both higher prices and reduced matching quality between consumers and products, one can show that aggregate consumer surplus and total welfare fall when firms use buy-now discounts. (See Figure 9 below.)

Next consider the regime where sellers offer deposit contracts. In the uniform example, the buy-now price P (the upper solid curve in Figure 7a below) is very slightly above the free-recall price P_F. (The lower solid curve is the corresponding buy-later price $P - D$.) As in the single-seller case, the almost unchanged price does not mean that consumers pay the same as they would with free recall. A consumer pays more in this regime, because with positive probability she pays a deposit to one firm and the whole price to the other. Figure 7b describes the impact on industry profit, and it shows that firms always earn less in this regime relative to the free-recall situation.

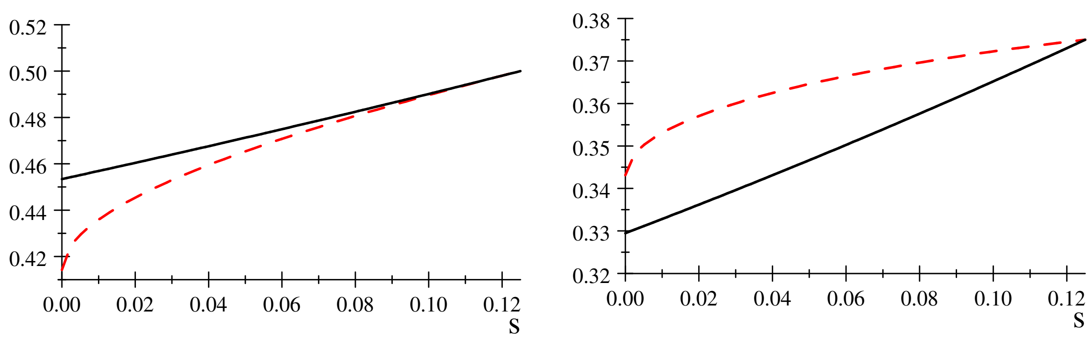


a: Prices

b: Industry profit

Figure 7: Equilibrium deposit contracts in duopoly

Finally, consider the outcome if sellers cannot commit to their buy-later price if a buyer does not buy immediately. When consumers face an intrinsic cost of returning to a previously visited seller, the "Diamond" argument in the monopoly setting continues to apply. In particular, as in Proposition 5, if sellers set an initial price on a buyer's first visit but cannot make any commitment about the future price if she returns later, firms will exploit those consumers who return to buy later such that the only equilibrium outcome is that firms set very high buy-later prices and no consumers ever return in equilibrium. The outcome is as if sellers make exploding offers to their prospective customers. When both firms make an exploding offer, the equilibrium price and profit in the uniform example is shown as the solid curves in Figure 8. The outcome is again that price is higher when exploding offers are made but industry profit is lower.

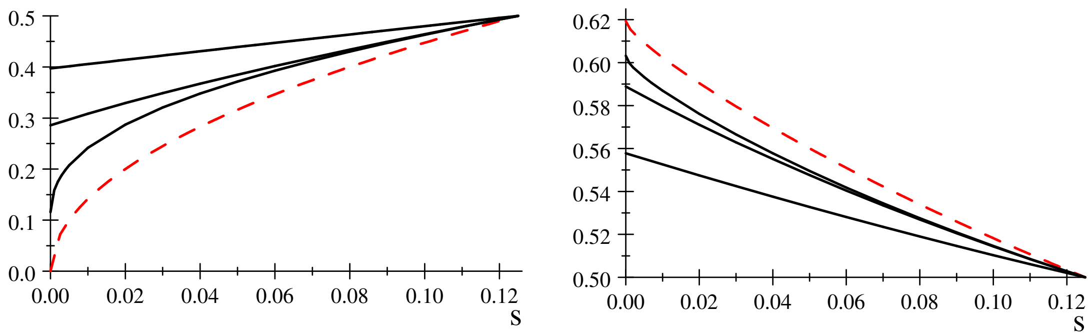


a: Prices

b: Industry profit

Figure 8: Equilibrium exploding offers in duopoly

At least in this uniform example, this market performs poorly when sellers can recognize customers. A seller has unilateral incentive to discriminate against those customers who wish to buy later, either because they have a strategic reason to deter search, or because they cannot refrain from exploiting information that a buyer has not found a satisfactory alternative. Except for a small parameter range in the buy-now discount regime, sellers are harmed by the use of search deterring strategies. Because of this, sellers might welcome a consumer protection policy which prevents the use of these tactics, if such regulation was feasible and applied to all sellers in the market.



a: Fraction who buy immediately

b: Welfare

Figure 9: Search deterrence and welfare in four regimes

When sellers pursue these sales tactics, prices rise *and* search is deterred. As a result consumers are harmed in two ways: the chosen product is on average a less good match with their tastes, and they pay more for this product. Figure 9a shows the proportion of consumers who buy immediately at the first seller—i.e., the fraction of consumers who do not search—in this uniform example. (From top to bottom, the curves correspond to the regimes with exploding offers, buy-now discounts, deposits, and free recall.) As one would expect, this fraction increases with the intrinsic search cost s in each case. The impact of search deterrence is most marked when s is small. Here, few consumers buy immediately with free recall, since there is usually a chance they will find a better offer from the rival firm, but with an exploding offer 40% of consumers do not search (and this is despite the fact that the price is higher with exploding offers). Finally, Figure 9b shows total welfare—consumer surplus plus industry profit—in the four regimes. (From bottom to top, the curves correspond to exploding offers, buy-now discounts, deposits, and free recall.) As is intuitive, these sales tactics cause limited harm in a market with significant intrinsic search frictions, since there is then little "buy later" demand even with free recall. When intrinsic frictions are small, though, the artificial search frictions induced by these tactics can lead to significant welfare losses.

4 Conclusions

This paper has examined a seller's incentive to discriminate against those consumers who return to buy later after investigating rival offers. In general, there are two reasons to discriminate in this way. The *strategic* motive reflects the seller's incentive to make post-search purchase difficult in order to deter search. By committing to make it costly to return, the seller reduces the option value of further search and a buyer is more inclined to buy without search. The *informational* motive to discriminate against customers who buy later reflects the relative demand elasticities of the two kinds of buyer. A customer who deferred purchase has relatively inelastic demand, since she has no other attractive option to the seller's offer. Both motives operate when a seller can commit to its selling strategy, in which case a seller had an incentive to deter search under mild conditions. When a seller cannot commit to future prices, only the informational motive is present. Especially when consumers have an intrinsic cost of returning to the seller, though, this motive is very powerful, and a seller's incentive to raise its price to post-search buyers is so strong that no consumer ever returns once she leaves the seller. Search deterrence is then a by-product of the seller's incentive to set prices which reflect demand elasticities.

This analysis could usefully be extended in a number of directions. In this paper, search deterrence required that a seller be able to recognize its customers. However, one could investigate if other selling techniques can profitably deter search even when consumers are anonymous. Flash sales, or very short-run discounts, are a common marketing tactic, and a number of "daily deal" websites operate on the internet.[28] A discount which is known to be short-lived can deter search, since consumers may be unable to take advantage of it if they take the time needed to search.

A second limitation of the model is that a seller had no information *ex ante* about the realization of the buyer's outside option. If the seller has information about the outside option which is bad for the consumer, it may disclose that information to deter search. For example, a gas station might display a sign stating "last fuel for 20 miles", or "cheapest fuel in town". (The credibility of such statements will determine how consumers react to

[28] For instance, in May 2011 a supplier of cosmetic surgery placed a deal on *Groupon* which offered surgery worth £5,000 for £1,999 if a consumer agreed on that day to the procedure.

them.) On the other hand, a seller who knows the outside option is likely to be attractive might make an exploding offer to prevent its discovery by the buyer. When a seller's choice of buy-later policy is made contingent on its knowledge of the outside option, a savvy buyer might use the seller's policy as a signal of her outside option.

The analysis in this paper suggests that search deterrence plausibly leads to significant welfare losses. Artificial search frictions drive up prices and reduce the quality of the match between product and consumer. These two kinds of harm can induce fewer consumers to buy, with the result that sellers in equilibrium can also be harmed when these sales tactics are feasible. Public policy might attempt to limit the use of such tactics. For instance, the *Unfair Commercial Practices Directive,* adopted in 2005 across the European Union, prohibits sellers in all circumstances "falsely stating that a product will only be available for a very limited time, or that it will only be available on particular terms for a very limited time, in order to elicit an immediate decision and deprive consumers of sufficient opportunity or time to make an informed choice".[29] Nevertheless, the enforcement of such policies will inevitably be difficult given the casual nature of much sales interaction and the frequency with which discounts from regular prices are offered. A less direct method to control aggressive sales techniques is to require a "cooling off" period for specified products, as is currently done in many jurisdictions. If a salesman manages to convince a consumer to buy immediately, through whatever means, the consumer then has the ability to cancel the deal within a specified period if she discovers a better deal elsewhere.

APPENDIX: Proofs and Omitted Analysis

Proof of Lemma 1: (i) It suffices to show that $\pi(p) \equiv pq_F(p)$ is strictly decreasing in p for $p \in [p_M, u_{\max})$. Assumption (2) implies that Q'/Q is strictly decreasing and that profit $pQ(p)$ is single-peaked. The latter observation implies that $p \geq -Q(p)/Q'(p)$ for

[29] The word "false" is difficult here, as it suggests that a seller is permitted to make an exploding offer (say), provided that the seller sticks to the promise not to sell if the buyer attempts to buy later.

$p \in [p_M, u_{\max})$. Thus, when $p \in [p_M, u_{\max})$ we have

$$\begin{aligned} \pi'(p) &= \mathbb{E}_v[Q(p+\min\{v,a\})] + p\mathbb{E}_v[Q'(p+\min\{v,a\})] \\ &\leq \mathbb{E}_v[Q(p+\min\{v,a\})] + \frac{Q(p)}{-Q'(p)}\mathbb{E}_v[Q'(p+\min\{v,a\})] \\ &< \mathbb{E}_v[Q(p+\min\{v,a\})] + \frac{Q(p)}{-Q'(p)}\mathbb{E}_v[\frac{Q'(p)}{Q(p)}Q(p+\min\{v,a)] = 0 \ . \end{aligned}$$

The first inequality follows from $p \geq -Q(p)/Q'(p)$, and the second follows from the observation that Q'/Q is strictly decreasing.

(ii) Let us first consider the case with $a + P_F < u_{\max}$, so that there is some buy-now demand at the free-recall price P_F. From Figure 1 we can see that when $a + p < u_{\max}$, the firm has a positive buy-now demand $N(p) \equiv Q(a+p)$, while its buy-later demand is $L(p) \equiv \int_0^a [Q(p+v) - Q(p+a)]dG(v)$.[30] We show that buy-now demand $N(p)$ is more elastic than buy-later demand $L(p)$. To see this, note that

$$-\frac{pL'}{L} < -\frac{pN'}{N} \Leftrightarrow LN' < NL' \Leftrightarrow Q'(p+a)\int_0^a Q(p+v)dG(v) < Q(p+a)\int_0^a Q'(p+v)dG(v) \ .$$

But since Q is strictly log-concave we have $Q'(p+a)Q(p+v) < Q(p+a)Q'(p+v)$ for all $v < a$, which establishes the claim. Since P_F maximizes $p(N(p)+L(p))$, an average of the elasticities of $N(p)$ and $L(p)$ at $p = P_F$ is equal to one. Since $L(p)$ is less elastic than $N(p)$, P_F satisfies

$$Q(a+P_F) + P_F Q'(a+P_F) < 0 \ ,$$

provided there is positive buy-now demand at P_F. The log-concavity of Q then implies that $P_F > \hat{p}$.

If $a+P_F \geq u_{\max}$, there is no buy-now demand and we cannot apply the above argument. However, since $\hat{p}$ maximizes $pQ(a+p)$, condition (5) implies that $\hat{p} < u_{\max} - a$ if $u_{\max} > a$ and $\hat{p} = 0$ if $u_{\max} = a$. So $\hat{p} < P_F$ given $P_F > 0$.

Proof of Proposition 4: In the text, we derived the optimal sales policy within the restricted class of mechanisms involving a buy-now price together with a menu of deposit contracts. Here, we show how no more general mechanism can do better for the seller. To prove this claim, we formulate the optimal mechanism design problem.

[30] When v has a mass point at zero, $L(p) \equiv \int_{0^+}^a [Q(p+v) - Q(p+a)]g(v)dv + G(0)[Q(p) - Q(p+a)]$. The following argument still works in this case.

Consider a two-stage direct mechanism consisting of the functions $\{x(u'); (q_0(u'), t_0(u')); (q(u', v'), t(u', v'))\}$. In the first stage, the buyer is required to report her valuation for the seller's product, u'. She will then be instructed whether to cease her search or whether to investigate the outside option. With probability $x(u')$, she is instructed to stop searching, in which case the buyer pays $t_0(u')$ and obtains the product with probability $q_0(u')$. With probability $1 - x(u')$, she is instructed to investigate the outside option. In that event she is required to report her new private information, i.e., the realization of the outside option, v'. Then contingent on the two reports, the buyer pays $t(u', v')$ and obtains the product from the seller with probability $q(u', v')$.

Define

$$U(u, u'; v, v') \equiv \max\{u, v\}q(u', v') + v(1 - q(u', v')) - t(u', v') - s \ . \tag{29}$$

This is the type-(u, v) buyer's expected surplus if she is instructed to search for the outside option after reporting u' in the first stage, and if she reports v' in the second stage. (Notice that if the buyer obtains both the product and the outside option, she consumes the better one.) According to the revelation principle in a dynamic setting (Myerson, 1986), without loss of generality we can focus on direct mechanisms such that (i) the buyer reports truthfully in the second stage *if* she has been truthful in the first stage and has been instructed to search, so that

$$U(u, u; v, v) = \max_{v'} : U(u, u; v, v') \ ; \tag{30}$$

and (ii) the buyer reports truthfully in the first stage, so that

$$\begin{aligned} \Phi(u) &\equiv x(u)[uq_0(u) - t_0(u)] + (1 - x(u))\mathbb{E}_v[U(u, u; v, v)] \\ &= \max_{u'} : x(u')[uq_0(u') - t_0(u')] + (1 - x(u'))\mathbb{E}_v[\max_{v'} U(u, u'; v, v')] \ . \end{aligned} \tag{31}$$

Note that if the buyer has lied in the first stage ($u' \neq u$), she is able—and in general has an incentive—to lie again in the second stage (so $v' \neq v$).[31] Here, $\Phi(u)$ defined in (31) is

[31] In the literature on sequential screening, a "strong truthtelling" condition is often imposed, which requires that the agent reports truthfully even if she previously lied. For example, see Courty and Li (2000), Krahmer and Strausz (2011), and section 5 of Pavan, Segal, and Toikka (2012). This is because in their settings, an agent's reporting incentives depend only on her previous reports, but not on whether

the buyer's surplus from participating in the mechanism. It is clear that Φ is an increasing function, and one can also show it is convex. From (31), the envelope theorem implies that

$$\begin{aligned}\Phi'(u) &= x(u)q_0(u) + (1-x(u))\left.\frac{\partial}{\partial u}\mathbb{E}_v[U(u,u';v,v)]\right|_{u'=u} \\ &= x(u)q_0(u) + (1-x(u))\int_0^u q(u,v)dG(v)\ ,\end{aligned} \tag{32}$$

where the second equality follows the definition of U in (29) which implies $\frac{\partial}{\partial u}U(u,u';v,v) = q(u',v)$ if $u > v$, and $\frac{\partial}{\partial u}U(u,u';v,v) = 0$ otherwise.

The seller's problem is to choose $\{x, q_0, t_0, q, t\}$ in order to maximize profit

$$\int_0^{u_{\max}} \{x(u)t_0(u) + (1-x(u))\mathbb{E}_v[t(u,v)]\}dF(u)$$

subject to the pair of incentive constraints (30)–(31) and the participation constraint $\Phi(u) \geq \bar{v} - s$. (It is without loss of generality to assume that the seller offers a mechanism which is accepted by all agents in equilibrium, as the non-participation option can be made available within the mechanism.)

In the following, we first solve a "relaxed" problem by imposing the participation constraint together with only the local incentive compatibility constraint (32). We will then show that the solution to this relaxed problem is the optimal menu of deposit contracts described in Proposition 4, which therefore constitute the optimal selling mechanism.

From the definition of $\Phi(u)$ in (31), we have

$$\begin{aligned}&x(u)t_0(u) + (1-x(u))\mathbb{E}_v[t(u,v)] = \\ &x(u)uq_0(u) + (1-x(u))\left\{\int_0^u (u-v)q(u,v)dG(v) + \bar{v} - s\right\} - \Phi(u)\ .\end{aligned} \tag{33}$$

Therefore, the seller's profit can be written as

$$\pi = \int_0^{u_{\max}} \left[x(u)uq_0(u) + (1-x(u))\left\{\int_0^u (u-v)q(u,v)dG(v) + \bar{v} - s\right\} - \Phi(u)\right] dF(u)\ .$$

those reports were truthful. Using our notation, this would be the case if U did not depend on the true u. In such cases, the incentive for a type-u' buyer to report truthfully in the second stage on the equilibrium path implies that a type-u buyer will report truthfully in the second stage even after reporting u' (rather than u) in the first stage. Because of this difference we cannot impose the strong truthtelling constraint in our model. Without a strong truthtelling constraint, the incentive compatibility condition in the first stage is more complicated than in the usual case since we need to consider the optimal lying strategy in the second stage.

Using

$$\int_0^{u_{\max}} \Phi(u)dF(u) = \Phi(0) + \int_0^{u_{\max}} \Phi'(u)[1-F(u)]du$$

and (32), we can rewrite this profit as

$$\int_0^{u_{\max}} \left[x(u)\lambda(u)q_0(u) + (1-x(u)) \left\{ \int_0^{u} (\lambda(u)-v)q(u,v)dG(v) + \bar{v} - s \right\} \right] dF(u) - \Phi(0) \ , \tag{34}$$

where λ is given in (18).

This expression can be maximized point-wise with respect to x, q_0 and q, where each of these probabilities is constrained to lie between 0 and 1. This entails that $q_0(u) = 1$ if and only if $\lambda(u) \geq 0$, i.e., if $u \geq p_M$. This also entails

$$q(u,v) = \begin{cases} 1 & \text{if } v \leq \lambda(u) \\ 0 & \text{otherwise} \end{cases} \ . \tag{35}$$

In particular, both q_0 and q are zero when $u < p_M$, and in this range the buyer never obtains the product. From (34), in this range it is therefore optimal to set $x(u) = 0$. Using $q(u,v)$ in (35) we obtain

$$\int_0^{u} [(\lambda(u)-v)q(u,v)]dG(v) = \int_0^{\lambda(u)} [\lambda(u)-v]dG(v) = R(\lambda(u)) \ .$$

Hence, the seller's profit (34) simplifies to

$$\pi = \int_{p_M}^{u_{\max}} [x(u)\lambda(u) + (1-x(u))\{R(\lambda(u)) + \bar{v} - s\}]\, dF(u) + F(p_M)(\bar{v}-s) - \Phi(0) \ . \tag{36}$$

From (12) we know that $R(\lambda(u)) = S(\lambda(u)) + \lambda(u) - \bar{v}$, and so the $\{\cdot\}$ term in the integrand is greater than $\lambda(u)$ if $\lambda(u) \leq a = S^{-1}(s)$, so that it is optimal to set $x(u) = 0$ if $\lambda(u) \leq a$ and otherwise to set $x(u) = 1$. As in the text, write $\hat{u} > p_M$ for the utility level which satisfies $\lambda(\hat{u}) = a$. Together with the participation constraint $\Phi(0) = \bar{v} - s$, this implies that profit in (36) is

$$\pi = \int_{p_M}^{\hat{u}} [R(\lambda(u)) + \bar{v} - s]\, dF(u) + \int_{\hat{u}}^{u_{\max}} \lambda(u)dF(u) - (1-F(p_M))(\bar{v}-s) \ . \tag{37}$$

Since

$$\int_{\hat{u}}^{u_{\max}} \lambda(u)dF(u) = \hat{u}(1-F(\hat{u})) \ ,$$

we see that profit in (37) is the same as in our earlier expression (19).

In sum, the maximum profits obtained in this relaxed problem, which are an upper bound on possible profits when we impose all incentive constraints, are the same as those achieved with our restricted instruments of a buy-now price together with a menu of deposit contracts. We can conclude that the seller's optimal selling strategy is as described in the statement of Proposition 4.

Details for the uniform example without commitment

If the seller offers the buy-now price P, for given consumer expectations about the buy-later price p^e, there will be an equilibrium threshold $\hat{u} \leq 1$ such that all buyers with $u \geq \hat{u}$ will buy immediately, while others will search.[32] (Note that p^e and $\hat{u}$ will depend on the buy-now price P.) Given this threshold $\hat{u}$, the seller chooses its buy-later price p to maximize its profits from the pool of searching consumers. A buyer who searches will buy from the seller if $u - p \geq v$, where p is the seller's actual buy-later price. Therefore, the seller's buy-later demand with price $p < \hat{u}$ is $\frac{1}{2}(\hat{u} - p)^2$, and so p is chosen to maximize $\frac{1}{2}p(\hat{u} - p)^2$, which entails $p = \frac{1}{3}\hat{u}$. The seller then makes profit $\frac{2}{27}\hat{u}^3$ in the buy-later market. If all consumers choose to search ($\hat{u} = 1$), the seller chooses the buy-later price $p = \frac{1}{3}$.

The buyer with type $\hat{u}$ is by construction indifferent between buying immediately at price P and searching with the option to buy later at the anticipated price p^e, so that

$$\hat{u} - P = \mathbb{E}_v[\max\{\hat{u} - p^e, v\}] - s = \tfrac{1}{2}(1 + (\hat{u} - p^e)^2) - \tfrac{1}{18} = \tfrac{1}{2}(1 + (\tfrac{2}{3}\hat{u})^2) - \tfrac{1}{18} \ , \qquad (38)$$

where the third equality follows from the equilibrium requirement that $p^e = \frac{1}{3}\hat{u}$. Note that if $1 - P \leq \mathbb{E}_v[\max\{1 - \frac{1}{3}, v\}] - \frac{1}{18}$, i.e., if $P \geq \frac{1}{3}$, then even the buyer with the highest u will prefer to search and have the option of buying later at price $p = \frac{1}{3}$. Thus, for $P \geq \frac{1}{3}$ there will be no buy-now demand, and the seller then sets $p = \frac{1}{3}$ to serve the buy-later market, thereby obtaining profit $\frac{2}{27}$. However, we see next that the seller can do better than this by inducing some buy-now demand.

Given an initial price $P \leq \frac{1}{3}$, the relevant solution to equation (38) is $\hat{u}(P) = \frac{9}{4} - \frac{1}{4}\sqrt{49 - 72P}$. The resulting buy-later price $p = \frac{1}{3}\hat{u}(P)$ is greater than P when $P \leq \frac{1}{3}$, so that a buy-later premium is imposed. Here, $\hat{u}(P)$ increases with P, so that a higher

[32] Suppose given initial price P that buyers anticipate the buy-later price p^e. They will buy immediately if and only if $u - P \geq \mathbb{E}_v[\max\{u - p^e, v\}] - s$, and this inequality holds if and only if u is sufficiently large.

buy-now price induces fewer buyers to buy immediately. If the seller chooses initial price $P \le \frac{1}{3}$, its profit is

$$\pi = P(1-\hat{u}(P)) + \tfrac{2}{27}(\hat{u}(P))^3 \ .$$

Maximizing this expression with respect to P, and calculating the corresponding buy-later price p, yields the outcome reported in the text.

Equilibrium analysis in the duopoly model.

(i) *Buy-now discounts.* Here we derive the symmetric equilibrium tariff (P,τ), where P is the buy-now price and τ is the buy-later premium (so the buy-later price is $P+\tau$). Suppose firm i deviates to (P_i,τ_i). It is without loss of generality that we consider deviations restricted to $\tau_i \le V(P)-s$.[33] For a buyer who visits firm i first and values its product at u_i, her surplus is $u_i - P_i$ if she buys immediately. If she chooses to search and visit firm j, her expected surplus is

$$\mathbb{E}_{u_j}[\max\{u_i-(P_i+\tau_i), u_j-P\}] - s = u_i-(P_i+\tau_i) + V(u_i-(P_i+\tau_i)+P) - s \ .$$

Therefore, this buyer will buy immediately if and only if $\tau_i > V(u_i-(P_i+\tau_i)+P)-s$, i.e., if $u_i > V^{-1}(s+\tau_i)+\tau_i+P_i-P$. If she visits both sellers, she will return to buy from i if $u_i-(P_i+\tau_i) > u_j-P$. The pattern of demand for these consumers who first visit seller i is depicted on Figure A1(a). Consumers who first visit seller j hold equilibrium beliefs about firm i's pricing strategy, and so their demand is as shown on Figure A1(b).

With the help of these figures, one can write down the first-order conditions for (P,τ) to be the equilibrium tariff. In the uniform example we have $V^{-1}(x) = 1-\sqrt{2x}$. As in the monopoly case, in this example a seller's total demand does not depend on its choice of buy-later premium τ_i and its buy-later demand does not depend on its choice of buy-now price P_i. As a result, a seller's profit is additively separable in τ_i and P_i. It is apparent from Figure A1 that in symmetric equilibrium a fraction $P(P+\tau)$ of consumers buy nothing, and so a seller's total demand is $\frac{1}{2}(1-P(P+\tau))$. Similarly to (28), then, the first-order condition for the buy-now price P is

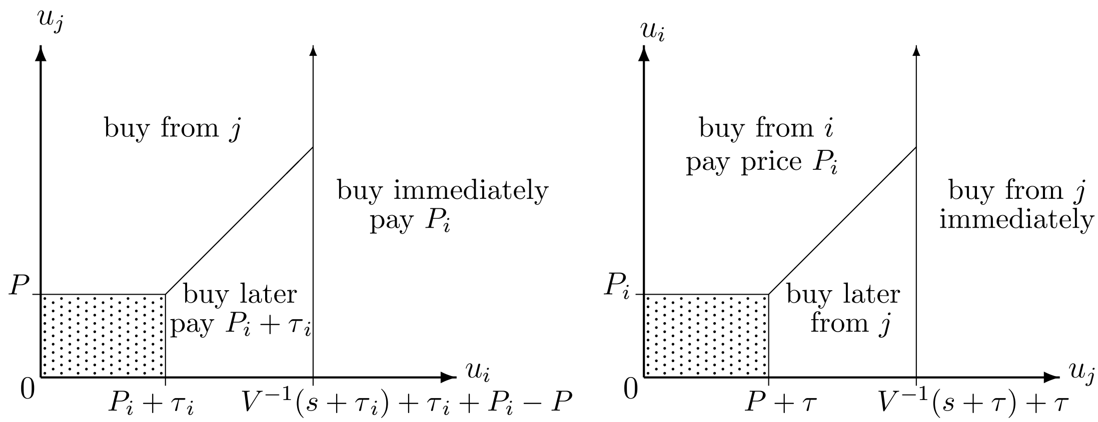
$$1-P(P+\tau) = (1+V^{-1}(s+\tau)+\tau)P \ .$$

[33] As can be seen from Figure A1(a), when $\tau_i > V(P)-s$, buy-later demand disappears and i's profit is independent of τ_i. Hence, our restriction to $\tau_i \le V(P)-s$ is without loss of generality.

Since a seller's choice of τ_i does not affect its total demand, but only the proportion of buy-later demand, a seller chooses τ_i to maximize its revenue from the consumers who buy later. Figure A1(a) implies that the volume of seller i's buy-later demand is proportional to $(V^{-1}(s+\tau_i))^2 - P^2$, and so the first-order condition for the buy-later premium τ is

$$(V^{-1}(s+\tau))^2 - P^2 = -2\tau V^{-1}(s+\tau)(V^{-1})'(s+\tau) \ .$$

Numerically solving this pair of first-order conditions yields the prices and profits shown on Figure 6 in the text.



a: seller i visited first

b: seller j visited first

Figure A1: Demand in duopoly with a buy-now discount

(ii) *Deposit contracts.* Here we derive the symmetric equilibrium deposit contract (P, D), where P is the buy-now price and D is the deposit (so the buy-later price is $p = P - D$). Suppose seller i deviates to (P_i, D_i). For a buyer who visits i first and values its product at u_i, her surplus is $u_i - P_i$ if she buys immediately. If she does not buy but pays the deposit D_i and continues to search, her expected surplus is

$$\mathbb{E}_{u_j}[\max\{u_i - (P_i - D_i), u_j - P\}] - D_i - s = u_i - P_i + V(u_i - (P_i - D_i) + P) - s \ .$$

Therefore, this buyer will buy immediately if and only if $u_i - (P_i - D_i) + P > A$. The buyer can also abandon seller i by not paying the deposit and then investigating the rival. In that case, her expected surplus is just $V(P) - s$. Similarly to (12) in the single-seller setting, given the equilibrium buy-now price P define

$$W(x) \equiv V(x) + x - V(P) - P = \int_P^x F(u)du \ .$$

Then paying the deposit is preferred to abandoning seller i altogether if $W(u_i - (P_i - D_i) + P) \geq D_i$, i.e., if

$$u_i > W^{-1}(D_i) + P_i - D_i - P \ .$$

After paying the deposit and visiting j, the buyer will return to buy from i if $u_j - P < u_i - (P_i - D_i)$. If the buyer abandons seller i, she will buy from j if $u_j \geq P$.

Therefore, the pattern of demand of those consumers who first visit seller i is described in Figure A2(a). This demand pattern assumes $D_i < W(A)$, so that there is some buy-later demand, as is the case in equilibrium for the uniform example. Note that $W^{-1}(D_i) > P$ if $D_i > 0$, as shown on Figure A2(a). Consumers who first visit seller j hold equilibrium beliefs about seller i's pricing strategy. Following the same logic as above, their demand pattern is as shown on Figure A2(b).

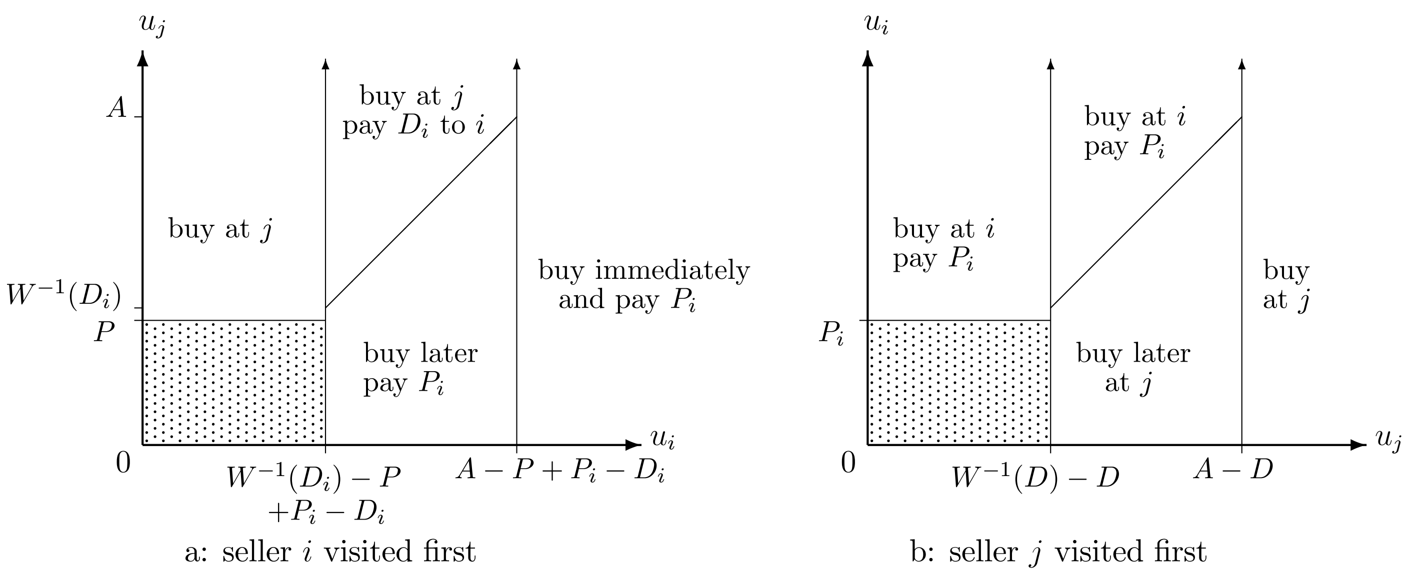


Figure A2: Demand in duopoly with a deposit contract

With the help of these figures, one can write down the first-order conditions for (P, D) to be the equilibrium deposit contract. In the uniform example, a seller's profit is additively separable in P_i and D_i and its demand does not depend on D_i. We have $W^{-1}(D) = \sqrt{2D + P^2}$ and $A = 1 - \sqrt{2s}$. It is apparent from Figure A2 that in symmetric equilibrium a fraction $P(W^{-1}(D) - D)$ of consumers buy nothing, and so a seller's total demand in equilibrium is $\frac{1}{2}(1 - P(W^{-1}(D) - D))$. Similarly to (28), the first-order condition for the buy-now price P is

$$1 - P(W^{-1}(D) - D) = (1 + A - D)P \Leftrightarrow P(1 + A + P^2 + x - x^2) = 1 \ ,$$

where we have written $x \equiv W^{-1}(D)$. Since a seller's choice of D_i does not affect its total demand, it chooses D_i to maximize its revenue from the consumers who pay the deposit but who do not end up buying. Figure A2(a) implies that the number of these consumers is proportional to $(A - W^{-1}(D_i))(2 - A - W^{-1}(D_i))$. If we write $x = W^{-1}(D_i)$, then the seller chooses x to maximize $W(x)(A - x)(2 - A - x)$ which has first-order condition

$$(A^2 + P^2 - 2A)x + 3x^2 - 2x^3 = P^2 \ .$$

Solving this pair of first-order conditions yields the prices and profits shown on Figure 7 in the text.

(iii) *Exploding offers.* Finally, we examine the equilibrium prices when exploding offers are made. Suppose the equilibrium price is P. If seller i deviates and sets price P_i, its total demand is

$$\tfrac{1}{2}Q(P_i + V(P) - s) + \tfrac{1}{2}[1 - Q(P + V(P) - s)]Q(P_i) \ . \tag{39}$$

Here, the first term represents demand from those consumers who first visit seller i: if they have match utility u_i, they will accept i's exploding offer if $u_i - P_i \geq V(P) - s$. The second term is the demand from those consumers who first visit the rival: a consumer will reject the rival's exploding offer if $u_j - P < V(P) - s$, since they anticipate that seller i offers the equilibrium price P, and then they buy from i if $u_i \geq P_i$.

In the uniform example, demand in (39) is linear in P_i, and the first-order condition for equilibrium price P is

$$Q(P + V(P) - s) + [1 - Q(P + V(P) - s)]Q(P) = P(2 - Q(P + V(P) - s))$$

or

$$P(2 - 2s + P^2) = 1$$

after substituting $V(P) = \frac{1}{2}(1 - P)^2$. Solving this first-order condition yields the price and profit shown on Figure 8 in the text.

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