Ordered Consumer Search

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Abstract

The paper discusses situations in which consumers search through their options in a deliberate order, in contrast to more familiar models with random search. Topics include: network effects (consumers may be better off following the same search order as other consumers); the use of price and non-price advertising to direct search; the impact of consumers starting a new search with their previous supplier; the incentive sellers have to merge or co-locate with other sellers; and the incentive a seller can have to raise its own search cost. I also show how ordered search can be reformulated as a simpler discrete choice problem without search frictions.

Keywords: Consumer search, sequential search, ordered search, directed search, discrete choice, oligopoly, advertising, obfuscation.

1 Introduction

Consider a consumer who wishes to purchase one product from several variants available. In some cases she might know exactly what she wants in advance, and no prior market investigation is needed. In other situations, she might be so ill-informed that she stumbles randomly from one option to another until she discovers something suitable. Between these extremes, though, the consumer has some initial idea about which options are more likely to be suitable, or cheaper, or easier to inspect, and she will deliberately investigate these first. (She will go on to investigate other options if she is disappointed by what she finds there.) For instance, in an online book market De los Santos, Hortacsu and Wildenbeest (2012, Table 6) report: of those consumers who searched for a book only once, 69% inspected

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Amazon; of those who searched two sellers, 57% inspected *Amazon* first, and *Amazon* also had a large share of the second inspections of those consumers who first inspected other sellers.

In more detail, there are several reasons why a consumer might choose to conduct her search for a product in a deliberate order. A consumer might have *ex ante* product (or brand) preferences in place from the start, and she anticipates she is more likely to like some products than others. Nelson (1970, page 312) writes that consumer search need not "be conducted at random. Prior to sampling, a consumer can obtain information from relatives and friends, consumer magazines, or even from advertising".[1] Relatedly, the consumer might consult an intermediary to recommend a search order to her. For instance, enquiring about hotels in a city on specified dates from an online travel agent may generate a list of available options ordered according to the travel agent's ranking algorithm, and if the algorithm is good the consumer will do well to search in the suggested order.[2] General purpose search engines also aim to order their non-sponsored (organic) results according to estimated relevance to the consumer.[3]

Search might be directed by prices, in the sense that sellers advertise their prices to consumers in advance (for instance on the internet). When products are otherwise symmetric consumers will then choose to inspect products in order of increasing price, and more generally prices can be used to attract consumers (which is not possible when prices are discovered after search, when a seller's price can be used only to retain consumers who choose to inspect that seller). Search might also be directed by non-price advertising, so that consumers start their search at the seller which advertises the most heavily. Rational consumers might anticipate that the seller that spends the most on advertising will turn out to offer the lowest price or the most suitable product. For instance, when consumers

[1]In footnote 9 Nelson writes that he has a detailed theory of "guided search" which "could not be included here because of space limitations".

[2]Ursu (2015) studies such a travel agent empirically. An important feature of her dataset is that the travel agent randomized its recommendations to some consumers, which allows her to study the effect of rank on click rates and purchase decisions in a clean way. In the random order treatment, consumers clicked on links with decreasing frequency further down the page (since presumably they believe the ranking has some content) but their purchase probability contingent on clicking does not depend on page position. However, when the travel agent's true ranking was displayed, the purchase probability did depend strongly on rank, suggesting that the ranking algorithm was indeed useful to consumers as a guide to search.

[3]Baye, De los Santos, and Wildenbeest (2016) document how the traffic generated by organic results from a search engine to a retailer depends on both the retailer's prominence on the results page and the prominence of the retailer's brand. (They estimate the latter by measuring how frequently consumers search for the brand by name when looking for a product.)

use a search engine it might be that the most relevant seller for them is the seller that bids the most to be displayed first in the sponsored search results, in which case consumers should inspect sellers in the order they appear on the results page.

If other consumers follow a particular search order, it can be optimal for an individual consumer to do the same. When many consumers search through sellers in the same order, a seller placed earlier in this order will often set a lower price than its rivals further back. A seller placed further back knows that a consumer it encounters is likely to have been disappointed in the offers received so far—from the seller's perspective, this is a form of advantageous selection—and so it can afford to set a high price. In such cases, an individual consumer then does better to search in the same order as other consumers. Because of this, if other consumers use a rule of thumb for choosing which seller to inspect first—for example, as above they first inspect the seller which advertises with the greatest intensity, or even if they use a more *ad hoc* procedure such as searching through sellers in alphabetical order—then an individual consumer should do the same. Similarly, it may be that one seller has managed to achieve a "low price image" which induces consumers to try there first, and in equilibrium this seller does have an incentive to choose lower prices. This kind of self-fulfilling prophecy means that a highly skewed pattern of sales can emerge even in symmetric environments.

Some products have lower search costs than others. For instance, geography or shop layout determines a consumer's search order, and she might choose to inspect the nearest option first (which might be different for different consumers). In a physical store it is easier to inspect products displayed at eye level or on the ground floor, regulation might require certain products to be on the "top shelf", while unhealthy products aimed at children might profitably be placed at a lower height. Judicious design of store layout might mean that a multiproduct seller can *force* the consumer to consider its products in a particular order. Consumers might find it less costly to inspect a new product from a supplier they have used before than from a new supplier, perhaps because they have contact details readily available.

Another way to reduce search costs is to first visit a location (either physical or online) known to have a concentration of varieties of the relevant product. A cluster with several suppliers not only allows a better chance of finding a good product, but competition between suppliers within the cluster might lead to lower prices. Similarly, a consumer might choose to first visit a "big box" store which stocks more varieties of the product in question. However, because pricing is coordinated within the store, it is likely that the store will set a higher price than its smaller rivals, and consumers choosing their search order have to trade off the one-stop shopping benefits of greater variety with the higher price they will have to pay there.

The rest of this paper is organized as follows. Section 2 describes the principles governing optimal sequential search in fairly general terms, and shows how the search problem can be reformulated as a simpler discrete choice problem without search frictions. Section 3 uses this theory to describe outcomes in a model where sellers choose prices for their products. In simple settings where each consumer views the sellers as symmetric *ex ante*, this model often exhibits multiple equilibria: the consumer search order depends on which sellers choose lower prices, and the prices that sellers choose depend on where they are in the search order. Random consumer search is one equilibrium (and is often the focus of existing oligopoly models), although it is often an unstable equilibrium. However, if the demand system is "smoothed", by making individual consumers have sufficiently heterogeneous preferences over sellers, the market might have a single equilibrium.

Extensions to this basic model are presented in section 4, which aim to illustrate several of the reasons for ordered search described above. These include discussions of how multi-seller clusters and "big box" sellers should often be inspected first by consumers, how sellers chooses prices when they anticipate that consumers start a new search process with their previous supplier, how it might be profitable for a seller to deliberately increase its inspection costs, and the impact of both price and non-price advertising on market outcomes. Section 5 suggests some promising options for further research. The relevant literature, much of which is very recent, is discussed as I present various aspects of ordered search in the paper.

2 Opening the box

Consider a consumer who wishes to select one product from several variants which are available. One way to model this decision problem is to suppose that the consumer knows in advance her idiosyncratic match utility for each product i, say v_i, and knows in advance each product's price, p_i, and chooses the option with the highest net surplus $v_i - p_i$ provided this is positive. This is the "discrete choice" problem. This paper studies another scenario, where before purchase the consumer needs to incur a cost s_i to discover product i's characteristics, v_i and p_i. (In section 4.5 I also study a scenario between these two extremes, where consumers know each product's price in advance but need to discover the associated match utility.[4]) The kinds of products where consumers have idiosyncratic tastes, and which they usually wish to inspect in some way before buying (even if they know the price in advance), include cameras, cars, clothing, furniture, hotels, novels, perfume, and pets.

Before studying in the next section how equilibrium prices in an oligopoly are determined, we first describe the risk-neutral consumer's optimal search strategy for a given set of options. Weitzman (1979) provides the key to understanding optimal sequential search through a finite number of mutually exclusive options ("boxes") with uncertain payoffs. The consumer's payoff from option i is a random variable $v_i \geq 0$, where her payoffs are independently distributed across options with CDF $F_i(v_i)$ for option i. (It is natural to suppose the payoff v_i is non-negative if the consumer has an outside option of zero.) To discover the realization of v_i inside box i involves the non-refundable inspection cost s_i. There is free recall, so that the consumer can costlessly return to claim the payoff from a box opened earlier. The consumer wishes to consume at most one of the options, and aims to maximize the expected value of the consumed option net of total search costs. To do this she decides both the order in which to inspect options and the rule for when to terminate search (in which case she consumes the best option opened so far). Weitzman refers to this as "Pandora's problem", and the consumer is female in this paper.[5]

For now, suppose that $\mu_i \equiv \mathbb{E}_i v_i > s_i$ for each i, for otherwise it is never optimal to open box i and this option can be eliminated from her choice problem. (Here, $\mathbb{E}_i$ denotes taking expectations with respect to the distribution for v_i.) Define the "reservation price" of box i to be the unique price r_i which satisfies

$$\mathbb{E}_i \max\{v_i - r_i, 0\} = s_i \ . \tag{1}$$

(Since $\mu_i > s_i$, this reservation price is positive.) In terms of demand theory, r_i is the highest price such that the consumer is willing to incur the sunk cost s_i for the right to purchase the product at that price once she has discovered her match utility. The expected incremental benefit of inspecting box i given that the consumer already has secured a

[4] The remaining configuration, where consumers know their match utilities in advance but must incur search costs to discover the associated prices, suffers from the problem of hold-up and market shut-down, as initially discussed by Diamond (1971).

[5] This is not particularly apt terminology, as in the myth there is just one box.

potential payoff $x \geq 0$ to which she can freely return is

$$\mathbb{E}_i \max\{v_i, x\} - s_i - x = \mathbb{E}_i \max\{v_i - x, 0\} - s_i \ , \tag{2}$$

which is positive if and only if her current payoff x is below the reservation price r_i.

Weitzman shows that an optimal search strategy in this context—"Pandora's rule"—is as follows.[6]

Selection rule: If a box is to be opened, it should be the unopened box with the highest reservation price;
Stopping rule: Terminate search whenever the maximum payoff discovered so far exceeds the reservation price of all unopened boxes (which is zero if no box remains unopened), and consume the option with this maximum payoff.

For instance, suppose there are three boxes with respective reservation prices r_i and realized payoffs v_i given by

$$(r_1, v_1) = (5, 2) \ ; \ (r_2, v_2) = (10, 4) \ ; \ (r_3, v_3) = (3, 7) \ . \tag{3}$$

Then the consumer (who of course does not know the realized payoff v_i until she opens that box) should first inspect box 2 as that has the highest reservation price, should go on to inspect box 1 (since that box has reservation price above her current payoff $v_2 = 4$), then come back to consume the payoff in box 2 without inspecting box 3 (since v_2 is above both v_1 and r_3).

The reservation price in (1) depends only on the properties of that option, i.e., s_i and F_i. The reservation price for a box is not the same as that box's stand-alone surplus, $\mu_i - s_i$. If the consumer could only choose one box to open, she would choose the box with the highest value of $\mu_i - s_i$, which need not be the box with the highest r_i.[7] As is intuitive, the reservation price in (1) is decreasing in s_i and increasing in $[1 - F_i(\cdot)]$. In addition, since it depends on the right-tail of the distribution, all else equal it is increasing in the "riskiness" of the option. As Weitzman (1979, page 647) puts it: "Other things

[6] The optimality of this rule depends on a number of factors. When the consumer cannot freely return to an earlier opened box, it may not be optimal to inspect boxes in order of their reservation values. See Salop (1973) for an investigation of optimal order of search when there is no recall (which is a common assumption in the job search literature). Olszewski and Weber (2015) discuss how the rule needs to be modified when the agent gains utility from all opened boxes, while Doval (2014) considers the situation where the agent can consume the contents of a box without inspecting it first (and without incurring the search cost).

[7] Chade and Smith (2006) analyze which boxes to inspect in non-sequential search.

being equal, it is optimal to sample first from distributions which are more spread out or riskier in hopes of striking it rich early and ending the search."

Pandora's rule can conveniently be re-expressed as a simpler discrete choice problem without search frictions.[8] Specifically, Pandora's rule is equivalent to the choice rule whereby the consumer chooses the payoff from the box with the highest index

$$w_i \equiv \min\{r_i, v_i\} \ , \tag{4}$$

where v_i is the realized payoff inside box i. (This is the case in the scenario in (3) above, when box 2 was ultimately selected.) To see this, we show that box j is not chosen under Pandora's rule when $w_j < w_i$. If $r_j < r_i$, then box i will be inspected before j, and j could then be chosen only if it is inspected, which requires $v_i < r_j$, and then only if $v_i < v_j$, which taken together contradict the assumption $w_j < w_i$. If instead $r_j > r_i$, then box j is inspected before i. But then $w_j < w_i$ implies $v_j < \min\{r_i, v_i\}$, which implies that box j is not consumed before first inspecting i, which then reveals a superior payoff. In either case, the inequality $w_j < w_i$ implies that box j is not chosen. Since some box is eventually chosen under Pandora's rule, we deduce it is the box with the highest w_i. In sum, while the box-specific index r_i determines which box the consumer opens first, the box-specific index w_i determines which box is ultimately selected.[9] As shown in Theorem 1 in Kleinberg, Waggoner, and Weyl (2016), which itself builds on Weber (1992), this reformulation of Pandora's rule allows for the elegant proof of Weitzman's result which is presented in Appendix A below.

When a population of consumers choose their options it will often be the case that consumers differ in their reservation price r_i for box i. For instance, consumers might differ in their cost of inspecting a given box (e.g., due to their different geographic locations) or in their prior distribution for a box's match utility. An individual consumer is characterized by her list of reservation prices $(r_1, r_2, ...)$ and her list of realized payoffs $(v_1, v_2, ...)$ which via (4) generate the list $(w_1, w_2, ...)$. This heterogeneous population of consumers selecting an option via optimal sequential search can equivalently be modelled as engaging in a discrete choice problem, where the type-$(w_1, w_2, ...)$ consumer simply selects the option

[8] This discussion develops the analysis in Armstrong and Vickers (2015, pages 303-4), where we showed how a search problem with free recall of earlier options can be recast as a discrete choice problem without search frictions. (This reformulation is not possible without free recall of earlier options.)

[9] Since $\mathbb{E}_i w_i = \mathbb{E}_i[v_i - \max\{v_i - r_i, 0\}] = \mu_i - s_i$, the expected value of the parameter w_i is the stand-alone surplus from box i.

with the highest w_i. The joint distribution of $(w_1, w_2, ...)$ in the consumer population then determines the demand for each option.

3 Ordered search with strategic sellers

We now put strategic sellers inside these boxes. Suppose there are a finite number of sellers, labelled $i = 1, 2, ...$, which each supply a single variant of a product, where seller i has constant marginal cost of production c_i. Consumers want at most one product and have idiosyncratic match utilities for the product from seller i, denoted v_i, where v_i is not observed by the seller. A particular consumer incurs search cost s_i to inspect seller i, anticipates that seller i's match utility comes from the CDF $F_i(v_i)$ and believes that her match utilities are independently distributed across sellers. Seller i chooses price $\tilde{p}_i$, and a consumer who buys from i obtains payoff $v_i - \tilde{p}_i$ (excluding her search costs). The consumer discovers seller i's price $\tilde{p}_i$ and the corresponding match utility v_i only after paying the search cost s_i. I assume that the consumer can freely return to a previously inspected product and there is no danger of a popular product being sold out. (These two assumptions distinguish consumer search from the typical job search model.)

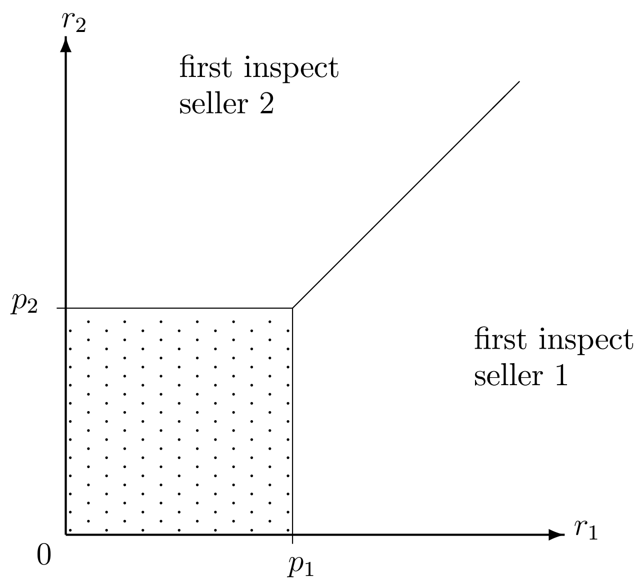

Figure 1: The optimal search order with two sellers

Since the consumer's decision to inspect a seller, and the order in which she inspects sellers, depends on anticipated, not actual, prices, write p_i for the anticipated price from seller i (while $\tilde{p}_i$ is that seller's actual price). In equilibrium we will require that $p_i =$

$\tilde{p}_i$. Given a list of anticipated prices $(p_1, p_2, ...)$, the consumer's optimal search order is described by Pandora's rule. To understand what this means we need to calculate the reservation price of the lottery inside box i, which has anticipated payoff $\max\{v_i - p_i, 0\}$. As discussed in section 2, if $p_i > r_i$, where r_i in (1) is the reservation price for the match utility v_i, it is not worthwhile for this consumer ever to inspect seller i. If $p_i < r_i$, though, the reservation price of the box with payoff $\max\{v_i - p_i, 0\}$ and search cost s_i is positive and equal to $r_i - p_i$.[10] Therefore, according to Pandora's rule this consumer should first inspect the seller with the highest $r_i - p_i$, if this is positive, and keep searching until her maximum sampled payoff $v_k - \tilde{p}_k$ (where $\tilde{p}_k$ is seller k's actual price) is above all of the $r_j - p_j$ for uninspected products. In general, consumers will differ in their reservation prices, and Figure 1 depicts the optimal search order with two sellers in terms of the pair (r_1, r_2). In particular, a consumer's decision about which seller to inspect first is akin to a discrete choice problem where a consumer values option i at r_i and chooses the option with the highest payoff $r_i - p_i$ (or, as shown in the shaded region, the outside option zero if that is superior to engaging in search).

While her search order depends on anticipated prices $(p_1, p_2, ...)$, a consumer's purchase decision depends also on the actual prices $(\tilde{p}_1, \tilde{p}_2, ...)$. Since the payoff from purchasing from seller i is $v_i - \tilde{p}_i$, the discrete choice reformulation in section 2 shows that seller i's demand is the fraction of consumers for whom the index

$$\min\{r_i - p_i, v_i - \tilde{p}_i\} \tag{5}$$

is positive and higher than the corresponding index from all rival sellers. For a given list of anticipated prices, this determines demand for the various sellers in terms of their actual prices. Equilibrium in this market occurs when the Bertrand equilibrium in actual prices $(\tilde{p}_1, \tilde{p}_2, ...)$ given anticipated prices $(p_1, p_2, ...)$ coincides with these anticipated prices. Equivalently, returning to the underlying search formulation, equilibrium occurs when (i) consumers choose their order of search optimally given the prices they anticipate sellers choose, and (ii) each seller chooses its price to maximize its profit given the consumer search order and the prices chosen by rival sellers, and this price coincides with the price anticipated by consumers.

From (5), a seller competes against its rivals (and the outside option) on two margins. If a consumer's preferences satisfy $r_i - p_i > v_i - \tilde{p}_i$, it is the size of the latter term

[10] The reservation price of this box is the x which satisfies $\mathbb{E}_i \max\{v_i - p_i - x, 0\} = s_i$, so that $x + p_i = r_i$.

which determines whether or not this consumer will buy from the seller, and the seller can affect this likelihood via its choice of price $\tilde{p}_i$. Otherwise, though, it is the former term which determines its demand, and this portion of demand is inelastic. If search costs become negligible, this oligopoly model converges to an oligopoly model where consumers have complete information about match utilities $(v_1, v_2, ...)$ and actual prices $(\tilde{p}_1, \tilde{p}_2, ...)$. Intuitively, the first term $r_i - p_i$ in (5) is rarely relevant when the search cost for seller i is small, and this seller sells when $v_i - \tilde{p}_i$ is positive and higher than the corresponding surplus from rivals.

To illustrate, consider an example with two sellers and costless production. Each consumer has match utility v_i for product $i = 1, 2$ which is uniformly distributed on the interval $[0, 1]$ and has reservation price r_i for this product which is also independently and uniformly distributed on $[0, 1]$. (From (1), the search cost corresponding to r_i is given by $s_i = \frac{1}{2}(1 - r_i)^2$ and so lies in the interval $[0, \frac{1}{2}]$.) Then w_i in (4) is the minimum of two independent uniform variables, and so has support $[0, 1]$ and density $2(1 - w_i)$. Among those situations where both sellers are active, this example has a unique equilibrium and in this equilibrium each seller chooses price $p \approx 0.49$.[11] (Details for this example are presented in Appendix B below.) As in Figure 1, if a consumer searches at all she will first inspect the seller for which she has the higher r_i. Each consumer searches in a deterministic order, but that order differs across consumers.

If this example is modified so that all search costs are zero—in which case $r_i \equiv 1$ and w_i in (5) is uniformly distributed on $[0, 1]$—the symmetric equilibrium price is $p = \sqrt{2} - 1 \approx 0.41$, which is below the corresponding price with search frictions. It is intuitive that more significant search frictions will tend to increase equilibrium prices. Consider a particular seller in the market. If the inspection costs for this seller rise, it will tend to encounter fewer but more "desperate" consumers who have not found a good option from other sellers, and this will typically give it the opportunity to raise its price. Likewise, if the inspection costs for its rivals increase, this reduces the distribution for r_j, and hence w_j, from rivals and again this tends to give the seller an incentive to raise its price. In sum, if inspection costs rise, either for a single seller or across the market, this is likely to

[11] As usual, there are also less interesting equilibria in which consumers anticipate that seller i chooses such a high price that it is not worthwhile to inspect this seller, and then this seller has no way to attract consumers to it and might as well set this very high price. In this example, for instance, there is also an equilibrium where seller 1 sets price $p_1 = 1$ and no one inspects it, while seller 2 sets the monopoly price $p_2 = \frac{1}{2}$ and a consumer inspects it if $r_2 \geq \frac{1}{2}$ (and then buys if $v_2 \geq \frac{1}{2}$).

raise each seller's equilibrium price.

The "double uniform" example above involves a demand system which is smooth, in the sense that small changes in anticipated prices p_i do not lead to discrete changes in demands. In other situations—which include those commonly studied in the literature—the demand system is not smooth. Specifically, consider the situation in which each consumer considers sellers to be symmetric *ex ante*, so that (in the duopoly case) reservation prices on Figure 1 lie on the 45^o line. Here, when one seller is expected to offer a lower price, *all* consumers who search will choose to inspect it first. There is a strong possibility of multiple equilibria in such a market: the consumer search order depends sensitively on anticipated prices, while a seller's price usually depends on where it is placed in the search order.

To discuss this point in more detail, suppose each consumer has the same CDF $F(v)$ for match utility and the same inspection cost s from each seller, and hence has the same reservation price r for each seller's product. Suppose also that each seller has the same production cost c. This is the framework analyzed in the influential models of Wolinsky (1986) and Anderson and Renault (1999), under the assumption that consumers search randomly through sellers. In contrast to these earlier papers, suppose instead that all consumers search through sellers in the same order.[12] If the hazard rate for match utility, $f(v)/(1-F(v))$, is strictly increasing in v, then more prominent sellers (i.e., sellers closer to the start of this search order) have more elastic demand than those sellers placed further back. For this reason, more prominent sellers typically set lower prices, which in turn rationalizes the assumed consumer search order. Intuitively, a seller inspected earlier in a consumer's search order knows that a prospective consumer is likely to have a superior outside option relative to the situation where a seller is inspected later—a later seller only encounters a consumer if that consumer was disappointed by her options so far—and with an increasing hazard rate, a seller who knows a consumer has a better outside option will choose to set a lower price. A more detailed argument for why a prominent seller faces more elastic demand is presented in Appendix C below.

To see how ordered search can be an equilibrium in a symmetric environment, suppose there are two symmetric sellers and look for an equilibrium where $p_i < p_j$ so that seller i is inspected first by all consumers. Here, the pattern of demand for the two sellers is shown

[12] The following discussion is based on the analysis (for the uniform distribution) in Armstrong, Vickers, and Zhou (2009) and Zhou (2011).

in Figure 2.[13] Appendix D below calculates equilibrium prices for various search costs when production is costless and match utility is uniformly distributed, and shows how the prominent firm indeed chooses a lower price in equilibrium (see Figure 4 in the appendix). Thus there are two equilibria with ordered search, one where all consumers inspect seller 1 first and one where they inspect seller 2 first. There is also a third, symmetric, equilibrium, where exactly half the consumers first inspect each seller and where the two sellers set the same price. However, this symmetric equilibrium—which is the focus of the analysis in Wolinsky (1986) and Anderson and Renault (1999)—is *unstable*: if slightly more consumers first inspect one seller, that seller chooses to set a lower price than its rival, so that all consumers will strictly prefer to visit that seller first. Thus, this is a classic "tipping" market, and we expect one low-price seller will be inspected first by all consumers even though sellers are symmetric *ex ante*.[14]

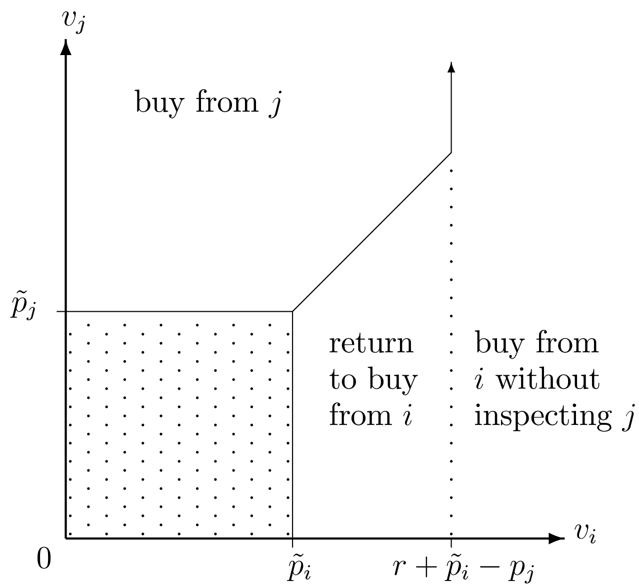

Figure 2: Demand for the two sellers when $p_i < p_j$

Consumers may well be worse off in an equilibrium with ordered search where they all inspect one seller first compared to the equilibrium with random search.[15] Intuitively,

[13]This pattern is generated by observing that a consumer buys from seller i if $\min\{r - p_i, v_i - \tilde{p}_i\}$ is positive and greater than $\min\{r - p_j, v_j - \tilde{p}_j\}$.

[14]In situations where the hazard rate is decreasing, a seller which is first inspected by more consumers sets a higher price than its rival, and the unique and stable equilibrium has the two sellers setting the same price and half the consumers first inspect each seller. (In the knife-edge case of an exponential distribution for match utility, where the hazard rate is constant, a seller's price does not depend on where it is in the search order, and no network effects are present.)

[15]Armstrong, Vickers, and Zhou (2009) and Zhou (2011) show this to be so in the case with a uniform distribution for match utilities. Zhou shows in this example that *all* prices can be higher with ordered

faced with the increasing price path which goes with ordered search, consumers cease their search too early and competition between sellers is weakened. In this market with ordered search, the seller which inspected first has larger demand for two reasons: even with equal prices its demand would be larger because it is inspected first (its extra demand the "north-east" region on Figure 2), while its lower price reinforces this effect. The result is that the distribution of sales across sellers is more skewed than it would be in a market with random search or in a market without search frictions. In the example analyzed in Appendix D, sales are equal for the two sellers when search frictions are absent, but the prominent seller sells up to twice as much as its rival when search costs are larger. As search frictions increase, we expect that the prominent seller's sales volume increases, while the non-prominent seller's sales volume will fall (see Figure 5).

In this market where sellers are symmetric *ex ante*, in the stable equilibrium where all consumers visit one prominent seller first this seller makes greater profit than its rival. (The prominent seller *could* choose the equilibrium price of its rival, in which case it has greater demand and more profit, but in general is even better off with another price.) The impact on profit of an increase in search frictions will often differ for the two sellers.[16] Profit for the prominent seller will rise with s since both its price and its demand do. The impact on the non-prominent seller's profit, though, depends on two opposing forces—its price rises, but its demand is likely to fall—and the result is that its profit can be non-monotonic in the search cost (see Figure 6). When there are no search frictions both sellers choose the same price and obtain the same profit. As s increases both sellers' profits initially rise, but for larger s the non-prominent seller's profit falls as search frictions increase. In this second region, less prominent sellers will favour consumer policy which reduces search frictions, while such a policy would be opposed by more prominent sellers.

The existence of multiple equilibria can make it hard to do comparative statics, such as whether a higher-quality firm (where the match valuation distribution comes from a better CDF) sets a higher price or is inspected first or whether a firm with a higher inspection cost is inspected later. For this reason a smooth demand system, where different consumers prefer to search in different orders, might work better (as well as often being more plausible). However, such a model can be cumbersome to work with beyond specific

search relative to the price with random search, provided there are at least four sellers.

[16] See also the discussion and Figure 2 in Zhou (2011). By contrast, with random search (and no outside option), Anderson and Renault (1999, Proposition 1) show that the symmetric equilibrium profit for each seller increases with the search cost, provided the hazard rate is increasing.

examples or without resorting to numerical methods.

One convenient way to simplify this framework is to study monopolistic competition with *many* symmetric sellers (Wolinsky, 1986), when a stable equilibrium with symmetric prices exists in a broad class of cases.[17] When a consumer expects all sellers to offer the same price $p < r$, a consumer will search until she finds a product with $v \geq r$ and will never return to a previous seller.[18] Thus a seller has no "return demand", which was the source of the incentive for prominent firms to set lower prices, and a seller sets the same price regardless of its place in the search order. The result is that consumers do not care how other consumers choose to search, and there is no tendency to tip. The symmetric equilibrium price, p say, when consumers are also symmetric is derived as follows. Consider a seller who meets a consumer. If it chooses price $\tilde{p}$ the consumer will buy from it if $v - \tilde{p} \geq r - p$, and so the seller's profit from this consumer is $(\tilde{p} - c) \times [1 - F(\tilde{p} + r - p)]$. In equilibrium, this must be maximized at $\tilde{p} = p$, which yields the unique first-order condition

$$p = c + \frac{1 - F(r)}{f(r)} \ . \tag{6}$$

The equilibrium markup and industry profit in this market, $(1 - F(r))/f(r)$, depends on the shape of the CDF $F(v)$ and the magnitude of search frictions. Consumers have an incentive to participate in this market provided that p in (6) is below r. When the hazard rate $f/(1 - F)$ increases, the equilibrium price in (6) decreases with r and hence increases with the search cost s. In such cases, a reduction in search frictions yields a double benefit to consumers: their average match utility is higher and the price they pay is lower. Although this model of monopolistic competition does not necessarily involve ordered search, it is useful starting point for some of the applications and extensions to this basic framework presented in the next section.

[17] Anderson and Renault (1999) show that a symmetric equilibrium with monopolistic competition exists provided that the hazard rate is increasing.

[18] Anderson and Renault (2015) discuss another way to obtain this simplifying feature. They suppose that the distribution for match utilities for a given seller has an atom at zero combined with a continuous distribution with a support well away from zero, and they find equilibria with ordered search where each seller sets price so that any consumer it encounters buys immediately when she has non-zero match utility.

4 Applications and extensions

4.1 Mergers and clusters

There are a number of situations in which consumers incur a single search cost to inspect several products at once. For instance, a single seller might stock several product variants, or several single-product sellers might cluster in a single location. Unless the equilibrium price is significantly higher in a multiproduct location, consumers may then choose to inspect such a location before any of the single-product locations.

To discuss this in more detail, consider a situation with monopolistic competition, where a large number of *ex ante* symmetric sellers each supply a single variant of the product, so that the equilibrium price is given by p in (6). Suppose that two of these sellers merge to form a "big box" seller which supplies two of the product variants. When a consumer inspects this seller, she incurs the same search cost s as with any other seller but sees two options (each with an independent match utility from the CDF $F(v)$ and an associated price), from which she will select the better one if she buys from this seller.[19] In regular cases, the merged firm will choose the same price for each variant, and so this seller can be considered to be another single-product firm but one that has a better CDF for its match utility given by F^2 instead of F. Typically, the merged firm will adjust its price upwards relative to its rivals, which in this monopolistic competition framework continue to set the same price p. To understand this, observe that when the merged firm meets a consumer it will sell when its match utility and price satisfy $v - \tilde{p} \geq r - p$, and so it chooses $\tilde{p}$ to maximize $(\tilde{p}-c)[1-F^2(\tilde{p}+r-p)]$. One can check that its profit is increasing at $\tilde{p} = p$—the demand function $[1 - F^2(\tilde{p})]$ is less elastic than $[1 - F(\tilde{p})]$—and the big box store will set a higher price than its single-product rivals.

Whether a consumer has an incentive to inspect this merged firm first depends on how high its price is. If its price does not rise by too much, a consumer will wish to inspect this multiproduct seller first, in which case the merger is profitable. For instance, in the example where v is uniformly distributed on $[0, 1]$, the search cost is $s = \frac{1}{32}$ and production is costless, then $r = \frac{3}{4}$ and $p = \frac{1}{4}$ in (6). The reservation price for the merged firm's match utility can be calculated to be about 0.817 and its price to be 0.268. Since the difference between these is greater than $r-p = \frac{1}{2}$, it is optimal for consumers to visit the merged firm

[19] Section 4.2 discusses issues of intra-firm search and store layout, which are sidestepped by the assumption that once at the seller the consumer costlessly observes all its options.

first. The better chance of finding a good product in the big store outweighs the higher price the consumer must pay there.[20] More generally, a group of sellers finds it profitable to merge if the merger serves to attract consumers to visit the merged firm first, and this can only be the case if consumer surplus rises as a result of the merger. Thus, in this framework there is a tendency for profitable mergers to benefit consumers, in contrast to the situation in many other oligopoly models.

This discussion is a simplified version of the model studied in Moraga-Gonzalez and Petrikaite (2013). That paper discussed the case of oligopoly rather than monopolistic competition, and showed that a merger which results in search economies can be profitable for the merging firms but reduces the profit of non-merging firms since they are pushed further back in the consumer search order.[21] This contrasts with a more standard analysis of Bertrand price competition, where a merger typically raises the profits of non-merging firms.

Related issues arise when one seller decides to co-locate with another seller. To discuss this point further, suppose that when this occurs a consumer pays the single search cost s to visit the cluster, where she then observes both firms' prices and match utilities. Unlike the case with a merger, here sellers in the cluster do not coordinate their pricing, and a seller aims to attract business from its neighboring rival as well as to prevent a consumer from leaving to inspect other locations. Provided the hazard rate is increasing, intra-cluster competition will typically mean that the price is lower in the cluster than elsewhere. If its rival sets price p' and offers match utility v', then a seller which sets price $\tilde{p}$ and offers v will sell if $v - \tilde{p} \geq \max\{v' - p', r - p\}$. (By contrast, a seller on its own will sell under the weaker condition $v - \tilde{p} \geq r - p$, so that its potential consumers have a worse outside option than those of a seller in the cluster). In the uniform example discussed in the merger scenario, one can check that the equilibrium price in the two-seller location is about 0.232, which is

[20]If *many* single-product sellers merge, however, then a consumer is almost sure to find a product with almost the maximum possible match utility, and so consumers essentially know their match utility from this seller. This implies that Diamond (1971)'s paradox applies, and the seller will set a price which just deters onward search, and this gives the consumer no incentive to incur the search cost to visit this very large store. (See Villas-Boas (2009) for related analysis in a monopoly context.) It may take many products for this effect to operate, however. In the example in the text, if the large store contains 50 product variants it is still worthwhile for the consumer to inspect this seller first, even though its price is nearly double that of single-variant sellers.

[21]One advantage of using a monopolistic competition framework is that the problem of multiple equilibria seems less severe. In oligopoly, when a merger occurs the new equilibrium might involve the merged firm being at the start, or at the rear, of the consumer search order.

below $p = \frac{1}{4}$. Therefore, since consumers obtain a better distribution for their match utility *and* a lower price, they will all choose to visit the cluster first. Because of this new-found prominence, both of the sellers there are better off despite the tougher competition they face in the shared location.

A number of papers have discussed a seller's choice between a concentrated location alongside other sellers, which attracts many consumers but where competition may be fierce, and having a more isolated location which allows the seller to exploit the few consumers who do pass through. These papers discuss the equilibrium configuration of sellers, including when it is an equilibrium for all sellers to locate in a single cluster.[22] The paper closest to my discussion above is Fischer and Harrington (1996), who present a model with differentiated products, one cluster location and many "peripheral" sellers, and consumers who choose their search order based on rational expectations of prices chosen by sellers in the cluster and by peripheral sellers and their own idiosyncractic search costs. They also document empirically which product sectors around Baltimore are more prone to clustering: shoes and antiques, where consumers like to inspect products before buying, tend to co-locate, whereas gasoline stations are more dispersed. Because of the advantages of clustering in terms of attracting consumers, a seller may be willing to sell its product through an electronic platform which also serves rivals, even though it faces strong price competition there and usually has to pay listing fees to the platform.[23]

4.2 Deliberate obscurity

In Fischer and Harrington (1996), firms could choose to locate in the cluster or in the periphery. Some firms choose the latter, in part because some consumers have search costs such that they only wish to inspect firms in the periphery. Another issue of interest is whether it might ever be profitable for a firm deliberately to raise its own inspection cost—that is, to "obfuscate"—in order to make its rival the prominent seller. For instance, in the UK some well-known insurance companies advertise that their products do *not* appear on price-comparison websites.

To discuss this in more detail, suppose the initial situation is that there are two sym-

[22] For instance, see Stahl (1982), Wolinsky (1983), Dudey (1990), Non (2010) and Ellison, Fudenberg, and Mobius (2004). Scitovsky (1950, page 49) writes: "the geographical concentration of the expert's market [...] should not be considered data, as Marshall did. [It is] the result of a deliberate effort on the part of producers [...] in response to the expert buyer's demand for easy comparability".

[23] See Song (2014) for an extension of Fischer and Harrington (1996) along these lines.

metric sellers and are no search frictions (so the market is a duopoly version of Perloff and Salop, 1985). Then consumers will investigate both sellers' offers and buy from the seller with the higher $v_i - p_i$ (if this is positive). In regular cases the equilibrium will be symmetric, and firms obtain equal profit. If one firm now artificially introduces a positive inspection cost, $s > 0$, this will induce all consumers to inspect the rival first (since they have nothing to lose by doing so). The new equilibrium prices will, given an increasing hazard rate, involve the prominent rival choosing the lower price, which reinforces consumer incentives to inspect this firm first. However, this lower price will typically still be higher than the equilibrium price without search frictions, and this could compensate the obfuscating seller for its disadvantaged position. As discussed in section 3, the non-prominent firm has an incentive to raise its price since the consumers it encounters are not satisfied with their offer from the prominent seller, and because prices are strategic complements this induces the prominent firm to raise its own price too. For instance, consider the example depicted on Figure 6 below. When one firm introduces a small inspection cost (i.e., reduces its reservation price r_i), the equilibrium profits are as shown on this figure, and we see that a small inspection cost boosts the obfuscating firm's profit a little (although the rival's profit is boosted more).

Wilson (2010) analyzes this question using a different duopoly model with a homogeneous product. There are two kinds of consumers: those who can see both prices without cost (even with "obfuscation"), and those who must pay the obfuscation costs artificially introduced. In this market with a homogeneous product, without obfuscation there is Bertrand competition and zero profit. Wilson shows that it is always in a firm's interest to obfuscate, with the result that firms choose their prices according to an asymmetric mixed strategy, costly searchers inspect the transparent firm first, and both firms make positive profit. One difference between Wilson's model and the one presented here is that in my model the obfuscating firm sets a higher price, while in Wilson's model that firm (on average) sets a lower price.[24]

The previous example was rather delicate, and a seller had only a small incentive to

[24] Ellison and Wolitzky (2012) also study a model with a homogeneous product but where consumers do not observe a firm's chosen inspection cost in advance, and so a firm cannot use obfuscation to influence search order. They assume that search costs are convex, in the sense that the more time a consumer spends obtaining one seller's offer, the less inclined she is to investigate other sellers. Armstrong and Zhou (2016) study another way to create search frictions artificially, which is when a seller chooses to make it hard for a consumer to return to buy from it after inspecting a rival seller, for instance by offering the consumer a discount if she chooses to buy without further search.

obfuscate. More striking and robust results are seen in the context of a multiproduct monopolist considering how best to price and present its products. For simplicity, consider a situation where the seller has costless production and supplies two symmetric products, 1 and 2, where each consumer's match utility for product i is an independent draw from the CDF $F(v)$. (The argument which follows is strengthened with asymmetric products, since then the seller can use artificial search frictions to divert demand from low-margin to high-margin products.) Suppose that unless the seller deliberately obfuscates, a consumer observes both prices and both match utilities from the start, and chooses the product with the higher surplus $v_i - p_i$ (if this is positive). In regular cases, the seller will then choose the same price for both products, which is chosen to maximize $p[1 - F^2(p)]$.

However, the seller can always do better than this by making one product, say product 2, costly to inspect, while leaving product 1 costless to inspect (which is therefore inspected first by all consumers). Indeed, we will see that the seller can then obtain as profit the maximum value of

$$p_1[1 - F(p_1)] + F(p_1)p_2[1 - F(p_2)] \ . \tag{7}$$

Here, (7) represents the profit obtained if the seller could first offer product 1 to the consumer, at price p_1, and the consumer chooses whether or not to buy this product myopically, without considering the subsequent option to buy product 2. Since the profit in (7) coincides with the "frictionless" profit $p[1 - F^2(p)]$ with uniform prices $p_1 = p_2 = p$, it is clear that the maximum profit in (7) is above the maximum profit without obfuscation.

Maximizing (7) involves choosing $p_2 = p^M$, where p^M is the monopoly price for a single product, i.e., which maximizes $p[1 - F(p)]$. Suppose the seller makes the consumer incur the search cost s for the second product so that a consumer just willing to inspect this product when priced at p^M if she has no other option, so that s satisfies

$$s = \mathbb{E} \max\{v - p^M, 0\} \ . \tag{8}$$

Suppose also that the seller chooses its prominent price p_1 to maximize (7) given $p_2 = p^M$, which implies $p_1 > p^M = p_2$. Although consumers cannot observe p_2 in advance, it is an equilibrium for consumers to anticipate the price $p_2 = p^M$ and for the seller to maximize its profit by choosing this price. (If consumers anticipate $p_2 = p^M$, and have to incur the search cost s in (8) to find the corresponding match utility, Pandora's rule states they will only choose to inspect this product if their match utility from the first product, v_1, is below the first price, p_1. Therefore, no consumer will ever return to buy the first product if they inspect the second, and so the seller chooses p_2 maximize its profit as if it only sold this single product.)

In sum, it is a credible strategy for the seller to choose the two prices p_1 and p_2 which maximize (7) and to introduce the artificial inspection cost s defined in (8) for product 2, and this strategy generates higher profit than the situation without search frictions. This policy involves an expensive product being prominently displayed, perhaps at eye level, while a cheaper product is deliberately displayed inconveniently and the consumer has to look "high and low" for a good deal. Somewhat akin to the model in Deneckere and McAfee (1996), where a seller deliberately reduces the quality of one product variant in order to facilitate price discrimination, here the seller chooses to "damage" its retail environment. In regular cases, the prominent product's price p_1 will rise while the obscure product's price p_2 falls, relative to the situation without search frictions.[25] In such cases, consumers are harmed by the obfuscation policy: the search cost (8) eliminates all consumer surplus from product 2, while the price for product 1 is increased.

I presented here a simple variant of the model in Petrikaite (2015), who analyzes cases with more products, with asymmetric products, and with competition between multiproduct sellers. For instance, she shows that when products differ in quality, the seller will choose to obfuscate the lower quality product. Gamp (2016) studies a related model where all prices are observed by consumers from the start, and the seller can choose to make it harder to inspect a product's match utility. Among other results, he shows by example that obfuscation of this form can increase total welfare: the benefits of the low price for the obscure product outweigh the extra search costs incurred.

4.3 Repeat business

In markets with ordered consumer search, tiny asymmetries between sellers can translate into major differences in their profits. There is a significant advantage to a seller being placed early in the consumer search order, simply because it meets more consumers than its rivals placed further back. Since consumers in near-symmetric situations are near-

[25] Starting from the uniform price which maximizes $p[1-F^2(p)]$, one can check that profit in (7) is locally increasing in p_1 and decreasing in p_2. Note in particular that with coordinated pricing the prominent product is likely to have a higher price than more obscure products, which is the reverse pattern predicted in section 3 when products are supplied by separate sellers. See Zhou (2009) for further discussion of this comparison.

indifferent about which seller to inspect first, it does not take much inducement to favour one seller in the search order, which then causes that seller to enjoy a discrete jump in its sales and profit. For instance, consider the case of monopolistic competition, where the equilibrium price from each seller is (6) regardless of the search order. With random search each seller obtains negligible sales and profit, while if one seller manages to be placed first in the search order—perhaps because it is slightly easier to inspect or it has a slightly superior CDF for match utility—its profit jumps to

$$(p-c)[1-F(r)] = \frac{[1-F(r)]^2}{f(r)} \ . \tag{9}$$

One way to introduce small asymmetries between sellers is to consider a framework where sellers supply various products over time and consumers purchase repeatedly. (This discussion is taken from Armstrong and Zhou, 2011, section 3.) Here, it seems plausible that a consumer who previously purchased from one seller might first inspect the same seller when she searches for a second product, even if there is no correlation in her match utilities for the various products.[26] For instance, she may have the contact details of this seller to hand. In this case, the supplier of one product to a consumer becomes prominent for that consumer when she starts the search process for the next product.

In more detail, suppose there are two product categories, 1 and 2, which consumers buy sequentially—for instance, a bank account first and then a mortgage—each of which is supplied by many sellers in monopolistic competition. For product category $i = 1, 2$, the reservation price is r_i, the CDF for the match utility is $F_i(v)$, the production cost is c_i, while the factor sellers use to discount profits from the second product when they supply the first product is δ. As in expression (9), when a supplier sells product 1 to a consumer, that consumer will go on to generate profit from the second product equal to $[1-F_2(r_2)]^2/f_2(r_2)$, and anticipating this profit the equilibrium price for the first product will be

$$p_1^* = c_1 + \frac{1-F_1(r_1)}{f_1(r_1)} - \delta\frac{[1-F_2(r_2)]^2}{f_2(r_2)} \ .$$

(All sellers set the same price for the second product.) Thus, the promise of profit from the second product induces firms to lower the price for the first product, perhaps to below its cost. When search frictions are larger for the second product, this will usually lead firms

[26] If a consumer's match utilities for a given seller's products were positively correlated, then presumably a consumer has a strict incentive to start her next search at the seller she purchased from previously. Such a model is considerably more complicated to analyze, however.

to offer a lower price for the first product. This outcome is reminiscent of markets with switching costs. When switching costs are small, though, they have little impact on the outcome, while here a tiny "default bias" leads to large effects, and these effects benefit consumers.

Garcia and Shelegia (2015) present a related model, where a consumer is inclined to start her search process at a seller where she has observed someone *else* make a purchase. Again, because making a sale makes the seller prominent in a consumer's mind, albeit a different consumer's mind, sellers have an incentive to price low in equilibrium.

4.4 Non-price advertising

Non-price advertising can be used by sellers to achieve prominence if consumers are more likely to first inspect those sellers which advertise most heavily. This consumer behaviour might stem from psychological factors, if consumers most easily recall sellers from which they have seen adverts. Alternatively, rational consumers could use advertising intensity as a means by which to coordinate on their search order or as a means to choose which seller is more likely to provide a suitable product.

Consider first a situation with rational consumers who use advertising to coordinate on their first seller, anticipating that the price will be lower from the seller which spends the most on advertising. (As discussed in section 3, of the hazard-rate condition holds and sellers are symmetric *ex ante*, when a fraction of consumers use the rule of thumb of first inspecting that seller which advertises the most, that seller will choose a lower price and it is optimal to mimic that search order.) Consider a two-stage framework where two risk-neutral sellers first choose their advertising intensities and then choose their prices. Let π_H be a seller's equilibrium profit (excluding advertising costs) in the second stage if it is prominent and let $\pi_L < \pi_H$ be the corresponding profit for the non-prominent seller. The first stage, in which sellers compete to become prominent by advertising the most, is then a symmetric all-pay auction with complete information.[27] It is clear that no pure strategy equilibrium for advertising can exist, since spending a little more than your rival on advertising generates a discrete jump in profit. However, a simple symmetric mixed strategy equilibrium for advertising exists. If $H(a)$ denotes the equilibrium probability

[27] See Barut and Kovenock (1998) for further analysis of this auction. A very similar model to the one presented here has sellers competing to pay an intermediary for prominent display, where the seller which pays the most obtains the prominent position (which all consumers inspect first) and the loser obtains a more obscure position, and then sellers choose their prices given their position.

that a seller spends less than a on advertising in the first stage, a seller's expected profit when it spends a on advertising is

$$H(a)\pi_H + [1 - H(a)]\pi_L - a \; . \tag{10}$$

(With probability $H(a)$ it wins the contest and enjoys high profit π_H, and otherwise it becomes the less prominent seller.) Since a seller can obtain profit π_L by not advertising at all, in equilibrium profit in (10) must be identically equal to π_L over the range of advertising used, so that $H(a) = \frac{a}{\pi_H - \pi_L}$ for $0 \leq a \leq \pi_H - \pi_L$. Thus in equilibrium each seller chooses its advertising according to the uniform distribution on the interval $[0, \pi_H - \pi_L]$.[28] The seller which advertises more will offer the lower price. Each seller spends $\frac{1}{2}(\pi_H - \pi_L)$ on advertising on average, and since we expect that the benefit of prominence, $\pi_H - \pi_L$, is higher when the search cost s is higher (for instance, see Figure 6), this model suggests that there is more advertising in markets with higher search frictions. Competition to advertise the most acts to dissipate profit so that sellers earn average profit equal to the low level associated with not being prominent, π_L, which as shown on Figure 6 can decrease with the search cost s.

This analysis is similar to Bagwell and Ramey (1994), who analyze a model where sellers offer a homogeneous product and consumers must choose from where to buy before they observe the seller's choice of price. Because sellers in their model have increasing returns to scale, when more consumers turn up to buy from a seller that seller offers a lower price. Thus, consumers benefit from coordinating on a seller, and a fraction of consumers rationally go to the seller which advertises the most heavily as the means with which to do this. By contrast, the model above assumes no economies of scale but instead uses the feature that sellers who attract more first visits have more elastic demand. Bagwell and Ramey (1994) also report empirical studies (for eye-glasses, liquor, and prescription drugs) which show how prices were lower and market structure was more concentrated in markets where advertising was permitted, even when prices could not be advertised.

Haan and Moraga-Gonzalez (2011) analyze a related model, but where a seller's share of first-inspections is continuous in its choice of advertising intensity instead of the "winner take all" formulation discussed here. They focus on a symmetric equilibrium where sellers

[28] Of course, here and elsewhere in this section another equilibrium exists: consumers do not respond to advertising and choose to inspect sellers in random order, in which case sellers are not prepared to invest in advertising. However, this equilibrium is fragile, in the sense that if some fraction of consumers do use advertising to guide their search order, it pays all consumers to do the same.

advertise with the same intensity, obtain the same share of initial searches, and so charge the same price. Their model involves behavioural rather than fully rational consumers: if one seller advertises slightly more heavily than its rival and this induces more consumers to inspect it first, that seller will charge a lower price and hence *all* consumers should rationally visit that seller first.

An alternative scenario involves advertising intensity being associated with the most suitable, rather than the cheapest, products. For instance, consider a stylized setting where prices are not modelled and sellers differ in how many consumers find their products suitable. Specifically, a type-q seller offers a product which each consumer has probability q of finding suitable, in which case the consumer obtains payoff 1, and with remaining probability $1-q$ she obtains payoff zero, while a seller obtains payoff 1 each time its product is sold. Here, sellers differ only in their probability of being suitable, q, which is private information and generated by the continuous CDF $G(q)$ with support $[q_{\min}, q_{\max}]$. Suppose a consumer's search cost s satisfies $0 < s < q_{\min}$, so that this cost is small enough that a consumer always wishes to inspect another seller if she has not yet found a suitable product. To minimize her search costs, a consumer would like to inspect sellers in order of decreasing q if she could identify that order.

One could study this market when, as above, a seller's advertising is simply "broadcast" without mediation and consumers first inspect the seller which advertises the most heavily. However, it is perhaps implausible that consumers can really detect accurately which seller advertises the most heavily, especially when sellers advertise a similar amount. An alternative scenario involves sellers paying to be advertised on a search engine, where the seller who chooses to pay more is listed higher up the sponsored results page (which is a transparent signal for consumers to observe). Provided that better sellers do choose to pay more, it is optimal for consumers to inspect sellers—that is, to click on their links—in the order they appear on the results page.[29] If a consumer clicks on its link a seller will obtain payoff 1 with probability q, and so q is the value of a click to the type-q seller.

In broad terms, sponsored search auctions allocate sellers to prominent positions, require sellers to pay the search engine fee each time a consumer clicks on their link, and use a second-price auction format. In more detail, consider the situation with just two sellers.

[29] Note that in this framework the top link is not intrinsically easier to inspect. It may be more realistic to suppose for psychological reasons that some consumers do find it easiest to work downwards through the links, but this will only reinforce the incentive to pay for prominence.

These sellers are invited to submit sealed bids, the higher bidder is listed first and pays the bid of the losing seller on a per-click basis, while the losing seller pays nothing but is placed second on the page. We look for a symmetric equilibrium in which the type-q seller bids $B(q)$, where $B(\cdot)$ is a strictly increasing function. Such a bidding function can be derived using standard auction techniques. Suppose that the type-q seller bids as if it had type q', i.e., bids $B(q')$, while its rival has uncertain type $\tilde{q}$ and bids $B(\tilde{q})$, in which case the seller is listed first when $\tilde{q} < q'$. When it is listed first, consumers inspect it first and so it sells to a consumer with probability q. If it loses the auction it is placed second, in which case it sells when the rival doesn't sell and when its own product is suitable, i.e., with probability $(1-\tilde{q})q$. Putting this together implies the seller's expected profit when it bids $B(q')$ is

$$\int_{q_{\min}}^{q'} [q - B(\tilde{q})]dG(\tilde{q}) + \int_{q'}^{q_{\max}} [(1-\tilde{q})q]dG(\tilde{q}) \ ,$$

and differentiating this expression with respect to q' and setting $q' = q$ reveals that the equilibrium bid function is

$$B(q) = q^2 \ . \tag{11}$$

Here, q^2 is the incremental profit for a type-q seller from being in the first versus the second position when its rival also has type q. Since the bidding function (11) is increasing, the more suitable seller is willing to pay more for the right to be listed first, with the result that consumers rationally sift through their options in the order they appear on the search engine's results page. In this setting, the observation that consumers click more often on results placed higher up the sponsored results page is driven by the information content of the ordering, rather than "inert" consumers who blindly follow the suggested order.

This discussion of advertising on a search engine is a simple variant of Athey and Ellison (2011).[30] As they put it (page 1215): "a search engine that presents sponsored links should be thought of as an information intermediary that contributes to welfare by providing information (in the form of an ordered list) that allows consumers to search more efficiently". Instead of the sealed bid format discussed here, they study an ascending bid auction in which bidders observe how many bidders remain in the auction when they decide when to drop out of the bidding. They allow for an arbitrary number of sellers, and consumers have heterogeneous search costs. Unlike the model presented above, this means that consumers face a complex decision about whether to click on one more link if they

[30] See also Chen and He (2011) for a related model.

have not been successful so far in their search. They also analyze auction design issues such as the choice of a reserve price.

Armstrong, Vickers and Zhou (2009, section 3) present a model of monopolistic competition, with endogenous prices, when sellers differ in the quality of the product they supply (in the sense that their distributions for match utilities are ordered in terms of first-order stochastic dominance). In a specific setting with uniform distributions for match utility, we show that the highest-quality seller is willing to pay the most to become prominent, and that consumers have an incentive to inspect this seller first (even though it chooses a higher price than other sellers). As with sponsored search, a seller's ability to compete for a prominent position can guide consumers towards better, and better value, products.

The models presented in this section provide the "best case" for non-price advertising to be used to guide search: the seller which is willing to pay the most to achieve prominence is the seller which consumers would like to inspect first. In other situations, this coincidence of interests need not hold perfectly or at all, and advertising is then a less reliable guide for consumers. For example, in the model of sponsored search, sellers might differ both in their likelihood of being suitable and in their expected profit from a click. In such a setting, the seller which is willing to bid the most per-click is not always the seller which the most consumers will find suitable. Because of this, search engines usually use measures of "relevance" as well as willingness-to-pay per click when they determine the order of sponsored links.[31]

4.5 Price advertising

The final extension to the basic model has consumers able to observe all prices from the start, and then choosing the order with which to inspect sellers to discover the corresponding match utility.[32] Unlike the model in section 3 where prices were hidden until inspection, when prices are advertised they can be used to influence a consumer's search order. In addition, because prices are known in advance, the network effects discussed in section 3

[31] See Athey and Ellison (2011, section VI) for further discussion. See also Gomes (2014) for a model in which an intermediary selects one seller from a pool of heterogeneous sellers to display to consumers. The revenue-maximizing mechanism for the intermediary, when it can only obtain revenue from sellers, is a "scoring auction" which balances a seller's willingness-to-pay for display with the consumer's valuation for clicking on the seller's link.

[32] We continue to assume that consumers cannot purchase from a seller without incurring the search cost. Even in cases where it is possible to buy without incurring the search cost and without observing the realized match utility, it will be optimal to inspect products before purchase if the search cost is small enough.

do not arise. In the model in section 3 a seller which is prominent often chooses to set a lower price, while in the current scenario with price advertising this causality is reversed and a seller can become prominent by virtue of advertising a lower price.

Consider first the monopolistic competition framework above, where the equilibrium price in the absence of price advertising was given in (6). When firms advertise their price, the only equilibrium involves all sellers choosing price equal to marginal cost.[33] Setting price equal to cost is an equilibrium because when all its rivals do so, a seller cannot do better with a higher price since no consumers will ever inspect it. However, if all firms advertised price $p > c$, then a seller could boost its profit by advertising a slightly lower price which attracts all consumers to inspect it first. Thus, even though there may be significant search frictions and horizontal product differentiation, using prices to become prominent in the consumer search order drives price down to cost.

This framework is more complicated in oligopoly, since sellers have some market power and price equal to cost cannot be an equilibrium. (For instance, with a finite number of rivals, there is a chance that a seller has the only product a consumer wants.) If consumers view sellers as symmetric *ex ante*, they will choose to first inspect the firm with the lowest advertised price and slightly undercutting a rival's price causes a discrete jump in profit.[34] In such situations, prices will be chosen according to mixed strategies in equilibrium. This is a difficult model to work with, however. Unlike more familiar models of random pricing, such as Varian (1980), here the prices offered by higher-price sellers continue to affect the demand of the "winning" seller, since some consumers will buy from more expensive sellers if their products have a better match. This combination of product differentiation and mixed strategies is usually hard to solve explicitly.[35]

The framework is made more tractable, as well as often more plausible, if consumer demand is smoothed by supposing that consumers differ *ex ante* in which seller they wish

[33] If sellers can *choose* whether or not to advertise their price (and can advertise costlessly), the following discussion remains valid if consumers anticipate that a seller which does not reveal its price in advance has in fact set a high price.

[34] Baye, Gatti, Kattuman, and Morgan (2009) document empirically that a seller on a price-comparison website has demand which jumps substantially when it reduces its price to become the lowest-price seller on the website.

[35] Armstrong and Zhou (2011, section 2) analyzes one version which can be solved, where a consumer's match utility from one seller is negatively correlated with her value for the rival's product. This implies that a consumer knows precisely her payoff at the second seller once she inspects the first, and so there is no "return" demand, and as usual this simplifies the demand functions.

to inspect first, given a set of advertised prices.[36] As discussed earlier, this sequential search problem can be reformulated as a discrete choice problem without search frictions. Given advertised prices $(p_1, ..., p_n)$, expression (5) implies that a consumer chooses to buy from the seller with the highest value of $\min\{r_i - p_i, v_i - p_i\} = w_i - p_i$, provided this is positive, where w_i is defined in (4). This demand system in the case of duopoly is depicted in Figure 3. The demand for each seller's product in terms of prices can then be calculated given the distribution for $(w_1, ..., w_n)$ in the consumer population.

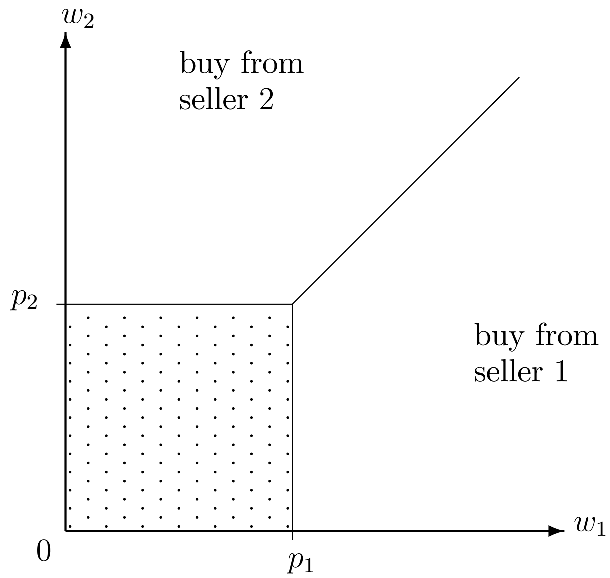

Figure 3: The choice of seller with advertised prices

Equilibrium prices in this market with advertised prices are likely to be lower than the corresponding market with hidden prices. Intuitively, a seller's demand is more elastic with respect to changes in its price with advertised prices than when its price is only discovered after the consumer pays the search cost. This can be seen formally from expression (5), where a seller's loss of demand when it increases its price $\tilde{p}_i$ is smaller than if both p_i and $\tilde{p}_i$ were increased simultaneously (as is the case with advertised prices). In addition, since the advantage of being prominent increases with search frictions, with advertised prices it is plausible that an increase in search frictions intensifies competition to be prominent, with the result that equilibrium prices fall. Again, this can be understood using the discrete

[36] Choi, Dai, and Kim (2016), Haan, Moraga-Gonzalez, and Petrikaite (2015) and Shen (2014) study models of price advertising in situations of this form. In each paper, the authors suppose that a consumer's match utility is the sum of two independent components, and the consumer knows one component from the start which gives rise to *ex ante* brand preferences. Choi, Dai, and Kim (2016) also use a discrete choice re-formulation of the search model to obtain their results.

choice perspective, where an increase in search costs reduces a consumer's list of reservation prices r_i and hence causes her adjusted valuations w_i to fall stochastically. It is natural that, in many cases, a fall in the distribution for valuations in an oligopoly discrete choice model will lead to lower equilibrium prices.

To illustrate these observations, consider the "double uniform" example from section 3, where variation in r_i stems from heterogeneous inspection costs s_i rather than from heterogeneous distributions for match utility F_i.[37] Using Figure 3 one can calculate the symmetric equilibrium price which in this example is about 0.31. In the same example with hidden prices, we saw that the symmetric equilibrium price was about 0.49 which, as expected, is above the equilibrium advertised price. If the example is modified so that search costs are identically zero, in which case w_i is uniformly distributed on $[0, 1]$, the equilibrium price (with or without price advertising) would be $\sqrt{2} - 1 \approx 0.41$, which is higher than in the situation with search frictions and advertised prices.[38]

5 Searching questions

This article has discussed a range of situations in which consumers plausibly search in a deliberate order. We saw how sellers which were first in line often had an incentive to set lower prices than those further back, and this gave a consumer an incentive to mimic the search order followed by other consumers. Likewise, consumers wish to click first on the advertiser which supplies the most relevant product, and advertisers with the most relevant products had the greatest incentive to pay for a prominent position. These kinds of self-fulfilling prophecies made ordered search a stable equilibrium.[39] Because the seller which is inspected first typically makes greater profit than its rivals, sellers have an incentive to move to the front of the queue for consumers. Ways they might have to do this include

[37] This contrasts with the models in Choi, Dai, and Kim (2016), Haan, Moraga-Gonzalez, and Petrikaite (2015) and Shen (2014), where variation in a consumer's r_i stems from their different distributions for match utility.

[38] Although the price is lower when search frictions are present, the price reduction in this example is not sufficient to outweigh the direct harm to consumers caused by costly search, and consumer surplus is higher when there are no search costs despite the higher price.

[39] Similar effects can arise in the labour market. Mailath, Samuelson, and Shaked (2000) present a model in which employers search for workers, and *ex ante* identical workers decide whether to invest in skills before they enter the labour market. Workers are exogenously labelled with one of two colours, which for a given skill level have no effect on their productivity, and colour is observed by employers before search. In this framework asymmetric equilibria exist in which employers concentrate their search efforts on workers of one colour, while workers of the other colour are less likely to invest in skills.

merging or co-locating alongside other sellers, advertising intensively, advertising the lowest price, or selling other products to the pool of consumers in the past.

There are two broad themes in this paper. One is more methodological, which is to show how the complex scenario with optimal sequential search can be reformulated as a simple discrete choice problem without search frictions. An implication of this is that oligopoly search models often "work better" when the demand system is smoothed by giving consumers heterogeneous preferences over which seller to first inspect. (This can be done by making consumers heterogeneous in their brand preferences or, perhaps more simply, making them heterogeneous with respect to their seller-specific search costs.) When each consumer views sellers as symmetric *ex ante*, small changes in anticipated or advertised prices lead to a discrete jump in a seller's demand. When prices are hidden, this often gives rise to the multiple equilibria discussed above, while when prices are advertised this feature leads to the use of mixed pricing strategies.

A second theme is how changes in search costs affect outcomes. A quite robust result was that a multiproduct seller had an incentive to "damage" its retail environment: instead of permitting consumers to see product characteristics transparently, it was more profitable to deliberately make it costly to inspect some products. When separate sellers each supply a single product and prices are hidden, a rise in one seller's inspection cost typically cause that seller and its rivals to raise prices. A higher inspection cost means that many of the consumers the seller encounters are unsatisfied with other options and so the seller can afford to set a high price, while a rival also usually has an incentive to raise its price since it knows consumers have less desirable alternative options. Thus, we expect there will be positive own- and cross-cost passthrough of inspection costs, as well as the more familiar positive passthrough of production costs. Because of this, a seller may have an incentive to raise its own inspection cost artificially as a way to relax competition. Although an industry-wide increase in search frictions will typically raise equilibrium prices when those prices are hidden, the opposite is likely to be the case when prices are advertised: higher search costs make a consumer more likely to buy at the first seller they inspect, and this intensifies competition to become the seller it is most attractive to investigate first.

Several interesting questions for further study remain. One of these is the issue of product design, where a seller has some freedom to choose the distribution for its match utility (as well as its price). By incurring a cost a seller might be able to shift this distribution upwards, so that it offers a higher-quality product. Alternatively, a seller might be able to choose between a "niche" or a "mass market" design, where the former is associated with a riskier distribution for match utility. Bar-Isaac, Caruana, and Cunat (2012) discuss this issue in the context of monopolistic competition and random consumer search, focussing on the impact of lower search costs on the choice of product design. It would be interesting to investigate this in the context of ordered search. Does a prominent seller have different incentives to choose its design from those sellers further back? While Pandora's rule suggests that consumers would like to inspect niche (i.e., riskier) products first, it is less clear that a prominent seller has an incentive to offer a niche product design.

It would interesting to study how knowledge of which product is the current "bestseller" can be used to guide optimal search. As with the classical herding models of Banerjee (1992) and Bikhchandani, Hirshleifer, and Welch (1992), suppose that consumers buy in sequence. Unlike these herding models, though, consumers have no private signal about which product is better, but merely observe which product has sold the most to date. Here, it seems plausible that, given that previous consumers have started their search process with the then-current bestseller, a consumer should optimally start her search with the current bestseller.[40] In this scenario, it seems possible that the first consumer buys an inferior product and all subsequent consumers follow suit, with the result that an inferior popular product becomes the best-seller in the long run. This would not be possible in an alternative situation where all consumers searched randomly.

The discussion of optimal pricing and store layout in section 4.2 introduces what seems to be a rich seam for further investigation, namely, how a multiproduct retailer should choose its prices and its retail environment to maximize profit. Related issues arise also in a number of public policy discussions, and this framework might be a fruitful way to add to those discussions. For instance, is the optimal way to discourage consumption of unhealthy products to tax them, to place them away from eye level, or to use a mixture of both policies? In addition, it would be interesting to investigate the *optimal* way to sell within some natural class of contracts and layout plans. If feasible, for instance, the multiproduct seller in section 4.2 could *charge* the consumer the cost s in (8) to inspect the product rather than make the consumer pay this cost as a search friction from which it obtains no direct gain.

[40] See Sorensen (2007) and Cabral and Natividad (2014) for evidence that becoming a best-seller boosts subsequent demand.

This paper focussed on situations in which consumers could freely choose their order of search. In other environments the search order is exogenously imposed. A driver on a motorway looking for fuel encounters service stations in order, and consumers have to decide now whether to buy the current model of phone or wait to see if a better or cheaper model is released next year. When consumers differ in their search costs, a likely outcome is that equilibrium prices *fall* as consumers move through the exogenous search order, in contrast to the situations discussed in section 3. Consumers with high search costs stop searching early, leaving later sellers to face consumers who are more inclined to shop around. For instance, currency exchange in an airport's arrivals hall might be more expensive than outside the airport, to exploit those travellers reluctant to search for a better deal.[41]

Relatedly, this paper has focussed on situations in which consumers are rational, and optimally choose the order in which they consider options. However, consumers sometimes search through options in the order they are presented, even when there is no obvious information content or differential inspection costs to being placed in certain positions. For instance, random position on the ballot paper can affect vote share in elections. Ho and Imai (2008) estimate that first-listed candidates in primary or non-partisan elections for US state or federal offices gain about two percentage points. They suggest voter behaviour can be modelled as a search problem, where voters work their way down the list of candidates on the ballot until they find one which meets the required quality threshold. Coauthors of an article are often ordered alphabetically and papers in the bibliography are listed in order of first author's name. This may mean that articles with one author early in the alphabet garner more citations and that scholars early in the alphabet are asked to act as referee more frequently.[42] Unlike people, firms can choose their name to affect alphabetic ordering. McDevitt (2014) describes how 21% of Chicago plumbing firms have listed names starting with 'A' or a number, and also that these firms attract a disproportionate number of consumer complaints. He interprets this as being consistent with a market with expert and uninformed consumers, where the latter are assumed to search for a supplier in alphabetic order (even though this is not the optimal way to search given that low-quality plumbers apparently are listed first).

While writing this paper, my own search for useful articles was far from random. I was guided by keyword searches combined with citation counts from search engines and by the

[41] For further discussion see Arbatskaya (2007) and Armstrong, Vickers and Zhou (2009, section 4).
[42] See Huang (2015) and Richardson (2008), respectively.

bibliographies in papers I had read previously, I investigated authors who worked in the wider area and whose work I already admired, I inspected journals I expected to contain good papers, I solicited recommended readings from colleagues, and was biased towards sources which were more easily inspected (journal articles and working papers rather than book chapters, say, or "economics" rather than "marketing" papers). Doubtless I have missed interesting and relevant work. One disadvantage of ordered search, relative to the ancient process of browsing more randomly through library shelves, is that serendipitous discovery becomes less likely.[43]

Technical Appendix

A. Proof of the optimality of Pandora's rule:

For a given search procedure, let $\mathbb{A}_i$ be the indicator function for the consumer selecting box i (so $\mathbb{A}_i = 1$ if the consumer selects this box and otherwise $\mathbb{A}_i = 0$), and let $\mathbb{I}_i$ be the indicator function for inspecting box i. Since the consumer can only select a single box, we have $\Sigma_i \mathbb{A}_i \leq 1$, and since she must inspect a box if she selects it we have $\mathbb{A}_i \leq \mathbb{I}_i$. The consumer's expected payoff from using the search procedure is

$$\begin{aligned}
\mathbb{E}\left(\Sigma_i \mathbb{A}_i v_i - \Sigma_i \mathbb{I}_i s_i\right) &= \mathbb{E}\left(\Sigma_i \mathbb{A}_i v_i - \Sigma_i \mathbb{I}_i \max\{v_i - r_i, 0\}\right) \\
&\leq \mathbb{E}\left(\Sigma_i \mathbb{A}_i [v_i - \max\{v_i - r_i, 0\}]\right) \\
&= \mathbb{E}\left(\Sigma_i \mathbb{A}_i w_i\right) \\
&\leq \mathbb{E}\left(\max\{w_i\}\right) \ .
\end{aligned}$$

Here, the first equality holds using the definition of r_i together with the fact that $\mathbb{I}_i$ and v_i are independent variables, while the first inequality holds since $\mathbb{A}_i \leq \mathbb{I}_i$. However, the search procedure determined by Pandora's rule has equality in these two inequalities. For the first, note that if the consumer inspects but does not select box i, i.e., if $\mathbb{A}_i < \mathbb{I}_i$, then it must be that $v_i \leq r_i$, and for the second we have already shown that the procedure selects the box with the highest w_i. We deduce that Pandora's rule generates the highest expected payoff for the consumer.

B. Duopoly example where r and v are each uniformly distributed on [0,1]:

Without loss of generality, look for an equilibrium in which equilibrium prices are $p_1 \leq p_2$ and let $\tilde{p}_i$ denote seller $i = 1, 2$'s actual price. In the region $0 \leq \tilde{p}_1 \leq p_1 \leq p_2 \leq 1$,

[43] See Foster and Ford (2003) for further discussion.

one can calculate that seller 1's demand as a function of $\tilde{p}_1$, which from (5) is the fraction of consumers for whom

$$\min\{r_1 - p_1, v_1 - \tilde{p}_1\} \geq \max\{\min\{r_2 - p_2, v_2 - p_2\}, 0\} \ ,$$

is

$$(1-p_1)(1-\tilde{p}_1)(1-(1-p_2)^2) + \int_{p_2}^{1} (2(1-w)(1-p_1-w+p_2)(1-\tilde{p}_1-w+p_2))dw$$

$$= \tfrac{4}{3}p_2 - \tfrac{2}{3}p_1 - \tfrac{2}{3}\tilde{p}_1 + \tilde{p}_1 p_2^2 - \tfrac{1}{3}\tilde{p}_1 p_2^3 + p_1 p_2^2 - \tfrac{1}{3}p_1 p_2^3 - p_2^2 + \tfrac{1}{6}p_2^4 + \tilde{p}_1 p_1 - \tilde{p}_1 p_2 - p_1 p_2 + \tfrac{1}{2} \ ,$$

which is linear in $\tilde{p}_1$. Since seller 1 chooses $\tilde{p}_1$ to maximize $\tilde{p}_1$ times this demand, and this optimal $\tilde{p}_1$ must equal p_1, we obtain the first-order condition for p_1 given p_2 given by

$$2p_1^2 - p_1 p_2^3 + 3p_1 p_2^2 - 3p_1 p_2 - 2p_1 + \tfrac{1}{6}p_2^4 - p_2^2 + \tfrac{4}{3}p_2 + \tfrac{1}{2} = 0 \ . \tag{12}$$

Similarly, in the region $0 \leq p_1 \leq p_2 \leq \tilde{p}_2 \leq 1$, one can calculate that seller 2's demand is

$$(1-p_2)(1-\tilde{p}_2)(1-(1-p_1)^2) + \int_{p_1}^{1-\tilde{p}_2+p_1} (2(1-w)(1-p_2-w+p_1)(1-\tilde{p}_2-w+p_1))dw \ ,$$

and so the first-order condition for p_2 given p_1 is

$$3p_1^2 p_2 - 2p_1^2 p_2^2 - p_1^2 + \tfrac{5}{3}p_1 p_2^3 - 3p_1 p_2 + \tfrac{4}{3}p_1 - \tfrac{1}{2}p_2^4 + 2p_2^2 - 2p_2 + \tfrac{1}{2} = 0 \ . \tag{13}$$

A candidate equilibrium consists of a solution to the pair of equations (12)–(13).

A symmetric equilibrium, where $p_1 = p_2 = p$ say, must satisfy the equation

$$(1-p)\left(3 - p - 13p^2 + 5p^3\right) = 0 \ ,$$

which has a unique root in the interval $(0, 1)$ equal approximately to $p \approx 0.49$. One can check that when $p_1 = p_2$ is equal to this root, it is indeed the optimal strategy for seller 1 to make the same choice $\tilde{p}_1 = p$, and so this constitutes an equilibrium.[44] One can manipulate (12)–(13) to obtain p_1 as an explicit function of p_2, and then substitute this p_1 back into one of (12)–(13). Doing so reveals there exists no asymmetric equilibrium with $0 < p_1 < p_2 < 1$.

[44] This procedure only allows for seller 1 to choose a lower price $\tilde{p}_1 < p$, but one can also check that an upward deviation in its price also reduces its profit.

C. Details of argument that more prominent sellers face more elastic demand:

Suppose all consumers search through the sellers in the same order. Suppose hypothetically that all sellers are expected to charge the same price p (where $p < r$ so that consumers search at all), and consider a seller's elasticity of demand with respect to a small change in its own price. By Pandora's rule, when consumers expect the same price $p < r$ from all sellers they will buy from the first seller which offers payoff $v - \tilde{p}$ above $r - p$ (where $\tilde{p}$ is a seller's actual price), and if no payoff meets this threshold they will buy from the seller with the highest payoff provided this is positive. Using the terminology in Armstrong, Vickers, and Zhou (2009), demand from consumers who buy immediately (i.e., if $v - \tilde{p} \geq r - p$) is a seller's "fresh demand", while demand from those consumers who buy from the seller only after exhausting all options is its "return demand".[45] The seller which is m^{th} in the search order has fresh demand in terms of its actual price $\tilde{p}$ equal to

$$q_F(\tilde{p}) = F^{m-1}(r)[1 - F(r + \tilde{p} - p)] \ . \tag{14}$$

(This is because a consumer only reaches it if she did not find a match v above r from the previous $m - 1$ sellers, and the consumer will then buy immediately if $v - \tilde{p} \geq r - p$.) If there are n sellers in all, this seller's return demand is

$$q_R(\tilde{p}) = \int_{\tilde{p}}^{r+\tilde{p}-p} F^{n-1}(v + p - \tilde{p})f(v)dv = \int_p^r F^{n-1}(\tilde{v})f(\tilde{v} + \tilde{p} - p)d\tilde{v} \tag{15}$$

where the first equality follows since a firm sells to a return consumer if $v - \tilde{p}$ is below the threshold $r - p$ (for otherwise she would have purchased immediately) and above all the other firms' offers and the outside option of zero, and the second follows after changing variables from v to $\tilde{v} = v + p - \tilde{p}$. Thus, fresh demand is proportional to $1 - F(r + \tilde{p} - p)$, scaled down geometrically as the seller is placed further back in the search order, while return demand does not depend on the the seller's position in the search order. When $f(v)/(1 - F(v))$ increases with v, any seller's fresh demand is more elastic than its return demand (evaluated at price $\tilde{p} = p$). To see this, note that

$$\begin{aligned} -q_R'(p) &= -\int_p^r F^{n-1}(\tilde{v})f'(\tilde{v})d\tilde{v} \leq \int_p^r F^{n-1}(\tilde{v})f(\tilde{v})\frac{f(\tilde{v})}{1 - F(\tilde{v})}d\tilde{v} \\ &\leq \frac{f(r)}{1 - F(r)}\int_p^r F^{n-1}(\tilde{v})f(\tilde{v})d\tilde{v} = -\frac{q_F'(p)}{q_F(p)}q_R(p) \ , \end{aligned}$$

[45] For the final seller in the search order, all of whose demand is "immediate", for consistency divide its demand into that portion with $v - \tilde{p} \geq r - p$ and with $v - \tilde{p} \leq r - p$.

which establishes the claim.[46] Since a more prominent seller (i.e., a seller with smaller m in (14)) has a greater volume of fresh demand relative to its return demand, it follows that this seller's total demand is more elastic than that of its rivals further back.

D. Duopoly example where r is constant and v is uniformly distributed on [0,1]:

Look for an equilibrium in which equilibrium prices satisfy $p_1 < p_2 < r$, so that all consumers inspect seller 1 first and if they do not buy immediately from seller 1 they go on to inspect seller 2. From Figure 2, one can calculate that seller 1's demand as a function of its actual price $\tilde{p}_1$ given the anticipated price p_2 from its rival is

$$\underbrace{\tfrac{1}{2}(r^2 - p_2^2)}_{\text{return demand}} + \underbrace{1 - (r - p_2 + \tilde{p}_1)}_{\text{immediate demand}}$$

which is linear in its price $\tilde{p}_1$. With costless production, seller 1 chooses $\tilde{p}_1$ to maximize $\tilde{p}_1$ times this demand, and this optimal $\tilde{p}_1$ must equal p_1, and so we obtain the first-order condition for p_1 given p_2 given by

$$\tfrac{1}{2}(r^2 - p_2^2) + 1 + p_2 - r = 2p_1 \ . \tag{16}$$

Likewise, seller 2's demand in terms of its actual price $\tilde{p}_2$ and anticipated prices (p_1, p_2) is

$$(1 - \tilde{p}_2)(r + p_1 - p_2) - \tfrac{1}{2}(r - p_2)^2$$

which again is linear in price $\tilde{p}_2$. Since seller 2 chooses $\tilde{p}_2$ to maximize $\tilde{p}_2$ times this demand, and this optimal $\tilde{p}_2$ must equal p_2, the first-order condition for p_2 given p_1 is

$$(1 - 2p_2)(r + p_1 - p_2) = \tfrac{1}{2}(r - p_2)^2 \ . \tag{17}$$

The equilibrium prices can then be explicitly (but messily) solved for each search cost such that $\frac{1}{2} \le r \le 1$ from the pair of conditions (16)-(17), and are depicted in Figure 4. (When $r < \frac{1}{2}$, the search cost is so high that there is no equilibrium where consumers participate in the market.)

[46] Here, the first inequality follows from the assumption that $f/(1-F)$ is increasing, the second inequality also follows from $f/(1-F)$ being increasing and the fact that $\tilde{v} \le r$, while the final equality follows from the definitions of q_F and q_R.

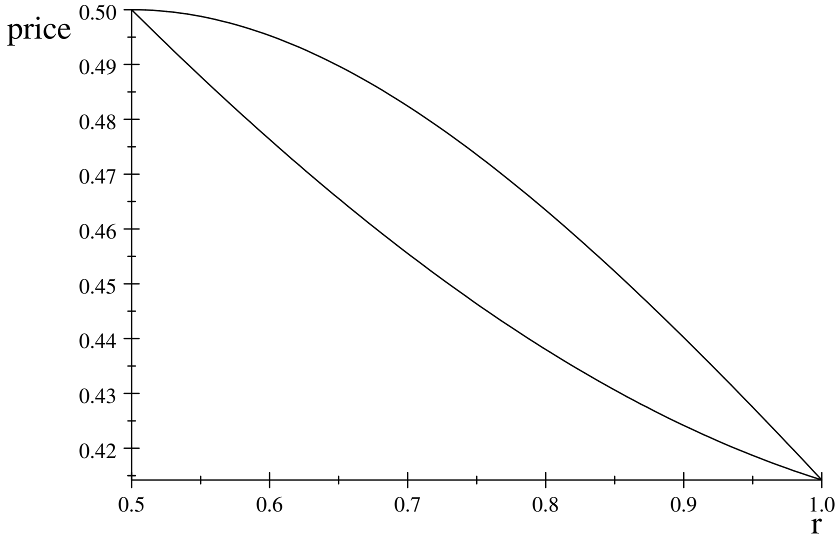

Figure 4: Price of the prominent seller (lower curve) and non-prominent seller

These prices decrease with r, i.e., increase with the search cost s. The prices coincide when there are no search frictions ($r = 1$) or when the search cost is so high that a consumer is just willing to inspect a seller which sets the monopoly price $p^M = \frac{1}{2}$ (when $r = \frac{1}{2}$). Otherwise, though, an equilibrium exists where all consumers first inspect seller 1 and that seller sets a strictly lower price. (Of course, a similar equilibrium also exists where all consumers first inspect seller 2.)

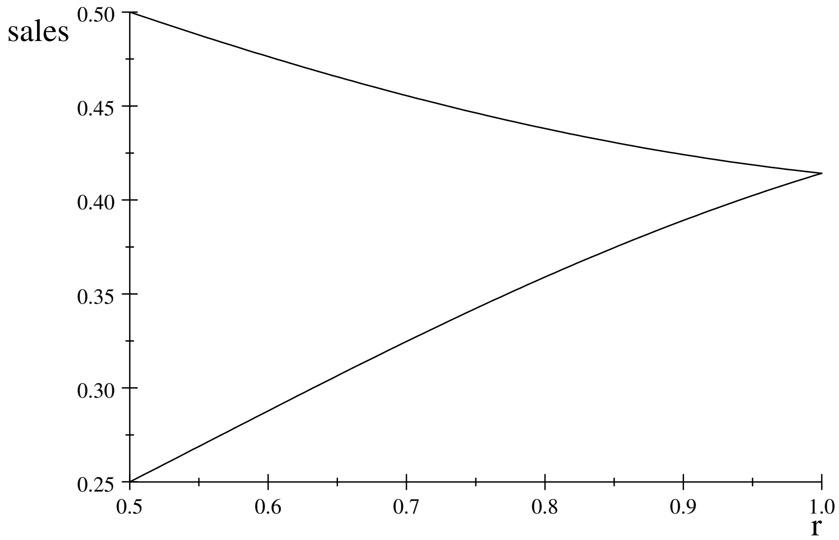

Figure 5: Sales of the prominent seller (higher curve) and non-prominent seller

The equilibrium demand for the two sellers is shown on Figure 5, where the prominent seller has the greater sales. Here, the prominent seller's equilibrium demand increases with s, while the non-prominent sellers sells less when search frictions are greater. The corresponding profits of the two sellers, which are the result of multiplying the curves on Figures 4 and 5, are shown on Figure 6 for the range $0.9 \leq r \leq 1$, where the prominent seller makes greater profit. The prominent seller's profit increases with the search cost s, since both its price and its demand do so, while the non-prominent seller's profit depends non-monotonically on s.

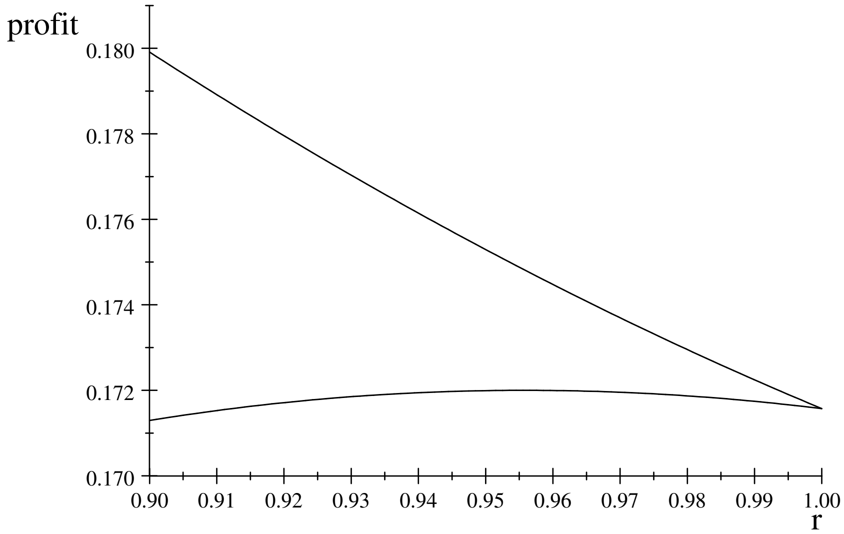

Figure 6: Profits of the prominent seller (higher curve) and non-prominent seller

When does an equilibrium exist in which sellers set the same price, say p, and consumers are indifferent about their order of search? Suppose a fraction σ of consumers first inspect seller 1 when anticipated prices are equal. By considering Figure 2 above, one can check that seller 1's demand when it chooses actual price $\tilde{p}$ is

$$\underbrace{\sigma\left(\tfrac{1}{2}(r^2-p^2)+1-(r-p+\tilde{p})\right)}_{\text{first inspect seller 1}}+\underbrace{(1-\sigma)\left((1-\tilde{p})r-\tfrac{1}{2}(r-p)^2\right)}_{\text{first inspect seller 2}} ,$$

and the first-order condition for this seller to choose $\tilde{p}=p$ is

$$\sigma\left(\tfrac{1}{2}(r^2-p^2)+1-(r+p)\right)+(1-\sigma)\left((1-2p)r-\tfrac{1}{2}(r-p)^2\right)=0 .$$

The corresponding expression for seller 2 to be willing to choose $\tilde{p}=p$ is the same except σ and $1-\sigma$ are permuted. As such, the only situation in which both sellers are willing to choose the same price is when $\sigma=\frac{1}{2}$, in which case the equilibrium price satisfies

$(1+r)p+p^2 = 1$. Thus, if the "tie-breaking" rule is such that more than half the consumers first inspect one seller when anticipated prices are equal, the only equilibria in this market involves ordered search where one seller sets a strictly lower price than its rival.

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