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Ordered search in differentiated markets

Jidong Zhou

Department of Economics, University College London, Gower Street, London WC1E 6BT, UK

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ABSTRACT

This paper presents an ordered search model in which consumers search both for price and product fitness. I construct an equilibrium in which there is price dispersion and prices rise in the order of search. The top firms in consumer search process, though charge lower prices, earn higher profits due to their larger market shares. Compared to random search, ordered search can induce all firms to charge higher prices and harm market efficiency.

1. Introduction

In a variety of circumstances, consumers need to search to find a satisfactory product. However, not as most of the search literature assumes, the order in which consumers search through alternatives is often not random. For example, when facing options presented in a list such as links on a search engine webpage and dishes on a menu, people often consider them from the top down; when shopping in a high street, a bazaar, or a supermarket, consumers' search order is restricted by the spatial locations of sellers or products; when we go to a travel agent to buy airline tickets or a financial advisor to buy a savings product, the advisor may tell us the options one by one in a predetermined order.

This paper intends to investigate how non-random consumer search affects firms' pricing behavior and market performance. I study an ordered search model with horizontally differentiated products where consumers search both for price and product fitness in an exogenously given order. I show that, when there are no systematic quality differences between products and the search cost is homogenous among consumers, there is an equilibrium in which prices *rise* with the rank of products. This is essentially because if a consumer visits firms positioned down in her search order, she must have relatively low valuations for early products, which provides later firms extra monopoly power.

The top firms in consumer search process, though charge lower prices, earn higher profits due to their larger market shares. This supports the fact that firms are willing to pay for top positions. For instance, manufacturers pay supermarkets for access to prominent positions; firms bid for sponsored links on search engines; and sellers pay more for salient advert slots in yellow page directories.

Compared to the case where consumers sample products in a random order, ordered search can induce *all* firms to charge higher prices, and it usually improves industry profit but lowers consumer surplus and total welfare. The reasons that ordered search harms market efficiency are twofold. First, it results in price dispersion in the market, which induces suboptimal consumer search behavior. Second, ordered search reduces total output and so causes an extra production efficiency loss.

Arbatskaya (2007) has studied an ordered search model where firms supply a homogeneous product. Since consumers only care about price, in equilibrium the price should decline with the rank of products, otherwise no rational consumer would have an incentive to sample products in unfavorable positions.[1] In our model with differentiated products, consumers may search on in pursuit of better matched products even if they expect rising prices. Then their search history reveals their preferences, which can significantly change firms' pricing incentive.

The search model with horizontally differentiated products is initiated by Wolinsky (1986) and further developed by Anderson and Renault (1999). Both papers consider random consumer search. More recently, Armstrong, Vickers, and Zhou (2009) (AVZ thereafter) use that framework to model prominence, in which all consumers sample

[1] An earlier paper on ordered consumer search is Perry and Wigderson (1986). There is two-sided asymmetric information in their model: the product is homogenous but each seller has an uncertain cost, and consumers differ in their willingness-to-pay for the product. They also assume no scope for going back to a previous offer. They argue that in equilibrium the observed prices, on average, could be non-monotonic in the order of sellers.

E-mail address: jidong.zhou@ucl.ac.uk.

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one prominent product first and, if it is not satisfactory, they will continue to search randomly among other non-prominent products.[2] AVZ show that the prominent product is cheaper than others and making a product prominent usually improves industry profit but lowers consumer surplus and total welfare. This paper generalizes AVZ by considering a completely ordered search model and obtains similar results. However, unlike the prominence model where the prominent firm always charges a lower price than in the random search case, in the ordered search model with four or more firms, *all* firms may increase their prices.

There are also other differences between the prominence model and the ordered search model. The consumer stopping rule in AVZ is stationary since all non-prominent firms charge the same price, while in this paper given that different firms charge different prices, the consumer stopping rule becomes non-stationary. This causes extra complication in the analysis and calls for new techniques in proving existence of equilibrium and some other results. In addition, the stopping rule in the ordered search model crucially depends on the rank of prices. For example, the stopping rule associated with a rising price sequence is qualitatively different from that associated with a declining price sequence. Hence, we need to deal with the issue of multiple equilibria, which is absent is AVZ. I show that a declining price sequence cannot be sustained in equilibrium.

The remainder of this paper is organized as follows. Section 2 presents the ordered search model, and it is analyzed in Section 3. Section 4 compares ordered search with random search. Section 5 concludes and discusses possible extensions. Technical proofs are included in the Appendix A.

2. A model of ordered search

There are $n\geq 2$ firms indexed by $1,2,\cdots,n$, supplying n horizontally differentiated products. The unit production cost is constant and normalized to zero. There are a large number of consumers with measure of one, and each consumer has a unit demand for one product. Consumers have idiosyncratic valuations of products. Specifically, $(u_1,u_2,\cdots,u_n)$ are the values attached by a consumer to different products, where u_k is assumed to be independently drawn from a common distribution $F(u)$ on $[u_{min},u_{max}]$ which has a positive and differentiable density function $f(u)$; and all match values are also realized independently across consumers. The common-distribution assumption means that there are no systematic quality differences among products. The surplus from buying one unit of firm k's product at price p_k is u_k-p_k. If all match utilities and prices are known, a consumer will choose the product providing the highest positive surplus. If $u_k-p_k<0$ for all k, she will leave the market without buying anything.

I assume that consumers initially have imperfect information about the product prices and the match utilities (but they hold the rational expectation). They can gather information through a sequential search process. By incurring a search cost $s>0$, a consumer can find out a product's price and match utility. I assume that the search process is without replacement and there is costless recall (i.e., a consumer can return to any previously sampled product without paying an extra cost). Departing from the traditional search literature, I suppose that all consumers sample firms in an exogenously specified order. Without loss of generality, firm k is sampled before firm $k+1$.

[2] Hortaçsu and Syverson (2004) construct a related empirical non-random search model, where investors sample differentiated mutual funds with unequal probabilities. But they did not explore theoretical predictions of their model, and there is also no empirical conclusion about the relationship between sampling probability and price.

Firms know their own positions in consumers' search process. They simultaneously set prices p_k $(k=1,2,\cdots,n)$ to maximize profit based on their expectations of consumer behavior. Both firms and consumers are assumed to be risk neutral.

3. Analysis

3.1. Demand

Let us first analyze consumers' search behavior. Their optimal stopping rule depends on the property of the price sequence in their expectation. Since I aim to construct an equilibrium with $p_1<p_2<\cdots<p_n$, I first assume that consumers hold an expectation of such an *increasing* price sequence. (I will discuss the optimal stopping rule for other forms of expectation and the issue of multiple equilibria in Section 3.3.[3])

I derive the optimal stopping rule by means of backward induction. Denoted by

$$v_k\equiv max\{0,u_1-p_1,\cdots,u_k-p_k\} \tag{1}$$

the maximum available surplus after sampling k products. Suppose a consumer has already sampled $n-1$ products and expects the last firm to charge a price p_n^e. Then she should sample the last product if and only if

$$\int_{p_n^e+v_{n-1}}^{u_{max}}(u-p_n^e-v_{n-1})dF(u)>s.$$

The left-hand side is just the expected incremental benefit from sampling the last product, and it is decreasing in $p_n^e+v_{n-1}$. That is, a higher available surplus so far or a higher future price makes the consumer less likely to continue to search. Let a solve

$$\int_a^{u_{max}}(u-a)dF(u) = s. \tag{2}$$

Then the consumer should sample the last product if $p_n^e+v_{n-1}<a$ or $v_{n-1}<a-p_n^e$. Otherwise, she should stop searching and buy the best product among the previous $n-1$ ones. (The search cost is assumed to be not too high such that Eq. (2) has a solution $a>u_{min}$ and all equilibrium prices are lower than a.)

Now suppose a consumer has sampled $n-2$ products and expects the last two products' prices are p_{n-1}^e and p_n^e with $p_{n-1}^e<p_n^e$. The expected benefit from searching on is at least

$$\int_{p_{n-1}^e+v_{n-2}}^{u_{max}}(u-p_{n-1}^e-v_{n-2})dF(u), \tag{3}$$

since the consumer can at least stop searching after sampling product $n-1$. Hence, if Eq. (3) exceeds the search cost, or equivalently, if $v_{n-2}<a-p_{n-1}^e$, the consumer should keep searching. On the other hand, if $v_{n-2}\geq a-p_{n-1}^e$ and the consumer continues to search, then regardless of what match utility she will find at firm $n-1$, she will have $v_{n-1}\geq v_{n-2}\geq a-p_{n-1}^e>a-p_n^e$ (due to the expectation of $p_{n-1}^e<p_n^e$) and so will stop searching after sampling product $n-1$ anyway. Thus, when $v_{n-2}\geq a-p_{n-1}^e$, the expected benefit from searching on is exactly Eq. (3) and less than s, and so the consumer should actually cease her search now. The analysis

[3] There is no such an issue when $n=2$ or when consumers sample randomly among all other firms after visiting firm 1 as in the prominence model in AVZ.