

Consumer Search with Price Sorting^{*}

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Abstract

This paper introduces price sorting into a consumer search model. Either ascending or descending price sorting can be applied before the sampling process. Consumers search sequentially for products with two types of qualities. We allow a fraction of consumers to have zero search costs, and all other consumers have the same positive search cost. Price dispersion exists in the unique symmetric equilibrium. We find that, when the search cost is small, using price sorting will improve both total welfare and consumer surplus, but have no impact on industry profits. Moreover, if consumers can choose the type of price sorting for their own interests, ascending price sorting (or descending price sorting, respectively) will be chosen if there are more high-quality products (or low-quality products, respectively) in the market.

Keywords: consumer search, product differentiation, sorting, price dispersion

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1 Introduction

The rapid technological growth of the Internet has dramatically changed people's way of shopping. Nowadays people can purchase almost everything online, from daily goods to various services such as car rental, flight and hotel booking. *Fortune* wrote in December 1996: "Buying many things on the Web will be easier, cheaper and more secure than going to stores or flipping through catalogs, credit card in hand." A recent research performed by *Statistic Brain* in 2013 shows that "Internet travel booking revenue has grown by more than 73% over the past five years." Statistics also show that a total number of 148.3 million travel bookings were made on the Internet each year, which constitutes up to 57% of all travel reservations.

An important feature of online purchases is the ease at which one can sample various products. Only with a few clicks, people can learn all the information of the products they are interested in, including prices and important attributes. The costs of sampling on the Web become even smaller when various types of sorting options are available. For example, both Amazon.com and eBay.com allow customers to sort the products by price either from low to high, or from high to low. Expedia.com offers various deals on flights and cruises, which allow customers to view the results from low rates to high rates. A price-sensitive consumer may save some clicks by starting with the cheapest products. On the other hand, customers who have a high standard for quality may quickly find their most desired products by sampling from high prices to low prices.

While there is a rich literature on consumer search, little has been said about sorting. Introducing sorting into the consumer search model has made two changes. First, while most of the consumer search literature considered random search models, the search order in the presence of sorting is not random any more. In other words, consumers can update the information of the next product at each stage during the search process. Second, the actual order in which consumers sample the products depends not only on the type of sorting, but also on firms' strategies. For example, if customers sort by price from low to high, then a firm can make its product sampled earlier by charging a lower price. This is in contrast with Arbatskaya (2007), Zhou (2011) and Armstrong et al (2009) who assumed that the search order is predetermined and does not change with players' actions.

In this paper, we examine the impact of price sorting in a consumer search model, in which consumers search sequentially for products that are either of high quality or of low quality. Three types of price sorting are commonly observed in the Web: random price sorting, ascending price sorting and descending price sorting. Under random price sorting, searchers sequentially sample the products in a random order, as is commonly assumed in the literature. When ascending (or descending, respectively) price sorting is applied, products are displayed from low prices to high prices (or from high prices to low prices, respectively).

The purchase surplus of a consumer is fully determined by the price and quality of the product he buys. This product information is not known to the consumer unless the product is sampled. For example, when consumers are seeking some product at a commerce website, all the search results are displayed in several pages, with the main information including price and product descriptions. In this case, taking another sample simply means clicking the "next page" button on the website. Consumers learn all the product information when they go to the new page. As a normalization, we assume that each web page shows only one product. While this normalization is made for analytical convenience, later we show that the main results of this paper will not change even when multiple products are observed in each sample.

Note that the assumption that searchers observe neither price nor quality before a product is sampled also avoids a complex search policy.¹ Moreover, we assume that consumers sample the products in the same order as they are displayed. That is, according to the sorting result, products should be sampled from the first to the last without any jumps. In the examples of online purchases, this means that the only button consumers can click is the "next page". Thus, instead of being chosen by consumers, the search order is determined by firms' pricing strategies and the type of sorting. As a result, the consumer search policy has a simple form: based on the samples they have already made, consumers only have to decide whether or not to search on.

The consumer search policy in our model is generally not optimal because we have limited consumers' ability to choose the best search order. However, our assumption on the search order can be justified for two reasons. First, if we look for the general optimality of the search rule, then there will be no difference between ascending and descending price sortings, since both types of price sorting reveal the same ordinal rank of prices. However, in reality, ascending and descending price sortings coexist at many commerce web sites such as Amazon.com, eBay.com and Taobao.com (the largest and most popular web site for online shopping in China). Thus, the function of price sorting is more than just providing searchers with products' price information. The positions in which products appear in the web pages should also matter. Taking this into consideration, it seems not quite restrictive to assume that searchers sample the products from the first page to the last without going back and forth. Second, we will later consider the case in which more than one products are displayed in each page, which makes it less restrictive to assume that all the pages are viewed without jumps.

We use random price sorting as the underlying model because it actually represents the traditional random-search case. We first assume that the type of

¹There are other situations in which the web pages only display products' prices, and consumers have to click each product to learn the detailed description. The search policy in this case becomes more complex: consumers not only decide whether to search on, but also decide which product to sample if continuing searching. Discussions for these situations are beyond the scope of this paper.

price sorting (ascending or descending) is publicly known and taken as given. By studying the equilibrium, we examine how each price sorting affects consumer choices and firms' pricing strategies. Moreover, we study how total welfare, consumer surplus and industry profit change with the type of price sorting. Finally, instead of fixing the type of price sorting exogenously, we consider the situation in which consumers choose the sorting pattern for their own interests, and study under what conditions will ascending/descending price sorting be chosen.

We find that when the cost of each search is small,² compared to the case of random price sorting, both ascending and descending price sortings improve total welfare and consumer surplus. This is because both types of sorting provide useful price information that prevents consumers from inefficient searches. More precisely, when search cost is very small, consumers under random price sorting almost always want to search on because the benefit of making an additional sample is very likely to be higher than the search cost. However, under ascending price sorting, a consumer who have sampled a high-quality product will stop searching, because the next product is still of high quality but with a higher price. Similarly, a consumer under descending price sorting never searches on when observing a low-quality product. Thus, consumers search less under both ascending and descending price sortings. We find that ascending price sorting has a greater improvement on total welfare and consumer surplus than descending price sorting does if and only if there are more high-quality products in the market. Intuitively, since consumers stop searching whenever observing a high-quality product under ascending price sorting, or observing a low-quality product under descending price sorting, ascending price sorting can better save the total search costs when there are more high-quality product in the market. We also find that in the case of small search costs, both types of price sorting have no impact on industry profit. Actually, the main impact of price sorting is to reduce the total occurrence of search costs, while it has negligible influences on firm's profits and consumers' purchase surplus.³ This explains why price sorting has similar effects on total welfare and consumer surplus.

Finally, when price sorting is chosen by consumers rather than exogenously given, with small search costs, random price sorting is never chosen in equilibrium. Consumers choose ascending price sorting (or descending price sorting, respectively) if there are more high-quality (or low-quality, respectively) products in the market. In other words, consumers always take advantage of sorting options whenever they are available. This is because switching from random

² We focus on the small search cost situations because during the online purchases, searching usually means clicking the links in the website. The cost of each search is believed to be quite small.

³ We use the notation "purchase surplus" to denote consumers' expected benefits from the trade, excluding the total costs of their search activities. In other words, consumer surplus equals purchase surplus, net of the consumer's total expected cost of sampling.

price sorting to either ascending or descending price sorting benefits consumers by saving their total search costs, with only negligible influence on their purchase surplus. Thus, our result on equilibrium price sorting is just a restatement that ascending price sorting better saves the total consumer search costs than descending price sorting does if and only if there are more high-type products in the market.

There is a rich literature on consumer search. One of the earliest work is Diamond (1971), who considered homogenous goods so that consumers search sequentially only for lower prices. Diamond showed that as long as the search cost is positive, the only equilibrium is that all firms set the monopoly price and search never occurs, which is known as the Diamond Paradox.⁴ Wolinsky (1986) resolved the Diamond Paradox by introducing horizontal product differentiation. He found an equilibrium in which search takes place and the equilibrium price converges to the competitive price as the search cost approaches zero. Anderson and Renault (1999) reconsidered Wolinsky (1986)'s model by introducing the heterogeneity of consumer tastes and studying how the degree of product differentiation affects firms' equilibrium prices. They showed that both the Bertrand result and the Diamond result can be considered as the limit cases of their model. Stahl (1989) avoided the Diamond Paradox in a different way by allowing some consumers to have zero search costs. These consumers are called "shoppers". In the equilibrium of his model, firms' pricing strategy is a mixed one and can be denoted by a price distribution.

All of the above models considered random search. Our model differs from theirs in that we introduce price sorting, so that consumers' search order is not random any more. Moreover, the product differentiation we consider is vertical instead of horizontal. In other words, we assume that products in the market have different types of quality. This is because the only reason a consumer will choose descending price sorting is that a higher price may reflect a better quality. We borrow from Stahl (1989) by assuming the existence of "shoppers" who have zero search costs. To relate our model to the above literature, we find that vertical product differentiation cannot "get around" the Diamond Paradox, as horizontal product differentiation does, unless a positive fraction of consumers are allowed to have zero search cost.

There is another strand of literature which considered non-random consumer search. Weitzman (1979) considered a quite general situation in which several heterogeneous alternatives are available for search, and the optimal search policy should specify not only when to terminate search, but also in which order the searcher should search on. Our model differs from his in two ways. First, Weitzman (1979) allowed the searcher to choose the best search order. In our

⁴Note that in Diamond's model, the Bertrand result is obtained when the search cost equals zero. Thus, as the search cost approaches zero, the equilibrium price changes discontinuously from the monopoly level to the competitive level.

model, however, the order that consumers sample the products is fully determined by firms' prices and the type of price sorting. Second, while Weitzman (1979) only studied the optimal search policy, our model explores the whole market equilibrium, including firms' pricing strategies, which endogenously affect consumers' search order.

Some recent non-random search models include Arbatskaya (2007), Zhou (2011) and Armstrong et al (2009), who assumed that the order in which consumers search the products is exogenously fixed and common knowledge. Our model differs from theirs in that the actual search order in our model can be affected by both consumers' and firms' behaviors.

The rest of this paper is organized as follows. Section 2 describes the market and three types of price sorting are introduced to the search model. Section 3 considers the case in which the type of price sorting is fixed and publicly known, and derives the equilibria for the three types of sorting, respectively. Section 4 studies the impacts of ascending/descending price sorting, using the case of random price sorting as the underlying model. Section 5 reconsiders the game by assuming that the type of price sorting is chosen by consumers instead of exogenously given. Section 6 concludes and discusses possible extensions in the future. All the technical proofs are included in the Appendix.