Lower Search Costs and Variance of Price Distribution

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ISBN 952-458-791-2
ISSN 1795-7885
no 34

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February 2006

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Abstract

The economic theory attributes search costs as the cause for price dispersion. Search costs are much lower in electronic markets than in conventional markets, yet various empirical studies have revealed that persistent price dispersion characterizes online markets. We examine a model of price dispersion, in which buyers face non-negative search costs in a known price distribution, while a distribution of search costs is known to sellers. We show that under certain conditions variance of the price distribution can actually increase even though search costs decrease. In addition, the market could display more extreme prices when a decrease of search costs affects the buyers disparately.

1 Introduction

Cost of information is one of the key determinants of an efficiently functioning market. A considerable amount of information is involved in production, negotiations, decisions and market transactions. Consumers and firms incur costs from gathering, processing and transmitting information. Since these costs are rarely equal to every market incumbent, information is often asymmetric in markets. As a consequence, asymmetric and costly information favors the market structures of imperfect competition.

The rise of electronic commerce spurred hopes that more competitive markets would emerge on the Internet. Electronic business processes lower various information costs, such as search costs. In this respect, electronic markets should be more efficient than the conventional markets. Neo-classical economic theory juxtaposes efficiency with competition. Competitive e-markets were even expected to gravitate towards marginal cost pricing. However, empirical research on e-markets has revealed that the opposite is true. Wide and persistent price dispersion seems to characterize even the online markets for homogenous products such as CDs, DVDs and books. For example, Bailey (1998), Brynjolfsson & Smith (2000) and Ancarani & Shankar (2004) have discovered significant price dispersion in the online retail markets. Moreover, a time span of these studies implicates that the condition is permanent.

Search costs have been under the loop since B2C-markets took off on the Internet. A widely accepted view is that superior search mechanisms on the Internet, such as shopbots, and the ease of accessing online market information will reduce search costs dramatically. The economic theory attributes search costs as a major reason for a distribution of prices commonly found in various markets (Stigler 1961, p. 214). Several theoretical models, such as Varian (1980) and Carlson & McAfee (1983), suggest that a dispersed price equilibrium is a consequence from heterogeneous consumer search costs. Since they are significantly lower in the e-markets, price dispersion seems to indicate that either electronic markets are not as efficient as was presumed, or lower information costs do not spawn a neo-classical competitive market that is ruled by the law of one price.

A few studies have offered insights to lay out reasons behind the persistence of price dispersion. According to Baye & Morgan (2001), an explanation could be that information flows on the Internet are regulated by the owners of search services. These "information gatekeepers" find it optimal to induce price dispersion to maximize their profits. Smith (2001) considers differences in consumers' awareness of sellers and their abilities to search to be the cause for dispersed prices. Dinlersoz & Yorukoglu (2004) argue that it could result from increased information in the market because many e-tailers have spent heavily on advertising to gain visibility in the market.

In this paper, we offer another explanation for dispersed prices in the e-markets. Our analysis shows that variance of a price distribution can actually increase even though consumer search costs decrease. We also offer an explanation why price dispersion could become permanent despite the inherently competitive business environment of e-markets.

2 Change in Search Costs and Price Dispersion

2.1 Search Costs and Variance in Known Distribution

Assume that there is a monopolistically competitive market for a homogeneous product. The market is populated by a large number of buyers and a finite number of sellers[1]. The sellers are profit-maximizing firms and the buyers are utility-maximizing consumers who look for the lowest price in the market. The interaction between the buyers and sellers can be considered a game in which the players move simultaneously. Before a more detailed descripition of the model, let us briefly examine the game between the buyers and sellers.

As in most real world situations, the buyers and sellers are not identical. Each firm has a different marginal cost of production. Each buyer incurs subjective costs from searching which are known to her, and these costs vary across buyer population. For example, consumers with high incomes are likely to have high opportunity costs for time. This can be considered as high search costs and thus, they avoid searching, have higher effective reservation prices and accept higher offers (Banks & Moorthy 1999, p. 376). The distribution of search costs among the buyer population is common knowledge to the sellers. While the distribution of prices is known to the buyers, they are not aware of the exact location of each seller. Hence, the buyers use a search rule, which will be defined later, to find acceptable prices. Since the sellers know this, they will set their prices accordingly, which creates a distribution of prices that is known to the buyers.

[1]To avoid repetition in text, we use interchangeably the terms 'consumer', 'customer' or the pronoun 'she' for 'buyer' and and 'firm' for 'seller'.

The characterization of the buyers and sellers is based on the model of a discrete equilibrium price dispersion by Carlson & McAfee (1983). We present it here only from those parts that are convenient to our analysis.

There are n profit-maximizing firms in the market. They differ from each other in their marginal costs of production. A cost function for a representative firm j is

$$c_j(q_j) = a_j q_j + b q_j^2, \tag{1}$$

where $a_j > 0$, $b > 0$, $a_j \leq a_{j+1}$ and $j = 1, 2, ..., n-1$. In consequence, the most efficient seller in the market, which is the one with the lowest marginal cost, is able to set the lowest price.

The buyers are assumed to know the distribution of prices in the market and the value of their subjective search costs, but they are not aware of the exact distribution of the sellers. To simplify the model, they expect the distribution to be of a uniform density. This is the same as to say that the consumers expect to find any price p_i with the same probability $f(p_i) = \frac{1}{n}$. Consumer search costs s_j are non-negative and exogenously defined in correspondence to an expected gain x_j from finding a price lower than the price p_j, which is an effective reservation price for a buyer with search costs s_j. The expected gain from finding a price lower than p_j is

$$x_j = \sum_{i=1}^{j-1} (p_j - p_i) f(p_i), \quad j = 2, \; ... \; , n. \tag{2}$$

This equation can also be expressed as

$$x_j = \left[\sum_{i=1}^{j-1} (p_j - p_i) \frac{1}{j-1} \right] \frac{j-1}{n}, \tag{3}$$

which states that the expected gain from searching is the difference between p_j and an average of $j-1$ lower prices times the probability of discovering one of these prices.

Two problems, which have to be accounted for, arise from costly search. First, the Diamond Paradox predicts that with positive search costs, every seller charges a monopoly price at the equilibrium (Anderson & de Palma 2005, pp.63-64). Second, Stiglitz (1979) points out that if the first quote is costly and every seller sets the monopoly price, the customers whose reservation prices are close to or below the monopoly price will not enter the market. To avoid these ramifications, we assume that there are some consumers with search costs s_1 equal to zero. These buyers search across the entire distribution of prices until they find the lowest price. Since setting the monopoly price would mean that the firms with low marginal costs of production would share the customers equally with other sellers, they have an incentive to undercut their rivals' prices and increase their profit. In addition, we assume that the first quote is free whereas further search is costly. As a result, the monopoly price equilibrium cannot prevail.

Given the subjective search cost s_j, the buyer's sequential search rule from the known distribution is:

$$\text{if } x_j > s_j \text{ , continue the search}$$
$$\text{if } x_j \leq s_j \text{ , terminate the search.}$$

This means that she compares the expected gain from searching to her search costs. As a result, she searches until a price that is equal or lower than her effective reservation price turns up.

A buyer will buy at or below a price p_j if $x_j \leq s_j < x_{j+1}$. The buyer is indifferent between searching for a lower price and buying at the price p_j when $x_j = s_j$. For example, a buyer with search cost of s_{j-1} has found the price p_{n-2} where $n-2 > j-1$. Since $x_{n-2} > s_{j-1}$, there is an incentive to continue the search. She will finish the search as soon as any price $p \leq p_{j-2}$ has been found. On the other hand, if the buyer finds a price lower than her effective reservation price at the first trial, there is no incentive to search further because the expected gain from the search is less than her cost from searching.

Applying the search rule to equation (3) and rearranging, the effective reservation price the buyer is willing to pay becomes

$$p_j = \frac{n}{j-1} s_j + \sum_{i=1}^{j-1} \frac{p_i}{j-1} \tag{4}$$

At the other end of the spectrum, the buyers whose search costs exceed s_n accept the first offer they receive. A partial derivative $\frac{\partial p_j}{\partial s_j} \geq 0$ (with strict inequality when $s_j > 0$) verifies that an increase in search costs also increases the effective reservation price.

The effective reservation price p_j for the buyer with search costs s_j consists of two components. These are the search component $\frac{n}{j-1} s_j$ and the product value component $\sum_{i=1}^{j-1} \frac{p_i}{j-1}$. An interpretation for this is that all buyers include an amount of search in their respective reservation prices p_j. If the first quote received is more than p_j then the acceptable price after searching is less than p_j. In the absence of search costs, the reservation price would be equal to an average of $j-1$ lower prices.

As was stated earlier, the sellers know the distribution of search costs among the buyer population. Consumer search costs constitute a demand system for the sellers. Let a continuous function $G(s)$ represent the number of buyers with search cost less or equal to x, which denotes an expected gain from finding a lower price. At $G(0) = 0$, and at $G(\infty)$ is equal to the total number of buyers. A seller with the highest price can expect to share the buyers who do not search equally with all other sellers. In consequence, the expected demand q_n when every seller has equal probability to be sampled is

$$q_n = \frac{1}{n}\left[G(\infty) - G(s_n)\right]. \tag{5}$$

The next seller receives q_n and the demand from the buyers with search costs at or below s_{n-1}. The demand facing the seller with price p_j can be written recursively

$$q_j = q_{j+1} + \frac{1}{j}\left[G(s_{j+1}) - G(s_j)\right]. \tag{6}$$

As a consequence, increasing the price decreases demand and decreasing the price has an opposite effect.

Since the market is monopolistically competitive, assume that the demand facing the firm j depends on the difference between the average market price and the firm j's price. The lower the price, the more customers a firm is able to lure in. Define $T > 0$ as the range of the search costs. A density for the distribution of search costs from $G(s)$ is denoted by k with $0 < k < T$. A demand function for the firm j becomes

$$q_j = \frac{1}{kn}\left[T - (p_j - \bar{p})\right], \tag{7}$$

where $\bar{p} = \sum_{i=1}^{n} \frac{p_i}{n}$ is the average market price.

Effects of price changes on search behavior can be examined by comparative static analysis. Keeping search costs constant, a partial derivative $\frac{\partial x_j}{\partial p_j} = \frac{1}{n} > 0$ indicates that increasing (decreasing) the effective reservation price increases (decreases) the expected gain from searching and encourages (discourages) searching. Changes in prices lower than p_j reverse the effect. $\frac{\partial x_j}{\partial p_j} = -\frac{1}{n} < 0$ shows that a rise (a decline) in the lower prices decrease (increase) the expected gain from searching. Notice, however, that $\frac{\partial x_j}{\partial p_{j+1}} = 0$ shows that changes in the prices above p_j do not have any significance for the buyer. The demand facing the firms that sell to the customers with search costs above s_j is independent on the demand at or below this cost, because the probability that the lower cost types would buy at price p_{j+1} is zero.

The firms set profit-maximizing prices by exploiting consumer search costs. This produces a price distribution in the market, which is in an ascending order with an equal probability for each p_i

$$p_1 \leq p_2 \leq ... \leq p_n. \tag{8}$$

Calculating the profit-maximizing level of production for the firm j is a mechanical task, which is of no interest here.

Next, we proceed to examining the impact of a change in search costs on the variance of a price distribution[2]. The formula to calculate the variance in our price distribution is

$$var(p) = \frac{1}{n}\sum_{j=1}^{n}(p_j - \bar{p})^2. \tag{9}$$

Substituting from (4), we can verify that for any price p_j, the variance is

$$var(p) = \left[\frac{n}{j-1}s_j + \sum_{i=1}^{j-1}\frac{p_i}{j-1} - \sum_{i=1}^{n}\frac{p_i}{n}\right]^2. \tag{10}$$

In other words, the variance in effective reservation prices can be expressed with search costs and the product value.

By examining this formula more carefully, we are able to observe how changes in search costs impact the variance of prices. Before embarking on this, we make an assumption that a reservation price p_j that is equal to the mean $\bar{p}$ exists. Denote this reservation price by p_m. This is an important boundary condition because if $p_j = \bar{p}$, then $var(p) = 0$. The prices that exceed p_m are higher reservation prices, and the prices below p_m are lower reservation prices. As a result, we can use equations (9) and (10) to write out the formula for variance explicitly:

$$\begin{aligned} var(p) = \frac{1}{n}\Bigg[&(p_1 - \bar{p})^2 + \sum_{j=2}^{m-1}\left(\frac{n}{j-1}s_j + \sum_{i=1}^{j-1}\frac{p_i}{j-1} - \bar{p}\right)^2 \\ &+ \left(\frac{n}{m-1}s_m + \sum_{i=1}^{m-1}\frac{p_i}{m-1} - \bar{p}\right)^2 + \sum_{j=m+1}^{n}\left(\frac{n}{j-1}s_j + \sum_{i=1}^{j-1}\frac{p_i}{j-1} - \bar{p}\right)^2\Bigg]. \end{aligned} \tag{11}$$

It is now straightforward to see, how reductions in search costs for any buyer type change the variance. There are two conditions that lead to a decrease in the variance.

[2]See Appendix for a more detailed treatment.

A reduction in search costs which is focused solely on the buyers with the reservation prices above the market average decreases the variance of prices. Another condition emerges when proportional values of the search components are greater with the higher reservation prices. This happens when

$$\frac{\frac{n}{j-1}}{p_j} s_j \leq \frac{\frac{n}{j-1+1}}{p_{j+1}} s_{j+1}, \quad j = 2, \ldots, n-1. \tag{12}$$

The real world examples of this could be a lack of expertise at using search technology, inadequate knowledge of the market or flaws in a market-mechanism design (Chiang et al. 2005, pp. 11-13). As a result, a universal reduction in search costs, which is proportionally equal to every buyer, tends to have a larger effect on the buyers with the higher reservation prices. This decreases the variance of prices.

There are some conditions in e-markets which lead to an increase in the variance of prices. As before, the reduction affecting only the buyers below the market average increases the variance. A rational assumption is that those buyers, which have the low reservation prices, are able to get better informed on the market conditions. They could, for instance, be more adept at searching, afford better equipment, or have lower opportunity costs for time. Consequently, they could be more willing to learn to use new search technologies and reap the most benefits from them. The values of their search components, therefore, are lower than for the buyers which have the high reservation prices (Baye et al. 2003, p. 18). It is also possible that the search components could become proportionally greater in value with the lower reservation prices. This takes place when large differences between the lower prices exist. In this case, a reduction in search costs has a larger effect on the buyers with the lower reservation prices. However, a universal proportional reduction leads to a decrease in the variance.

Recent studies on consumer search behavior in the online B2C-markets have revealed evidence that disparately reduced search costs could create price dispersion. For example, a study by Johnson (et al. 2004) indicated that lower search costs do not necessarily lead to more intense search activity in online markets. The number of consumer searches in the purchases of books was on average merely 1.1. Similarly, with purchases of travel services, which are usually of higher value than books, the number of searches was only 1.8. The amount of search, however, was noticed to increase over time. This could implicate that consumers learn to take advantage of the available search technology which leads to a gradual decrease in search costs. Smith (2001) argues that some segments of the consumer market can adapt to a new search technology faster than others and benefit from the lower search costs. He found that computer books have a lower price dispersion and lower prices than other types of books. As an explanation for this, Smith suggests that the consumers buying the computer books are more sophisticated at using better search mechanisms, such as shopbots, than an average consumer. Baye (et al. 2003) notes that the consumers who use the shopbots pay on average 16% less for their purchases in the online markets.

2.2 Market Dynamics

Search procedures that utilize marginal calculations are practical in predicting market dynamics. According to Rothschild (1974), if all buyers are assumed to follow a similar rule, the firms in the market face demand that is a non-increasing function of price. The higher (the lower) the price, the less (the more) customers a firm attracts. In a market that is characterized by monopolistically competitive firms with free entry and constant returns to scale heterogeneous production technology, an increase in consumer search activity means that there is a downward pressure on pricing. Low-priced sellers have large sales volumes while high-priced sellers settle for a lesser transaction volume (Stigler 1961, p. 217).

Since the impact of the reduced search costs is likely to affect the buyers asymmetrically, a firm that loses customers has to adjust to the situation. If it cannot compete with lower prices, the firm may exit from the market. Generally, monopolistically competitive firms are not expected to make supernormal profits in the long run. For this reason, the price set by the firm j must be equal to its average cost $AC_j = \frac{c_j(q_j)}{q_j}$. By substitution from equations (1) and (7), we obtain

$$AC_j = a_j + \frac{b}{kn}\left[T - \frac{n}{j-1}s_j - \sum_{i=1}^{j-1}\frac{p_i}{j-1} + \bar{p}\right] \tag{13}$$

A comparative static result from the partial derivative $\frac{\partial AC_j}{\partial s_j} < 0$ shows that a decrease in search costs leads to an increase in average costs. All things equal, the firm with an eroding customer base has to raise prices to maintain profitability. More efficient firms, on the other hand, receive more customers. For this reason, they can increase their output and lower their prices further. On the whole, this could mean that the market displays more extreme prices, which increases the variance of a price distribution.

In the long run, it is likely that the distribution of prices shifts towards a "U-shaped" distribution where the probability mass is concentrated in more extreme prices (Varian 1980, p. 656). Consequently, as the higher-priced firms receive more customers, they are able to increase output and lower prices, whereas the lower priced firms will have to raise their prices as a response to a decline in demand. Ultimately, this could induce cyclical price fluctuations as the firms adapt to changing demand conditions. As a consequence, price dispersion becomes a permanent phenomenon on the e-markets.

3 Conclusion

Various empirical studies have revealed that price dispersion is a permanent condition in electronic markets. According to the economic theory, the markets where information costs are low should be characterized by marginal cost pricing of free competition or at least a lesser degree of price dispersion. However, several studies have shown that e-markets display persistent price dispersion.

Heterogeneous consumer search costs could explain the existence of price dispersion in e-markets. Our analysis shows that reductions in search costs can either decrease or increase the variance of a price distribution. A universal reduction in search costs or a reduction that has a bias on the buyers with higher search costs decreases the variance. The variance can increase, if the reduction is affecting only the buyers who have lower search costs. Therefore, price dispersion cannot be automatically interpreted as evidence of non-competitive pricing. On the contrary, this could be evidence of decreasing search costs among the buyers who already face lower search costs in e-markets.

Disparate search costs may have impacts on market dynamics. They can make the prices in a market more extreme because the less efficient firms have to adjust to a shift in demand by increasing their prices. Therefore, price dispersion persists or even increases, if only a small fraction of the buyers is able to use the new search technology to reduce their search costs.

Acknowledgements

The author would like to thank Mika Linden for helpful comments.

Appendix

A formula to calculating the variance for variables y_i, where $i = 1, \ldots, n$ is by a definition

$$var(y) = \frac{1}{n}\sum_{i=1}^{n}(y_i - \bar{y})^2, \tag{A.1}$$

where

$$\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i \tag{A.2}$$

is the mean calculated from n observations.

For n prices, the variance of a price distribution is

$$var(p) = \frac{1}{n}\sum_{j=1}^{n}(p_j - \bar{p})^2. \tag{A.3}$$

Writing out the formula explicitly for all p_j, where $j = 1, \ldots, n$, we get that

$$var(p) = \frac{1}{n}\left[(p_1 - \bar{p})^2 + (p_2 - \bar{p})^2 + \ldots + (p_n - \bar{p})^2\right]. \tag{A.4}$$

Using the average price $p_m = \bar{p}$ as a boundary that divides the $1, \ldots, n$ reservation prices into lower and higher reservation prices, the equation becomes

$$var(p) = \frac{1}{n}\left[(p_1 - \bar{p})^2 + (p_2 - \bar{p})^2 + \ldots (p_m - \bar{p})^2 + \ldots + (p_n - \bar{p})^2\right]. \tag{A.5}$$

For any single effective reservation price p_j, the variance can be calculated by substituting p_j with the expression from the equation (4), which yields

$$var(p) = \left(\frac{n}{j-1}s_j + \sum_{i=1}^{j-1}\frac{p_i}{j-1} - \sum_{i=1}^{n}\frac{p_i}{n}\right)^2. \tag{A.6}$$

Substituting this into equation (A.5) and using sum operators, the variance can be written as

$$var(p) = \frac{1}{n}\left[(p_1 - \bar{p})^2 + \sum_{\substack{j=2\\ j\neq m}}^{n}\left(\frac{n}{j-1}s_j + \sum_{i=1}^{j-1}\frac{p_i}{j-1} - \bar{p}\right)^2\right.$$
$$\left. + \left(\frac{n}{m-1}s_m + \sum_{i=1}^{m-1}\frac{p_i}{m-1} - \bar{p}\right)^2\right]. \tag{A.7}$$

Notice that p_1 cannot be expressed with search costs because of equation (2).

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