SUBJECTIVE PRICE SEARCH AND PRICE COMPETITION

by

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Abstract

In this paper we analyze price formation in an industry where consumers have a priori beliefs on prices, and firms are aware of this fact. We show that if all consumers are identical, a (Nash) price equilibrium exists in which all firms quote a price which makes consumers expectation of finding a still smaller price not sufficient to bear the search cost. A similar analysis is performed for the case where search costs differ among the consumers in the framework of a location model.
INTRODUCTION

In most models analyzing markets with dispersed prices, one assumes that consumers know the distribution of prices while they ignore which seller quotes which price. Then consumers search sequentially for the lowest price, stopping to search when the expected gain from leaving the last shop visited for a further search becomes non positive. On the other hand, if firms know this search procedure, they can manipulate the distribution of prices by choosing their own price in a manner which is most advantageous to them. An 'equilibrium' distribution of prices may emerge, in which no firm can increase its revenue by unilateral deviation from the price it has chosen. This approach, initiated by Stigler (1961) has given rise to a significant research area, represented, among others, by the following papers: Carlson and McAfee (1983), Reinganum (1979), Rothschild (1973) and (1974), Salop and Stiglitz (1977), Stahl (1982).

With few exceptions (see for example, Rothschild (1974)) nobody has questioned the basic assumption of the above approach, namely that consumers are initially endowed with the knowledge of the true distribution of prices. Presumably the plausibility of this assumption relies on the fact that, in many market places, consumers can repeatedly observe the price fluctuations decided by the sellers, generating thereby a kind of learning process of the price distribution. Nevertheless, as long as the mechanism through which consumers 'learn' the distribution, has not been made explicit, it seems difficult to avoid questioning this assumption. Moreover this assumption is particularly inaccurate when no learning process can be experienced, simply because the product has not yet been sold before on the market. How could consumers know the true distribution of prices when these prices have never been set beforehand? At best, consumers rely on apriori beliefs about prices in orienting their search process on a particular path. This suggests that an alternative assumption, -which fits better the situation just depicted-, can be proposed to represent the informational endowments of consumers. This assumption asserts that consumers have prior beliefs about the price set by the sellers, and use these beliefs in their sequential search for the lowest price. In other words, it is assumed that the price of each firm is viewed by a consumer as a random variable defined on some pre-assigned range. Then, if firms do not face any shortage of information, they can predict exactly how consumers search decisions depend on their prior beliefs and on the price they set. Accordingly they can manipulate information gathering by the buyers in a way similar to the one described above, leading eventually to an equilibrium distribution of prices, in which no firm would gain by deviating from the price chosen at equilibrium.

In the present paper we retain the alternative assumption about the informational endowments of the consumers, and study the resulting equilibrium price distribution in two different models.
In the first model, we suppose that the unit search cost is the same for all consumers, who are also assumed to share identical prior beliefs on the price set by each firm. Then we prove that there always exists a price equilibrium, which is either the monopoly price, or that price which makes a consumer indifferent between buying at that price from the last shop visited, or undertaking a further search for a lower price.

In the second model, we assume that the unit search cost varies from consumer to consumer, because consumers are located at varying distances from the sellers; in other words, we combine a model of price search with a model of spatial competition. Then we derive necessary and sufficient conditions for the existence of a price equilibrium when there are two sellers, and all consumers have the same prior beliefs on prices represented by a uniform distribution over a given interval of prices.

2. THE HOMOGENEOUS CASE

Let us first consider a situation with \( n \) 'population centers' \( h, h = 1, \ldots, n \), and a single shop at each center. Demand at that shop is equal to \( D(p) \), where \( D(p) \) denotes the demand function at the shop if the search cost would be infinite: in that case no consumer from other population centers than \( h \) would buy from seller located in the \( h \)th population center. If all firms quote the same price \( p \), we assume that the expected demand at firm \( h \) is equal to \( D(p) \). Consumers search sequentially with recall; no cost is incurred by a customer if he visits the shop in his own population center, but he must pay a unit search cost \( c, c > 0 \), per visit, to get information on any other price. We assume: \( D(p) \) concave, \( D'(p) < 0 \) and there exists \( p \) such that \( D(p) = 0 \), \( \forall p \geq p \). Each consumer buys at most a single unit of the (homogeneous) product, and is willing to buy a unit at zero price. Also zero production cost is assumed throughout.

The price \( p \) at each shop is viewed as a random variable by the consumers. This random variable is independently and identically distributed across firms and consumers ('homogeneous' case). We denote by \( F(p) \) the distribution function of \( p \), and by \( f(p) \) the corresponding density; \( p \) takes its values in \( [0,\bar{p}] \): both \( F \) and \( f \) are assumed continuous functions of \( p \). Finally we assume

\[
c + E(p) \leq \bar{p},
\]

where \( E(p) \) is equal to \( \int_0^{\bar{p}} pf(p)dp \): the expected price plus the unit search cost does not exceed the highest possible price. Next we prove

PROPOSITION 1

In the homogeneous case there exists a (Nash) price equilibrium
\( \tilde{p}, \ldots, \tilde{p}, \ldots, \tilde{p} \), with \( \tilde{p} = \min(p_M, p^*) \), where \( p_M \) denotes the maximizer of \( pD(p) \) (the monopoly price) and \( p^* \) the solution of

\[
\int_0^{p^*} F(p) \, dp = c. \tag{1}
\]

Proof:

First it is wellknown that if consumers search sequentially, they leave a firm if, and only if, the price \( \tilde{p} \) observed at that firm exceeds \( p^* \) (see, for instance, Rothschild, M. (1974)) : the price \( p^* \) makes the expected gain from leaving a shop quoting \( p^* \) for a further search exactly equal to zero. Indeed, denoting by \( \varphi(p) \) the expected gain if a price \( \tilde{p} \) is observed, it is easily derived that

\[
\varphi(\tilde{p}) = \tilde{p} - c - \tilde{p}(1-F(\tilde{p})) - \int_0^{\tilde{p}} pf(p) \, dp
\]

\[
= \int_0^{\tilde{p}} F(p) \, dp - c
\]

To show that \( p^* \) exists is equivalent to showing that there exists, \( p^* \) such that \( \varphi(p^*) = 0 \). Notice that \( \varphi(0) = -c \) and \( \partial \varphi / \partial \tilde{p} > 0 \). Furthermore

\[
\varphi(\tilde{p}) = \tilde{p} - c - \tilde{p}(1-F(\tilde{p})) + \int_0^{\tilde{p}} pf(p) \, dp
\]

\[
= \tilde{p} - c + E(\tilde{p}) > 0,
\]

where the last inequality follows by assumption. Accordingly, by continuity of \( \varphi \), which follows from the continuity of \( F \), there must exist \( p^* \) such that \( \varphi(p^*) = 0 \), \( p^* \) in the compact interval \([0, \tilde{p}]\).

Now assume that \( p^* \leq p_M \) and that, contrary to the proposition, the n-tuple \((p^*, \ldots, p^*)\) is not a price equilibrium. Then there exists a firm \( h \) and a price \( p_h \neq p^* \) yielding a strictly higher expected revenue than \( E(\Pi(p^*, \ldots, p^*)) \) (\( E \) denotes the expectation operator and \( \Pi \) the revenue function). Notice that \( p_h \) cannot exceed \( p^* \); otherwise all the customers in the \( h^{th} \) population center who have visited firm \( h \) at first, leave that firm, searching for a lower price, and they find it indeed in any other shop than \( h \) (namely they find \( p^* \)). But then

\[
0 = E(\Pi(p^*, \ldots, p_h, \ldots, p^*)) < E(\Pi(p^*, \ldots, p^*, \ldots, p^*)) = D(p^*) \cdot p^*,
\]

a contradiction. On the other hand, if \( p_h \) is strictly smaller than \( p^* \), then all customers in the \( h^{th} \) population center who have first visited firm \( h \), remain in that firm and

\[
E(\Pi(p^*, \ldots, p_h, \ldots, p^*)) = p_h D(p_h) < p^* D(p^*) = E(\Pi(p^*, \ldots, p^*, \ldots, p^*)),
\]

where the last inequality follows from the fact that \( p^* \leq p_M \) and strict concavity of \( p \cdot D(p) \).
Finally if \( p_M < p^* \), each firm is not constrained by \( p^* \), and setting the monopoly price \( p_M \) it keeps in the shop all its potential customers, while simultaneously maximizing its expected payoff.

\[
Q.E.D.
\]

Thus the mechanism of price competition underlying the above analysis is much different from the mechanism of non cooperative price competition for an homogeneous good when there is perfect information. Thère we know that prices have to descend to zero, because at any strictly positive price, it pays to undercut the competitor. This cutthroat competition remains valid here, for all prices which exceed \( p^* \). However no firm has an interest to undercut \( p^* \) itself: In any case customers remain in the shop, and the firm may behave as a 'local monopolist' on this segment of the market.

On the other hand we notice that
\[
\frac{\partial p^*}{\partial c} = \frac{1}{F(p^*)} > 1 \quad \text{and that} \quad p^* = c + p^*(1-F(p^*)) + \int_0^p pf(p) \, dp > c.
\]
Furthermore it is worth noticing that the price equilibrium does not change with the number of firms, at least as long as the unit search cost \( c \) does not depend on the number of firms. One should expect however the search cost \( c \) to be a decreasing function of \( n \): when the 'density' of firms increases on the network where consumers are located, the unit search cost should diminish. Since \( \frac{\partial p^*(n)}{\partial n} = \frac{\partial p^*(c)}{\partial c} < 0 \), a reasonable conjecture is that the price equilibrium tends to zero when the number of firms tends to \( \infty \). Finally we notice that no price dispersion arises at equilibrium, and that at the same price, no consumer undertakes any search.

A natural question to raise is whether the above properties continue to hold when consumers are no longer identical. In the next section we analyze this question assuming a continuum of consumers with varying search costs and a uniform distribution as representing their prior beliefs.

3. THE HETEROGENEOUS CASE

We consider in the following a classical Hotelling's location model. On a line of length \( L \), two sellers, 1 and 2, of a homogeneous product, with zero production cost, are located at respective distances \( a \) and \( b \), from the end points of this line (\( a + b < L; \ a > 0, b > 0 \)). Customers are evenly distributed along the line and each customer, indexed by \( t \), is \( t} \in [0,L] \), consumes exactly a single unit of this commodity, irrespective of its price. In Hotelling's original model the prices quoted by each seller are known from the start to all consumers, who place their purchase order to the seller quoting the lowest delivered price. Here, it is assumed alternatively, that each customer only knows with certainty the price announced by the seller nearest to him on the linear segment. While each customer ignores, therefore, one of the two prices it is assumed that he can acquire this information at a cost which depends linearly on the distance separating his own location from the location of the more distant seller. The buyer can,
accordingly, either buy at the known price from the nearest shop, or postpone
the purchase until he has first searched for the price set by the more distant
seller. The decision whether to purchase at the known price without search or
whether to solicit the other seller depends on the expectation of finding a
lower price. Here, as in section 2, we shall represent consumers expectations
about the unknown price by a probability function \( F(p) \) defined over some range
\([0, \tilde{p}]\). Again \( F(p) \) has to be interpreted as a probability distribution, the form
of which is determined by the consumers prior beliefs about prices. Since we
have assumed that consumer \( t \) has no information on the price quoted by the more
distant seller, it is natural to assume that \( F(p) \) is an uniform distribution
on \([0, \tilde{p}]\) with corresponding uniform density \( f(p) \). We normalize prices so that
\( p = 1 \). To summarize: all customers \( t \) share the same prior uniform distribution
\( F(p) \) on \([0,1]\), where \( p \) denotes the price set by the firm located at the farthest
distance from customer \( t \). Since all consumers \( t \) in the set
\[
A_1 \overset{\text{def}}{=} \{ t \mid 0 \leq t \leq \frac{L + a - b}{2} \}
\]
are located closer to seller 1 than seller 2, they have perfect information on
the price \( p_1 \) set by seller 1. Similarly consumers in the set
\[
A_2 \overset{\text{def}}{=} \{ t \mid \frac{L + a - b}{2} < t \leq L \}
\]
have perfect information on the price \( p_2 \) (see figure 1).

![Figure 1](image_url)

The cost of acquiring information about the price at the more distant of
the two sellers is then given by
\[
c(t) = \begin{cases} (L-b) - t & \text{if } t \in A_1 \\ (t-a) c & \text{if } t \in A_2 \end{cases}
\]
The decision to buy from the nearest seller, without search, rather than
searching and then choosing the most favourable opportunity depends upon
whether the search is expected to be profitable or not. The expected gains
from the search for customer \( t \) is given by (for \( t \in A_1 \))
\[
\varphi(p_1, t) = p_1 - \int_0^{\tilde{p}_1} [p_2 + c(t)] f(p_2) - \int_{\tilde{p}_1}^1 f(p_2) dp_2
\]

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where \( p_1 \) represents the observed value of \( p \) at location \( a \). Then customer \( t \) in \( A_1 \) (resp. \( A_2 \)) will search if and only if \( \varphi(p_1, t) \) (resp. \( \varphi(p_2, t) \)) is greater than zero; then he may buy from one or the other shop according as \( p_1 > p_2 \) (resp. \( p_2 > p_1 \)).

An important role in the following will be played by that price, -call it \( p^*(t) \) for \( t \in A_1 \) and \( p_2^*(t) \) for \( t \in A_2 \) - which, when observed at the nearest shop makes consumer \( t \) indifferent between buying instantaneously without search, and searching. It is easily found that

\[
p_1^*(t) = \sqrt{2c(L-b-t)} , \quad t \in A_1
\]

and

\[
p_2^*(t) = \sqrt{2c(t-a)} , \quad t \in A_2
\]

In order to have \( p_1^*(t) \) and \( p_2^*(t) \) in \([0,1]\) the condition \( L \leq \frac{1}{2c} \) is held throughout.

The next proposition describes the market outcome resulting from the situation just described when the two sellers choose their price in a non cooperative manner. To this end let us derive the (contingent) demand functions of both sellers \( D_1(p_1, p_2) \) and \( D_2(p_1, p_2) \). To simplify the analysis, consider figure 2, which describes the reservation prices, \( p_1^*(t) \) and \( p_2^*(t) \) as function of \( t \).

![Figure 2](image-url)
If \( p_1 \leq \sqrt{c(L-a-b)} = p_1^*(\frac{L+a-b}{2}) \), all customers \( t \) in \( A_1 \) who first visit seller 1 remain in his shop and buy from him since \( p_1 \leq p_1^*(t) \) for all \( t \in A_1 \). If \( \sqrt{c(L-a-b)} < p_1 < p_2 \), all customers in the set

\[
\{ t \mid p_1 \leq p_1^*(t) \} = \{ t \mid t \in A_1, p_1 \leq \sqrt{2c(L-b-t)} \} = [0, \frac{p_2^2}{2c}]
\]

still remain in the shop of seller 1, while customers in \([L-b-\frac{p_2^2}{2c}, -\frac{p_2^2}{2c}]\) leave and visit seller 2 where they find a price \( p_2 \) higher than \( p_1 \) : accordingly they come back to seller 1 and buy from him. Moreover customers in the set

\[
\{ t \mid t \in A_2; p_2^*(t) < p_2 \} \text{ who first visit seller 2 leave him and visit seller 1.}
\]

Since \( p_1 < p_2 \), they also buy from seller 1. Finally if \( \sqrt{c(L-a-b)} \leq p_2 < p_1 \), all customers in the set

\[
\{ t \mid t \in A_1 \} \cup \{ t \mid t \in A_2; p_2^*(t) < p_2 \}
\]

visit both shops, but buy from seller 2 (as a convention we shall assume that if both sellers quote the same price, each of them serves all customers the closest to him, i.e. \( A_1 \) for seller 1, and \( A_2 \) for seller 2). From this analysis, it follows that

\[
D_1(p_1, p_2) = \frac{L + a - b}{2}, \quad \text{if } p_1 \leq \sqrt{c(L-a-b)} \text{ and } p_2 \leq \sqrt{c(L-a-b)}
\]

\[
= a + \frac{p_2^2}{2c}, \quad \text{if } p_2 > \sqrt{c(L-a-b)} \text{ and } p_1 < p_2 < \sqrt{2c(L-a)}
\]

\[
= L - b - \frac{p_1^2}{2c}, \quad \text{if } p_1 > \sqrt{c(L-a-b)} \text{ and } p_2 < p_1 < \sqrt{2c(L-b)}
\]

\[
= \frac{L + a - b}{2}, \quad \text{if } p_1 = p_2 > \sqrt{c(L-a-b)}.
\]

Performing a similar analysis from the view point of seller 2 yields

\[
D_2(p_1, p_2) = \frac{L - a + b}{2}, \quad \text{if } p_2 \leq \sqrt{c(L-a-b)} \text{ and } p_1 \leq \sqrt{c(L-a-b)}
\]

\[
= b + \frac{p_1^2}{2c}, \quad \text{if } \sqrt{c(L-a-b)} < p_2 < p_1 < \sqrt{2c(L-b)}
\]

\[
= \frac{L - a + b}{2}, \quad \text{if } p_2 = p_1 > \sqrt{c(L-a-b)}
\]

\[
= L - a - \frac{p_2^2}{2c}, \quad \text{if } p_2 > \sqrt{c(L-a-b)} \text{ and } p_1 < p_2 < \sqrt{2c(L-a)}.
\]

We are now in a position to prove


PROPOSITION 2

There is a price equilibrium if, and only if,

\[ b + 3a \leq L \]  \hspace{1cm} (3)

and

\[ a + 3b \leq L \]  \hspace{1cm} (4)

and, whenever it exists, the price equilibrium is uniquely determined by

\[ p^* = p^*_1 = p^*_2 = \sqrt{c(L-a-b)} \]

**Proof:**

First let us show that there exists no pair of prices \((\tilde{p}_1, \tilde{p}_2) \neq (p^*, p^*)\) which is a price equilibrium. Assume on the contrary that the pair \((\tilde{p}_1, \tilde{p}_2)\) is a price equilibrium with \(\tilde{p}_i \neq p^*\) for at least some \(i, i = 1, 2\). It is easy to see that no \(\tilde{p}_i\) can be strictly smaller than \(p^*\): otherwise seller \(i\) could increase \(\tilde{p}_i\) while keeping in his shop all customers that are nearest to him, thereby increasing his revenue, a contradiction. Accordingly \(\tilde{p}_i \geq p^*\) and \(\tilde{p}_2 > p^*\) with at least a strict inequality for some \(i\). On the other hand, we must have \(\tilde{p}_1 = \tilde{p}_2\).

Assume on the contrary that \(\tilde{p}_1 > \tilde{p}_2\), say. Then \(D_2(\tilde{p}_1, \tilde{p}_2) = b + \frac{p_1^2}{2c}\), and

\[ \tilde{p}_2 \cdot (b + \frac{p_1^2}{2c}) < p_2 \cdot (b + \frac{1}{2c}) \]  \hspace{1cm} for \(\tilde{p}_2 < p_2 < \tilde{p}_1\), a contradiction. So assume finally \(\tilde{p}_1 = \tilde{p}_2 > p^*\). Then

\[ \tilde{p}_1 D_1(\tilde{p}_1, \tilde{p}_2) = \tilde{p}_1 \left( \frac{L+a-b}{2} \right) < (\tilde{p}_1 - \epsilon) \cdot D_1(\tilde{p}_1 - \epsilon, \tilde{p}_2) = (\tilde{p}_1 - \epsilon) \left( \frac{a+\frac{p_2^2}{2c}}{2c} \right), \]

for \(\epsilon\) sufficiently small, since \((a+\frac{p_2^2}{2c}) > \frac{L+a-b}{2}\). Consequently there exists no pair of prices different from \((p^*, p^*)\) which yields a price equilibrium.

Now let us show that \((p^*, p^*)\) is a price equilibrium if and only if both inequalities (3) and (4) hold simultaneously. To this end let us assume that \(p_2 = p^*\), and compute the revenue \(R_1(p_1, p^*) = \text{def} P_1 D_1(p_1, p^*)\) for seller 1. Then

\[ R_1(p_1, p^*) = p_1 \cdot \frac{L+a-b}{2} \]  \hspace{1cm} if \(p_1 \leq p^* = p_2\);

\[ = p_1 \cdot (L-b-\frac{p_1^2}{2c}) \]  \hspace{1cm} if \(p_1 > p^*\).

(the graph of \(R_1(p_1, p^*)\) is depicted on figure 3).
Consequently $p^* = p_1$ is a best reply against $p^* = p_2$ if, and only if, the solution $\hat{p}_1$ to the problem

$$\max_{p_1} p_1^2 (L-b-\frac{a}{2c})$$

is smaller or equal to $p^*$, i.e. iff $\hat{p}_1 = \sqrt{\frac{(L-b)^2}{3}} \leq \sqrt{c(L-a-b)} = \eta^*$, i.e. if and only if (3) holds. Similarly assume $p^* = p_1$ and compute the revenue $R_2(p^*,p_2) = p_2 D_2(p^*,p_2)$. As above, $p^* = p_2$ is a best reply against $p^* = p_1$ if, and only if, the solution $\hat{p}_2$ to the problem

$$\max_{p_2} p_2^2 (L-a-\frac{b}{2c})$$

is smaller or equal to $p^*$, i.e. iff $\hat{p}_2 = \sqrt{\frac{(L-a)^2}{3}} \leq \sqrt{c(L-a-b)} = \eta^*$, i.e. if, and only if, (4) holds.

Q.E.D.

Notice that if we restrict ourselves to symmetric locations (i.e. $a = b$), the pair of prices $(p^*, p^*)$ is a price equilibrium if, and only if, both firms are located outside the quartiles $(a = b \leq \frac{1}{4})$. Figure 4 depicts the set of location pairs $(a, b)$ for which $(p^*, p^*)$ is a price equilibrium.

On the other hand no price dispersion arises at equilibrium when it exists, exactly as in the homogeneous case; and again, no customer undertakes any search at equilibrium.
Finally, it is worth noticing, for further comparison, that performing a similar analysis, -but assuming that search costs are quadratic with respect to the distance- leads to drastically different conclusions. It can then be shown (see appendix) that a price equilibrium exists, if and only if, both firms are located at the two extremes of the road. To all pair of locations interior to the linear segment \([0,L]\) no price equilibrium exists.

4. CONCLUSION

In this paper we have analyzed how price competition operates when a 'subjective' price search, relying on a priori consumers' beliefs about prices, is substituted to the objective price search, relying on the knowledge of the true distribution of prices. In the first model (the 'homogeneous case' of section 2) the equilibrium price is either the monopoly price, or the price which makes each consumer indifferent between buying at that price at the local shop, or searching. An analogous conclusion has been reached by Reinganum (1979) in a model of objective price search with a continuum of firms. As for the results of the second model, -when the search behaviour is presented in a spatial framework-, they have to be confronted with Hotelling's original work (Hotelling (1929)) and another paper which the authors are completing (Gabszewicz and Garella (1985)). In both Hotelling's model, -where consumers are perfectly informed,- and in the present one, there is a wide domain of location parameters entailing the absence of price equilibrium. However the mechanisms which causes the existence of a price cycle, is very different in the two cases. In Hotelling's case, it relies on the incentive to each firm to undercut the price of its competitor when sellers are too close to each other; here, whatever the locations, the only possible equilibrium obtains at that price at which no consumer searches. But when firms are too close to
each other, the revenue at that pair of prices, is 'beated' by a higher price where the firm quoting that price looses some customers. Thus the beating strategy is not the undercutting price but, on the contrary, a price which is higher than the candidate for an equilibrium. The difference between the two models is even more apparent in the case where search costs are assumed to be quadratic with the distance. While a price equilibrium exists at all location pairs under perfect information about prices (see d'Aspremont et al. (1979)), a price equilibrium never exists under imperfect information (except in the degenerate case where firms are located at the two extremes of the line).

We have shown elsewhere (Gabszewicz and Garella (1985)) that if 'objective' price search, -meaning by this that consumers know the true distribution of prices,- is combined with a spatial framework, the nature of the price equilibrium is drastically different. First prices must necessarily be different at each shop; second, for the existence of an equilibrium, firms cannot be too far apart from each other; finally there is search at equilibrium. From these examples we may conclude that the existence of competition between firms and the resulting equilibrium configurations of prices and firms' locations show substantial differences when different consumers' price information patterns are assumed.
FOOTNOTES

1 Subscript 1 and 2 for prices must be interchanged in order to get $\varphi(p_2, t)$ for $t \in \Lambda_2$.

2 For any distance $x$, search costs are given by $cx^2$. 
APPENDIX

Consider the case where the cost of acquiring information about the price at the more distant of the two sellers is given by quadratic costs, i.e.

\[ c(t) = c[(L-b-t)]^2, \text{ if } t \in A_1 \]

\[ = c(t-a)^2, \text{ if } t \in A_2. \]

For \( t \in A_1 \), the expected gain from search for customer \( t \) obtains as

\[ \tilde{p}_1 - \left\{ \int_0^{p_1} [c(L-b-t)^2] dp_2 + \int_1^{c(L-b-t)^2} c(L-b-t)^2 dp_2 \right\} \]

if the price \( \tilde{p}_1 \) is observed at shop 1. Consequently, the price \( p_1^*(t) \) which makes consumer \( t \), \( t \in A_1 \), indifferent between buying instantaneously without search and searching, is given by

\[ p_1^*(t) = 2 \sqrt{c(L-b-t)}. \]

Similarly, the price \( p_2^*(t) \) which makes consumer \( t \), \( t \in A_2 \), indifferent between buying instantaneously at shop 2, without search and searching is given by

\[ p_2^*(t) = 2 \sqrt{c(t-a)}. \]

If \( p_1 < \sqrt{c(L-a-b)} = p_1^*(\frac{L+a-b}{2}) \), all consumers \( t \) in \( A_1 \) who first visit seller 1, remain in his shop and buy from him since \( p_1 < p_1^*(t) \) for all \( t \) in \( A_1 \). If \( \sqrt{c(L-a-b)} < p_1 \) all customers in the set

\[ \{t|p_1 < p_1^*(t)\} = \{t|t \in A_1, p_1 < 2 \sqrt{c(L-b-t)}\} = \{0,L-b, \frac{L}{2\sqrt{c}}\} \]

still remain in the shop of seller 1, while customers in \( \{L-b, \frac{L}{2\sqrt{c}}, \frac{L+a-b}{2}\} \) leave and visit seller 2.

Now assume that seller 2 quotes \( p_2^* = \sqrt{c(L-a-b)} \). If seller 1 quotes a price \( p_1 \) smaller than \( p_2^* \) his revenue is equal to \( p_1 \cdot \frac{L+a-b}{2} \), while if he quotes a price \( p_1 \) higher than \( p_1^* \), his revenue is equal to \( p_1 (L - b \frac{1}{2\sqrt{c}}) \). Accordingly \( p_1 = p_2^* = \sqrt{c(L-a-b)} \) is a best reply against \( p_1^* \) if and only if the solution \( \tilde{p}_1 \) to the problem

\[ \max_{p_1} p_1 (L-b \frac{p_1}{2\sqrt{c}}) \]

is smaller or equal to \( \sqrt{c(L-a-b)} \), i.e. iff \( \tilde{p}_1 = \sqrt{c(L-b)} \leq \sqrt{c(L-a-b)} \), a condition which can be satisfied if and only if \( a = 0 \).
A similar analysis performed from the viewpoint of seller 2 shows that
\[ p_2 = \sqrt{L-a-b} \] is a best reply against \[ p_1^* = \sqrt{L-a-b} \] if, and only if, \( b = 0 \).
Accordingly the pair of prices \( (\sqrt{L-a-b}, \sqrt{L-a-b}) \) is a price equilibrium
only if both sellers are located at the two extremes of the road.

On the other hand, using arguments similar to those used in the beginning
of the proof of proposition 1, leads to the conclusion that no other pair of
prices can be a price equilibrium. In conclusion, there exists no price equilibrium
when information costs are quadratic, except in the degenerate case where both
sellers are located at the two extremes of the road.
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