SIGNALLING PRICE IMAGE USING
ADVERTISED PRICES

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This paper addresses the issue of retail price image by offering an explanation for how and when stores can use their advertised prices to signal the prices of other products in the store. A model of a two-product retail market is presented in which stores advertise the price of one product and customers do not know the price of the other product before selecting which store to visit. In a model with full customer information, stores with different marginal costs charge different prices for each product. When customers do not know each store's marginal cost type, an opportunity arises for each store to signal its cost type using its advertised prices. In such a model, additional equilibria exist. In particular, stores with different costs may charge the same advertised price while continuing to charge different prices for the unadvertised product. Data from competing drycleaning stores is generally consistent with the model predictions. A number of additional properties of the equilibria are discussed and possible extensions to the model are proposed.

(Signalling; Pricing; Price Image; Advertising)

Introduction

A typical supermarket stocks more than 25,000 products but advertises fewer than 200 of these products and prices.\(^1\) Advertising influences store choice by setting price expectations for the advertised products. Store choice may be influenced further if the advertised prices allow customers to form reliable inferences about the prices of the unadvertised products. There is widespread belief in both the industry\(^2\) and the literature\(^3\) that customers do use advertised prices to form expectations about the prices of other products. However, there is no theory explaining how this can occur. What prevents high-priced stores from advertising the same prices as low-priced stores, thus making it impossible for customers to form a meaningful inference?

This paper offers an explanation for how and when stores can use their advertised prices to signal the prices of other products in the store. The underlying rationale is that stores can only afford to advertise low prices if the stores are relatively efficient. When these efficiencies affect many products in the store's product range,\(^4\) then customers may find that the efficient stores also charge lower unadvertised prices.

\(^{1}\) To advertise more would incur unsustainable advertising costs and/or diminish the effectiveness of the advertising.

\(^{2}\) This paper was motivated by discussions with executives of several supermarket chains.


\(^{4}\) Consider for example purchasing power or distribution efficiencies.
Feichtinger et al. (1988) investigate the interaction of pricing and advertising strategies when different products have different influences on customers' overall price expectations for a store. The authors show that if lower prices are needed to enhance price expectations then price promotions should be accompanied by a relatively low level of advertising. Customers do not ignore their previous experience when interpreting the advertising. Rather, high price expectations reduce the impact of advertising so that low advertised prices are a more credible signal when price expectations are favorable.

The use of advertising to commit to a sample of advertised prices has been used to explain loss leader behavior and has received extensive attention in the literature. Empirical studies can be found in Walters (1988) and Walters and MacKenzie (1988), both of which report that some, but not all, loss leaders increase store profit by stimulating store traffic. Theoretical contributions have been made by Gerstner and Hess (1990), Hess and Gerstner (1987) and Lal and Matutes (1994). Gerstner and Hess (1990) discuss bait and switch pricing, in which retailers advertise low-priced understocked brands and convince customers to purchase higher-priced substitutes. Hess and Gerstner (1987) illustrate increased sales of complements, while Lal and Matutes (1994) portray additional sales of goods with independent demands.

The latter paper analyzes the pricing and advertising strategies of two firms when store choice relies on advertised prices and expectations of the unadvertised prices. Both firms advertise the same good and in equilibrium commit themselves to charging relatively low prices for that product while setting relatively high prices for the unadvertised good. This result relies on an assumption of symmetry across goods and firms and is limited to the case in which customer expectations about unadvertised prices are the same for all goods and firms. Customers have no need to update their expectations about unadvertised prices after seeing the advertised prices, as they recognize that it is optimal for stores to set the unadvertised prices at their customers' common reservation levels.

All of these theoretical contributions either assume perfect information or define customers' price expectations exogenously. Consequently, the literature lacks a formal investigation of the role that advertising plays in signalling the prices of unadvertised products. The model presented in this paper will investigate price signalling effects. It will be shown that the unique pure strategy equilibrium in a full customer information model only exists in a portion of the parameter space when customers have incomplete information. Price signalling results in the existence of two additional pure strategy equilibria and provides a further explanation for loss leader behavior.

A formal model of a retail market is presented in §1, and a full customer information model is analyzed in §2. The additional impact of price signalling is investigated in §3 by introducing incomplete customer information, while testable properties of the various equilibria are reviewed in §4. Section 5 describes an empirical test of some of the model predictions, and the paper concludes with a summary of the findings and a discussion of opportunities for further research.

1. A Model of a Retail Market

A model of a multiproduct market incorporating imperfect information and both demand and supply sided heterogeneities is constructed. An economic representation of this market will demonstrate the influence that price has upon customer store selection and competitors' price responses.

Consider two stores competing for heterogenous customers. The stores are differentiated and the customers are heterogenous on the same dimension, so that (with no additional information) different customers a priori prefer different stores. The differentiation and heterogeneity may reflect either location or consumer preferences. For example, consumers may place different levels of importance on different store attributes, such as
product availability, cleanliness, and length of queues, while stores may vary in these attributes. For ease of exposition, it will be assumed that location is the basis of customer heterogeneity and store differentiation. Let the stores be located at the two ends of a linear city \([0, 1]\) with a unit mass of customers distributed between them. Assume that the distribution of customers between the two stores is uniform.

The stores sell two products labelled \(a\) and \(b\). The stores advertise the price of product \(a\). Without loss of generality the advertising cost for each store is set to zero. Customers incur a constant marginal travelling cost equal to \(t\). It is assumed that customers visit only one store.

The products are homogenous between stores; thus the utility that customers enjoy when consuming a product does not depend on where the product was purchased. Within store demand for each product is independent but differs between the products. Customers have unit demand for product \(a\) subject to a reservation price.\(^5\) For product \(b\), customer surplus and demand are defined as follows:

\[
U^*_b(p^*_b) = f(p^*_b, q^*_b(p^*_b)), \quad \text{where}
\]

\(U^*_b = \) the surplus customers derive from purchases of product \(b\) when shopping at store \(j\);

\(p^*_b = \) the price charged for product \(b\) by store \(j\);

\(q^*_b = \) the quantity of product \(b\) purchased from store \(j\) by each customer; and

\[
\frac{\partial f}{\partial q^*_b} > 0; \quad \frac{\partial f}{\partial p^*_b} < 0; \quad \text{and} \quad \frac{\partial q^*_b}{\partial p^*_b} < 0 \Rightarrow \frac{df}{dp^*_b} < 0. \tag{2}
\]

The stores may be of a high or a low cost type. The marginal costs for each good are perfectly correlated, so a low cost store enjoys cost efficiencies over a high cost store when selling both product \(a\) and product \(b\). The correlation between marginal product costs is reflected by:

\[
\theta^j = (c^*_a, c^*_b), \quad \theta^j \in \{\theta, \bar{\theta}\}, \quad \bar{\theta} = (\bar{c}_a, \bar{c}_b), \quad \theta = (c_a, c_b),
\]

\(\theta^j = \) the cost type of store \(j\); and

\(c^*_a(b) = \) the cost of each unit of product \(a\) \((b)\) to store \(j\).

The profit earned by a store from sales of product \(b\) to each customer is equal to revenue minus costs:

\[
\pi^b(p^b, c^b) = p^b q^b(p^b, c^b) - C(q^b(p^b, c^b)), \quad \text{where}
\]

\[C(q^b(p^b, c^b)) = C(q^b(p^b, c^b)), \quad \text{and}
\]

\[
\frac{\partial C(q^b(p^b, c^b))}{\partial q^b} > \frac{\partial C(q^b(p^b, c^b))}{\partial q^b} \tag{5}
\]

Overall store profit and customer surplus are equal to

\[
\pi^j = N^j[q^a(p^a - c^a) + \pi^b(p^b, c^b)],
\]

\[U^j = q^a(v_a - p^a) + U^b(p^b) - t|j - j|, \quad \text{where}
\]

\(N^j = \) the proportion of customers who shop at store \(j\);

\(v_a = \) the customers’ value parameter for product \(a\);

\(\footnote{Unit demand functions are common in the marketing and economics literature. Recent examples in the literature include: Narasimhan (1988), Lal and Matutes (1989), Gerstner and Hess (1990), Klemperer (1992) and Lattin and Ortmeyer (1991). The use of a unit demand in this instance greatly simplifies the analysis with little influence on the results (see note 10 below).}
$i$ is the location of customer $i$, $i \in [0, 1]$; and

$j$ is the location of store $j$, $j \in \{0, 1\}$.

Unit demand for product $a$ requires that for each customer: $q^i_a$ equals one if $v^i_a > p^i_a$, and equals zero otherwise. The market begins with the stores simultaneously setting prices for both goods and advertising the price of good $a$. Customers observe the advertised prices and select a store to visit. On arrival at the chosen store they observe the posted price of good $b$ and decide on purchase quantities for each product. Stores cannot change the price of product $a$ after it has been advertised and must charge all customers the same prices.

**Sequence of actions**

- **0** Stores set $p_a$ and $p_o$
- **1** Customers observe $p_a$
- **2** Customers select a store to visit
- **3** Customers visit the store and observe $p_o$
- **4** Customers select purchase quantities

### 2. A Model Without Price Signalling

A model without price signalling will be presented first in order to provide a benchmark for later evaluating the role of signalling. Signalling is excluded from this initial model by assuming that customers know each store’s cost type before they decide where to shop. To permit comparison with a signalling model, full information does not extend to the stores: while each store knows its own cost type it will be assumed that neither store knows the cost type of its competitor. Instead, each store believes (without loss of generality) that its competitor is equally likely to be a high or a low cost store. While it is acknowledged that assuming that customers know each store’s cost type but the competing store does not is unrealistic, if both store and customer knowledge were allowed to vary between this model and the later signalling model, the impact of signalling would be less apparent. This assumption is therefore convenient and has no meaningful impact on the results.

On arrival at a store, all customers behave in the same manner. Heterogeneities between customers influence their store selection but do not affect their product selections. If $v^i_a > p^i_a$ they will each select one unit of product $a$. For simplicity, the paper will focus on markets in which $v_a$ and the surplus derived from purchases of product $b$ are sufficiently high to ensure that all customers prefer to participate in the market, rather than choosing not to shop at all.

In equilibrium, stores will charge (and customers will expect stores to charge) their profit maximizing prices for the unadvertised product. From the first order condition for equation (3) we can derive $p_{b}^{i*}(c_{b})$: the store’s profit maximizing monopoly price for product $b$ (as a function of the store’s cost type). Substituting equations (4) and (5) into equation (3) and the first order condition for (3) we see that

$$p_{b}^{i*}(c_{b}) > p_{b}^{i}(c_{b})$$

An alternative approach would be to assume that in both models the stores do recognize their competitor’s cost type. However, this would create an opportunity for stores to signal both their own cost type and the cost type of their competitor through their advertised prices.

A store cannot gain from charging less than its profit-maximizing price for product $b$ because customers must make their store selection decisions before they are able to learn that a store has reduced its price for this product.
and that
\[ \pi_b'(p_b^r(c_b^h), c_b^h) < \pi_b'(p_b^r(c_b^l), c_b^l). \]  

Because the surplus that customers derive from purchases of product \( b \) is a decreasing function of \( p_b^r \), equation (6) implies that:
\[ U_b'(p_b^r(c_b^h)) < U_b'(p_b^r(c_b^l)) \]  

Low cost stores charge a lower price for product \( b \) and earn more profit from sales of that product to each customer than do their high cost counterparts. As a result, customers enjoy greater surplus when purchasing product \( b \) from a low cost store. Later analysis will be simplified by making the following substitutions:
\[ \begin{align*}
&\pi_b'(p_b^r(c_b^h)) = k, \\
&\pi_b'(p_b^r(c_b^l)) = \bar{k}, \\
&\pi_b(p_b^r(c_b^h), c_a) - c_a = w, \\
&\pi_b(p_b^r(c_b^l), c_a^l) - c_a = \bar{w}, \quad \text{and} \quad W = \bar{w} - w.
\end{align*} \]

\( K \) may be interpreted as the additional surplus that a customer derives when purchasing the unadvertised product at a low cost rather than a high cost store. \( W \) represents the additional profit earned from each customer by low cost stores over the corresponding profit earned by high cost stores, net of the sales revenue from the advertised product. Note that equations (7) and (8) imply that \( W > 0 \) and \( K > 0 \) (respectively).

Consider how changes in the price of product \( a \) affect store profit. A decrease in the price of product \( a \) decreases the revenue received from each customer’s unit purchase of product \( a \) and attracts more customers to the store because the store has committed itself to charging less for product \( a \). The unique pure strategy optimal price for stores of each cost type can be found by defining each store’s expected market share as a function of the relative prices, calculating the respective first order conditions and equating the resulting reaction functions. Parameter representations of the optimal advertised prices for high cost \( (H^F_L) \) and low cost \( (L^L_F) \) stores are set out in Appendix 1. The difference between these prices is equal to:
\[ H^F_L - L^L_F = \frac{1}{2}(W - K) \]

When \( W \) is large, low-cost stores set a lower unadvertised price than high-cost stores because they benefit more from attracting additional customers to the store. Alternatively, when \( K \) is large, low-cost stores do not need to set the unadvertised price as low in order to attract customers, and, instead, they are able to charge a premium and extract some of the additional surplus that customers enjoy from shopping at their store.

The intuition in the remainder of the paper will argue that, when customers do not know store cost types a priori, low-cost stores may signal their cost type to customers by lowering their advertised price. Although it is possible to develop an equilibrium of this type without assuming that \( H^F > L^F \), we will adopt this assumption for the remainder

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8 See equation (2).

9 Readers should exercise caution and note that \( k \) and \( \bar{k} \) correspond to a high cost store, while \( \bar{k} \) and \( \bar{w} \) are associated with a low cost store.

10 If a downward sloping demand replaces the unit demand for product \( a \), a decrease in the price of product \( a \) will have the additional consequence of increasing the quantity of product \( a \) purchased by each customer. However, total expenditure by each customer will still decrease as long as marginal revenue is greater than zero. In the region of an optimal price, marginal revenue will always exceed zero as the marginal gain from customers switching to the store is always positive (except in a degenerate case where one of the stores has zero market share) and at an optimum price these two marginal effects are equal. Therefore, introduction of a downward sloping demand for product \( a \) gives an analogous result.

11 Recall that neither store knows its competitor’s cost type.

12 If \( H^F < L^F \), only a costly signalling equilibrium would be consistent with this intuition. A cheap separating equilibrium (if feasible) would result in a high-cost store charging a lower advertised price than a low-cost store (see later discussion).
of the paper. This implies that \( W > K \), so that the model is more likely to apply to markets in which the profit that stores earn from sales of unadvertised products is relatively sensitive to the store's cost type. This assumption excludes the possibility that low-cost stores charge higher prices than high-cost stores when customers have complete information, but lower prices than high-cost stores when customers are uncertain of competing stores' cost types.

3. Signalling

When customers are uncertain of a store's cost type an opportunity arises for the store to use its advertised price to signal its cost type (and the price of its unadvertised product). To investigate price signalling, customer uncertainty is introduced by disregarding the assumption that each store's cost type is common knowledge. It will now be assumed that while each store knows its own type, neither the competing store nor the customers can observe a store's cost type. The competing store and customers are assumed to have the same prior beliefs about each store's type and, without loss of generality, the prior beliefs will be that each cost type is equally likely.

The intuition proposed in this section relies on the assumption that customers do not know the prices of all products at each retail location but instead rely on an overall price image for the store. When customers do know all of the prices, there is no need to signal unadvertised prices, and the market will be expected to revert to the full customer information equilibrium described in the previous section. This may occur if the purchase occasion is repeated frequently or when stores are located very close to each other (so that customers are able to visit each store before deciding where to purchase).

Customers are less likely to have full price information if the purchase occasion occurs infrequently, as in the purchase of durables such as furniture, stereo equipment or computers. Customers may also exhibit imperfect memory if the effort of learning all of the prices outweighs the expected benefit. This may occur when there are so many products at a store (recall that a typical supermarket stocks more than 25,000 SKUs) or the cost to the consumer of an incorrect price expectation is low (few customers know all of the prices charged by their local dry-cleaners). Price signalling may also be relevant if there are many new customers entering the market (as in the petrol and airport rental car markets) or in markets such as the fruit and vegetable industry in which marginal costs change frequently.

Alike the full customer information model, in equilibrium, stores charge (and customers expect stores to charge) their profit maximizing monopoly prices when setting their unadvertised prices. Because customers earn more utility when they purchase product \( b \) at a lower price,\(^{13}\) customers would like to know each store's cost type when deciding which store to visit. In this model the only information customers have available from which to infer a store's cost type is the store's advertised price.

An additional profit implication may now be observed upon a change in the price of product \( a \). Changes in the advertised price may result in a revision of customers' beliefs as to the store's cost type, which will influence the number of customers that switch between competing stores. A change in customer beliefs also changes the advertised price that a store would like to be able to charge. If customers' believe that it is likely that a store is low cost, then the advertised price does not need to be as low in order to attract customers.

Before formally summarizing this discussion in Finding 1 it is useful to introduce a standard notation for representing store profit. Let \( \pi(P, \gamma, \theta) \) represent the profit earned by a store of cost type \( \theta \)^{14} charging \( P \) for product \( a \), when customers believe that the

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\(^{13}\) Recall that \( k > k \).

\(^{14}\) Where \( \theta \in \{\theta, \tilde{\theta}\} \).
store is high cost with probability \( \gamma \) and that the store's competitor is pricing at its equilibrium price. The analysis need only consider unilateral deviations from a proposed equilibrium, so including arguments describing the competitor's pricing strategy and/or customer's beliefs about the competitor's cost type is unnecessary.

In Finding 1, the prices \( P_1, P_{1/2} \) and \( P_0 \) are the prices at which the profit functions \( \pi(P, 1, \theta), \pi(P, \frac{1}{2}, \theta) \) and \( \pi(P, 0, \theta) \) (respectively) are maximized. A formal proof for this finding is obvious when the market share functions are substituted into the store profit functions (see Appendix 1). It should be noted that Finding 1 is not an equilibrium result because in equilibrium the advertised price levels do influence customers beliefs.

Finding 1. Independent of the effect of price on customers' beliefs, as customers become more confident that a store is a low-cost type, the store (whether a high or low-cost store) would like to charge higher prices for product \( a \), \( P_1 < P_{1/2} < P_0 \), and earns greater total profits, \( \pi(P, 1, \theta) < \pi(P, \frac{1}{2}, \theta) < \pi(P, 0, \theta) \) for all \( P \).

It will be assumed that customers adopt the intuitive criterion to eliminate unrealistic beliefs. Under this criterion, customers believe that a store will only deviate from an equilibrium price if it is possible for the store to profit from the deviation. Store types which cannot gain from an observed deviation, even if the deviation resulted in the most favorable customer beliefs (that the store is a low cost type), are thought not to be the deviating store. For some deviations the intuitive criterion may eliminate both cost types or may not eliminate either type. If so, assume that customers continue to maintain their prior beliefs about the deviating store's cost type, unless (given those prior beliefs) only one cost type can gain by deviating. If only one cost type can benefit from a deviation, then a deviating store is believed to be the type for which such a deviation may be profitable.

The utility relationships summarized in Figure 1 will be used to illustrate conditions for the existence of two types of pure strategy equilibria in which both stores have positive market share and customers purchase positive quantities of both goods. The first is a fully separating equilibrium, with stores of different types charging asymmetric prices for both goods. Customers are able to correctly infer each store's cost type from the advertised prices before selecting which store to visit. In the second, stores of different cost types advertise and charge the same price for product \( a \), while continuing to charge different prices for product \( b \). Under this partially pooling equilibrium, customers learn no additional information about the stores' cost types from the advertised prices.

In a separating equilibrium, high-cost stores can pretend to be low cost by advertising the same price for product \( a \) that a low cost store would charge. Such a strategy is costly because the store must charge a lower price for product \( a \) than it would like. The strategy may be profitable, however, if convincing customers that the store is low cost results in a sufficient increase in store traffic. In order to sustain a separating equilibrium, a high-cost store must prefer not to mimic a low-cost store. Figures 2 and 3 demonstrate two circumstances in which this condition is satisfied.

In Figure 2 the proposed equilibrium prices are \( H^Ch \) and \( L^Ch \) for high and low-cost stores respectively. When a low cost store charges \( L^Ch \), which is the low-cost store's profit maximizing price (when customers believe that the store is low cost), a high-cost store must charge \( L^Ch \) to convince customers that it too is low cost. When charging \( L^Ch \) it

15 Defined with respect to Figure 1.
17 Attention is restricted to equilibrium in which \( u_k \) exceeds \( p_j \) for all \( j \in \{0, 1\} \).
18 The stores always maximize their in-store monopoly profits when setting the price of product \( b \), see earlier discussion.
19 An implication of both Finding 1 and the assumption that, in the absence of signalling, high cost stores prefer to advertise a higher price than low cost stores.
FIGURE 1.

FIGURE 2. Existence of a Cheap Separating Equilibrium.
expects to earn $\pi(L^c, 0, \hat{\theta})$, which is strictly less than what the store can expect to earn if it reveals itself to be high cost, $\pi(H^c, 1, \hat{\theta})$. Therefore, $\pi(L^c, 0, \hat{\theta}) < \pi(H^c, 1, \hat{\theta})$ represents a sufficient condition for a separating equilibrium. This equilibrium results in stores of each cost type charging the same prices as stores in the full customer information model.

When this condition is not satisfied, a low cost stores may choose to lower its advertised price in order to further dissuade a high cost store from mimicking it. In Figure 3, the proposed equilibrium prices are $H^c$ and $L^c$. The low cost equilibrium price, $L^c$, is located at the price at which the profit function $\pi(P, 0, \hat{\theta})$ equals $\pi(H^c, 1, \hat{\theta})$. Because the high-cost store can always charge $H^c$ and reveal itself to be high cost, $L^c$ represents the lowest price that the high cost store would be willing to charge in order to convince customers that it is low cost. In order to ensure that customers can correctly identify their cost type, low cost stores must lower their advertised price to the price at which high cost stores would no longer prefer to mimic them ($L^c$). Alternatively, low cost stores may prefer to charge an advertised price that maximizes their profits when customers are uncertain of the store’s cost type, $P_1$. Therefore, a separating equilibrium may also exist when $\pi(L^c, 0, \hat{\theta}) > \pi(P_1, \frac{1}{2}, \hat{\theta})$.

To facilitate later discussion, the separating equilibrium corresponding to Figure 3 will be described as the costly separating equilibrium. The separating equilibrium depicted in Figure 2 will be referred to as the cheap separating equilibrium. The equilibrium beliefs that underlie each equilibrium are depicted in Appendix 2.

**Proposition 1.** A cheap separating equilibrium exists if

\[
\pi(H^c, 1, \hat{\theta}) > \pi(L^c, 0, \hat{\theta}), \quad (C1)
\]

\[
L^c > 0. \quad (C2)
\]

Assuming that all prices are positive (see Condition C2 which follows).

Under the process by which customers update their beliefs defined earlier, customers revert to their prior beliefs when they are unable to identify the store’s cost type from the advertised prices.
When condition C1 is not satisfied, a costly separating equilibrium exists if condition C2 is satisfied, and

$$\pi(L^{C_o}, 0, \theta) > \pi(P_1, \frac{1}{2}, \theta).$$

(C3)

Condition C2 ensures that it is possible to find a positive equilibrium price for low-cost stores. Parameter representations of all of these conditions may be found in Appendix A.

Care should be exercised when comparing Figures 2 and 3 as the expected utility functions in each figure differ. A store’s expected utility depends on the prices that a competing store is expected to charge. In the cheap separating equilibrium, low-cost stores are able to set their prices at the profit maximizing price for a store recognized to be low cost. In the costly separating equilibrium, low cost stores are restricted to a price of $L^{C_o}$. The difference between these low cost equilibrium prices results in different profit maximizing prices for separating high-cost stores; in general $H^{C_h} \neq H^{C_o}$. An exception arises if $\pi(L^{C_h}, 0, \theta) = \pi(H^{C_h}, 1, \theta)$. When this occurs both types of separating equilibria predict the same equilibrium prices.

Under a pooling equilibrium both stores charge and advertise the same price for product $a$, so customers rely on their prior beliefs about each store’s cost type when deciding which store to visit. It was earlier assumed that when stores with different costs face the same customer beliefs, the low-cost stores will wish to charge a lower price for product $a$ than the price charged by high-cost stores. Using this assumption and Figure 4, it can be shown that a pooling equilibrium may exist with both high and low-cost stores charging $P^{P_o}$.

Under the intuitive criterion, if a store charges a price in the region $[P_2, P_3)$ customers will believe that the store is low cost because only low-cost stores can earn more than their equilibrium profit by pricing in this region. Both high and low-cost stores would be willing to deviate in the region $[P_3, P^{P_o})$ if as a result customers believed that the store was low cost. Because the intuitive criterion does not eliminate either cost type, customer’s beliefs revert to their priors, under which neither cost type earns more than its equilibrium profit.

In the region $(P^{P_o}, P_3]$ the intuitive criterion again does not eliminate either cost type, but when customers’ beliefs revert to their priors, high cost stores earn more than their equilibrium profit by pricing in this region. Therefore, under the belief refinement discussed earlier, customers believe that a store deviating in this region is a high cost store. Prices greater than $P_3$ and prices less than $P_4$ never result in customers believing that the store is low cost and it is not possible for either cost type to benefit by pricing in these regions.

The only profitable deviation from a pooling equilibrium at $P^{P_o}$ is for low-cost stores to charge a price in the region $[P_2, P_3)$. For a pooling equilibrium to exist, $P_3$ must be less than zero, preventing a low-cost store from pricing at or below this point. A formal proof that the pooling equilibrium requires $P_3 < 0$ (which is implied by $P_2 < P_3$) is contained in the proof to Result 2(b) in Appendix 3. This condition implies that the profits earned from the sale of product $b$ are large enough to make the high-cost stores willing to give away product $a$ in order to attract customers by appearing to be a low-cost store.

22 If $L^{C_h} < 0$ a low cost store can charge zero for its advertised product. In these circumstances a cheap separating equilibrium continues to exists as long as high cost stores do not want to mimic (which is satisfied whenever $L^{C_o} > 0$).

23 This condition is perhaps conservative as arbitrage opportunities probably limit the price of product $a$ to a level strictly greater than zero.

24 See later discussion.

25 Or sell for less than some limiting arbitrage price.
Two further conditions are required to establish the existence of a pooling equilibrium. High-cost stores must prefer the profit they expect to earn by charging $P^{po}$, and hiding their cost type, to the maximum profit they can earn when their unfavorable cost type is revealed: $\pi(P^{po}, \frac{1}{2}, \bar{\theta}) > \pi(P_4, 1, \bar{\theta})$. Furthermore, the equilibrium pooling price, $P^{po}$ must not be negative.

**Proposition 2.** A pooling equilibrium exists if

\[ P_3 < 0, \]
\[ P^{po} > 0, \]
\[ \pi(P^{po}, \frac{1}{2}, \bar{\theta}) > \pi(P_4, 1, \bar{\theta}). \]

Parameter representations of these conditions are presented in Appendix 1.
4. Testable Properties of the Equilibria

In the full customer information model, a unique pure strategy equilibrium exists in which stores predict their competitors' prices and set profit-maximizing prices in response. This results in high-cost stores charging higher prices than low-cost stores for both products.

When customers are uncertain of stores' cost types, an opportunity arises for each store to signal its cost type to the customers through its advertised prices. A *cheap* equilibrium corresponding identically to the full customer information equilibrium may exist. Both store types prefer to reveal their cost types, fully and they each charge their profit maximizing prices. However, this equilibrium only exists in a limited region of the parameter space because eventually high-cost stores prefer to charge the low-cost store's profit maximizing price in order to avoid revealing their unfavorable cost type. When this occurs, two further pure strategy equilibria are possible. A *costly* separating equilibrium may exist in which low-cost stores reduce their advertised prices in order to protect their low cost image. In addition, there is potential for a pooling equilibrium in which stores of different types charge the same advertised price while continuing to charge different unadvertised prices.

Investigation of the equilibria and their necessary conditions yields a number of additional insights. The results describe predictions yielded from the full customer information and signalling equilibria described above. Additional equilibria may exist, including mixed strategy equilibria, for which some of these results may not hold. The results are discussed in the text, while the proofs may be found in Appendix 3.

When would we expect to see competing stores charging different advertised or unadvertised prices?

**RESULT 1.** Identical unadvertised prices is a sufficient but not a necessary condition for identical advertised prices.

In Section 2 it was shown that $p^*_b(c'_b) > p^*_b(c'_b)$ (see equation (6)) so competing stores would only be expected to charge the same unadvertised prices if they have the same cost type. Stores with the same cost type would also be expected to charge the same advertised price so identical unadvertised prices is a sufficient condition for identical advertised prices. It is not a necessary condition, however. Stores of different cost types may be competing in a pooling equilibrium in which case their advertised prices may be the same although their unadvertised prices differ.

**RESULT 2.** (a) Pooling equilibria cannot exist in the same conditions as cheap separating equilibria.

(b) Low cost stores always prefer to deviate from a pooling equilibrium and reveal their favorable cost type to customers.

(c) Low cost stores expect to earn more profit in a cheap separating equilibrium (or when customers know their cost type) than in a pooling or a costly separating equilibrium.

For a pooling equilibrium to exist, high-cost stores must earn more when pooling than what they earn when their unfavorable cost type is revealed (Condition C6). For a cheap separating equilibrium to exist, high-cost stores must prefer to reveal their high cost type rather than mimic the price charged by low cost stores (Condition C1). These two conditions are mutually exclusive. Mimicking a low-cost store results in more favorable customer beliefs than pooling, yet it is achieved at a lower cost. By pooling, a high-cost

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26 The paper only considers pure strategy equilibria. Mixed strategy equilibria are possible, and indeed expected, in the regions in which the pure strategy equilibria can not exist.

27 This result would not hold if customers had unit demand for the unadvertised product because both stores would charge the customers' reservation price for that product giving $p^*_b(c'_b) = p^*_b(c'_b)$. This exception can only arise when customer demand is not continuously differentiable in price which is inconsistent with the assumption in equation (2).
store is able to prevent customers from recognizing its cost type, but customers simply revert to their prior beliefs. When mimicking, a high-cost store is able to convince customers that it is low cost. Consistent with Finding 2, the price reduction required to pool in a pooling equilibrium is greater than the price reduction required to mimic in a cheap separating equilibrium: \( P_4 - P^{Po} \) is greater than \( H^{Ch} - L^{Ch} \). As a result, if a high cost store prefers to pool, it will also prefer to mimic a low cost cheap separating store.

Low-cost stores earn more profit per customer than their high cost competitors. For this reason, a low-cost store is always willing to offer a deeper discount (in the advertised price) than a high cost store in order to deviate from a pooling equilibrium and convince customers that it is low cost \( (P_2 < P_3) \). A pooling equilibrium can only exist if arbitrage opportunities or nonnegative price constraints prevent the low-cost store from discounting to a price level that high-cost stores would not mimic (Condition C4).

The high cost equilibrium price is higher in a cheap separating equilibrium than a pooling equilibrium \( (L^{Ch} > P^{Po}) \) that enables low-cost stores to also charge a higher price \( (P_L^{Ch} > P^{Po}) \). Notwithstanding, low-cost stores expect to attract larger market shares in a cheap separating equilibrium, because customers recognize that they are low cost and their advertised price is lower than high-cost competitors. Expected profits for a low-cost store, therefore, are higher under a cheap separating equilibrium than in a pooling equilibrium. As the label implies, low-cost stores also expect to earn more under a cheap separating equilibrium than under a costly separating equilibrium because they are able to charge their profit maximizing price rather than being forced to discount in order to avoid being mimicked.

**RESULT 3.**  
(a) All equilibria predict that advertised prices for both high and low cost stores are higher when travelling costs are high and that unadvertised price levels are independent of travelling costs.
(b) The difference in advertised prices charged by separating stores of different cost types is a continuous monotonically increasing function of the cost of travelling between stores.
(c) The difference in unadvertised prices charged by separating stores of different cost types is independent of the cost of travelling between stores.
(d) Differences in expected market share between separating stores of different cost types are lower when travelling costs are high.

When travelling costs are high customers are not willing to travel as far in order to visit a store with a low price image. As a result, expected market shares are less sensitive to price differences, and stores of both cost types concentrate more on increasing the revenue they earn from their local customers when setting their advertised prices. Consistent with this argument, differences in expected market share and the average distance travelled are expected to be higher when travelling costs are low. Unadvertised prices do not influence expected market shares and are therefore independent of travelling costs.

When expected market shares and profits are less sensitive to price differences, low cost stores are forced to offer deeper discounts in order to avoid being mimicked by high cost stores. As a result, price differences between high and low cost stores in a costly separating equilibrium increase when \( t \) is high:

\[
H^{Co} - L^{Co} = \left( \frac{K^2}{4} + 4tK \right)^{1/2} - \frac{3K}{4}.
\]

This result is tempered by the lessened impact of customer beliefs on store profit, which reduces the willingness of high cost stores to reduce profit in order to attract customers.

\[28\] The average travelling cost is a strictly increasing monotonic function of the difference in expected high cost and low cost market shares.
When customers have unit demand for the advertised product, cheap separating and full customer information equilibria predict that price differences between high and low cost stores are independent of travelling cost. Introduction of downward sloping customer demand for the advertised product may alter this finding and result in price differences which are higher when travelling costs increase.

**RESULT 4.** (a) Market share differences between separating stores of different cost types are lower when there is less difference in the surplus that each customer derives from purchases of unadvertised products at these stores.

(b) High costs stores find it less attractive to hide their identity (by either pooling or charging the low cost separating price) when the difference in the surplus that each customer derives from purchases of unadvertised products is low.

(c) High costs stores find it more attractive to hide their identity (by either pooling or charging the low cost separating price) when the profit that high cost stores earn from each customer's purchase of unadvertised products is similar to the profit earned by low cost stores.

When there is little difference in the surplus that each customer derives from purchases of unadvertised products at high and low-cost stores then customers are less willing to travel further in order to visit a store that has a more favorable price image so differences in expected market shares are reduced. Moreover, as the stores become more identical from the customers' perspective, the value of signalling is reduced so pooling and mimicking low-cost stores is less attractive to the high-cost stores.

When high and low-cost stores earn similar profits from each customer, there is less difference in the profit maximizing prices stores of each cost type would like to charge. This reduces the cost to a high cost store of hiding its identity by pooling or mimicking a low-cost store.

5. **Empirical Tests of Hypotheses**

Data was collected from the Boston dry-cleaning market to test Results 1, 3(b) and 3(c):

1. **Identical unadvertised prices is a sufficient but not a necessary condition for identical advertised prices.**

3(b). **The difference in advertised prices charged by separating stores of different cost types is a continuous monotonically increasing function of the cost of travelling between stores.**

3(c). **The difference in unadvertised prices charged by separating stores of different cost types is independent of the cost of travelling between stores.**

The pooling equilibrium contemplated in Result 1 is the only result that discriminates between the complete customer information and signalling models. This result requires a signalling explanation—when customers have complete information about the stores' cost types identical unadvertised prices is a sufficient and necessary condition for identical advertised prices.

The objective of the empirical testing in this section is not to validate the arguments advanced in this paper by excluding all rival explanations. That is too ambitious. Rather it is hoped to demonstrate that the results are generally consistent with pricing strategies in one relevant market.

Although not all Boston dry-cleaning stores regularly advertise, the price charged to launder mens' shirts appears to be the most salient cleaning service. It is one of the most frequently used and frequently advertised services. The single period nature of the model excludes the possibility of learning prices through repeated purchasing. However, this does not necessarily negate the relevance of the model to this industry unless, as a result
of repeat purchasing, customers have full price information. The price of many less frequently purchased cleaning services appear to be less salient than the mens' shirt prices. This suggests imperfect memory arises because the effort of remembering the price of infrequently used services exceeds the benefit of doing so. The price charged to dry clean mens' woolen suits is used as an example of a less salient price. To minimize confusion, the term salient will be used instead of advertised to describe the price charged to launder mens' shirts. Dry-cleaning prices for suits will be described as non-salient in lieu of unadvertised.

The model assumes that the distance between stores is fixed, but the cost of travelling may vary. Equivalent results are obtained if it is assumed that the cost of travelling is fixed but the distance between stores may vary. This latter approach was adopted in order to operationalize the travelling cost variable. Each store was visited to determine its exact location and to check whether the store had a cleaning plant on the premises. None of the stores in the final sample appeared to perform their cleaning services on the shop premises. Other potential sources of variance in marginal costs between stores include different supply agreements negotiated with central dry-cleaning facilities or variance in transportation arrangements between the store and the facility. Some evidence of variance in marginal costs may be inferred from the variance in the (nonsalient) price differences for cleaning suits, although this offers only limited evidence because price differences may also be explained by market features not included in the model (such as quality differences). The intuition does not require perfect correlation between cost types for each product. The extent of correlation between the products' cost types will determine how accurately the advertised prices signal the unadvertised price levels (and will therefore influence the resulting equilibrium conditions). If laundering and dry-cleaning costs are sufficiently uncorrelated we might expect to see examples of competing stores that contradict the sufficiency element of Result 1.

The data included individual store prices and the road distance from each store to its closest competitor. To ensure that the price comparisons were between competing stores, any store whose nearest neighbor faces (geographically) closer competition from a third store was excluded from the sample. Where multiple stores set identical prices as a result of either a franchising, cooperative or single-owner relationship, these stores and all stores for which one of these stores is a closest neighbor were also excluded from the sample. The remaining dataset contained 26 pairs of competing stores.

To investigate Result 3(c), differences in the prices that the competing store charge to dry clean suits were correlated with the distance that the stores are apart. The correlation was $-0.27$, which is not significantly different from zero ($\alpha = 0.10$). It was therefore not possible to reject the null hypothesis that there is no correlation between store location and suit price differences. Although this finding is based upon few observations, the finding is consistent with the prediction that price variation for nonsalient prices (suits) is independent of the distance between competing stores. In order to obtain a more reliable measure of the consistency of Result 3(c) with the Boston dry-cleaning market, additional data collection is required to determine whether the introduction of additional observations yields a similar result.

To investigate the consistency of the dry cleaning data with Result 3b, the association between salient price differences for laundering mens' shirts and the distance between competing stores is approximated using a linear relationship. Equation (9) predicts that advertised price differences in a costly separating equilibrium are also a function of the difference in surplus that each customer derives from purchases of unadvertised products at high and low cost stores ($K$). In equation (2) it is assumed that $K$ is a monotonically

\[ p^*_h (c^*_h) > p^*_l (c^*_l) \]
increasing function of the difference in the competing stores’ non-salient prices. Therefore, to control for \( K \) when investigating Result 3(b), \( K \) will be approximated by the non-salient price differences for drycleaning suits. A limitation of this approach is that \( K \) is itself an endogenous variable, which introduces a potential specification error.\(^{30}\)

The following model was estimated:

\[
\Delta_{\text{shirts}} = \alpha + \beta_1 t + \beta_2 \Delta_{\text{suits}},
\]

where

\( t = \) the geographic distance between stores by road;

\( \Delta_{\text{shirts}} = \) the difference in price for drycleaning mens’ shirts; and

\( \Delta_{\text{suits}} = \) the difference in price for drycleaning mens’ suits.

The results are summarized in Table 1.

The sign of the \( t \) coefficient is positive (as predicted by Result 3(b)) but is not significant. Again, additional data collection is required to obtain a more reliable assessment of the consistency between the model’s predictions and actual practice in the Boston dry-cleaning market. It would be helpful if data could be collected to accurately measure the relative marginal costs faced by each store and to discriminate between stores operating in a costly versus cheap separating equilibrium.\(^{31}\) Future research should also confirm that the shirt prices are more salient than the price charged to dry clean suits and investigate whether there are perceived quality differences between stores (which may also influence prices).

Three of the 26 pairs of competing stores charge the same price for both cleaning services, suggesting that the stores in each pair face the same marginal costs. Of the remaining 23 pairs of competing stores, no pairs charge the same (nonsalient) price to dry clean suits and different (salient) prices to launder shirts. The absence of stores charging the same nonsalient prices, but different salient prices provides support for the sufficiency element of Result 1.

Three pairs of competitors charge the same (salient) price for mens’ shirts and different (nonsalient) prices for drycleaning suits. This finding is consistent with a pooling strategy as contemplated by the not necessary element of Result 1. Although three pairs of pooling stores represents only slightly more than 10% of the total sample, the model merely predicts that pooling equilibria may exist; it does not predict that pooling equilibria will be common. Indeed, if the sample of competing stores was increased to 200, and 20 of these pairs were found to be charging identical shirt prices and different suit prices, while no stores charged identical suit prices but different shirt prices, it could be concluded that the data strongly supports the model’s predictions.

\(^{30}\) The resulting model maybe further mis-specified if competing stores and their pricing policies differ because of variance in quality, parking availability, promotions (such as cents-off coupons) or turn-around time.

\(^{31}\) Price differences are only expected to increase as a function of travelling costs if the stores are operating in a costly separating equilibrium (see earlier discussion).
While none of this empirical inquiry provides a conclusive test of the validity of the analytical results, the outcome is still reassuring. Particularly encouraging is the discovery of a sample of stores competing in an apparent pooling equilibrium while no pairs of stores contradict the sufficiency element of Result 1. This predicted pattern of pricing strategies is an important, although not unique, consequence of the intuition advanced in this paper.

Conclusions

A full customer information model and a signalling model have been developed. In each model customers know the price of one product but not the price of a second product when deciding which store to visit. In the full customer information model, a unique pure strategy equilibrium exists in which stores predict their competitors' prices and set profit-maximizing prices in response. This results in high-cost stores charging higher prices than low-cost stores for both products.

When customers are uncertain of stores' cost types, the opportunity for stores to signal their types using the advertised prices results in a variety of equilibria. An equilibrium corresponding to the pure customer information equilibrium may exist with stores of different types again charging different profit maximizing prices for both products. Both store types prefer to reveal fully their cost types when setting the price of the advertised product. It is clear that low-cost stores will never attempt to convince customers that they are high cost types as the profit that they can earn from doing so is less than what they can earn if customers believe that they are efficient. However, under appropriate parameter conditions, high cost stores will prefer to sacrifice marginal revenue from their unit sales of product a in order to attract more customers by pretending to be low cost types. Therefore, the equilibrium corresponding to the full customer information outcome only exists in a limited region of the parameter space in the signalling model.

Outside this region, high-cost stores may set advertised prices that imitate the prices charged by a low-cost store. This may result in at least two alternative outcomes. First, low-cost stores may choose to reduce their advertised prices to discourage high-cost stores from pretending to be low cost. Second, if low-cost stores are prevented from pricing low enough to accurately signal their cost type, a pooling equilibrium may result. In the pooling equilibrium stores of different cost types charge the same price for product a while continuing to charge different prices for product b. In such an outcome, the advertised prices provide customers with no information about the prices of the unadvertised products.

Tests of the model predictions were conducted using data from the Boston dry-cleaning industry. The data is generally consistent with the predictions that unadvertised prices are independent of the relative location of competing stores while differences in advertised prices are higher when stores are more dispersed. The data is also generally consistent with the equilibrium implications of price signalling: there was some evidence of pooling between stores of different types on the salient (advertised) prices and no counterexamples were found to rebut the claim that identical unadvertised prices is a sufficient condition for identical advertised prices.

These results clarify the role that price signalling plays in a multi-product retail market. Signalling may result in an additional incentive for low cost stores to reduce their advertised prices in order to ensure that customers can distinguish between store types. In this respect, signalling provides an additional explanation for loss leader behavior. Furthermore, the seemingly familiar equilibrium in which stores charge the same advertised price but different prices for the unadvertised products requires a signalling explanation.

32 See Finding 1.
Signalling through advertised price levels is only one of a number of alternative mechanisms to signal unadvertised price levels. Advertising an *Everyday Low Price* strategy is an alternative as is dissipative advertising\(^{33}\) or a guarantee to match competitors' prices. However, price signalling using advertised prices is a relatively efficient signal. Low-cost stores are better able to sustain the marginal revenue loss when price is lowered as they earn higher profits than high cost stores from any additional customers who come to the store. Indeed, in a cheap separating equilibrium low cost stores can credibly signal their cost type without cost.

The selection of which product to advertise is exogenously determined for the stores in the current model. Lal and Matutes (1992) consider which of two products stores in a competitive duopoly would choose to advertise. They found multiple equilibria, in which firms advertising either the high or the low reservation-valued product, with customers enjoying the same overall surplus and stores earning the same profit under either strategy. In general, customers prefer stores that advertise the product for which they face the greatest danger of being exploited once they arrive at the store.

Retailing and purchase decisions are repeated over many periods. Extending the model to include multiple periods would allow customer loyalty and repeat purchasing behavior to be considered. Stores may choose to disguise their true cost type by initially setting low prices for both salient and nonsalient products in an effort to attract customers back to the store in subsequent periods. This would suggest that stores may charge less than the monopoly price for their unadvertised products.

Stores differ in the quality of the products that they sell and/or in the quality of the shopping experience that they offer, while customers differ in their propensity to pay for product quality and shopping pleasure. Where a high quality shopping environment can be maintained by increasing variable cost, and customers have different propensities to pay for an improvement in quality, an asymmetric pricing equilibrium may result. One group of stores may choose to incur the additional marginal cost of maintaining high quality, while other stores are able to attract less quality conscious customers by offering a lower price.

Adding features to the present model may enrich the legitimacy of the equilibria but is likely to confuse the intuition and detract from the clarity of the results. Indeed, a strength of the results is their generality and the paucity of assumptions upon which they rely.\(^{34}\)

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\(^{33}\) See Milgrom and Roberts (1986).

\(^{34}\) This paper was received December 15, 1992, and has been with the author 6 months for 2 revisions. Processed by Anne T. Coughlan, Area Editor.

**Appendix I**

**Parameter Representations of Equilibrium Conditions, Equilibrium Prices, and Equilibrium Profits**

Derivations of each of these parameter representations may be found in a technical appendix available from the author.

**Full Customer Information and Costly Separating Equilibria**

\[
L^{Fu} = L^{Ch} = t + \frac{K}{4} - \frac{w}{4} - \frac{3w}{4},
\]
\[ H_{Fu} = H^{C_h} = t - \frac{K}{4} - \frac{3w}{4} - \frac{\tilde{w}}{4}, \]

\[ \pi(L_{Fu}, 0, \bar{\theta}) = \pi(L^{C_h}, 0, \bar{\theta}) = \frac{1}{2t} \left[ t + \frac{(W + K)^2}{4} \right], \]

\[ \pi(H_{Fu}, 1, \bar{\theta}) = \pi(H^{C_h}, 1, \bar{\theta}) = \frac{1}{2t} \left[ t - \frac{(W + K)^2}{4} \right]. \]

**Costly Separating Equilibrium**

\[ L^{C_o} = t + \frac{5K}{8} - w - \frac{3R}{4}, \text{ where } R = \left[ K^2/4 + 4tK \right]^{1/2} \]

\[ H^{C_o} = t - \frac{K}{8} - w - \frac{R}{4}, \]

\[ \pi(L^{C_o}, 0, \bar{\theta}) = \frac{1}{2t} \left[ t + \frac{K}{8} + \frac{R}{4} \right] \left[ t + \frac{5K}{8} + W - \frac{3R}{4} \right], \]

\[ \pi(H^{C_o}, 1, \bar{\theta}) = \frac{1}{2t} \left[ t - \frac{K}{8} - \frac{R^2}{4} \right]. \]

**Pooling Equilibrium**

\[ P^{Po} = t - \tilde{w}, \quad -(P^{Po}, \frac{1}{2}, \bar{\theta}) = \frac{t}{2}, \quad \pi(P^{Po}, \frac{1}{2}, \bar{\theta}) = \frac{t - W}{2}. \]

**Proposition 1.**

\[(C1) \quad W(K + W) > 4tK,\]

\[(C2) \quad t + \frac{5K}{8} - w - \frac{R}{4} > 0, \]

\[(C3) \quad \frac{K}{2} \left[ \frac{K}{8} + \frac{R}{4} \right] - \frac{(w - R)^2}{4} > 0. \]

**Proposition 2.**

\[(C4) \quad t - \frac{1}{2}(w + \tilde{w}) + \frac{K}{4} - \frac{1}{2} \left[ \frac{(2W - K)^2}{4} + tK \right]^{1/2} < 0, \]

\[(C5) \quad t - \tilde{w} > 0, \]

\[(C6) \quad tK - \frac{(2W + K)^2}{8} > 0. \]
Appendix 2

Beliefs are only defined for the relevant prices ranges. From inspection of each figure it is obvious that neither cost type could benefit by pricing outside these ranges.

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**Figure A1.** Existence of a Cheap Separating Equilibrium.
FIGURE A2. Existence of a Costly Separating Equilibrium.

Appendix 3

Proofs of Results 1-4.

RESULT 1. Sufficiency element: recall $p_{\tilde{r}}(\tilde{c}_b) > p_{\tilde{r}}(\tilde{c}_b)$ so stores charging the same unadvertised price are the same cost type. All of the equilibria are symmetric so stores with the same cost type charge the same advertised price. Not necessary element: obvious from possible existence of a pooling equilibrium.

RESULT 2(a). Satisfaction of Condition (C6) requires $8Kt > (2W + K)^2$ while Condition (C1) requires $8Kt < 2W(W + K)$. $(2W + K)^2 > 2W(W + K)$ so Condition (C1) and Condition (C6) are mutually exclusive.

RESULT 2(b). It is sufficient to show $P_3 < P_2$: 
\[
P_2 = t - \bar{w} + \frac{K}{4} - \frac{1}{2} \left[ \frac{K^2}{4} + 2tK \right]^{1/2},
\]
\[
P_3 = t - \frac{1}{4} (\bar{w} + \bar{w}) + \frac{K}{4} - \frac{1}{2} \left[ \frac{(2W-K)^2}{4} + 2tK \right]^{1/2},
\]
\[
P_3 - P_2 = \frac{W}{2} - \frac{1}{2} \left[ \frac{(2W-K)^2}{4} + 2tK \right]^{1/2} + \frac{1}{2} \left[ \frac{K^2}{4} + 2tK \right]^{1/2}.
\]

Algebraic manipulation confirms that \( P_3 - P_2 > 0 \).

**RESULT 2(c).** Obvious from algebraic manipulation of the expected profit expressions.

**RESULT 2(a).** Advertised prices: obvious from differentiation of the equilibrium advertised price expressions (for the costly separating equilibrium prices substitute in the complement of condition (C1)). Unadvertised prices: these prices do not influence the customers' store selection decision so, when setting these prices, stores maximize their in-store monopoly profits which are independent of \( t \).

**RESULT 3(a).** Advertised prices: obvious from differentiation of the equilibrium advertised price expressions (for the costly separating equilibrium prices substitute in the complement of condition (C1)). Unadvertised prices: these prices do not influence the customers' store selection decision so, when setting these prices, stores maximize their in-store monopoly profits which are independent of \( t \).

**RESULT 3(b).** \( H^{C_h} - L^{C_h} \) is independent of \( t \) so in the cheap separating equilibrium the difference in equilibrium advertised prices between stores of different cost types is independent of travelling cost. In the costly separating equilibrium, \( H^{C_c} - L^{C_c} \) is an increasing function of \( t \). If condition (C1) is binding the costly and cheap separating equilibria predict the same equilibrium prices so the difference in equilibrium prices is continuous.

**RESULT 3(c).** See proof to Result 3(a).

**RESULT 3(d).** The difference in expected market share between stores of different cost types in a cheap separating equilibrium is equal to
\[
N(L^{C_h}, 0, \bar{\theta}) - N(H^{C_h}, 1, \bar{\theta}) = \frac{W + K}{4t}.
\]
In a costly separating equilibrium the difference in expected market share between stores of different cost types is equal to
\[
N(L^{C_c}, 0, \bar{\theta}) - N(H^{C_c}, 1, \bar{\theta}) = \frac{2R + K}{8t}.
\]
Differentiation of each expression function with respect to \( t \) confirms that each function is a decreasing function of \( t \).

**RESULT 4(a).** Obvious from differentiation of the expressions for the expected market share differences (above).

**RESULT 4(b).** Obvious from differentiation of conditions (C1) and (C6) with respect to \( K \) (noting the boundary conditions \( t > W \) in a pooling equilibrium and \( 4t > (W + K) \) in a separating equilibrium).

**RESULT 4(c).** Obvious from differentiation of conditions (C1) and (C6) with respect to \( W \).

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