PRICE COMPETITION WITH A DISTRIBUTION
OF SWITCH COSTS AND RESERVATION PRICES

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Abstract

When there is a distribution of switch costs and of reservation
prices for a good, and marginal cost of producing the good is zero,
equilibrium in pure price strategies may (and sometimes must)
exhibit price dispersion. Equilibrium may or may not exist, and
there may be a continuum of equilibria. When there are no fixed
costs, equilibrium with entry will not exist when there are any
switch costs low relative to the reservation prices.

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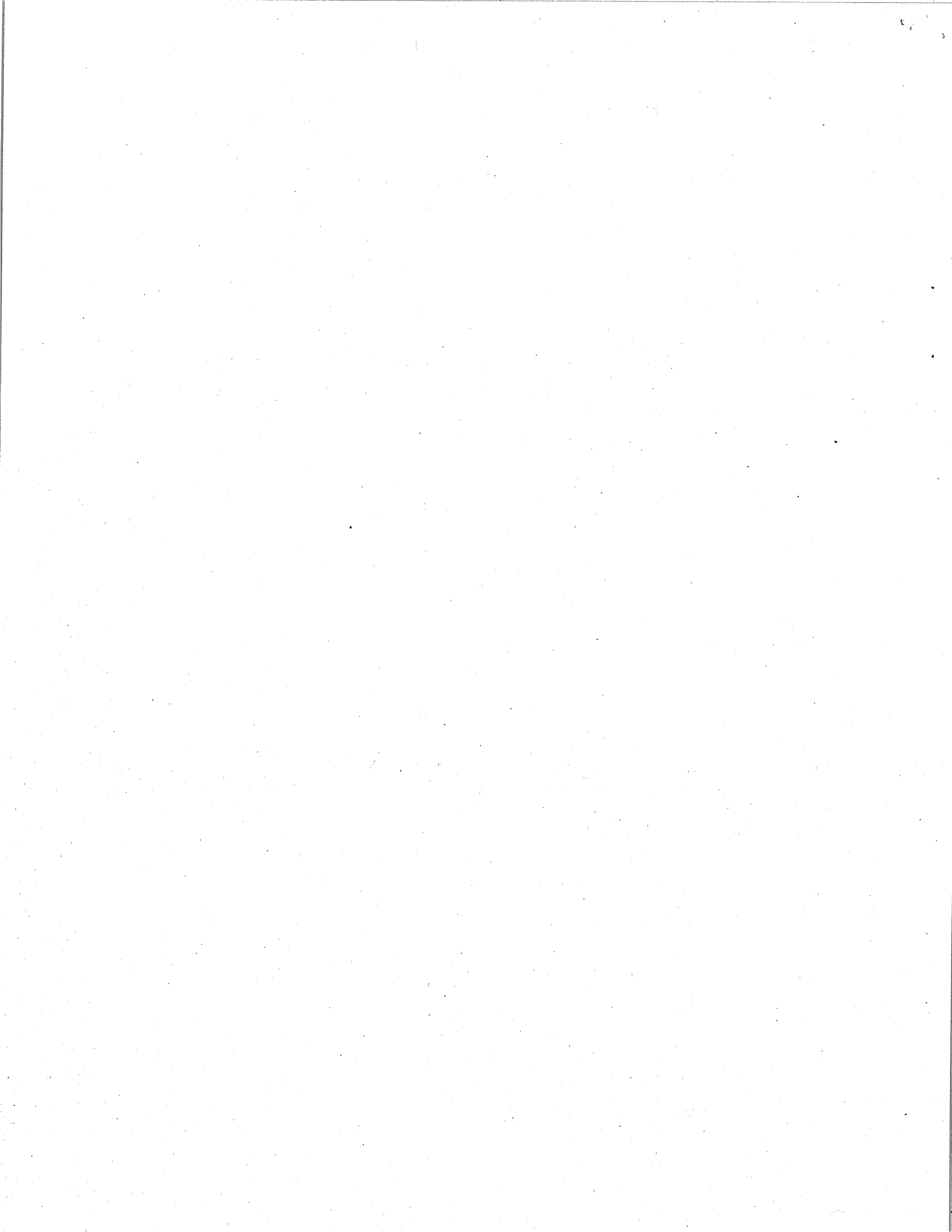
1. Introduction

Price competition, as originally formulated by Bertrand, assumes that consumers always purchase from the lowest-priced firm. If this assumption is true, then when each firm has constant marginal cost, the unique market price will equal the second-lowest marginal cost available in any firm. Equilibrium in pure price strategies will not exist if firms have increasing marginal cost.

But there are many markets, such as law, accounting, medicine, and consulting services, in which there is price dispersion, and, furthermore, the dispersed prices seem stable. Several explanations for price dispersion have been advanced, without throwing out the basic paradigm of price competition. The most obvious is that quality varies, so that the dispersed prices are not prices for the same good. Another explanation is that it is costly for the consumer to find out whether his firm has the lowest price, and this leads him to undertake a search. Search theory can, under some conditions, produce a stable dispersion of prices.

A recently emerging literature attacks the premise that consumers will switch firms for any trivial price advantage; that is, each consumer has a "switch cost" for switching to another firm. For example, a consumer must make a substantial outlay to inform a new law firm about the details of his legal affairs. The more complicated is his business, the larger the price difference required for a switch. This phenomenon has been called cost of information (Sutton, 1980), loyalty (Rosenthal, 1982), cost of substitution (von Weitzsacker, 1984), inertia (Farrell, 1986,

Scotchmer, 1986a,b), lock-in (Farrell, 1985), switching costs
(Klemperer, 1984, Green and Laffont, 1985).

The cited papers vary according to the switching behavior and
the equilibrium concept, although each is a version of price
competition. Sutton assumes that, once in a firm, consumers never
switch, and therefore competition is only for the new customers
exogenously entering the market place. Rosenthal assumes customers
perceive price changes in their own firms, but not in other firms.

Our own assumption, that whether a customer switches depends
only on the price difference between his current firm and the
lowest-priced firm, is that of Klemperer, Farrell, Scotchmer, Green,
and Laffont.

Klemperer, Farrell and Green and Laffont study dynamic
equilibrium in a two- period model. The difficulty with dynamic
equilibrium is that prices in the first period are set before
customers are distributed, and must be chosen rationally by firms
based upon their belief in the perfect equilibrium which will ensue
in subsequent periods. Customers predict future prices as well.
This is a very difficult problem, and no general conclusions have
emerged. Von Weitzsacker ignores the problem of perfect equilibrium
and examines an equilibrium in which firms commit to a price, but
consumers can make switches as their tastes evolve through time.
These authors focus on symmetric equilibrium,[1] and do not address

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1. Except for Farrell (1986) who shows that if arbitrarily
chosen first period market shares are asymmetric, prices in the
second period will be asymmetric, and the firm with larger market

the general question of price dispersion.

Our approach foregoes the complexity (and apparent intractability) of dynamic equilibrium and returns to static Nash Equilibrium in prices. Thus we do not ask how customers initially got distributed among firms, but only whether this distribution and the associated prices are stable. Although this simplification ignores interesting intertemporal strategy, it allows us to return to the two issues of price dispersion and existence of equilibrium in a manner which isolates the effect of switch costs on Bertrand competition.

Price dispersion might arise quite naturally from the fact that to some extent each firm's customers are "captive." If in equilibrium the switch costs and reservation prices of firms' clients differ, then the price sensitivity of their individual demands might differ and price dispersion might result. In markets with a fixed number of firms we show that equilibria may, and in some cases must, have price dispersion.

Turning to existence,[2] one might have thought that, except in pathological cases, equilibrium in pure price strategies would exist. Increasing marginal cost, which is the source of trouble in Bertrand competition, is not part of the model we discuss.

But Scotchmer (1986a,b) shows that when total demand is fixed,

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share will have higher second-period price.

    2. For the case of dynamic equilibrium, Klemperer shows existence in several special cases with two firms. Other than that, the question of existence has not been addressed for the switching behavior we consider.

and there are more than two firms, no equilibrium in pure price strategies exists.[3] But the assumption of fixed total demand, meaning that each customer must buy from <u>some</u> firm, turns out to be important.[4] When each consumer has a reservation price, as well as a switch cost, a firm that raises its price may lose customers out of the market, as well as losing customers to lower-priced firms. Thus its profit opportunities are different. This paper studies the nature and existence of equilibrium when each customer has both a reservation price and a switch cost.

Section 2 presents the simplest possible model that includes the features of interest. Section 3 discusses equilibrium in pure price strategies with a fixed number of firms. We turn first to the case that consumers have a common reservation price and show that equilibrium must have one of two price configurations: Either all prices are equal to the reservation price, or all prices except two are equal to the reservation price, and the two lower prices must be the same. Thus, in contrast to Bertrand competition with no switch costs, firms get the surplus rather than consumers.[5] With no switch costs, the equilibrium prices would all be zero. A surprising result is that no equilibrium exists when there are many firms, although equilibrium may exist with a few firms. When there is dispersion in reservation prices as well as switch costs, we use a

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3. This is when there is a positive density of consumers with zero switch costs, but not a mass point at zero.
4. The cited papers all assume a fixed aggregate demand.
5. C.f., Diamond (1971) on search equilibrium.

graphical description of equilibrium to show how price dispersion may be sustained, and then give an example which shows equilibrium may not exist. There do not appear to be "credible" conditions on a joint distribution of reservation price and switch cost under which equilibrium can be guaranteed to exist. Moreover, when equilibrium exists, there may be a continuum of equilibria!

Section 4 introduces the possibility of entry. That is, equilibrium is a set of prices and market shares for incumbents, such that there is a Nash Equilibrium in pure price strategies among incumbents, and furthermore, no firm could enter at any price and make a profit. This additional equilibrium condition is so powerful that equilibrium does not exist when some consumers have low (relative to reservation prices) switch costs. If there are customers with zero switch costs, the lowest price must be zero in order to deter entry. But a firm with zero price makes zero profit, and will be able to increase profit by increasing price.

2. The Model and the Equilibrium Concept

Each consumer in our model has a reservation price w and a switch cost c. Each will be assigned to one of the firms, or to none of them. This assignment should be interpreted as describing an ongoing relationship between the consumer and the firm. Purchasing from this firm yields the full benefit w to the consumer, less any price he pays. Purchasing from any other firm entails the switch cost, so that gross benefits will be only w-c. However, switching "out-of-the-market," that is, not purchasing, does not

entail a switch cost--the consumer gets a zero surplus. Switching from "out-of-the-market" into any firm costs c, which is also the cost of switching between firms. This is because c is the cost of forming a new relationship with the firm in question.

Firms, which produce the good at zero marginal cost, choose prices, assuming that all other firms' prices are fixed. Their perceived demand curves are generated by the assignment of individuals to firms, and other firms' prices.

We will characterize those assignments of customers to firms and firms' prices which are stationary in the sense that no firm has an incentive to deviate in price, and no movements of customers among firms will occur. An alternative would be to start from an arbitrary assignment of customers to firms and to find Nash equilibrium in prices, along with the resulting interfirm movements of customers that these prices induce. Equilibrium, if it existed, might require randomized prices and would, in general, involve some interfirm movements. At best one might discover conditions for such an equilibrium to exist, or might discover when equilibrium requires random prices, but an informative characterization of equilibrium with this level of complexity would be unlikely, especially with many periods and firms.[6] For this reason we concentrate on stationary equilibria, without describing how the stationary

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6. The only result to emerge so far along these lines is due to Farrell (1986), who shows in a two-period model with two firms that the firm with the most customers in the first period will have the highest price in the second period.

assignment emerged. Further research in explicitly dynamic models
is necessary to explore convergence from an arbitrary assignment of
customers, or from no initial assignment at all.

Another reason for examining stationary assignments is that in
many of the markets where our analysis might apply there is, in
fact, a very high degree of apparent customer loyalty. Moreover,
this loyalty persists despite significant and easily discoverable
price differences in the market. We feel that an adequate
internally consistent explanation of this situation is lacking, and
we hope to provide that in this paper.

$F(w,c)$ shall denote the distribution of reservation prices and
switch costs. If w is fixed, we may abuse notation and describe the
population by distribution $F(c)$. The total measure of people with
reservation price less than w and switch cost less than c is
$NF(w,c)$, where N is the population size. We will assume that F has
a continuous density function f.

Let $\{p^j\}$ be the prices for firms $j=1...T$, ordered such that p^1
is the lowest price. (We shall sometimes refer to the lowest price
as p^L.) Customers are distributed among firms according to
$\{n^j F^j(w,c)\}$, $j=o...T$, where $\{n^j\}$ are the numbers of people in firms
and F^j describes the firm-specific distribution of reservation
prices and switch costs.[7] Index o refers to customers who are out

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7. We will only consider distributions F^j which have density
functions which are either continuous or have simple
discontinuities—that is the right and left limits may differ along
sequences approaching any point, but they both exist. This
assumption is important only to insure that the density function at

of the market. Then an <u>equilibrium with a fixed number of firms</u> is a $\{p^j\}$ and market shares $\{n^j F^j(w,c)\}$ such that (i), (ii) and (iii) hold.

(i) The distribution of customers accounts for all of them:

$$\sum_{j=o}^{T} n^j \, F^j(w,c) \; = \; N \, F(w,c) \qquad \text{for all } w,c$$

(ii) No customer could increase utility by exiting from the market: For each j, $F^j(w,c)=0$ for all (w,c) such that $w \leq p^j$. That is, all customers in firm j must have reservation price at least as large as p^j.

No customer could increase utility by switching to another firm: For all j, and all w, $F^j(w,p^j-p^1)=0$, where p^1 is the lowest price. That is, customers with switch cost less than p^j-p^1 will switch to the lowest-priced firm.

(iii) No incumbent firm could increase profit by changing price. Although we will not use the profit function in the general form given here, we write it down for completeness. The profit function simply recognizes the switch behavior described by (ii). If the firm raises its price, it may lose customers out of the market and to the lowest-priced firm. If the firm lowers its price below the lowest price p^1, then it may get customers from out of the market and from other firms. Any price between the lowest price and the firm's equilibrium price leaves the firm with the same number of

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zero approximates the limit of $F^j(\varepsilon)/\varepsilon$, as ε goes to zero.

customers as it initially had, and cannot be an improvement. With
such prices, its own customers stay in the firm. If customers
outside the firm were tempted to switch, they would switch to the
lowest-priced firm.

The following profit function applies to all incumbent firms
except the lowest-priced firm. For $j \neq 1$,

$$
\Pi^j[p; \{p_i\}_{i \neq j}] = \begin{cases} n^j \displaystyle\int_{p-p^1}^{\infty} \int_{p}^{\infty} f^j(w,c) \, dw \, dc & p^j \leq p \\[2em] n^j & p^1 \leq p \leq p^j \\[2em] n^j + \displaystyle\sum_{i \neq j, o} n^i \int_0^{p^i - p} \int_0^{\infty} f^i(w,c) \, dw \, dc \\[1em] \qquad + n^o \displaystyle\int \int_{p+c}^{\infty} f^o(w,c) \, dw \, dc & p \leq p^1 \end{cases}
$$

The lowest-priced firm, $j=1$, loses customers out of the market
when it raises price, but not to other firms, unless it raises price
above the next price, p^2. Then it loses those customers with switch
cost less than $p-p^2$ to firm 2. As before, if it reduces price below
the lowest price, which is its own price, it gains customers from
out of the market and from other firms. Therefore,

$$\Pi^1[p;\{p_j\}_{j\neq 1}] = \begin{cases} n^1 \displaystyle\int_{\max\{0,p-p^2\}}^{\infty} \int_p^{\infty} f^1(w,c)\,dw\,dc & p^1 \leq p \\[2em] n^1 + \displaystyle\sum_{i\neq 1,o} n^i \int_0^{p^i-p} \int_0^{\infty} f^1(w,c)\,dw\,dc \\[1em] \qquad + n^o \displaystyle\int \int_{p+c}^{\infty} f^o(w,c)\,dw\,dc & p \leq p^1 \end{cases}$$

The equilibrium condition (iii) is that $\Pi^j[\bullet]$ is maximized at $p=p^j$ for all j.

An equilibrium with entry requires in addition that no firm could profitably enter. The profit function of an entrant would be

$$\Pi^e[p;\{p_j\}] = \begin{cases} 0 & p^1 \geq p \\[2em] \displaystyle\sum_{j\neq o} n^j \int_p^{\infty} \int_0^{p^j-p} f^j(w,c)\,dc\,dw \\[1em] \qquad + n^o \displaystyle\int_0^{\infty} \int_{p+c}^{\infty} f^o(w,c)\,dw\,dc & p \leq p^1 \end{cases}$$

An <u>equilibrium with entry</u> adds condition (iv) to (i), (ii) and (iii):

(iv) For all p, $\Pi^e[p;\{p^j\}] \leq 0$.

3. Equilibrium with a Fixed Number of Firms

We first consider the case that no entry is allowed. The number

of firms is fixed.

Proposition 1: If (i) the density of switch costs is positive at zero and (ii) w does not vary across consumers, then only two price configurations are possible in equilibrium. Either p^j=w for all j, or p^j=w for all firms except two, which have a common lower price.[8]

Proof: We show this by showing that any other configuration of prices is not an equilibrium.

Lemma 1: In a Nash Equilibrium, more than one firm has the lowest price.

Proof: Suppose not. Then the one lowest-priced firm can increase profit by raising its price, since raising the price will not cause customers to flee. Q.E.D.

Lemma 2: There cannot be three or more lowest-priced firms if the lowest price is less than w.

Proof: First, all of the customers with zero-switch costs would be in the lowest-priced firms. Otherwise they would switch out of the higher-priced firms. Let j∈K index the lowest-priced firms. There are k such firms. Let j∈J index the remaining firms, with

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8. If there is fixed total demand, so that customers are unquestionably in the market and there is no maximum willingness to pay w, then Proposition 1 implies no equilibrium exists with more than two firms. Neither of the two permissible cases is possible, since there is no maximum possible price, w.

higher price.

For some i which has the lowest price, $i \in K$, $\sum\limits_{j \neq i, j \in K} n^j f^j(0) >$

$n^i f^i(0)$. (One firm has less than half the price-sensitive

portion of the market, defined as those people for whom switch costs

are zero.) If not, then for all i, $\sum\limits_{j \neq i, j \in K} n^j f^j(0) \leq n^i f^i(0)$.

Summing both sides over i yields $(k-1) \sum\limits_{j \in K} n^j f^j(0) = (k-1)Nf(0) \leq$

$Nf(0)$. This is a contradiction for $k > 2$.

But then some firm with the lowest price faces a demand function

which is kinked toward the origin at the common lowest price. A

positive deviation dp^i by a firm with the lowest price will generate

marginal profit in the amount $d\Pi^i(\bullet)/dp^i = n^i - p^i n^i f^i(0)$. The first

term represents the increased revenue from current clients, and the

last term is the loss of profit due to customers leaving.

Analogously, a negative price deviation dp^i by this firm will

generate marginal profit in amount

$$-d\Pi^i(\bullet)/dp^i = -n^i + p^i \sum\limits_{j \neq i, j \in K} n^j f^j(0) + p^i \sum\limits_{j \in J} n^j f^j [p^j - p^i].$$

If the marginal profit for raising the price is positive, the

firm should do it and is not in equilibrium. Suppose then that the

marginal profit for raising the price is nonpositive,

$n^i - p^i n^i f^i(0) \leq 0$. Then, since $\sum\limits_{j \neq i, j \in K} n^j f^j(0) > n^i f^i(0)$, the

marginal profit for a price reduction is positive and the firm will

reduce price. Therefore the firm is not in equilibrium. Q.E.D.

Lemma 3: If there is an equilibrium in which exactly two firms
have the lowest price, then all other firms have price w.

Proof: First we show that the two lowest priced firms must have
the same numbers of customers and the same numbers with zero switch
costs. Then we show that such firms are not in equilibrium if there
are any customers in the higher-priced firms who are on the margin
of switching to a lowest-priced firm. Thus, for higher priced firms
we need $f^j(p^j-p^L)=0$. But if the higher price is less than the
reservation price, $p^j<w$, the higher-priced firm could increase
profit by raising price, since it would not lose customers by doing
so. Hence, the only possible equilibrium is one in which the two
lower-priced firms have the same numbers of customers and the same
numbers of zero-switch-cost customers, and all higher-priced firms
have price $p^j=w$. In that case, higher-priced firms cannot increase
profit by raising price, even though no customers are on the margin
of switching to a lower-priced firm. This is because the customers
are on the margin of switching out of the market.

We give the intuitive argument that the lowest-priced firms must
have the same numbers of zero-switch costs and then argue formally.

All the customers with zero switch cost are in the lowest-priced
firms. If the two lowest-priced firms have different numbers of
customers with zero switch costs, then the firm with fewer such
customers has a demand curve kinked toward the origin. When this
firm lowers its price it gets the numerous price-sensitive customers

from the other firm. When the firm raises its price, it gives up fewer of its own customers with zero switch cost. Thus the demand curve kinks toward the origin. This kink will be exacerbated if there are customers in higher-priced firms who are on the margin of switching. In that case, the increase in demand when the firm lowers price will be even larger. Therefore, the lower-priced firms must have the same numbers of customers with zero switch costs.

Now suppose there are customers in higher-priced firms who are on the margin of switching to a lower-priced firm; that is, $f^j(p^j-p^L)>0$ for some higher priced firm, j. Then even if the two firms have the same numbers of customers with zero switch-cost, the response in demand when price is lowered will exceed the reduction in demand when price is raised. When price is raised, no customers are given up to the higher-priced firm, but when price is lowered, customers are gained from the higher-priced firm. Thus at least one firm has a demand curve kinked toward the origin.

Thus, if equilibrium exists, $f^j(p^j-p^L)=0$ for all higher-priced firms j. But if $f^j(p^j-p^L)=0$, and $p^j<w$, then firm j can increase price without losing customers, and is therefore not at a profit maximum. If $p^j=w$, any increase of price will drive the customers out of the market and will therefore not increase profit.

Thus, if equilibrium exists with two lowest-priced firms, $f^j(p^j-p^L)=0$ for all higher priced firms, and $p^j=w$.

We now repeat the argument more formally.

We call the two lowest-priced firms 1 and 2. If firm 1 raises its price to p, it loses customers in amount $n^1F^1[p-p^L]$, where p^L is

the price in the other firm, $F^1[.]$ is the distribution of switch costs in firm 1 and n^1 is the total number of customers in firm 1 when the prices are both p^L. If firm 1 lowers its price, it gains customers from two sources: the other lowest-priced firm, firm 2, and from the higher priced firms. Thus, firm 1's profit function is

$$(1) \quad \Pi^1[p;p^2,\ldots,p^H] = \begin{cases} p\{n^1 - n^1 F^1[p-p^L]\} & p > p^L \\ \\ p\{n^1 + \sum_{j \neq 1} n^j F^j[p-p]\} & p \leq p^L \end{cases}$$

In order for firm 1 to be in equilibrium, it must be the case that $\partial\Pi^1[p;p^2,\ldots,p^H]/\partial p \leq 0$ for $p > p^L$, and $\partial\Pi^1[p;p^2,\ldots,p^H]/\partial p \geq 0$ for $p < p^L$. Using the fact that $F^j[p^j - p^L] = 0$ for all j, these derivatives imply (evaluating at $p = p^L$)

$$(2) \quad n^1 f^1[p^L - p^L] \geq \sum_{j \neq 1} n^j f^j[p^j - p^L].$$

Firm 2's profit function reverses the 1's and 2's in equation (1). The first order condition is, analogously to (2),

$$(3) \quad n^2 f^2[p^L - p^L] \geq \sum_{j \neq 2} n^j f^j[p^j - p^L]$$

Rearranging (2) and (3) respectively,

$$(4) \quad n^1 f^1[p^L - p^L] - n^2 f^2[p^L - p^L] \geq \sum_{j \neq 1,2} n^j f^j[p^j - p^L] \quad \text{and}$$

$$-n^1 f^1[p^L - p^L] + n^2 f^2[p^L - p^L] \geq \sum_{j \neq 1,2} n^j f^j[p^j - p^L]$$

These inequalities are consistent only if the righthand side is zero. This can occur in equilibrium only if $f^j[p^j-p^L]=0$, for all other firms j, which, by the reasoning above, implies that for all other firms, $p^j=w$.

We notice that if there is an equilibrium with two lowest-priced firms, not only do they have equal numbers of customers with zero switch costs, but they also have equal numbers of customers in total. Otherwise the first-order condition $n^i-p^L\frac{1}{2}Nf(0)=0$ could not be satisfied for the two lowest-priced firms.

<div align="right">End of Proposition 1.</div>

For a fixed number of firms, either of the two price configurations might be an equilibrium. However, the following Proposition says that for sufficiently many firms, there is no equilibrium, although equilibrium may well exist with few firms. After presenting this Proposition, we give an example which shows (i) equilibrium, if it exists, may require price dispersion, (ii) there may be a continuum of equilibria and (iii) equilibrium may exist among a small number of firms.

When the number of firms is large, average profit in the industry is no greater than wN/T, where w is the reservation price, N is the population size, and T is the number of firms. Therefore, the least-profitable firms' profit does not exceed wN/T. But as long as the smallest price, p^L, is strictly positive, the least profitable firm can deviate to a price which is ε below the lowest price, and get all the customers with switch cost smaller than ε.

For large enough T, the least-profitable firm is making little enough profit that such a deviation is advantageous.

Proposition 2: If customers have a common reservation price w, then for a sufficiently large number of firms, no equilibrium exists, provided f(c) has support on an interval including zero.

Proof: We argue separately for the two possible price configurations, as restricted by Proposition 1.

(a) The firm with smallest market share makes profit less than or equal to wN/T. Suppose the least-profitable firm reduces price to $w-\varepsilon$. Then it gets all the customers with switch cost less than ε, whether they come from other firms or from out of the market. This price deviation earns for the firm profit in amount $(w-\varepsilon)F(\varepsilon)$, which is price times quantity. For large enough T and all larger T, there exists ε such that $(w-\varepsilon)F(\varepsilon)>wN/T$, and hence a price deviation by the least profitable firm is an improvement.

(b) We now argue for the case that all firms except two have price w. We need the following lemma.

Lemma 4: There exists $p^L>0$ such that (i) $F[p^L]>0$ and (ii) for all equilibria, with any number of firms, the lowest price is larger than p^L.

Proof: Lemma 3 above points out the following two facts: First, each of the two lowest-priced firms has half the customers with zero switch cost, $\frac{1}{2}Nf(0)$, and the same number of customers n^L. Second, there are no customers in the other firms (with price w) who are on the margin of switching; that is, who have switch cost $w-p^L$.

Thus a marginal decrease in price by one of the lowest-priced firms will gain customers in amount $\frac{1}{2}Nf(0)$ from the other lowest priced firm (but not from any high-priced firm), and a marginal increase in price will lose customers in the same amount. Hence, a necessary condition for a lowest-priced firm to be in equilibrium is that neither a marginal increase nor a marginal decrease in price increases profit:

$$(5) \qquad n^L - p^L \frac{1}{2} N\, f(0) = 0$$

There are no customers in the high-priced firms with switch cost less than $w-p^L$. (Otherwise, they would switch.) Hence, $n^L \geq N\frac{1}{2}F(w-p^L)$. Substituting into equation (5), this implies that $p^L f(0) \geq F(w-p^L)$. Suppose we let p^L approach zero. Then the righthand side of this expression gets arbitrarily close to $F(w)$, while the lefthand side gets arbitrarily close to zero, which is a contradiction. Hence there must be a lower bound on p^L such that $F(p^L)>0$. This argument has made no reference to the number of high-priced firms, and we thus conclude that there is a lower bound which applies irrespective of the number of firms. End of Lemma 4.

The profit of the least profitable high-priced firm does not exceed wN/T. In order for a high-priced firm to increase profit, it must deviate to a price less than p^L. Suppose it deviates to $p^L-\varepsilon$. The profit it achieves by this deviation is at least $F(\varepsilon)[p^L-\varepsilon]$, which is the number of customers with switch cost less than the price advantage, times the price. Since $F(p^L)>0$, there is

an ε such that $p^L-\varepsilon>0$ and $F(\varepsilon)>0$. The bound on profit of the least profitable high-priced firm, wN/T, can be made as small as possible by choosing T large. For large enough T, the deviation to $p^L-\varepsilon$ enhances profit.   Q.E.D.

The following example is one in which every equilibrium has price dispersion. With three firms, there is no equilibrium with $p^j=w$, all j, since each firm could increase profit by a marginal reduction in price. We exhibit a continuum of equilibria, each with price dispersion. One firm has price w and there are two lowest priced firms. In equilibrium the lowest price will be higher if the low-priced firms have more customers. There is more incentive to raise price, since gains are made on more inframarginal customers within each firm.

Example 1: Suppose $w=1$, and $f(c)=1$, $c\in[0,1]$. Then the following is an equilibrium: The high-priced firm, H, has $p^H=1$, and all the customers with $c \geq c^*$. There are two low-priced firms, each with $p^L=c^*$. All customers with $c<c^*$ are distributed symmetrically between the low-priced firms, so that each has customers in amount $\frac{1}{2}c^*$. This is an equilibrium for $(1/3)^{1/2} < c^* < 3/4$.

We must check that no firm can profitably deviate in price. In order to get more customers, H must lower price below p^L, in which case it gets customers in amount $[p^L-p]$. (All the customers in the low priced firms with switch cost less than p^L-p will switch. There are p^L-p such customers.) Firm H's profit function is

$$\Pi^H[p;p^L,p^L] = \begin{cases} p(1-c^*) & p \geq p^L \\ p[1-c^*+p^L-p] & p \leq p^L. \end{cases}$$

Maximum profit with $p \leq p^L$ is achieved at $p=\frac{1}{2}$. Profit at $p=\frac{1}{2}$ is $\frac{1}{4}$, less than the profit of $w(1-c^*)$ which is achieved at $p^H=1$, provided $c^*<\frac{3}{4}$. Thus the high-priced firm is in equilibrium with $p^H=1$.

We now check that the low-priced firms are in equilibrium. When a low-priced firm raises price above p^L, it loses customers to the other low-priced firm in amount $\frac{1}{2}(p-p^L)$. When it lowers price below p^L it gains customers from the other low-priced firm in amount $\frac{1}{2}(p^L-p)$. When it lowers price below $1-c^*$, it also gains customers from the high-priced firm, in amount $(1-c^*-p)$. Hence the profit function is

$$\Pi^L[p;p^H,p^L] = \begin{cases} p[\frac{1}{2}c^* - \frac{1}{2}(p - p^L)] & p \geq p^L \\ p[\frac{1}{2}c^* + \frac{1}{2}(p^L - p)] & 1 -c^* < p < p^L \\ p[\frac{1}{2}c^* + \frac{1}{2}(p^L - p) + (1 - c^* - p)] & p < 1-c^*. \end{cases}$$

The maximum of $\Pi^L[p;p^H,p^L]$ is achieved at $p^L=c^*$, provided $c^*>(1/3)^{1/2}$. End of Example

The fact that there may be price dispersion in which some prices are less than willingness to pay follows from the fact that there are some customers with zero switch cost. Otherwise, firms with price lower than willingness to pay could profitably raise price without losing customers. The following proposition states that if

willingness to pay were constant as above, and if, in addition, there were no customers with zero switch cost, then there would be no price dispersion in equilibrium (if it exists). Prices in equilibrium would all be at maximum willingness to pay, w.[9] The positive switch costs effectively give to each firm monopoly power over its own customers.[10]

Proposition 3: If switch cost has a lower bound $\underline{c} > 0$ and w is constant, $w > 0$, then in equilibrium $p^j = w$ for all j.

Proof: Suppose we had an "equilibrium" with some prices less than w. Then the lowest-priced firm (whether or not it is the only firm with the lowest price) could raise its price to the minimum of $p^j + \underline{c}$ or w without losing any customers, and make more profit. Q.E.D.

Propositions 1 and 2 focussed on the case that w is constant and there is dispersion in c. Another polar case is that c is constant and there is dispersion in w. We have found that the latter case is not qualitatively different from the case that there is dispersion in both c and w, in which case equilibrium may (or may not) exist, and there may (or may not) be price dispersion.

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9. The argument here is very similar to Diamond's (1971) argument for the case of search costs.
10. One would expect this monopoly power to disappear if there were no switch costs; that is $c = 0$, for all customers. The latter case is Bertrand competition and $p^j = 0$ for all j, irrespective of whether there is dispersion in willingness to pay.

Conditions under which existence of equilibrium can be guaranteed are more complicated than, for example, mere smoothness of distributions. In order to show how the nature and existence of equilibrium depend on global properties of the distribution of w and c, we present a graphical characterization of equilibrium.

Suppose there are three firms with prices p^L, p^M, and p^H (for Low, Middle and High). If there were no dispersion in w, then the lowest-priced firm would want to raise its price, since it could do so without losing customers. But if the lowest-priced firm has customers with low willingness to pay, raising the price will cause such customers to leave the market, reducing profit. In equilibrium the lowest-priced firm is deterred from raising price by the possibility of losing customers out of the market. Hence a market in which there is dispersion in w may have more price dispersion than a market with constant w.

A complete description of equilibrium is a set of prices $\{p^L, p^M, p^H,\}$ and a distribution of customers among the three firms and out of the market: $\{f^L(w,c), f^M(w,c), f^H(w,c), f^o(w,c)\}$. These distributions have the property that for each firm j, if $f^j(w,c)>0$, then $w \geq p^j$ and $c \geq p^j - p^L$. Consider first demand in the highest-priced firm. When the highest-priced firm raises price, it loses customers out of the market and also loses customers to the lowest-priced firm. When it lowers price, there is no increase in demand until price is less than the lowest price p^L. (If customers leave the firm, they prefer going to the lowest-priced firm. Every firm "competes" with the lowest-priced firm and not with the other
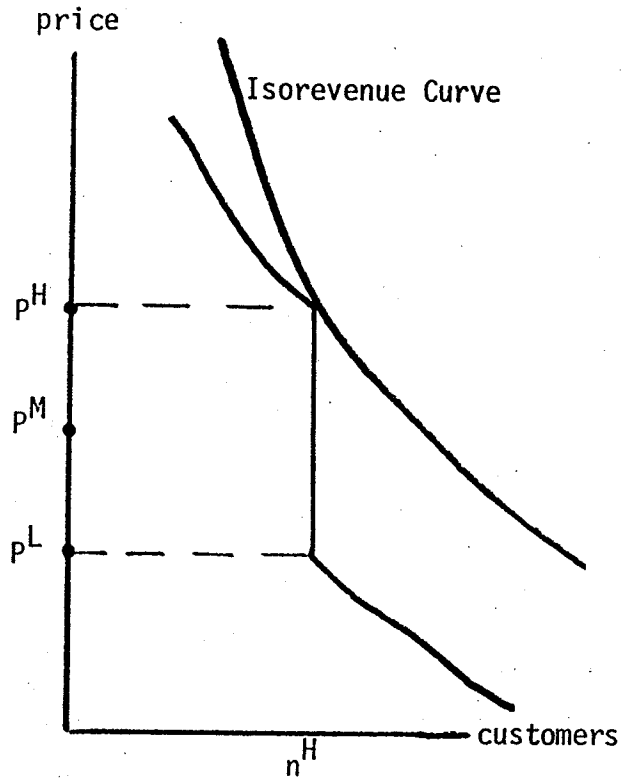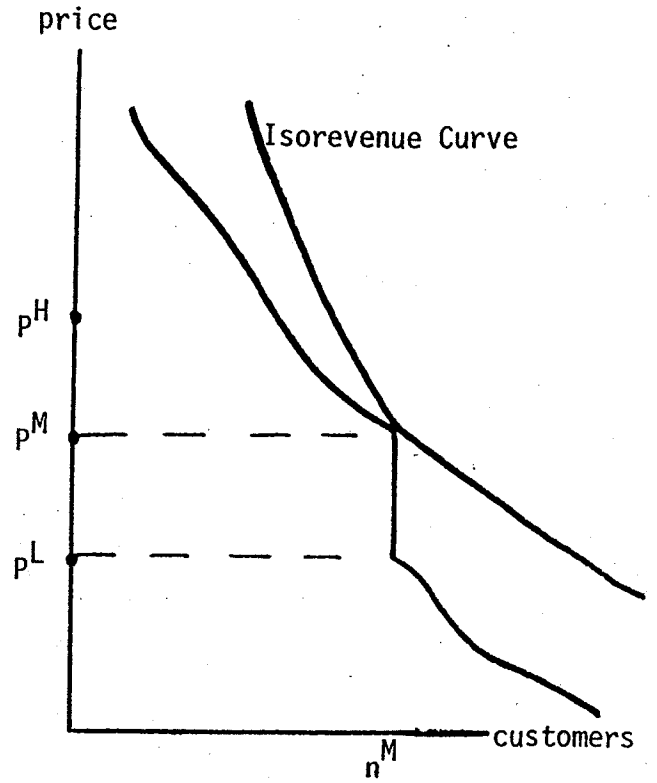
price

Isorevenue Curve

p^H

p^M

p^L

customers

n^H

Figure 1: Demand in Firm H

price

Isorevenue Curve

p^H

p^M

p^L

customers

n^M

Figure 2: Demand in Firm M

price

p^H

p^M

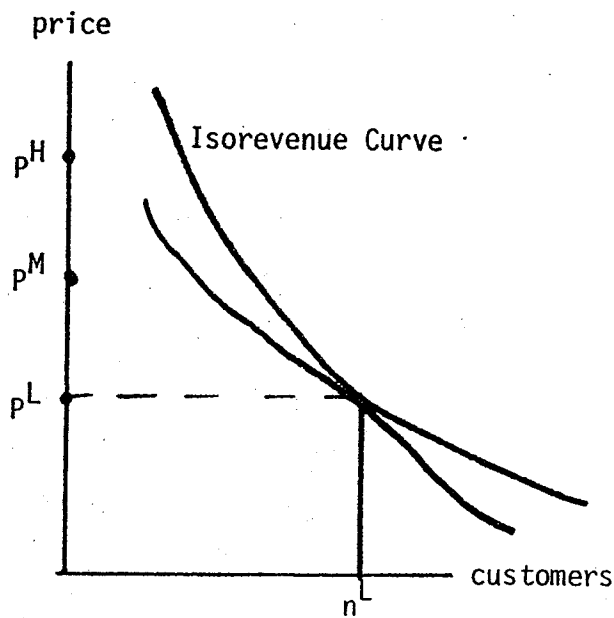Isorevenue Curve

p^L

customers

n^L

Figure 3: Demand in Firm L

higher-priced firms.) When price falls below p^L, customers are picked up from the lowest-priced firm and from the middle-priced firm. A similar description applies to the middle firm. The low-priced firm will lose customers out of the market if it increases price. For prices above p^M, these losses will be enhanced by losses to the middle firm of the customers with low switch costs. If the low-priced firm lowers the price, it will gain customers from the two higher-priced firms, and may attract some customers from out of the market who have low switch costs.

Figures 1, 2 and 3 show the demand curves for the three firms. Firms have market shares $\{n^L, n^M, n^H\}$ when the equilibrium prices are maintained. Figure 1 shows the demand curve in firm H when price is raised or lowered from p^H. Similarly, Figures 2 and 3 for the other two firms.

The demand curves reflect both the properties of the population density function $f(w,c)$, and the way in which this market is divided up among firms and out of the market. It should be apparent from the diagrams that the high- and middle-priced firms may be quite robustly at a profit maximum, since they may be at kinks in their demand curves. This suggests that some perturbations around the equilibrium may also be equilibria.

To see that many equilibria may occur, suppose we transfer some customers from the high-priced firm to the low-priced firm. This can be done in such a way that the same price p^H continues to be an equilibrium price for the high-priced firm. (For example, take the customers with the highest willingnesses to pay and the highest

switch costs. n^H decreases, but the kink in the demand curve continues to be a profit maximum.) Since n^L is now larger, the entire demand curve of the low-priced firm will shift right. Since the low-priced firm's demand is now higher, this transfer of people would generally require the equilibrium price of the low-priced firm to be higher than before. Thus, within some range of prices, one could imagine shifting market share in such a way as to generate a continuum of equilibria. This is similar to what we did in Example 2, where there was no dispersion in w. These shifts could be done in such a way that the optimal prices p^H and p^M do not change.

However, the abundance of equilibria which may occur does not guarantee than an equilibrium always exists. Following is an example in which no equilibrium exists.

Example 2: Suppose the distribution of w and c is concentrated on two points, (w^H, c^H) and (w^L, c^L), with N^H and N^L people respectively. We shall call these consumers type-L and type-H. Suppose furthermore that $c^H/w^L \geq N^L/N^H$, $w^H > w^L > c^H > 0$, $w^H - w^L > c^H$, and $w^H > 2c^H > 0$.[11] Then no equilibrium exists.

First, neither price is less than w^L. We argue separately for the cases $c^L > 0$ and $c^L = 0$.

Suppose $c^L > 0$. If the lowest-priced firm has price less than w^L, it could profitably raise its price without losing customers, since

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11. Parameters which satisfy are $w^H = 10$, $w^L = 4$, $c^H = 2$, $c^L = 1$, $N^L = 1$, $N^H = 10$.

customers will not flee to the other firm (which has higher price), and will not flee out of the market, since willingness to pay of all customers exceeds the lowest price. This argument also applies if both firms have the lowest price, provided $c^L > 0$.

If $c^L = 0$ and the lowest price is less than w^L, that firm can raise price without losing customers, provided $p^H > p^L$. If $0 < p^L = p^H < w^L$ at least one firm has type-L customers. The other firm can decrease price marginally and increase profit by stealing all the type-L customers. The only remaining possibility is that both prices equal zero. But then both firms make zero profit and at least one of them can make positive profit by increasing price and retaining his type-H customers. We conclude that if equilibrium exists, neither price is less than w^L.

Second, if both prices exceed w^L, then the prices must equal w^H. If both prices exceed w^L, then the only customers in the firms have willingness to pay w^H. The lower-priced firm could profitably raise price without losing any customers, since all of its customers have willingness to pay $w^H \geq p^H > p^L$. If the prices are equal, but less than w^H, then either firm could profitably raise price without losing customers.

Thus, there are only three possible price configurations: Both prices equal w^L, both prices equal w^H, or $p^L = w^L$ and $p^H = w^H$. In the first case, there may be type-L and type-H customers in each firm. If a firm raises price by c^H, it loses all of its customers with willingness to pay w^L, but retains all the customers with willingness to pay w^H. Suppose n_H^i and n_L^i, $i = L, H$, are the numbers of

type-H and type-L customers in firms $i=L,H$. Then if firm i deviates
to price w^L+c^H, his increase in profit is $c^H n_H^i - w^L n_L^i$. But since
$c^H/w^L > n_L^i/n_H^i$ for at least one firm i, such a price deviation by
firm i is profitable. This inequality holds for at least one firm i
because $c^H/w^L > N^L/N^H \geq n_L^i/n_H^i$ for one of the firms, i. The first
inequality is by assumption. We show the second inequality.
Suppose $N^L/N^H < n_L^i/n_H^i$ for all i. Cross-multiplying, and summing
over i, $N^L \Sigma n_H^i = N^L N^H < N^H \Sigma n_L^i \leq N^L N^H$. This is a contradiction.
[Although some of the type-L customers may not be in the market, all
of the type-H are in the market. $w^L+c^H < w^H$.]

The second case, with both prices equal to w^H, cannot be an
equilibrium because the firm with fewer customers could profit by
reducing price to w^H-c^H. Suppose n_H are the total number of type-H
distributed between the two firms. The firm with smaller market
share has $n_H^i \leq \frac{1}{2} n_H$. If it reduces price to w^H-c^H, it gets all of
the customers from the other firm, and the increment to profit is
$(w^H-c^H)n_H - w^H n_H^i \geq (w^H-c^H)n_H - w^H \frac{1}{2}n_H = n_H[\frac{1}{2}w^H-c^H]$, which is positive
by assumption.

The third case, $p^L=w^L$ and $p^H=w^H$, is not an equilibrium because
none of the type-H customers remain in the high-priced firm. w^H is
greater than w^L+c^H. Hence the high-priced firm is making zero
profit and could increase profit by setting price equal to w^L-c^H,
which is positive by assumption, because it would gain some type-H
customers.

We conclude that no equilibrium exists.

4. Equilibrium with Entry

In this section we consider the case in which entry of new firms can occur. In a price-setting equilibrium the market, F, is divided among firms with distributions F^j at firm $j=1,\dots,T$, and F^0 not purchasing the good at all. Firm j charges its customers p^j and finds it profit-maximizing to do so. Finally, no new firm could enter and profitably attract any customers, assuming the incumbents keep their prices fixed. We will assume that F has as its support a rectangle $[\underline{w},\bar{w}]\times[\underline{c},\bar{c}]$. This is consistent with w and c being independently distributed.

As above, we will look for conditions on F under which the equilibrium exists and is symmetric, or necessarily fails to exist, or may exist but is not necessarily symmetric.

Since unprofitability of entry is an additional equilibrium condition, price configurations which were equilibria with a fixed number of firms may cease to be equilibria with entry. The main result of this section is that whenever $\underline{c}<\underline{w}$, or if $\underline{c}=\underline{w}=0$, no equilibrium will exist. In order for there to be any possibility of an equilibrium, we must have large switch costs, relative to willingness to pay, for at least some of the population.

Proposition 4: If the minimum switch cost is positive and less than the minimum willingness to pay, $0<\underline{c}<\underline{w}$, no equilibrium with entry exists.

Proof: The lowest price must be equal to the lowest switch cost, $p^L=\underline{c}$. If the lowest price is below $\underline{c}$ then a lowest-price firm

can raise its price without losing customers. And if the lowest price is above $\underline{c}$ an entrant can successfully take some customers from the lowest-priced firm at a positive entry price. However, any firm charging $p^L=\underline{c}$ can profit by raising its price. Since all its customers have a positive switch cost, they will not go to any other firm, and since they have a reservation price strictly above p^L, they will not drop out of the market. Q.E.D.

Proposition 5: If $\underline{c}=0$, $0<\bar{c}$,[12] and $\underline{w}\geq 0$, no equilibrium with entry exists.

Proof: As in the proof of Proposition 4, the lowest price must be zero to deter entry. But, since a firm with zero price is earning zero profit, such a firm will always want to raise its price and retain some of its customers with positive switch costs, making positive profit instead. Q.E.D.

A consequence of Proposition 5 is that the equilibrium discussed in Proposition 1 ceases to be an equilibrium if entry is possible, and no equilibrium exists.

By virtue of these two propositions, equilibrium can exist only if $\underline{c}\geq\underline{w}$ and $\underline{c}>0$. We now give a simple example of a distribution F for which an equilibrium does exist, but these conditions, although necessary to existence, are not sufficient.

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12. Equilibrium exists if every customer's switch cost is zero. All prices are zero, and entry is deterred.

Example: Let c and w be independently distributed with the
distribution of w uniform on $[0,\bar{w}]$ and let $\underline{c} > \frac{\bar{w}}{2}$. The following
situation, with one active firm, is an equilibrium. All agents with
$w \geq \frac{\bar{w}}{2}$ purchase from the firm at a price $p = \frac{\bar{w}}{2}$. Those below $\frac{\bar{w}}{2}$ are out
of the market. The firm is in equilibrium because $p = \frac{\bar{w}}{2}$ maximizes
its profit, the marginal profitability of a price increase is zero,
and for a price decrease is strictly negative. No outside firm can
enter with any non-negative price because switch costs will make the
effective cost of purchasing at best $\frac{\bar{w}}{2}$, and this exceeds the
willingness to pay of all consumers who are out of the market.

5. Conclusion

We have explored the implication of switch costs for a price-
setting oligopoly. With no free entry and with reservation prices
constant across consumers we showed that an equilibrium may exist
only if the number of firms is small. In that case the prices will
generally equal the reservation price, except that there may be
exactly two firms who charge a lower price. With heterogeneous
reservation prices, no general conclusions about the existence or
nature of equilibria are possible.

With free entry of firms, the only cases in which equilibria
exist are when switch costs are high relative to reservation prices.
In this case customers are essentially under the monopoly power of

the firm from which they are buying. However, if there were

positive finite entry costs, then these may be equilibria. It would

be interesting to characterize them and their dependence of these

costs--a problem that we leave to future work in this area.

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