# Flexible Manufacturing and Market Structure

*By* B. Curtis Eaton and Nicolas Schmitt*

*In this paper we investigate the implications of flexible manufacturing for market structure. In the received theory of market structure, based largely on inflexible techniques of production, a number of well-known forces work to limit concentration. In our model none of these forces exists. Hence, we conclude that flexible manufacturing promotes concentration through preemption and mergers, or equivalently through cartels. Interestingly, the concentrated market structures associated with flexibility may or may not be welfare-dominated by a regime in which monopolization is not allowed.* (*JEL* D42, D43, L11, L12, L13)

This paper is motivated by two observations: (i) aside from the literature on contestable markets, economies of scope play no role in standard theories of market structure; (ii) increasingly, manufacturing firms produce an impressive array of differentiated products, using flexible techniques that exhibit economies of scope. This paper begins the development of the theory of market structure for such industries. In our model, flexibility promotes concentration through preemption and mergers, or the functional equivalent through cartels.

Although there exists no widely accepted definition of flexible manufacturing, there is agreement regarding certain features of it. Richard B. Chase and Nicholas J. Aquilano (1985) and Paul Milgrom and John Roberts (1990) focus on the ability to produce a variety of similar products, in random order and in small batches. Similarly, for Nigel R. Greenwood (1988 p. 7), the principal advantage of flexible manufacturing is that "[i]t makes possible the manufacture of the same basic product ... with a certain degree of customer-selectable variation." The following examples illustrate these features: Peerless Saw Company in Groveport, Ohio, whose computerized laser cutter is able to deliver customized sawblades (Jack R. Meredith, 1987); Toyota's car production system, described by its inventor as being "born of the need to make many types of automobiles, in small quantities with the same manufacturing process" (quoted by George Stalk, Jr. [1988 p. 44]); and Benetton, the Italian fashion company, whose information and production systems allow immediate response to hot-selling items and colors (Kim B. Clark, 1989). *Recent Trends in Flexible Manufacturing* (United Nations, 1986) documents the spread of such techniques on a country-by-country basis.

These few examples suggest that the essence of flexible manufacturing is *economies of scope* in the production of *differentiated goods*, and this is the approach we adopt. To incorporate product differentiation in our model, we adapt the familiar Hotelling model.[1] We introduce economies of scope by the device of a *basic product*. By incurring a sunk cost of product development, firms develop the ability to produce a basic product, described by a point in Hotelling's attribute space, at a constant marginal cost. A basic product can be modified to produce any other variant in the attribute space, but such modification in-

*Department of Economics, Simon Fraser University, Burnaby, BC V5A1S6, Canada. We thank two anonymous referees for helpful comments. Financial support from the Social Sciences and Humanities Research Council of Canada (grant 410-92-0880) is gratefully acknowledged.

[1]Equally, we could have used some version of the J. Jaskold Gabszewicz and Jacques-François Thisse (1980) model of vertical differentiation (see Section IV).

volves additional costs; the *cost of switching* the production process from one variant to another, and a per-unit *cost of modification* that is proportional to the difference (in the attribute space) between the basic product and the variant. The model has three parameters related to economies of scope which we believe capture fundamental aspects of flexible manufacturing: the cost of developing the basic product, the cost of switching the production process from one variant to another, and a parameter that governs the rate at which the cost of modification increases with the extent of modification. Our model is essentially the same as that of W. Bentley MacLeod et al. (1988), but applied to different economic issues.

Lars-Hendrik Röller and Mihkel M. Tombak (1990) also model flexibility in terms of economies of scope but focus on different issues. They look at the choice of technology in a framework where there are two products, two firms, and three technologies: two are inflexible one-product technologies, and the third is a flexible two-product technology. Milgrom and Roberts (1990) and Milgrom et al. (1991) formulate a wide-ranging theory of the firm in which firms exercise flexibility in a number of dimensions, including inventory policy, product market strategy, and the internal organization of the firm, as well as the number and attributes of products. Our model captures only some of these concerns, but it does allow us to explore in some detail the implications of flexibility for market structure.[2]

In our model, provided that the technology is sufficiently flexible, firms choose to produce a continuum of goods. We develop five results concerning market structure for this case: (i) the ownership structure of basic products has no bearing on the expected profitability of an entrant; (ii) the possibility of entry has no bearing on the incentives of incumbent firms to merge or form a cartel; (iii) an entrant can never induce an incumbent to abandon one of its basic products; (iv) the firms involved in a merger (cartel) capture all the added profit created by their activity; and (v) in a game of sequential entry, monopoly preemption is the inevitable outcome. When manufacturing is inflexible, none of these results is true in general. Hence, we are led to the conclusion that flexibility, as we have modeled it, promotes concentration. Interestingly, the normative implications of flexibility in our model are ambiguous. Although flexibility leads to more concentrated market structures, the resulting equilibrium is not always welfare-dominated by the equilibrium in which firms are not allowed to merge, form cartels, or engage in market preemption.

[2]There is a well-known literature, initiated by George J. Stigler (1939), that focuses on an entirely different sort of flexibility, the trade-off between the curvature of the average cost function and its level.

## I. The Model

We cast our analysis in an address model, similar in most respects to Harold Hotelling's (1929) model. In such models, each good is described by a point $x$ in some continuum of product attributes. We choose to work in a one-dimensional attribute space with support $[0,1]$.

### A. *Preferences*

We begin with a standard, though quite restrictive representation of preferences, which we relax somewhat in Section III. From a consumer's perspective, any good is completely described by its address $x$ in the attribute space and by its price, $p(x)$. Faced with the possibility of buying a number of goods, we suppose that any consumer buys exactly one unit of (at most) one good that he/she cannot customize. The utility from buying one unit of good $x$ at price $p(x)$ is

$$(1)\quad U(x,p(x)) = V - p(x) - t|x - x^*|$$

where $x^*$ in $[0,1]$ describes the consumer's most preferred good (or the consumer's address), and $V$ is the consumer's reservation price for that good. Given a choice among many goods, the consumer buys one unit of the good for which $U(x,p(x))$ is a maximum, provided that the maximum is positive. If the maximum is negative, the consumer buys none of these goods. The distance from $x$ to the consumer's most preferred good is $|x - x^*|$; hence $t$ is the marginal disutility of distance in the attribute space. We assume that the parameters $t$ and $V$ are identical for all consumers, but that $x^*$ varies from one consumer to another. Specifically, we suppose that $x^*$ is uniformly distributed on $[0,1]$ with unit density. We have then a continuum of consumers (each one characterized by its most preferred good) that is coincident with the continuum of possible goods. Notice that equation (1) implies that a consumer may choose not to consume the product with most preferred characteristic $x^*$ even if it is available. Whether the consumer chooses to do so or not will depend on the prices and addresses of all the available products.

### B. *Flexibility*

In most models of product differentiation the costs of producing a particular good are composed of a sunk product development cost and a constant marginal cost of production. Regardless of how many goods a firm is currently producing, if it wants to produce another, the firm must incur the product development cost for that good. In this sense, the technology is perfectly inflexible, and there are no economies of scope. We introduce flexibility into this model by supposing that firms first develop one or more *basic products*, and then produce variations on those basic products.

We denote the location in the attribute space of basic product $i$ by $X_i$, and the location of variant $j$ by $x_j$. Letting $q_j$ denote the quantity of variant $j$, we can describe a production plan by

$$(2)\quad (\mathbf{x},\mathbf{q}) = [(x_1,q_1),(x_2,q_2),\ldots,(x_m,q_m)]$$

where $m$ is the total number of variants in the production plan. The *span of a production plan* is defined to be the maximal value of $x_j$ minus its minimal value, and it is a measure of the diversity of goods included in the production plan.

The cost of producing $(\mathbf{x},\mathbf{q})$, using basic product $X_i$ as an anchor, is given by the following expression:

$$(3)\quad C((\mathbf{x},\mathbf{q});X_i) = K + (m-1)s + \sum_{j=1}^{m}[q_j(c + r|x_j - X_i|)].$$

The parameters $K$, $s$, $c$, and $r$ are nonnegative. $K$ is the cost of developing basic product $X_i$, $s$ is the cost of switching from one variant to another, and $c + r|x_j - X_i|$ is the marginal cost of producing a unit of variant $x_j$. We assume that the product development cost $K$ is sunk and attribute-specific, which allows firms to commit to their basic products.[3] Interpret $c$ as the marginal cost of producing a unit of the basic product, and $r|x_j - X_i|$ as the incremental cost of modification; the further variant $x_j$ is from basic product $X_i$, the larger is the cost of modification.

We will say that there are *strong economies of scope* for a production plan $(\mathbf{x},\mathbf{q})$ if the least costly way to produce it involves just one basic product, and *weak economies of scope* if the least costly method of production involves fewer basic products than the number of goods in the production plan. Clearly, this technology exhibits strong economies of scope for some production plans. Consider, for example, the following plan: $[(0.25,100),(0.75,100)]$. The least-cost method of producing this plan involves either one basic product located in the interval $[0.25,0.75]$ or two basic products, one at 0.25 and the other at 0.75. The cost of the first method is $K + s + 200c + 50r$, and the cost of the second is $2K + 200c$. The first method is therefore cheaper, and the technology exhibits strong economies of scope for this production plan, if $K$ exceeds $(s + 50r)$.

[3]It is customary to interpret the development cost $K$ as a flow associated with a stock of expenditures on product development. If $I$ is spent on product development and if $i$ is a time-invariant interest rate, then $K$ is equal to $iI$.

A necessary condition for economies of scope, weak or strong, is that $K$ exceeds $s$. Beyond that, we have the following straightforward results. Assuming that $K$ exceeds $s$, the technology exhibits strong economies of scope for any production plan $(\mathbf{x},\mathbf{q})$ if the following conditions hold:

(i) $r$ is sufficiently small;
(ii) $(K-s)$ is sufficiently large;
(iii) the span of $(\mathbf{x},\mathbf{q})$ is sufficiently small.

It exhibits weak economies of scope if the number of variants in the production plan is sufficiently large (holding $\sum_{j=1}^{m} q_j$ constant).

To generate an extreme case of flexibility, we assume that the switching cost $s$ is equal to zero and that the development cost $K$ is strictly positive.[4] In addition, and with no further loss of generality, we assume that $c$ is zero. Thus we use the following cost function:

$$(4)\quad C((\mathbf{x},\mathbf{q});X_i) = K + \sum_{j=1}^{m} q_j\big(r|x_j - X_i|\big).$$

Let $\mathrm{MC}_i(x)$ denote the marginal cost of good $x$ using basic product $X_i$. Thus,

$$(5)\qquad \mathrm{MC}_i(x) = r|x - X_i|.$$

As the reader familiar with Hotelling's (1929) classic model will recognize, there is just one major difference between his model and ours. In our model, once a firm has developed a basic product it can produce any good in the [0,1] attribute space, whereas in Hotelling's model, firms have no such flexibility. Note however that our model encompasses Hotelling's since as $r$ approaches infinity, we obtain Hotelling's perfectly inflexible technology. Note also that, like Hotelling's model, ours can be interpreted in two ways. We have explicitly cast the model as one of differentiation in an attribute space, but it can also be interpreted as a model of spatial competition; the parameters $r$ and $t$ then represent the firm's and the consumer's costs of transportation, respectively.

### C. *Price Equilibrium*

Now suppose that a number of different basic products, say $l$, have been developed by a number of different firms, say $n$, and let $X_i$ denote the address of the $i$th basic product.[5] Taking these basic products and their ownership as given, four types of Nash price equilibrium are possible, depending upon the relative magnitudes of the parameters $t$ and $r$. Here we discuss only two of these; a complete discussion of the price equilibria in these types of models can be found in Eaton and Schmitt (1992, 1993). One price equilibrium is familiar: when $r$ is very large relative to $t$, only basic products are produced, and the price equilibrium is identical to the one in which the technology is completely inflexible.

In this article we focus on the price equilibrium for the case in which $r < t$. Since each firm can produce each good in the [0,1] continuum, a price equilibrium involves a complete price schedule for each firm. To find the equilibrium price schedules when $r$ is less than $t$, think of a series of Bertrand price games involving all $n$ firms, one game for every good $x$ in [0,1]. Supposing for the moment that the parameter $V$ is arbitrarily large, Bertrand competition will drive the price for good $x$ down to the marginal cost of the second most efficient firm. For this to be an equilibrium, the most efficient firm must make the sale of

[4]This assumption not only simplifies the analysis, but as will become clear, it also brings significant insights into flexible manufacturing. Nonetheless relaxing this assumption is an important item on our research agenda.

[5]We assume that all basic products are unique, thus ignoring the possibility that two firms choose to develop the same basic product. This assumption has no bearing on our results, but it does allow us to ignore a number of uninteresting special cases.

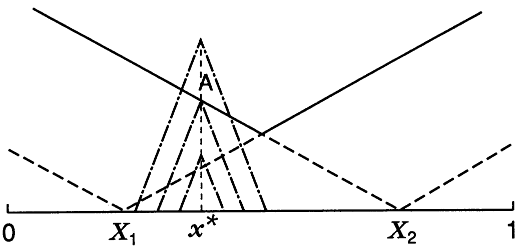


FIGURE 1. CONSUMER CHOICE GIVEN EQUILIBRIUM PRICES

good $x$.[6] We have then one set of equilibrium price schedules: for every good $x$, each firm's equilibrium price is the marginal cost of the second most efficient firm. For the 3rd, 4th, ..., and $n$th most efficient firms at attribute $x$, any higher price is also an equilibrium price.

Since $t$ exceeds $r$, the consumer will always choose to buy her most preferred good in such a price equilibrium even though she is free to buy any good in the entire spectrum. This point is illustrated in Figure 1. In this figure, there are two basic products, located at $X_1$ and $X_2$, owned by different firms. The dashed lines represent marginal costs of production for any good in the attribute space, using $X_1$ and $X_2$ as bases, and the solid line represents the equilibrium price schedule. The slopes of these schedules are, in absolute value, equal to $r$. The dot-dashed lines represent the indirect indifference curves of the consumer whose most preferred good is $x^*$, and the slopes of the indifference curves are, in absolute value, equal to $t$. Consumer $x^*$ buys good $x^*$ since, of all the points on the equilibrium price schedule, point A is on the lowest, and therefore most preferred, indirect indifference curve. Hence, in this price equilibrium, the entire continuum of goods is produced, and each consumer buys her most preferred product.

Two refinements are necessary when we drop the assumption that $V$ is arbitrarily large. Let $\mathrm{MC}^1(x)$ denote the smallest, and $\mathrm{MC}^2(x)$ the second smallest, marginal cost of producing good $x$ among all the firms.[7] First, if $V$ is less than $\mathrm{MC}^1(x)$, then the equilibrium price for $x$ is any price greater than $V$; for concreteness, it is $\mathrm{MC}^1(x)$. Second, if $V$ lies between $\mathrm{MC}^1(x)$ and $\mathrm{MC}^2(x)$, then the equilibrium price is $V$. The following is then a Nash equilibrium price schedule for all firms when $t$ exceeds $r$:

$$(6)\quad p^*(x) = \begin{cases} \mathrm{MC}^1(x) & \text{if } V < \mathrm{MC}^1(x) \\ V & \text{if } \mathrm{MC}^1(x) \le V \\ & \quad \le MC^2(x) \\ \mathrm{MC}^2(x) & \text{if } \mathrm{MC}^2(x) < V. \end{cases}$$

In equilibrium, the two lowest-cost firms necessarily announce price $p^*(x)$, but any price greater than or equal to $p^*(x)$ is an equilibrium price for higher-cost firms. The equilibrium market segment captured by basic product $i$, $\mathcal{M}_i^*$, is

$$(7)\quad \mathcal{M}_i^* = \{x : \mathrm{MC}_i(x) \le \min[\mathrm{MC}_j(x), V] \text{ for } j \ne i\}.$$

In the case where individual demand is not perfectly inelastic, simply interpret $V$ as the monopoly price for the individual demand function. This price equilibrium is, in effect, the familiar discriminating-price equilibrium of spatial competition, originally identified by Edgar M. Hoover (1937) and reconsidered by Eaton and Richard G. Lipsey (1979), Philip J. Lederer and Arthur P. Hurter (1986), and MacLeod et al. (1988), among others.

[6]If the most efficient firm did not make the sale, it would have an incentive to shave price. Hence, if it does not make the sale, we have not found the equilibrium. But there can be no equilibrium in which the most efficient firm's price is less than the marginal cost of the second most efficient firm, since at any such price, the most efficient firm has an incentive to raise its price.

[7]A firm's marginal cost is the minimum of $\mathrm{MC}_i(x)$ over all basic products $i$ owned by that firm.

## II. Contrasting Implications of Flexible Manufacturing

In this section we establish four implications of flexibility for market structure, contrasting each with corresponding results for inflexible manufacturing. By flexibility, we mean both $s = 0$ and $r < t$. We show that certain forces that tend to limit concentration in other models are inoperative in ours.

We begin with a lemma concerning the link between a firm's equilibrium profit and the ownership structure for established basic products owned by other firms. An ownership structure for a set of basic products specifies the firm that owns each basic product.

LEMMA 1: *Given a fixed set of basic products owned by firm A, $\mathcal{S}_a$, and a fixed set of basic products owned by firms other than A, $\mathcal{S}_o$, the equilibrium profit of firm A is independent of the ownership structure of $\mathcal{S}_o$.*

PROOF:

Consider the case in which firm $A$ owns just one basic product with address $X_a$ and associated market segment $\mathcal{M}_a^*$. Firm $A$'s profit is

$$(8)\quad \pi_a^* = \int_{x \in \mathcal{M}_a^*} [p^*(x) - \mathrm{MC}_a(x)]\,dx - K.$$

From (6) and the definitions of $\mathrm{MC}^1(x)$ and $\mathrm{MC}^2(x)$, we see that the equilibrium price schedule $p^*(x)$ depends on the parameters $V$ and $r$ and on the addresses of basic products, but not on the ownership structure of basic products in $S_o$. Similarly, from (7), we see that firm $A$'s market segment, $\mathcal{M}_a^*$, is determined by the same list of arguments. Hence, $\pi_a^*$ does not depend on the ownership structure of existing basic products. This argument clearly generalizes to the case in which firm $A$ has many basic products.

The following special case helps to provide an intuitive understanding of Lemma 1 and a link to MacLeod et al. (1988). Suppose that the reservation price $V$ is arbitrarily large so that all goods in the attribute space are produced. Then, from (6) we see that the equilibrium price for any variant $x$ in $\mathcal{M}_a^*$ is equal to the marginal cost of the second most efficient firm for that variant, $p^*(x) = \mathrm{MC}^2(x)$. Of course, in the absence of firm $A$, variant $x$ in $\mathcal{M}_a^*$ would be produced at cost $\mathrm{MC}^2(x)$. From (8) it is then clear that firm $A$'s profit is equal to the cost savings attributable to its basic product. This cost savings is independent of ownership structure since, in equilibrium, goods are produced by the most efficient firm. The result that a firm's profit is equal to the cost savings attributable to that firm is, for a general attribute space, lemma 1 in MacLeod et al. (1988). In this sense, our Lemma 1 is a corollary of their lemma 1.

If in Lemma 1 we interpret firm $A$ as an entrant and $\mathcal{S}_o$ as the set of basic products owned by established firms, we get our first proposition.

PROPOSITION 1: *The profitability of entry does not depend on the ownership structure of existing basic products.*

In other words, if entry is deterred for one structure of ownership, say, the case in which each basic product is owned by a separate firm, it is also deterred for any other structure, including the one in which all basic products are owned by just one firm. Figure 2 illustrates the point. In Figure 2A, basic products $X_i$ and $X_j$ are owned by separate firms, and in Figure 2B they are owned by the same firm; in both, $X_h$ is the entrant's basic product. In both Figure 2A and Figure 2B, the dashed lines represent the marginal-cost schedules, the solid line is the equilibrium price schedule, and the shaded area is the entrant's profit. The entrant's profit is, of course, identical in Figure 2A and 2B.

By way of contrast, in any address model of which we are aware, Proposition 1 does not hold in the absence of flexible production; roughly, the more concentrated is ownership, the more attractive is entry. The same conclusion holds for nonaddress models as well. James A. Brander and Jonathan

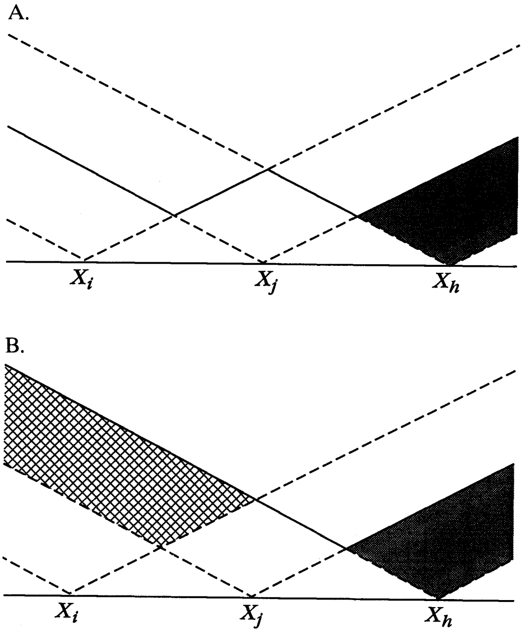


FIGURE 2. OWNERSHIP STRUCTURE, MERGERS, AND PROFIT: A) BASIC PRODUCTS OWNED BY SEPARATE FIRMS; B) TWO BASIC PRODUCTS OWNED BY THE SAME FIRM

Eaton (1984) is particularly instructive in this regard.

Proposition 1 has an obvious, though we think important, corollary:

PROPOSITION 2: *Mergers among incumbent firms (or cartelization) cannot induce entry.*

To put the point differently, since the configuration of basic products, not their ownership structure, determines the profitability of entry, the threat of this sort of entry is not a barrier to merger in our model. Like Proposition 1, Proposition 2 clearly does not hold with inflexible manufacturing.

If now we interpret firm $A$ in Lemma 1 as being an established firm not participating in a merger (or a cartel), we have our third proposition.

PROPOSITION 3: *Mergers (or cartels) confer no profit externalities on firms not involved in the merger (cartel).*

Figure 2 also illustrates Proposition 3. In Figure 2A, there are initially three independent firms, and each firm owns one basic product; in Figure 2B the firms that initially owned basic product $X_i$ and $X_j$ have merged. The crosshatched area in Figure 2B represents the added profit created by the merger, all of which is captured by the merging firms.

There is a long literature, going back at least to Stigler (1950), in which it is shown that mergers and cartels may not be profitable, because the involved firms cannot capture all the profit created by their cooperative efforts. In this literature, if a merger does not involve all relevant firms, there is a positive profit externality conferred on noninvolved firms and, hence, an incentive for each firm to free-ride on the cooperative efforts of others. Proposition 3 shows that this possibility does not exist with flexible manufacturing.

In Propositions 1 and 2 we considered what might be called *augmenting entry*, entry which simply augments the capacity devoted to the market. Kenneth L. Judd (1985) shows that with inflexible manufacturing, the possibility of *predatory entry* sometimes limits the ability to monopolize a market via preemption.[8] Consider, for example, a market for two close substitutes, say widgets and gadgets, and suppose that costs for each product are composed of a sunk product development cost and a constant marginal cost. Now imagine that firm $A$ attempts to preempt by incurring the sunk costs for both products. Clearly, the preemption strategy would work if firm $A$ were committed to produce both goods, since if firm $B$ also produced one of the goods, say gadgets, the equilibrium price of gadgets would be equal to its marginal cost, and there would be no quasi-profit to cover $B$'s product development cost. Unless there are significant exit costs, however, $A$ is not committed to

[8]There is a third type of entry that is potentially important, entry for buyout, which we ignore; see Eric Rasmusen (1988).

producing gadgets since, given competition in gadgets from $B$, $A$'s profit would increase if it exited from the gadget market. In effect, by ceasing to produce gadgets, $A$ loses nothing in the gadget market and gains something in the widget market, since the price of gadgets increases, which tends to increase $A$'s profit from the sale of widgets. Thus, when exit costs are insignificant, $A$ cannot preempt both markets; if it tried to, $B$ could, and would, drive $A$ from one market.

That is, when technology is inflexible, the possibility of predatory entry implies that preemption is not always possible. In Judd's (1985) story, a necessary condition for predatory entry is that there exist circumstances such that a firm's profit increases when it abandons capacity. In Proposition 4 we show that such circumstances do not exist in our model. Hence, given the preferences and technology of Section I, and the dynamic structure of Judd's model, predatory entry is not possible.

PROPOSITION 4: *Given the set of basic products owned by other firms and the ownership structure for those basic products, a firm's equilibrium profit cannot increase if it abandons one or more of its basic products.*

PROOF:

Notice that the costs associated with product development are sunk and thus have no bearing on the exit decision, and also note that the equilibrium price for any good that a firm sells is never less than its marginal cost for that good. Suppose then that there exists at least one basic product owned by a firm other than $A$ and that firm $A$ has a number of basic products and abandons one of them. There are two sorts of effect on $A$'s profit. First, its market gets smaller, an effect that can decrease but cannot increase its profit. Second, for any $x$ that remains in firm $A$'s market after abandonment, $A$'s marginal cost may increase, but its price does not change; as a result, its profit from any such point may decrease but cannot increase. This argument clearly generalizes to the case in which firm $A$ abandons any number of basic products.

A common theme runs through all four of these propositions: mergers, cartels, and preemption are all easier to pursue or are more attractive where technology is flexible than where it is inflexible. Accordingly, in the next section, we consider some positive and normative implications of preemption in a game of sequential entry.

## III. Sequential Entry and Flexible Manufacturing

To determine the limits of concentration, the modern literature on market structure in differentiated product industries has focused on games of sequential entry. The early literature seemed to point to monopolistic preemption by means of product proliferation (see e.g., Edward C. Prescott and Michael Visscher, 1977). The currently accepted wisdom is somewhat different. Since the ownership structure of existing products affects the profitability of entry (as in Brander and Eaton [1984]), the first mover will sometimes allow entry of one or more additional firms because, relative to oligopolistic entry deterrence, monopolistic entry deterrence requires too many products and is therefore too costly. In addition, as Judd (1985) shows, preemption through product proliferation is not always credible because the would-be preemptor is sometimes vulnerable to predatory entry. Neither of these concentration-limiting forces exists in our model, and accordingly sequential entry necessarily generates monopoly preemption.[9] In this section, we examine some positive and normative implications generated by monopolistic preemption in two versions of our model: when individual demand is inelastic and when it is elastic.

[9] It is sometimes argued that there is a public-good aspect to entry deterrence which constitutes in itself a limit to monopolization (see e.g., Richard Gilbert and Xavier Vives, 1986). An obvious corollary of Proposition 3 is that such an externality does not exist in our model.

### A. *Entry with Perfectly Inelastic Demand*

The first result that we establish is that the first mover preempts the market by establishing the configuration of basic products that maximizes profit, ignoring the possibility of subsequent entry. In other words, the first mover is unconstrained by the threat of subsequent entry. To show this, we use an argument by contradiction. Assume that (i) the first mover has chosen its basic products to maximize profit unconstrained by the possibility of entry, and (ii) given the first mover's choice, entry is profitable.

Let $\mathcal{S}$ denote the segment of the entrant's market that would have been served by the first mover had entry not occurred, and let $\mathcal{U}$ denote the segment of the entrant's market that would not have been served had entry not occurred.[10] Assumption (ii) can then be expressed by the following inequality:

$$(9)\quad [R_e(\mathcal{U}) - \mathrm{VC}_e(\mathcal{U})] + [R_e(\mathcal{S}) - \mathrm{VC}_e(\mathcal{S})] - n_e K > 0$$

where $n_e$ denotes the number of basic products established by the entrant, $R_e(\mathcal{U})$ and $R_e(\mathcal{S})$ denote the entrant's revenues from the two segments of its market, and $\mathrm{VC}_e(\mathcal{U})$ and $\mathrm{VC}_e(\mathcal{S})$ denote the entrant's variable costs from the two segments. Observe now that, given the post-entry price equilibrium and price inelastic demand, the entrant's total revenue from segment $\mathcal{S}$ is equal to the variable costs the first mover would incur if it served segment $\mathcal{S}$. In other words, $R_e(\mathcal{S}) = \mathrm{VC}_m(\mathcal{S})$, where $\mathrm{VC}_m(\mathcal{S})$ denotes the first mover's variable costs when it serves segment $\mathcal{S}$. Hence,

$$(10)\quad [R_e(\mathcal{U}) - \mathrm{VC}_e(\mathcal{U})] + [\mathrm{VC}_m(\mathcal{S}) - \mathrm{VC}_e(\mathcal{S})] - n_e K > 0.$$

[10]Although we would often expect the market to be covered ($\mathcal{U} = 0$), our argument does not depend on this assumption.

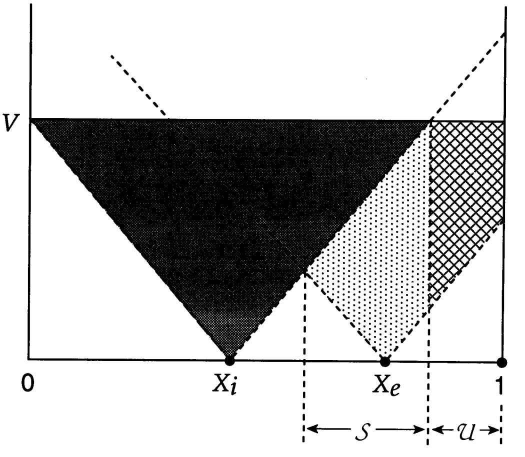


FIGURE 3. MONOPOLY PREEMPTION WITH INELASTIC DEMAND

But this inequality contradicts assumption (i)—that the first mover chose its basic products to maximize profit unconstrained by the possibility of entry—because it implies that the first mover's profit would have been larger had it established the $n_e$ additional basic products. Supposing that the first mover did establish these additional basic products, the first term in square brackets of (10) represents the net revenue the first mover would earn from segment $\mathcal{U}$, the second term in square brackets is the reduction in costs the first mover would enjoy from serving segment $\mathcal{S}$, and the last term represents the development costs of the additional basic products. Since from (10) the first mover's profit from serving segments $\mathcal{S}$ and $\mathcal{U}$ is positive, and since these additional basic products could not possibly decrease the first mover's profit from the rest of the market, the first mover is not initially maximizing profit. That is, assumption (ii) contradicts assumption (i).

Figure 3 illustrates the argument. Assume (i) that the first mover maximizes profit (unconstrained by entry) by establishing basic product $X_i$ and (ii) that the entrant gets a positive profit by establishing the additional basic product $X_e$. From (ii) we infer that, with reference to Figure 3,

$$\text{cross-hatched area} + \text{dotted area} - K > 0.$$

Given $X_i$ and no entry, the first mover's profit is the shaded area in Figure 3, less $K$. If it had also established basic product $X_e$ its profit would have been equal to

shaded area + cross-hatched area + dotted area − $2K$.

The incremental profit associated with basic product $X_e$ is then equal to

cross-hatched area + dotted area − $K$

which, given (ii), is positive. Hence (ii) contradicts (i).

Proposition 5 then follows.

PROPOSITION 5: *When individual demand is perfectly price-inelastic, the first mover will choose the configuration of basic products that maximizes total profit, and no other firms will enter the market.*

Given this sort of monopoly preemption, all the customers who are served pay their reservation price $V$ for the product they buy. Hence, the preemptor captures the entire surplus that is created. Since it also bears all the costs, the monopoly preemption equilibrium is cost–benefit optimal.

PROPOSITION 6: *When demand is perfectly price inelastic, monopoly preemption is cost–benefit optimal.*

### B. *Entry with Responsive Demand*

In this subsection we consider an example in which individual demand is responsive to price. In this example, the first mover cannot in general ignore the possibility of subsequent entry, nor is monopoly preemption necessarily cost–benefit optimal. To generate exact results we would have to consider two types of basic product: peripheral products (the first and last products in the attribute space) and interior products. Instead we generate approximate results by focusing exclusively on interior products. One can provide an exact justification of this simplification by supposing that the attribute space is the circumference of a circle, or by supposing that it is unbounded. In addition, we suppose that the number of basic products is a real number. We use the following individual demand function:

$$(11)\quad q(x)=\begin{cases}\dfrac{1}{p(x)} & \text{if } p(x)\le V\\ 0 & \text{if } p(x)>V.\end{cases}$$

Notice that price equal to $V$ is the monopoly price for this demand function.

We start by solving the first mover's problem, ignoring the possibility of entry and assuming that parameter values are such that the market is viable and covered.[11] Since $p(x)$ equal to $V$ maximizes revenue in (11), the first mover sells each good in $[0,1]$ at $V$, producing $1/V$ units of each. Its total revenue is then equal to 1. The cost of producing $1/V$ units of each good using $n$ evenly spaced basic products is

$$(12)\quad \mathrm{TC}(n)=n\left[K+\frac{2}{V}\int_0^{1/2n}(rx)\,dx\right].$$

The cost-minimizing number of basic products, $n^*$, is then

$$(13)\qquad n^*=\frac{1}{2}\left(\frac{r}{VK}\right)^{1/2}$$

and minimized costs are

$$(14)\qquad \mathrm{TC}(n^*)=\left(\frac{rK}{V}\right)^{1/2}.$$

Hence, unconstrained by entry, a first mover would establish $n^*$ evenly spaced products if TC($n^*$) is less than 1, and none if TC($n^*$) exceeds 1.

To discover when the entry constraint is binding, we compute the expected profit of an entrant given $n$ basic products evenly spaced. The entrant can do no better than

[11]A sufficient condition for the market to be covered is that $V > r/2$.

to enter at the middle of the segment between two of the first mover's basic products, where its profit is

$$\pi_e(n) \tag{15}$$

$$= 2\int_0^{1/4n} \{[p(x) - rx]q(x)\}\,dx - K$$

or

$$\pi_e(n) = \frac{a}{n} - K \tag{16}$$

where

$$a = 1 - \ln(2). \tag{17}$$

Hence the no-entry condition is

$$n \geq \frac{a}{K}. \tag{18}$$

Surprisingly, although there are three parameters in this model ($r$, $K$, and $V$), its behavior is dependent on just one (composite) parameter, defined as

$$Z = \frac{V}{rK}. \tag{19}$$

As the reader can easily verify by comparing (13) and (18), the first mover is constrained or unconstrained by entry as $Z$ is greater than or less than $1/(4a^2)$.

Combining results, the solution to the first mover's problem is: (i) establish no basic products if $Z < 1$; (ii) establish $n^*$ basic products if $1 \leq Z \leq 1/4a^2$; or (iii) establish $a/K$ basic products if $1/4a^2 \leq Z$.

Given any set of basic products, cost–benefit optimality requires that all goods be priced at marginal cost. Trivially, the market structure generated by sequential entry is thus not cost–benefit optimal when individual demand is responsive to price.

It is perhaps more instructive to make welfare comparisons between the monopoly preemption equilibrium and the equilibrium that emerges when each firm is constrained to establish no more than one basic product. The results in Prescott and Visscher (1977) suggest that, in the one-firm/one-basic-product equilibrium, the number of basic products will be the smallest number consistent with no entry. The appropriate no-entry condition is, of course, given by inequality (18). Hence, there will be $a/K$ evenly spaced basic products when firms are constrained to have no more than one basic product.

We have computed the standard cost–benefit welfare index (profit plus consumer's surplus) for these two cases, and we find that when $Z$ is small, monopoly preemption is welfare-dominant, but when $Z$ is large the one-firm/one-product solution is clearly preferable. When $Z$ is small, more competitive market structures do not substantially decrease the deadweight losses associated with monopoly pricing, and it involves too many basic products relative to the preemption solution. When $Z$ is large, the one-firm/one-product market structure is more desirable since not only does price competition offset to a significant degree the deadweight loss associated with monopolistic pricing, but preemption entails far too many products. Proposition 7 summarizes the results.

PROPOSITION 7: *When demand is not perfectly price inelastic, monopoly preemption is not cost–benefit optimal, and it may or may not be welfare-dominated by the equilibrium in which firms are constrained to have no more than one basic product.*

## IV. Conclusions

We chose to use the Hotelling model as the kernel of ours because it is the most familiar address model of product differentiation. As regards address models, it is clear from MacLeod et al. (1988) that our results are quite general. And the following discussion indicates that the address framework itself is not necessary.

To see this, consider a less specific model with many goods and many technologies.

Assume the following:

(i) Firms choose prices noncooperatively.
(ii) Each technology is flexible in that it permits the production of all the goods.
(iii) For each technology, the cost of producing any mix of goods is a linear function of quantities produced; that is, there are no fixed costs, and the marginal costs of the different goods are all constant.
(iv) Each consumer consumes at most one unit of one good.

To identify each consumer's most preferred good, imagine that each good is priced at its smallest marginal cost over all technologies. A consumer's most preferred good is the one she would choose at these prices. Now, given any set of technologies and any ownership structure, suppose that all firms price all goods at the marginal cost of the second most efficient firm. Then assume:

(v) given these prices, all consumers buy their most preferred product.

Given the five assumptions above, for all goods, price equal to marginal cost of the second most efficient firm is an equilibrium. The most efficient firm for any good, say, good $i$, clearly will not raise the price of good $i$ since by doing so it would lose all its sales and hence profit from good $i$, without affecting its sales and profit from other goods. Nor will it lower price: a price reduction will not attract new customers since all customers are initially buying their most preferred goods, nor will a price reduction increase sales to existing customers, since demand is unresponsive to price. In addition, none of the other firms has an incentive to change the price it charges for good $i$: a reduction in price entails sales at less than marginal cost in the market for good $i$ and has no implications for sales of other goods; an increase in price leaves the firm's profit unchanged since it initially sells nothing, and no consumer responds to its price increase.

Lemma 1 states that the equilibrium profit of an arbitrary firm $A$ is independent of the ownership structure of the existing technologies owned by other firms. The equilibrium prices of the goods produced by firm $A$ are clearly independent of ownership structure of the technologies owned by other firms, and since in equilibrium consumers buy their most preferred product, so too are quantities demanded of firm $A$'s products. Hence, assumptions (i)–(v) imply Lemma 1 and the three propositions that follow from it: 1) the profitability of entry is independent of ownership structure of existing technologies; 2) mergers among incumbent firms cannot induce entry; and 3) a merger confers no profit externalities on firms not involved in the merger.

Proposition 4, that multiproduct firms are not vulnerable to predatory entry, also follows from these assumptions. If a firm abandons a technology, neither the equilibrium prices nor quantities of the goods it produces subsequent to abandonment will change, and hence its profit cannot increase as a result of abandoning a technology.

Finally, make the following additional assumptions:

(vi) All firms have access to all technologies.
(vii) There is a positive sunk cost associated with each technology.

Then, the solution to the game of sequential entry in which no technologies have yet been created involves monopoly preemption by the first mover, and the monopoly-preemption equilibrium is cost–benefit optimal. (The argument presented in Subsection III-A is directly applicable.)

Assumption (v) merits some elaboration. It requires that customers have access to a less efficient customizing technology than do firms, as argued by MacLeod et al. (1988). If this were not the case, consumers might choose to buy only basic products as inputs into their own customization process. In addition, as we have stressed in this paper, when goods are priced at the marginal cost of the second most efficient firm, the money equivalent of the utility loss a consumer incurs by consuming a good other than her most preferred good must be larger than the price/marginal-cost differential between the two goods. Otherwise, all goods may not be produced in equilibrium, and equilibrium prices for the goods that are produced will be less than the marginal cost of the second most efficient producer as firms reduce price to draw customers away from their rivals.

The contribution of our version of the Hotelling model is to provide one set of circumstances in which these more general assumptions hold. Fairly clearly, any of a variety of familiar address models of competition could be adapted to serve the same purpose.

We are led then to two main conclusions. First, many of the forces that tend to limit concentration in standard theories of market structure are completely suppressed when these assumptions are satisfied. Second, the associated high level of market concentration may not reflect inefficiency—it all depends on the elasticity of individual demand. Hence, given the central role that flexibility plays in our results, and given the growing importance of flexible manufacturing techniques, a rethinking of competition policy in the context of flexible manufacturing seems called for.

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