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FLEXIBLE MANUFACTURING, UNCERTAIN CONSUMER TASTES, AND STRATEGIC ENTRY DETERRENCE*

MYONG-HUN CHANG

This paper investigates the strategic use of "flexible manufacturing" technology as an entry-deterring mechanism. It is shown that, when consumers' tastes fluctuate probabilistically, an incumbent threatened with potential entry installs flexible manufacturing technology for a larger set of probabilities that consumers' tastes will change, than the perfectly protected monopolist. The differential probability sets represent the intent of the monopoly incumbent strategically to use product-design flexibility for deterring entry into the potential market and maintain its dominance under fluctuating consumer tastes. This purely preemptive flexibility is shown to exist under reasonable assumptions on the firms' payoff structure.

I. INTRODUCTION

IN RECENT years, global competition has taken on a new dimension: flexibility in manufacturing (Jaikumar [1986], Dertouzos *et al.* [1989]). In the face of fast-changing consumers' tastes, the outcome of competition seems to be heavily influenced by the degree of flexibility in manufacturing, which allows the firms to adapt quickly to the changing environment. While the issue of flexibility has been addressed by several economists in the past, it is notable that the bulk of the literature is limited to the type of flexibility that deals with fluctuation in demand for the output of a single homogenous product.[1]

While production volume flexibility remains an important aspect of modern manufacturing, recent academic research has been increasingly directed toward the type of flexibility that can be classified as "product-design flexibility". Product-design flexibility is mainly pursued by producers in order to adapt quickly to consumers' changing tastes by switching between different product designs with relative ease.[2] Consequently, the optimal degree of

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[1] See Stigler [1939], Sheshinski and Dreze [1976], Mills [1984], and Vives [1986, 1989].

[2] For example, see the discussion by Milgrom and Roberts [1990] of GM plants in the automobile industry and of Benetton in the garment industry.

product-design flexibility is a function of the variability in consumer tastes.

With perfectly stable consumer tastes, competitiveness of a firm depends on the extent of scale economies realized in the production of a single homogeneous good.[3] Typically, in this environment, the manufacturing technology entails a mass production system that is dedicated to producing the desired product. However, in markets where consumers' tastes fluctuate frequently, commitment to such a dedicated manufacturing system could prove to be disastrous. A good example of the negative consequence of commitment to dedicated manufacturing is Ford Motor Company's transition from the Model T to the Model A. Henry Ford's production of the Model T entailed extensive use of highly dedicated technology, which was devoted to producing a large volume at a low cost. While mass production via dedicated technology boosted volume and profits in times of stable consumer taste, it was unable to accommodate model changes necessitated by the eventual shift in public taste coupled with Chevrolet's entry into the market. The extent of the inflexibility in its production facilities was so great that the transition from the Model T to the Model A took over a year, during which period all of Ford's manufacturing plants had to be closed down for retooling and redesigning (Rae [1984]; pp. 61–63).

Flexibility in manufacturing serves two distinct purposes (Fine [1990]). The first is purely economic: it hedges against the uncertainty in future market conditions. (See Carlsson [1989], Fine and Freund [1990], Milgrom and Roberts [1990]. For a "real options" approach to flexibility, see Mason and Merton [1985] and Pindyck [1988].) The second is strategic: interactions among firms and agents generate incentives to be flexible in efforts to influence each other's behavior (see Kulatilaka and Marks [1988], Röller and Tombak [1990], Chang [1992], and Fine and Pappu [1990]). One of the important issues that arises frequently in analyses of strategic firm behavior is that of entry-deterrence. However, it has never been addressed in the context of flexible manufacturing with uncertain consumer tastes.[4] When a shift in consumer tastes is expected in the future with a positive probability, an incumbent enjoying the monopoly position in the current market must be

[3] I am implicitly assuming that consumers' tastes are homogeneous. Thus, multi-product firms are ruled out.

[4] One exception is Röller and Tombak [forthcoming], which looks at the timing of entry with multiproduct technologies. However, their modelling framework is different from mine. Their model describes flexible manufacturing as a firm's capability to produce more than one product in a differentiated products market, when the preferences of consumers are assumed stable and stationary. Specifically, they utilize the multiproduct demand functions based on the representative consumer model of product differentiation. Different products are offered because consumers value diversity. Firm's technology decision is then a choice between a single product operation and a multiproduct operation. In my model, the principal aim is to address the *intertemporal flexibility* aspect of manufacturing technology, which enables the firm to respond to changes in consumer preferences, fashion trends, and overall market environments. Consumers are assumed to have homogeneous tastes as a group at any given time, but their tastes tend to fluctuate probabilistically from one period to another.

concerned about the possibility of an outsider's entry into the potential market. It is then straightforward that the initial choice of flexibility would to some degree reflect the incumbent's desire to keep entrants away from the potential market: by maintaining additional flexibility, it commits itself to redesigning the product in the event consumer tastes change, thereby reducing the outsider's incentive to enter the potential market. If and when the potential market is realized in actuality, the incumbent maintains its monopoly position over the new product.

The purpose of this paper is to build a stylized model of flexible manufacturing and analyze the entry-deterrence issue in a sequential game between an incumbent and a potential entrant. The ultimate goal is to prove that for relevant parameter values, the incumbent indeed holds flexibility in excess of that which it would hold in the absence of entry possibility. This excess flexibility—the "zone of strategic flexibility"—serves no other purpose for the incumbent but to deter entry into the potential market. The existence of strategic flexibility is seen to depend upon the probability of a shift in taste, the acquisition costs of technology, and the cost of switching production from one product to another.

The paper is organized as follows. In Section II, the model of flexible manufacturing is described. In Section III, we examine the optimal choice of flexibility by a monopolist who is perfectly protected from the threat of potential entry. The outcome of this section serves as a benchmark in evaluating the choice of flexibility by an entry-deterring incumbent. Section IV analyzes the game of entry and derives the subgame perfect equilibrium. The equilibrium choice of flexibility is then compared to that of the protected monopolist in Section III. Section V concludes the paper.

II. THE MODEL

Let us define a set, X, of products that can be produced with existing technology. While X could realistically contain a large number of products, we shall limit our analysis to the two-good case so as to keep it simple and tractable: $X \equiv \{A,B\}$. Thus, there are only two potential products, A and B.

All consumers are identical, and they either prefer A to B or B to A at any given time. The degree to which one product is preferred over another is assumed to be exogenous.

There are two periods in the game. In period 1, the tastes of consumers are such that everyone prefers A over B. In period 2, with probability β consumer tastes will remain in favor of A, and with probability $1\text{-}\beta$, they will switch to product B. $(\beta,1\text{-}\beta)$, thus, captures the *ex ante* uncertainty over what future consumer tastes will be in an intertemporal setting.

Production technology is such that a firm may choose either a flexible technology (FT) or a dedicated technology (DT). The investment into the manufacturing technology is irreversible, once made. FT allows the firm to convert its production process from one mode to another at zero switching cost. In other words, given that the firm currently produces A, having an FT enables the firm to switch to production of B costlessly if necessary. DT, on the other hand, is designed specifically for only one of the goods. If a firm needs to convert a DT designed for product A to producing B, it must incur the (one-time) fixed cost of switching, $f > 0$. The switching cost entails anything from that of simply resetting the current equipment for changes in product specification to that of completely retooling and redesigning factories and retraining workers. While FT offers a higher degree of flexibility than DT by making it easier for firms to switch between products, there is a cost to having this flexibility. The one-time acquisition cost (C_H) of FT is higher than that (C_L) of DT; i.e. $C_H > C_L$. We further assume that the marginal cost of production is the same for both technologies. This assumption has been used by Röller and Tombak [1990]. A justification is given by Fine and Pappu [1990] that most of the variable costs in highly automated manufacturing systems are material costs.

The basic structure of the entry game is as follows. In period 1, given the consumer taste of A, the incumbent makes an investment decision as to the level of flexibility in manufacturing technology by choosing from $\{FT,DT\}$. Once the production technology is installed, the incumbent chooses the product from $\{A,B\}$ and earns monopoly profits in period 1. In the beginning of period 2, the new consumer taste is revealed. Upon observing the incumbent's technology and the new customer taste, the potential entrant makes its entry decision.[5] If entry occurs, the incumbent and entrant simultaneously choose products and make duopoly profits.[6] If entry does not occur, the incumbent chooses a product from $\{A,B\}$ and once again enjoys the monopoly profits. If the consumer taste in period 2 differs from that in period 1, then the incumbent has the option to continue to produce its existing product rather than change its product to offer the more desired version of the consumers. By continuing the existing product, the firm makes lower sales profits than if it offered the more desired product. But it also saves the cost of redesigning the product. Note that FT has no value to the incumbent in our model, if the switching cost of production is sufficiently low that $f < (1/\delta)(C_H - C_L) \equiv f_0$, where δ is the discount factor. Hence, we shall restrict our attention to only those values of $f \geqslant f_0$.

In order to concentrate on the issues of technology and product choices without having to specify any particular pricing strategies, I use the following reduced form payoffs:

[5] This assumes that the entry process is relatively quick and does not require prior committment.

[6] Note that an entrant always chooses DT in this two-period setting. Flexibility has no value to the entrant, since the second period is the terminal period. This asymmetry in the choice of technology between the incumbent and the entrant will tend to diminish as the horizon is lengthened.

$\pi_M^H \equiv$ Profits of the monopolist supplying the more desired variety.
$\pi_M^L \equiv$ Profits of the monopolist supplying the less desired variety.
$\pi_D^N \equiv$ Profits of a duopolist when both firms supply the more desired variety.
$\pi_D^H \equiv$ Profits of a duopolist if it supplies the more desired variety and the rival supplies the less desired variety.
$\pi_D^L \equiv$ Profits of a duopolist if it supplies the less desired variety and the rival supplies the more desired variety.
$\pi_D^S \equiv$ Profits of a duopolist if both firms supply the less desired variety.

These payoffs are per-period sales profits earned on a given product. The costs of acquiring the technology and redesigning existing products are not part of these profits. The following assumptions are made on these payoffs:

(A1) $\pi_M^H > \pi_M^L$

(A2) $\pi_D^H > \pi_D^N \geqslant \pi_D^L$

(A3) $\pi_D^H > \pi_D^S$

(A4) $\pi_M^L > \pi_D^L$

(A5) $\pi_M^H - \pi_M^L > \pi_D^N - \pi_D^L$

(A1) means that a monopolist earns higher profits by producing the more desired variety than the less desired one. The first inequality of (A2) implies that a duopolist supplying the more desired variety makes higher profits if its rival supplies the less desired variety than if its rival also supplies the more desired variety. The second inequality (equality) implies that given that the rival firm supplies the more desired variety, a duopolist earns higher (equal) profits by also producing the more desired variety rather than the less desired one.[7] (A3) means that given that the rival firm supplies the less desired variety, a duopolist earns higher profits by producing the more desired variety rather than the less desired one. (A4) means that the profits from supplying the less desired variety are greater for a monopolist than for a duopolist whose rival is currently supplying the more desired variety. (A5) implies that the value of redesigning one's product from the less desired variety to the more desired variety is greater for a monopolist than for a duopolist whose rival is already supplying the more desired variety. The first four assumptions are quite reasonable. While (A5) is somewhat arbitrary, reversing the inequality will not affect the qualitative nature of my results.[8]

[7] The case of $\pi_D^N < \pi_D^L$ seems rather unlikely and is ruled out in this paper.

[8] It is straightforward to show the existence of a "zone of strategic flexibility" with the inequality reversed. The proof of this alternative case may be provided by the author upon request.

Given the structure of the game and the related payoffs, the strategy of the incumbent, denoted $\psi(\beta)$, is a mapping from the probability distribution over future consumers' taste, $(\beta, 1-\beta)$, to the set of technology, {FT,DT}. Let S denote the set of all possible states which may be observed by the potential entrant in the beginning of period 2. It is straightforward that $S \equiv \{s_i\}_{i=1,2,3,4}$, where each s_i is characterized as follows: ($s_1 \equiv$ Incumbent has FT and consumer taste is in favor of A), ($s_2 \equiv$ Incumbent has FT and consumer taste is in favor of B), ($s_3 \equiv$ Incumbent has DT and consumer taste is in favor of A), and ($s_4 \equiv$ Incumbent has DT and consumer taste is in favor of B). The strategy of the potential entrant, $\phi(s)$, is then a mapping from the observed state, $s \in S$, to the entry decision, {Enter, Do Not Enter}. The solution concept is that of subgame perfect equilibrium, in which a pair of strategies, $(\psi^*(\beta), \phi^*(s))$, forms the mutual best responses to one another for all $\beta \in [0,1]$ and $s \in S$.

III. CHOICE OF FLEXIBILITY BY A PROTECTED MONOPOLIST

In this section, I analyze the choice of flexibility by the monopolist who is perfectly protected from potential entry. Such a monopolist has no incentive to use flexibility in a strategic manner to deter entry. The value of flexibility is solely to protect the monopolist against the uncertain consumer taste.

The favored product of consumers in period 1 is assumed to be A. In period 2, consumer taste will remain in favor of A with probability β, and it will switch to B with probability 1-β. Period 1 flexibility choice is then dependent upon the monopolist's expectation of consumer taste in period 2. Thus, a dynamically consistent decision-making would first solve for the monopolist's optimal action in period 2 given the revealed consumer taste. In the beginning of period 2, the monopolist could be in one of the four states in S. In states, s_1, s_2, and s_3, the monopolist always produces the more desired variety and makes the corresponding monopoly profits, π_M^H. In state s_4, however, the monopolist must make a choice of which product to produce. If the monopolist decides to switch and produce the more desired item, B, then it makes $\pi_M^H - f$. If it maintains the current item, A, and avoids the switching cost, it makes π_M^L. Thus, the monopolist will switch if and only if the fixed cost of switching is sufficiently low so that $f < \pi_M^H - \pi_M^L \equiv f_H$. Otherwise, it continues to produce its existing product, A.

Given the optimal action of the monopolist in period 2, it is then straightforward to determine the present value of the expected payoff discounted with a discount factor, δ, to the beginning of period 1 as a function of its choice of technology. Evaluating the respective expected profits, one reaches the following proposition, which characterizes the choice of technology for the perfectly protected monopolist:

Proposition 1. Let $f_H \equiv \pi_M^H - \pi_M^L$. There exists $\hat{\beta}_m(f) \in [0, 1]$ such that the

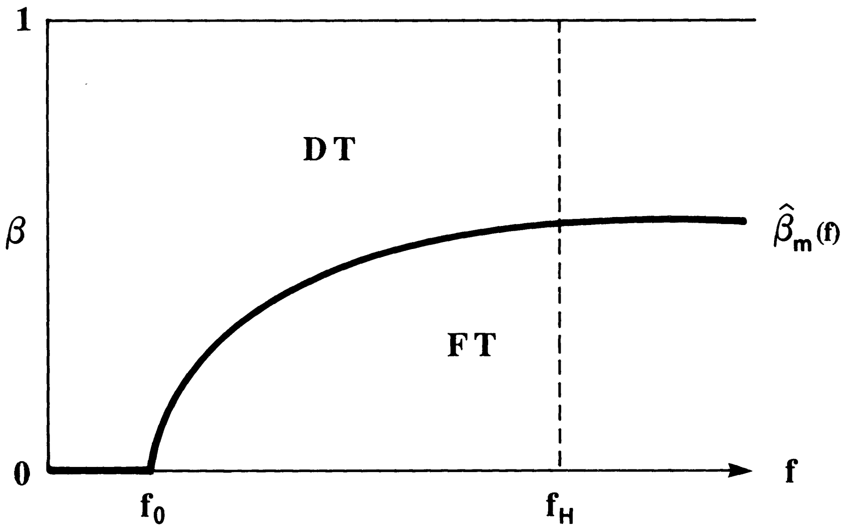

Figure 1
Protected Monopolist's Choice of Technology

protected monopolist installs FT if and only if $\beta < \hat{\beta}_m(f)$, where

$$\hat{\beta}_m(f) = \begin{cases} 1-(1/\delta f)(C_H-C_L) & \text{for } f_0 \leqslant f < f_H \\ 1-(1/\delta f_H)(C_H-C_L) & \text{for } f \geqslant f_H. \end{cases}$$

Otherwise, it installs DT.

Proof. (i) Given $f_0 < f < f_H$, FT is preferred if and only if $\pi_M^H - C_H + \delta[\beta\pi_M^H + (1-\beta)\pi_M^H] > \pi_M^H - C_L + \delta[\beta\pi_M^H + (1-\beta)(\pi_M^H - f)] \Rightarrow \beta < 1 - (1/\delta f)(C_H - C_L)$. (ii) Given $f \geqslant f_H$, FT is preferred if and only if $\pi_M^H - C_H + \delta[\beta\pi_M^H + (1-\beta)\pi_M^H] > \pi_M^H - C_L + \delta[\beta\pi_M^H + (1-\beta)\pi_M^L] \Rightarrow \beta < 1 - (1/\delta f_H)(C_H - C_L)$. ■

Figure 1 illustrates the shape of $\hat{\beta}_m(f)$ and the range of probabilities for which FT is chosen by the monopolist for a given level of f: DT is preferred to FT if and only if the probability that the consumer taste will remain fixed is sufficiently high.

IV. SUBGAME PERFECT EQUILIBRIUM IN THE GAME OF FLEXIBILITY AND ENTRY

In this section, we analyze a game between a monopoly incumbent and a potential entrant in which the incumbent could strategically use its choice of technology to affect the entry decision of the potential entrant. The structure of the game is as defined in Section II. In solving for the subgame perfect equilibrium, we first examine the Nash equilibrium in product choice in post-entry duopoly.

IV(i). *Post-entry equilibrium in product choice*

The post-entry payoff matrix for each state is given in Figure 2. The first entry in each cell represents the payoff to the incumbent, and the second entry is the payoff to the entrant. It is important to note that these payoffs, where relevant, include the cost of switching, *f*, and the acquisition cost of DT, C_L, as well as the sales profits, for the incumbent and the entrant, respectively.

Entrant

Incumbent

S_1	A	B
A	$\pi_D^N, \pi_D^N - C_L$	$\pi_D^H, \pi_D^L - C_L$
B	$\pi_D^L, \pi_D^H - C_L$	$\pi_D^S, \pi_D^S - C_L$

Entrant

Incumbent

S_2	A	B
A	$\pi_D^S, \pi_D^S - C_L$	$\pi_D^L, \pi_D^H - C_L$
B	$\pi_D^H, \pi_D^L - C_L$	$\pi_D^N, \pi_D^N - C_L$

Entrant

Incumbent

S_3	A	B
A	$\pi_D^N, \pi_D^N - C_L$	$\pi_D^H, \pi_D^L - C_L$
B	$\pi_D^L - f, \pi_D^H - C_L$	$\pi_D^S - f, \pi_D^S - C_L$

Entrant

Incumbent

S_4	A	B
A	$\pi_D^S, \pi_D^S - C_L$	$\pi_D^L, \pi_D^H - C_L$
B	$\pi_D^H - f, \pi_D^L - C_L$	$\pi_D^N - f, \pi_D^N - C_L$

Figure 2
Post-Entry Duopoly Equilibrium in Product Choice

Lemma 1. Post-entry Nash equilibrium in product choice for a given state $s \in S$ entails: (A,A) in s_1, (B,B) in s_2, (A,A) in s_3, and (B,B) in s_4, if $f_0 \leqslant f \leqslant f_L$, (A,B) in s_4, if $f > f_L$, where $f_L \equiv \pi_D^N - \pi_D^L$, and the entries in the parenthesis denote the product choices of the incumbent and the entrant, respectively.

In s_1 and s_3, producing the more desired variety, A, is a dominant strategy for both the incumbent and the entrant (weakly dominant if $\pi_D^N = \pi_D^L$). Conversely, in s_2, when the consumer taste shifts in favor of B, producing B is a dominant strategy for both of the firms (weakly dominant if $\pi_D^N = \pi_D^L$). In s_4, producing B is a dominant strategy for the entrant (weakly dominant if $\pi_D^N = \pi_D^L$). Given the entrant's choice of B, the incumbent's best response is then to produce B, if $f_0 \leqslant f \leqslant f_L$, and A, if $f > f_L$.

IV(ii). *Subgame perfect equilibrium and strategic entry deterrence*

Given the post-entry equilibrium presented in Lemma 1 and its associated payoffs in Figure 2, we may now examine the optimal strategies of the incumbent and the potential entrant.

Proposition 2 (Accommodated entry). For $C_L \leqslant \pi_D^N$, there exists $\hat{\beta}_a(f)$ for all $f \geqslant f_0$, such that the following pair of strategies forms a subgame perfect equilibrium:

$$\psi^*(\beta) = \begin{cases} \text{FT} & \text{for } \beta < \hat{\beta}_a(f) \\ \text{DT} & \text{for } \beta \geqslant \hat{\beta}_a(f) \end{cases}$$

$$\phi^*(s) = \text{Enter} \quad \text{for all } s \in S$$

where

$$\hat{\beta}_a(f) = \begin{cases} 1-(1/\delta f)(C_H - C_L) & \text{for } f_0 \leqslant f \leqslant f_L \\ 1-(1/\delta f_L)(C_H - C_L) & \text{for } f > f_L \end{cases}$$

Proof. The post-entry payoffs in Figure 2 indicate that the optimal strategy of the potential entrant for $C_L \leqslant \pi_D^N$ is to enter in all states. Given this strategy of the potential entrant, the incumbent's choice of FT is optimal for $f_0 \leqslant f \leqslant f_L$ if and only if: $\pi_M^H - C_H + \delta[\beta\pi_D^N + (1-\beta)\pi_D^N] > \pi_M^H - C_L + \delta[\beta\pi_D^N + (1-\beta)(\pi_D^N - f)] \Rightarrow \beta < 1-(1/\delta f)(C_H - C_L)$. For $f > f_L$, FT is optimal if and only if: $\pi_M^H - C_H + \delta[\beta\pi_D^N + (1-\beta)\pi_D^N] > \pi_M^H - C_L + \delta[\beta\pi_D^N + (1-\beta)\pi_D^L] \Rightarrow \beta < 1-(1/\delta f_L)(C_H - C_L)$. Otherwise, DT is optimal. ■

Corollary. $\hat{\beta}_a(f) < \hat{\beta}_m(f)$ for all $f \geqslant f_L$.

Proof. For $f_L \leqslant f < f_H$, $\hat{\beta}_m(f) \equiv 1-(1/\delta f)(C_H - C_L) \geqslant 1-(1/\delta f_L)(C_H - C_L) \equiv \hat{\beta}_a(f)$. For $f \geqslant f_H$, $\hat{\beta}_m(f) \equiv 1-(1/\delta f_H)(C_H - C_L) > 1-(1/\delta f_L)(C_H - C_L) \equiv \hat{\beta}_a(f)$. ■

For sufficiently low values of C_L such that $C_L \leqslant \pi_D^N$, the potential entrant always enters regardless of the state it is in. Entry is thus "accommodated." Since the incumbent knows that it must share the potential market with the entrant, the attractiveness of having flexibility is somewhat diminished. Consequently, the set of βs for which the incumbent installs FT is a strict subset of that of the protected monopolist. Since entry cannot be deterred, the incumbent installs DT for a wider set of βs than the protected monopolist in order to avoid the high acquisition cost of FT.

Proposition 3 (Blockaded entry). For $C_L \geqslant \pi_D^H$, there exists $\hat{\beta}_b(f)$ for all $f \geqslant f_0$, such that $\hat{\beta}_b(f) \equiv \hat{\beta}_m(f)$ and the following pair of strategies forms a subgame perfect equilibrium:

$$\psi^*(\beta) = \begin{cases} \text{FT} & \text{for } \beta < \hat{\beta}_b(f) \\ \text{DT} & \text{for } \beta \geqslant \hat{\beta}_b(f) \end{cases}$$

$$\phi^*(s) = \text{Do Not Enter} \quad \text{for all } s \in S$$

Proof. For $C_L \geqslant \pi_D^H$, entry is never profitable. Given the potential entrant's strategy of "No-Entry," the incumbent faces a problem that is qualitatively identical to that of the protected monopolist presented in Section III. Hence, FT is optimal for $\beta < \hat{\beta}_b(f)$, where $\hat{\beta}_b(f) \equiv \hat{\beta}_m(f)$. ■

For $C_L \geqslant \pi_D^H$, the acquisition cost of DT is sufficiently high that the potential entrant never finds it attractive to enter. Entry is thus "blockaded." Since the incumbent maintains its monopoly position for all states, $s \in S$, in period 2, its initial choice of technology in period 1 then coincides with that of the perfectly protected monopolist. Consequently, $\hat{\beta}_b(f) \equiv \hat{\beta}_m(f)$ for all $f \geqslant f_0$. There is no need to have flexibility for strategic reasons, since it does not affect the potential entrant's decision to enter.

Proposition 4. For $\pi_D^N < C_L < \pi_D^H$, there exists $\hat{\beta}_d(f)$ for all $f \geqslant f_0$, such that the following pair of strategies forms a subgame perfect equilibrium:

$$\psi^*(\beta) = \begin{cases} \text{FT} & \text{for } \beta < \hat{\beta}_d(f) \\ \text{DT} & \text{for } \beta \geqslant \hat{\beta}_d(f) \end{cases}$$

$$\phi^*(s) = \begin{cases} \text{Enter} & \text{for } s = s_4 \text{ and } f > f_L \\ \text{Do Not Enter} & \text{otherwise} \end{cases}$$

where

$$\hat{\beta}_d(f) = \begin{cases} 1-(1/\delta f)(C_H-C_L) & \text{for } f_0 \leqslant f \leqslant f_L \\ 1-[1/\delta(\pi_M^H-\pi_D^L)](C_H-C_L) & \text{for } f > f_L \end{cases}$$

Proof. Entry is optimal if and only if the potential entrant finds itself in s_4 and f is sufficiently high that the incumbent will not switch to the production of B in post-entry equilibrium, i.e. $f > f_L$. Given the potential entrant's strategy, the incumbent optimally chooses FT for $f_0 \leqslant f \leqslant f_L$ if and only if: $\pi_M^H - C_H + \delta[\beta\pi_M^H + (1-\beta)\pi_M^H] > \pi_M^H - C_L + \delta[\beta\pi_M^H + (1-\beta)(\pi_M^H - f)] \Rightarrow \beta <$

$1-(1/\delta f)(C_H - C_L)$. For $f > f_L$, FT is optimal if and only if: $\pi_M^H - C_H + \delta[\beta\pi_M^H + (1-\beta)\pi_M^H] > \pi_M^H - C_L + \delta[\beta\pi_M^H + (1-\beta)\pi_D^L] \Rightarrow \beta < 1 - [1/\delta(\pi_M^H - \pi_D^L)](C_H - C_L)$. Otherwise, DT is optimal. ∎

Theorem 1. For $\pi_D^N < C_L < \pi_D^H$ and $f > f_L$, there exists a "zone of strategic flexibility" in which the incumbent holds flexibility purely for the purpose of deterring entry into the potential market.

Proof. All that needs to be shown is $\hat{\beta}_d(f) > \hat{\beta}_m(f)$ for $\pi_D^{\sim} < C_L < \pi_D^H$ and $f > f_L$: $\hat{\beta}_d(f) > \hat{\beta}_m(f) \Rightarrow 1 - (1/\delta f_H)(C_H - C_L) < 1 - [1/\delta(\pi_M^H - \pi_D^L)](C_H - C_L) \Rightarrow f_H < \pi_M^H - \pi_D^L \Rightarrow \pi_M^H - \pi_M^L < \pi_M^H - \pi_D^L \Rightarrow \pi_D^L < \pi_M^L$. The last inequality is true by (A4) that the monopoly profit is greater than the duopoly profit. ∎

The intuition behind Proposition 4 and Theorem 1 can be seen as follows. If consumers' tastes remain in favor of A in period 2, whether the incumbent has FT or DT makes no difference to its period 2 profits (π_D^N in both s_1 and s_3). Since the potential entrant must share the market upon entry, it never enters for $\pi_D^N < C_L < \pi_D^H$. The incumbent produces A and makes the monopoly profits. However, if the tastes shifted in favor of B, the incumbent would find itself in s_2 by holding FT, while it ends up in s_4 by holding DT. In s_2, the incumbent with FT surely switches its production to B. While the potential entrant would like to come into the market for B, its consequent duopoly profits, π_D^N, are not sufficient to cover the cost of DT needed to enter. Hence, the incumbent maintains its monopoly position and makes π_M^H. On the other hand, if the incumbent happened to have DT and thus realizes s_4, then for a sufficiently high cost of switching such that $f > f_L$, it must maintain production of A. Consequently, it cannot prevent the potential entrant from coming into the market to offer the more desired product, B: the incumbent, thus, ends up earning only π_D^L from offering the less desired variety in period 2. Since the potential entrant's decision to enter is dependent upon the state it is facing, the incumbent can influence that decision by appropriately choosing its initial technology. Specifically, it could deter entry by choosing FT in period 1 and, thus, committing itself to realizing s_2 in the event consumers' tastes shift in favor of B. Therefore, for $\pi_D^N < C_L < \pi_D^H$ and $f > f_L$, there exists a strategic incentive to install FT for an incumbent facing potential entry, which did not exist for the protected monopolist.

Flexibility has the strategic value of entry deterrence if it is held only in the presence of potential entry. Since the choice of flexibility made by the protected monopolist represents the economic value of flexibility, any additional flexibility held by the entry-fearing incumbent represents the intention of deterrence. In our framework, the entry-deterrent nature of flexibility is represented by the additional set of βs for which the incumbent installs FT. In the absence of potential entry, DT would have been installed for those values of β. Figure 3 portrays the "zone of strategic flexibility" as the

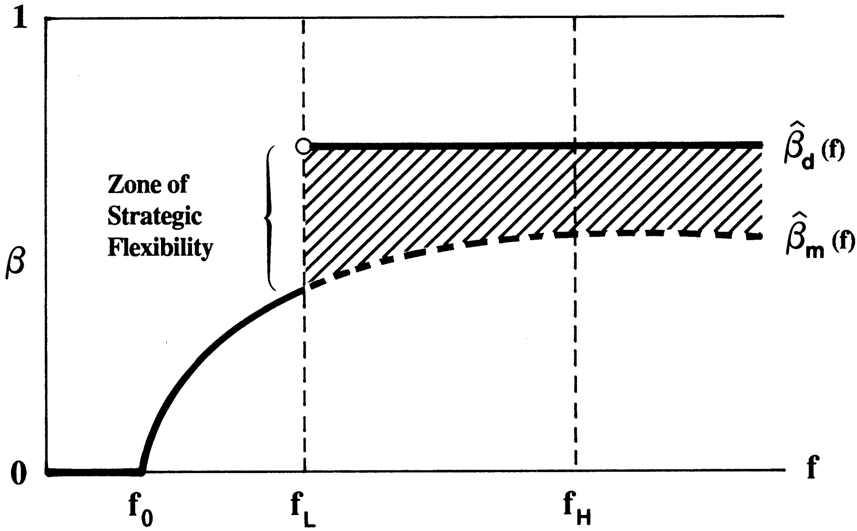

Figure 3
Flexible Technology as an Entry-Deterring Mechanism

shaded area which exists for all $f > f_L$ and $\pi_D^N < C_L < \pi_D^H$. For $f > f_L$, a protected incumbent installs FT for all βs below $\hat{\beta}_m(f)$ (the dotted curve). The entry-fearing incumbent, on the other hand, would prefer to install FT for all βs below $\hat{\beta}_d(f)$ (the solid line). The differential probability set (the shaded area), thus, represents the incumbent's intention to use flexibility as an entry-deterring mechanism. When f is sufficiently low, i.e. $f_0 < f \leqslant f_L$, switching production is easily accomplished and the need for strategic behavior is eliminated.

The "zone of strategic flexibility" depends on three major factors: (i) the fixed cost of switching production for the established firm, (ii) the acquisition cost of the dedicated technology for the entrant, and (iii) the severity of the expected competition between the new entrant and the incumbent. While the impact of the latter two elements on entry is relatively straightforward, that of the first element requires some explanation. The first element is what Caves and Porter [1977] called a "mobility barrier" for an established firm in repositioning itself from one market segment to another. The extent of this mobility barrier inherent in the incumbent's chosen technology affects the potential entrant's decision to enter by signalling what the incumbent's post-entry position (product choice) will be. Because its relative immobility tends to facilitate entry into the newly available and attractive market segment, the incumbent has an incentive to invest in a production technology with a low mobility barrier so as to maintain its market dominance.

V. CONCLUDING REMARKS

It was shown that flexibility in manufacturing serves two distinct purposes. The first is that it hedges against the uncertainty in future market conditions. In our framework, it protected a firm from fluctuating consumer tastes for product design. The second purpose of flexibility addressed in this paper was its role of entry deterrence in the face of fluctuating consumer tastes. It was shown that an incumbent threatened with potential entry installs flexible manufacturing technology for a larger set of probabilities that consumers' tastes will change than the perfectly protected monopolist. The differential probability sets represented the intent of the monopoly incumbent strategically to use product-design flexibility for deterring entry into the potential market and maintain its dominance under fluctuating consumer tastes.

Our result implies that the installation of a flexible production system is likely to lead to a more monopolistic market structure. Specifically, one would expect to observe a positive relationship between the extent of flexibility in manufacturing technology and the degree of concentration in a given industry. This intuition is somewhat supported by the findings of Röller and Tombak [1991] that over 85 percent of the FMS (Flexible Manufacturing System) implementation occurred in industry sectors characterized by large firms. While the size of the firms gives us some indication of market concentration, it is not fully satisfactory. A fruitful direction for future research would then be to test empirically the direct relationship between flexibility and market concentration.

MYONG-HUN CHANG,
Department of Economics,
Cleveland Sate University,
Cleveland, Ohio 44115,
USA.

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