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Preemptive Patenting and the Persistence of Monopoly

By RICHARD J. GILBERT AND DAVID M. G. NEWBERY*

The problem of dominant firms has received much attention in the antitrust literature. One strand of thought, exemplified by George Stigler, argues that the forces of natural selection are strong and that firms which stay dominant are firms with superior managerial or technological performance. Others, notably Oliver Williamson (1977a), have argued that market imperfections and chance events contribute to the persistence of dominant firms. This paper takes a different tack and inquires whether institutions such as the patent system create opportunities for firms with monopoly power to maintain their monopoly power. The results apply to other situations such as brand identification, spatial location, and capacity expansion, which share the characteristic that early, or preemptive, actions may lower the returns to potential competitors.

Preemptive invention is not without topical interest. In a recent antitrust case—the longest jury trial on record in the federal courts—the SCM Corporation sought more than $500 million in damages on its claim that the Xerox Corporation, among other alleged anticompetitive behavior, had maintained a "patent thicket" where some inventions were used while others were neither used nor licensed to others.[1]

This paper shows that, under certain conditions, a firm with monopoly power has an incentive to maintain its monopoly power by patenting new technologies before potential competitors and that this activity can lead to patents that are neither used nor licensed to others (sometimes called "sleeping patents"). Section I examines the incentives for preemptive invention in an illustrative market model with an existing monopolist and a single patentable substitute technology. While highly simplified, the example serves to identify the incentives for preemptive patenting. The monopolist will preempt if the cost is less than the profits gained by preventing entry, which follows whenever entry brings about an anticipated reduction of total industry profits below the monopoly level.

Section II examines several questions that arise in the context of the simple example, such as threat credibility, the occurrence of sleeping patents, and limits to the span of control by the monopolistic firm. Section III develops a more general model that permits analysis of the interaction of patenting and strategic investment activity, the consequences of limited patent protection and many potentially patentable technologies, and the effects of uncertainty on the preemption decision. These considerations significantly affect attainable monopoly profits with and without patenting, but they do not necessarily destroy incentives for preemption.

Although patents serve to illustrate incentives for preemptive activity, the complexities of research and development limit preemptive patenting to exceptional circumstances. Patent protection is typically quite limited and even modest prospects for developing new products can make the cost of entry deterrence by preemptive patenting excessively costly.[2] In addition, complementarities

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[1] *New York Times*, "Damages Denied in Xerox Case," December 30, 1978. The case reference is 463 F. Supp. 983 (1978). Other cases involving alleged anticompetitive research and development include the *U.S. v. IBM* and the *U.S. v. AT & T.*

[2] The survey by Chris T. Taylor and Z. Aubrey Silberston (1973) reveals the scope of patent protection in the United Kingdom.

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between patentable product components encourage cross-licensing agreements and discourage restrictive patent enforcement. Preemptive patenting may be unnecessary if potential entrants can be deterred more cheaply by other behavior, such as capacity expansion. Preemption is too costly if an established firm has a sufficient comparative disadvantage in research or production; and uncertainty about the expectations and resulting investment activities of potential rivals may lead an established firm to choose a *R&D* strategy that allows entry by optimistic firms.

The existence of patent rights is neither necessary nor sufficient for preemptive activity. The crucial element is that the rewards from acting first must be sufficiently large relative to the gains to subsequent investors. Patents provide a vivid example where the award goes only to the first firm, although in practice the advantage offered by patent protection is typically small. The acquisition of technical know-how, with or without patent protection, provides the significant returns from accelerated investments in research and development.

Several examples of preemptive competition have appeared recently. Preemptive brand proliferation is discussed by Richard Schmalensee. One-dimensional spatial location models where preemption may occur are described by B. Curtis Eaton, Edward Prescott and Michael Visscher, and Robert Reynolds; these are similar in structure to the problem discussed by Nicholas Kaldor. Examples of preemption by accelerated investment in new plant capacity appear in Gilbert and Richard Harris, A. Michael Spence (1977, 1979), and Ram Rao and David Rutenberg.

I. The Elements of Preemptive Patenting

The incentives for preemptive patenting emerge most clearly in a simple model. Suppose an established firm has a monopoly position in the sale or manufacture of a product (labelled product 1). The monopoly may be the consequence of an earlier patent or unique access to factors of production or distribution. Entry into the monopolized industry can take place only through the invention and patenting of a single patentable substitute for the monopolist's product. The cost of inventing the substitute (labelled product 2) depends only on the expected lag before a patentable design can be produced. In its simplest representation the date of invention, T, is a deterministic function of the time path of expenditures. The present value of an optimal expenditure path defines a cost function $C(T)$, that is a decreasing function of the invention date.[3] The cost function is the same for all firms engaged in research and development for the substitute product.

The strategy space for each firm is restricted to the research and development expenditure on product 2 and the price(s) the firm charges for the product(s) it sells. Let P^j represent the product price ($j=1,2$). Product 1 is sold only by the established firm (i.e., the monopolist); either the monopolist (labelled $i=m$) or an entrant ($i=e$) can patent product 2. Demand is known with certainty and is unchanging over time.

Before patenting of the substitute product, the monopolist earns profits at the rate $\pi_m(P_m^1)$. If the monopolist patents the substitute, profits are $\pi_m(P_m^1, P_m^2)$. If an entrant patents the substitute, the former monopolist's profit is $\pi_m(P_m^1, P_e^2)$ and the entrant earns profits at the rate $\pi_e(P_m^1, P_e^2)$. Profits are written as independent of time, which implicitly assumes any capital expenditures are included as fully amortized costs. In all cases P_i^j ($j=1,2$; $i=m,e$) denotes firm i's maximizing choice of price for product j, given the prevailing market structure.

The monopolist has the option of patenting the substitute technology or allowing entry to occur. We allow the monopolist to

[3]Although studies by Edwin Mansfield (1968) and others suggest a positive relation between perceived profitability and the commitment of funds to research and development, the relation between *R&D* expenditures and the timing of product development and patenting is more difficult to substantiate. R. G. Richels and J. L. Plummer (1977) cite an example of the cost-time tradeoff in the development of the nuclear breeder reactor. The cost should be a strictly decreasing function of the invention date with any positive discount rate if it is possible to postpone expenditures.

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choose a patent date under the assumption that competitors will patent at the date determined by free entry into the patent competition. Questions relating to the credibility of the preemption threat are deferred until Section II. The return to the monopolist from patenting is the difference between monopoly profits with the patent and profits when entry is allowed to occur. The firm should patent the substitute product and preempt potential entrants whenever this difference exceeds the cost of securing the patent. A simple comparison of profit streams shows that, under a general set of conditions, the monopolist will always gain by spending more on inventive activity than the present value of returns a rival can expect to earn from the new product. Specifically, the monopolist will spend more on $R\&D$ than rival firms *if entry results in any reduction of total profits below the joint-maximizing level.*

The demonstration of this result is straightforward. Let r represent the rate of interest (the same for all firms). The reward to any entrant depends on the price set by the former monopolist for product 1, P_m^1, and the price set by the entrant, P_e^2, as well as the entry date, T. Free entry into the patent race will dissipate profits so that

$$(1) \qquad C(T)=\int_T^{\infty} \pi_e(P_m^1, P_e^2)e^{-rt}\,dt.$$

If equation (1) is satisfied for more than one invention date T, competition for the patent will select the earliest date. When entry occurs at the competitive entry date, the former monopolist's profits are

$$(2) \qquad V_e=\int_0^T \pi_m(P_m^1)e^{-rt}\,dt + \int_T^{\infty} \pi_m(P_m^1, P_e^2)e^{-rt}\,dt.$$

Now suppose the monopolist takes the competitive invention date as determined by equation (1) and considers inventing before this date. If the cost of invention is continuous at date T, the monopolist can preempt rivals (i.e., invent at a date $T-\varepsilon$ for some arbitrarily small positive ε) by spending an amount $C(T)+\delta(\varepsilon)$. The firm remains a monopolist and earns

$$(3) \quad V_p=\int_0^{T-\varepsilon} \pi_m(P_m^1)e^{-rt}\,dt + \int_{T-\varepsilon}^{\infty} \pi_m(P_m^1, P_m^2)e^{-rt}\,dt - [C(T)+\delta].$$

The difference between profits with preemption and profits with entry is, in the limit as ε and δ approach zero,

$$(4) \quad V_p-V_e=\int_T^{\infty} \pi_m(P_m^1, P_m^2)e^{-rt}\,dt - \int_T^{\infty} \pi_m(P_m^1, P_e^2)e^{-rt}\,dt - C(T).$$

Note that the monopolist's price of product 1 with entry may differ from the price the monopolist sets when entry is preempted. Indeed, the monopolist need not even produce the patented substitute technology.

Substituting equation (1) for $C(T)$ gives an alternative expression for the relative benefits of preemptive patenting;

$$(5) \quad V_p-V_e=\int_T^{\infty} \{\pi_m(P_m^1, P_m^2) - [\pi_m(P_m^1, P_e^2)+\pi_e(P_m^1, P_e^2)]\}e^{-rt}\,dt.$$

The monopoly profits from preemptive patenting strictly exceed the monopolist's profits with entry if

$$(6) \quad \pi_m(P_m^1, P_m^2) > \pi_m(P_m^1, P_e^2)+\pi_e(P_m^1, P_e^2).$$

The left-hand side of equation (6) is the maximum monopoly profit attainable with both product 1 and product 2, while the right-hand side is the total industry profit earned when a rival patents. The former will exceed the latter whenever entry results in some reduction in total profits, provided the monopolist suffers no diseconomies in the production of the substitute relative to production by a rival firm.[4] Moreover, the same

[4]Clearly there is no incentive for preemption if production of product 2 has no effect on the profits from product 1. Also, if the entrant's profit-maximizing price for product 2 results in zero profits for the former monopolist, then $\pi_m(P_m^1, P_m^2)=\pi_e(P_m^1, P_e^2)$ and again there is no incentive for preemptive patenting.

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argument holds if competition for the patent is less intense, so that the potential entrant anticipates positive profits instead of the zero profits implied by equation (1).[5]

Kenneth Arrow observed that, with patent protection, the incentive to invest in research and development is less under monopoly than under competitive conditions, which would suggest that monopolistic firms would be slower than competitors in developing new products or processes, *ceteris paribus*. This does not contradict the arguments in Section I because Arrow assumed that entry was blockaded in the monopoly case. This paper does show that allowing for the possibility of entry can have a marked effect on monopoly incentives for *R&D*.

II. Comments on the Simple Model

The preceding example illustrates the source of incentives for preemptive patenting. The incentives are not the result of market failures which Williamson (1977a) describes as shielding dominant firms from the forces of competition. In the preemption example, markets operate efficiently except for the assumed prior existence of a firm with substantial monopoly power. The firm can sustain its monopoly if potential entrants rationally expect that rivalry will erode total industry profits. This does require some foresight on the part of potential entrants, and it implicitly assumes entrants are large enough to have some effect on total industry profits.

The example ignores several potentially significant complications. Those which can be addressed without a more general model are discussed below, while more involved issues are deferred to the next section.

A. *Monopoly Expenditure on R&D*

The monopolist prevents entry by patenting before the competitive date. If a potential competitor knows this strategy is rational for the monopolist, entry through research and development will not occur. This raises the question of whether the monopolist actually has to carry out an *R&D* plan which produces a patent before the competitive date. The preemption threat would be credible if the monopolist could accelerate *R&D* activity in response to *R&D* spending by potential rivals without incurring significant additional costs or delays. In this case, the potential of entry does not alter the behavior of the monopolist, and the monopolist invests in research and development as if entry were blockaded. Potential competitors do not invest in *R&D* because they know it is rational for the monopolist to accelerate his research if any competitor enters the patent race.

Conversely, if the monopolist incurs substantial costs by speeding up *R&D* in response to the inventive activities of rivals, the monopolist may be forced to play the preemption threat. This would be rational if the cost of waiting for a competitor to begin a research and development program exceeded the return from preemption. In this circumstance, research is carried out at the intensity determined by competitive forces, but it is the monopolist who performs the research (as, indeed, Joseph Schumpeter argued).

The remainder of this paper assumes the monopolist must play the preemption threat. A formal model of the patent competition is that of an auction market. Each firm enters a bid which is the maximum present-value amount that the firm will spend on research and development. (Firms can be thought of as bidding for *R&D* services.) With free entry, competitors will bid up *R&D* expenditures to the level determined by equation (1). At this level of investment in *R&D*, monopoly profits are strictly higher if the monopolist patents and if equation (6) is satisfied. Hence the established firm will enter a slightly higher bid which preempts the competitive patent date. Preemption is a Nash equilibrium of this bidding game.

B. *Preemption and "Sleeping Patents"*

A sleeping patent is an invention that is not put to commercial use. In a world of

[5]A potential competitor may patent with the expectation of bargaining with the monopolist for a share of the difference between monopoly profits with and without competition. This does not change the incentive to preempt provided the rival expects his share of monopoly profits to be less than unity.

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certainty, a monopolist protected from entry would never invest resources to produce a sleeping patent, since the monopolist could postpone the patent date until the best moment for innovation and reduce present discounted costs.[6] Yet a sleeping patent may occur as the consequence of preemptive patenting by the monopolist. As an illustration, consider the case where the patented substitute product has the same production cost and the same demand characteristics as the product controlled by the monopolist, except that development of the substitute from the patented design to the production state is costly. This means that any revenue stream can be earned at lower cost by producing product 1 than by developing and producing the substitute product. In particular, when amortized development costs are deducted from profits,

$$\pi_m(P_m^1, P_m^2) < \pi_m(P_m^1) \tag{7}$$

for any P_m^2 at which demand and production of the substitute is positive.[7]

With these assumptions a profit-maximizing monopolist will never choose to produce the substitute product, but might the monopolist patent the substitute and let it sleep? If entry of a rival is profitable, the argument developed in the simple model is still valid and the monopolist will preemptively patent the substitute whenever entry is expected to lower total industry profits.

The possibility of sleeping patents strengthens the argument for preemptive patenting by the monopolist. The monopolist's decision to let a patent sleep is efficient given the monopolist's choice of output(s). If a rival uses the patent, the effect of entry is to lower industry profits by using an inefficient production technology as well as possibly lowering profits through price competition. Both effects serve as incentives for preemptive patenting.

The monopolist must patent before potential competitors to deter entry, and this determines the invention date. The date at which the monopolist actually uses the patent depends on the characteristics of the new technology and the characteristics of the monopolist's existing capital stock. In this illustration the monopolist will never use the patent, but more generally Yoram Barzel and Dasgupta et al. show that a monopolist's optimal date for use of a patented technology will be later than the date determined by competition (the preemption date).

C. *Managerial Diseconomies*

Managerial diseconomies exist if the monopolist cannot conduct a research program or production plan as efficiently as any rival. Formally, managerial diseconomies make no difference to the monopolist's decision problem. Preemption is a rational strategy if the cost of securing the patent is less than the difference between monopoly profits with the patent and the profits when entry is allowed to occur. Obviously if managerial diseconomies are significant, preemption is less likely to occur. What is more important is that in such cases the monopolist may dissipate much of the producers' surplus potentially available to the most efficient research group. For it may still pay the monopolist to preempt more efficient rivals, perhaps at the expense of almost all the potential profit.

III. Strategic Behavior, Uncertainty, and Multiple Competitive Threats

The illustrative example described in Section I was sufficient to introduce the monopolist's decision problem and show the incentives for preemptive patenting. The general problem is much more complex. The monopolist can pursue strategic activities that lower

[6] A monopolist protected from entry may hold a sleeping patent if the patent represents a step in the development of a more advanced technology or if the patent is a joint product from another line of research. Sleeping patents are not limited to monopoly since, as Partha Dasgupta, Gilbert, and Joseph Stiglitz show, free entry can lead to sleeping patents in a competitive *R&D* market.

[7] Peter Swan (1970) argued that a monopolist would use any new technology that a competitor would use, but his argument required the assumption of convex cost functions, which is ruled out by consideration of development costs.

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the profitability of the patent to a potential competitor. The value of a patent and the process of invention are clouded by uncertainty. The assumption of a single patentable substitute for the monopolized product is clearly extreme, and in practice the protection afforded by a patent is limited by the ability to invent around and imitate the patent.

This section shows that these additional considerations do not destroy the incentives for preemptive patenting. The monopolist should take advantage of entry-deterring strategies, but these strategies should be used as complements to preemptive patenting, unless the strategies used alone efficiently impede entry. With uncertainty, preemption remains desirable if the expectations of potential entrants are known, but without this knowledge, optimistic competitors may succeed in patenting before the monopolist. The existence of more than one patentable substitute will generally have a large effect on the monopolist's maximum attainable profits, but these multiple potential patents need not alter the desirability of preemptive activity.

A. *Strategic Behavior*

In the simple example, firms' strategies were limited to setting a price and producing sufficient quantities to meet demand at that price. This ignores the possibility of strategic behavior by an incumbent firm with the objective of either deterring entry or reducing the losses from competition. This section shows that in the case of a single competitive threat, strategic behavior does not alter the incentive for preemption. Strategies that lower the expected profits to potential entrants make preemption more attractive by lowering the cost of an *R&D* program designed to patent before rivals. Strategic investments and preemption generally go hand-in-hand as components of the incumbent firm's business strategies, although investments can be so effective in preventing entry as to make preemptive patenting unnecessary.

We choose an illustrative example of strategic investment following the analysis in Avinash Dixit (1980) where a dominant firm acts as a Stackelberg leader in the choice of capacity. Investment in capacity may benefit the incumbent firm by increasing profits in the event of entry and by possibly delaying the date at which entry occurs. The latter follows in our patenting model because the date of entry (patenting) depends directly on anticipated profits through the cost of invention function. In particular, firms may abandon the patent race if the returns from entry are sufficiently small.

Industry capacity affects the profits of both the incumbent and entering firm directly through costs and indirectly through the selection of product prices. We assume strategic behavior takes place only in the selection of production capacity by the incumbent for the manufacture of product 1 and we amend the notation for profits to include this capacity choice, represented by K. For simplicity the choice of production capacities for product 2, which should be conditional on K, is suppressed in the notation.

One result emerges immediately. Suppose in the absence of preemptive patenting the incumbent firm chooses a strategy that results in entry at date T when capacity is K. If monopoly profits exceed total profits with entry, *the incumbent firm is at least as well off choosing the same investment strategy and patenting before date* T. The proof of this result is exactly the same as in Section I where only pricing decisions were considered. Note that the argument in Section I holds for any market environment described by demands, technology, and capacities, provided the environment is the same whether or not preemption occurs. What remains unanswered is the effect of preemption on the choice of strategic investment. Consider equation (5), the difference between incumbent profits with and without preemption, augmented to include capacity choice. Technically we should write profits as the time dependent flow of net revenues corresponding to a particular investment strategy, but we shall simply append the variable K to represent the actual capacity at the date of entry and omit time as an explicit argument of the profit functions. If capacity choice is

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the same with and without preemption, the difference in incumbent profits is

$$(8)\quad (V_p - V_e) = \int_T^{\infty} \{\pi_m(P_m^1, P_m^2, K) - [\pi_m(P_m^1, P_e^2, K) + \pi_e(P_m^1, P_e^2, K)]\} e^{-rt}\, dt.$$

The entry date T depends on the choice of K through the straightforward extension of equation (1) to include the effect of capacity on entrant profits.

Let P denote the price vector (P_m^1, P_m^2, P_e^2) and define

$$(9)\quad \Delta(P, K) = \pi_m(P_m^1, P_m^2, K) - [\pi_m(P_m^1, P_e^2, K) + \pi_e(P_m^1, P_e^2, K)],$$

the difference between monopoly and competitive profits, or the loss from competition given capacity choice and prices at a particular (suppressed) date. Assuming continuity of the entry date and profits, differentiating equation (9) with respect to K gives the relative effect of a local change in capacity on incumbent profits with and without preemption.

$$(10)\quad \frac{d}{dK}(V_p - V_e) = \int_T^{\infty} \frac{d\Delta(P, K)}{dK} e^{-rt}\, dt - \Delta(P, K) e^{-rT} \frac{dT}{dK}.$$

The first term in equation (10) is the change in the loss from competition due to a change in the level of capacity. Since the loss from competition is the incentive to preempt conditional on a capacity choice, if this increases (decreases) with capacity, it increases (decreases) the marginal value of capacity in the preemption decision. The second term represents the effect on the preemption decision of a change in the entry date due to a change in the capacity choice. This term is always nonpositive because T is a nondecreasing function of K and $\Delta(P, K)$ is nonnegative ($\Delta(P, K)$ is evaluated at date T in equation (10)).[8] Hence a sufficient condition for

$$(11)\quad \frac{d}{dK}(V_p - V_e) < 0$$

is that the loss from competition decrease with an increase in capacity investment by the dominant firm. Simple models show that the loss from competition may increase or decrease with capacity, although it should be noted that a decrease is not necessary for the marginal value of capacity in the preemption decision to be less than the marginal value of capacity in strategic entry deterrence without preemption.

The opportunity to preempt competitors alters incentives for strategic investment in capacity. Preemption profits exceed profits without preemption whenever the loss from competition is positive. If the loss from competition does not increase with capacity, the marginal value of capacity is lower in the preemption decision. Then at least in the neighborhood of the capacity choice without preemption, allowing for preemption reduces the optimal capacity choice. If incumbent profits are a concave function of capacity, then the optimal capacity choice with preemption is less than the optimal choice without preemption when inequality (11) holds.

It could be the case that the capacity choice without preemption blockades entry, corresponding to $T \to \infty$. Preemption is unnecessary if entry never occurs, hence profits with and without preemption are identical. One can show that reducing capacity below the level that blockades entry and preemptively patenting is a preferred strategy if the entry date is a continuous function of the capacity choice. The intuition here is that the cost of preemption is negligible if the entry date is sufficiently distant, and at any finite entry date preemption is desirable. If a small change in the capacity choice leads to a

[8] Output is a nondecreasing function of capacity if capacity lowers, or does not increase, marginal production cost. Thus entrant profits are a nonincreasing function of incumbent firm capacity, and lower profits imply a later entry date.

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discontinuous change in the entry date, the gain from avoiding rivalry may be offset by the nonnegligible cost of preemption. In this case blockading entry through strategic investment in capacity can prove superior to preemptive patenting.

B. *Uncertainty*

Several sources of uncertainty may affect the preemption decision. The invention process, the characteristics of the invention and the market, the competitive strategies of an entrant, and the appropriate response by the original monopolist are all more or less uncertain. Uncertainty in the invention process means that the patent date is not a deterministic function of the expenditure on *R&D*. Uncertainty in the characteristics of the invention and in the strategies used by competitors after entry affect the value of the new technology after it is patented.

Consider first the implications of a patent with an uncertain value. If all agents are risk neutral, the analysis is essentially unchanged. The preceding results hold with the profit terms replaced by their expected values, conditional on those actions (price, capacity, etc.) under the control of the firm.

Preemption is desirable only if the expected loss from competition is positive for every potential entrant. Define the expectations of the monopolist and a potential entrant as consistent if the sum of the returns expected by each firm with entry are no greater than the monopolist's expected return without entry. The monopolist is better off preempting if expectations are consistent for the most optimistic entrant. If expectations are not consistent, either the monopolist or the entrant is unduly optimistic. In the former case, the monopolist's realized profits would be greater with preemption. The latter case is an example of the winner's curse; the entrant's realized profits fall short of expectations and may fail to cover the costs of product development.

Of course the monopolist need not know and may not be able to infer the expectations of potential rivals. Even if all expectations are consistent, uncertainty about competitors' expectations may lead the monopolist to choose a strategy that allows entry with positive probability. For example, suppose profits expected by an entrant of \$100 are consistent, but the monopolist thinks it is unlikely that any rival expects to earn more than \$50. An investment program that preempts only those rivals with profit expectations of no more than \$50 costs less than a program that preempts all rivals with consistent expectations, and it would have higher expected profits if the probability that any entrant expects to earn more than \$50 is sufficiently small.

The presence of risk aversion alters incentives for preemptive activity, as suggested by the analysis of Spence and Michael Porter. Risk aversion has consequences similar to managerial diseconomies, in that both imply a lower expected return from a given level of effort.

Similar results are obtained when the assumption of a deterministic patent date is replaced by a more general stochastic function which describes the probability of invention at date T conditional on a particular *R&D* plan. Various authors have constructed models which suggest that the competitive equilibrium will be one in which several firms pursue research programs, each expecting to make sufficient profits if successful in the patent race to offset the risks of failure.[9] It might be thought that such models imply that the monopolist cannot guarantee successful preemption, but this is not so, at least on our present set of assumptions. If expectations are consistent, *R&D* inputs are observable, and there are no managerial diseconomies, the monopolist can guarantee negative expected profits to any potential entrant, and knowing this, firms would not invest in *R&D*.

The argument is the same as before, except that the monopolist has to set up the correct number of rival research teams—the same number as the number of firms who would choose to enter under competitive conditions. If the monopolist is able to do so (the assumption of no managerial economies, that

[9]Stiglitz (1971), Glenn Loury (1979), and Dasgupta and Stiglitz (1978) characterize equilibrium research for patent rights with stochastic returns.

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he is as good at research as anyone else) then no extra firms will be tempted to enter and compete.[10]

C. *Multiple Competitive Threats*

The assumption that entry can be blockaded by a single patent is a convenient simplification to emphasize the strategic value of patents as barriers to entry, but it remains to be seen whether the results in Sections I and II extend to more realistic situations. Typically, many different design routes lead to the development of products with similar market characteristics. Patents may not be effective in preventing potential competitors from making relatively minor design changes which avoid infringement. The cost of an infringement suit relative to the potential gains from patent enforcement may be so large as to discourage legal proceedings. In addition, potential competitors are often dependent on each other for the use of patented technology. This encourages cross licensing of patents and discourages attempts at restrictive patent enforcement. Finally, any monopoly power afforded by patent protection may be ephemeral or trivial if the firm does not continue to introduce improved technology and develop a range of products necessary to capture a substantial market.

This section examines the preemption decision in the situation where entry can occur over time by developing any of several technologies with or without patent protection. The problems of cross licensing and developing new and improved technology are ignored, and in order to focus on the questions of entry deterrence, all patentable technologies are assumed perfectly substitutable with each other and with the monopolist's existing technology. This removes any incentive for a monopolist to engage in *R&D* for reasons other than entry deterrence. Let t index discrete time periods ($t=0,1,\ldots,T$), and assume there exists a mapping from the time path of investments into a statistic $A(t)$, which provides all relevant information pertaining to cumulative *R&D* knowledge at date t. Given the current state of knowledge, the firm has an estimate of the number of new technologies that can be developed and patented. The estimate can change over time and may decrease as well as increase. For simplicity, assume the number of new *R&D* paths can only increase, and let $\sigma(n|A(t),t)$ denote the probability that n new paths will be discovered at date t given $A(t)$.[11]

Assume, as in Section I, that the monopolist has no strategic choices other than preemptive patenting. This permits specifying the monopoly return as conditional only on whether entry occurs. Since patentable designs are perfect substitutes, the value of a patent to a potential entrant should be the same for all patentable designs. (Alternatively, entrants might place different values on different designs, provided the highest valuation by any entrant is the same for all designs.) Let π_m represent the monopolist's amortized profit per period if no rival firm patents a new design, and let π_0 be the profit if a rival patents. The per period return to a rival who wins a patent is π_e. The present value of rival profits with an interest rate r and discount factor $\beta=1/1+r$ equals $\pi_e/(1-\beta)$, which determines the cost of preempting each patent, provided all firms have access to the same *R&D* technology.

An attempt to blockade entry by preemptive patenting may prove excessively costly. Even if a firm succeeds in patenting all product innovations, the patents may not seriously encumber potential competitors who

[10] The reason why these models predict more than one firm undertaking research is that there are essentially U-shaped costs curves to a particular research laboratory, and hence an optimum level at which to run a given program. Rather than putting more eggs into one basket, it is argued that it pays to pursue several parallel lines each at the optimum rate. Our argument is that, if this is a rational way to organize *R&D*, the monopolist could replicate it, and perhaps improve on it by having more exchange of ideas between rival laboratories. If, on the other hand, monopolies are bad at optimally subdividing research tasks between competing teams and choose to have just one research team, they could be described as being relatively inefficient, and suffering from managerial diseconomies.

[11] This assumption, to the extent that it is significant, exaggerates the cost of preemptive patenting, and should lead to an underestimate of the value of a preemption strategy.

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can invent around and imitate new designs.[12] Since patenting cannot prevent this activity, it is convenient to include the effect of imitators in the profit terms, π_m and π_0. This convention permits a distinction between competitors who invent around existing patents and competitors who develop new patented designs. A rival may patent a new design first if the monopolist overlooks a patentable design or fails to develop ideas which could lead to new patents. Let $\mu(A(t),t)$ represent the probability that a preemption strategy fails to prevent entry because the monopolist missed a patentable design and a rival succeeds in patenting. The probability depends on cumulative $R\&D$ experience and could decrease with $A(t)$ if the firm is able to cast a wider net with more experience, or could increase with $A(t)$ if the $R\&D$ experience spills over to potential competitors and generates opportunities for product innovation external to the firm.

If $C=\pi_e/(1-\beta)$ is the cost of preempting each patent, the expected returns from a preemption strategy in the current period is

$$(12)\quad (1-\mu(A(t),t))\pi_m+\mu(A(t),t)\pi_0 - \sum_{n=0}^{\infty}\sigma(n|A(t),t)nC\equiv\pi_p(A(t),t).$$

Let $V(A(t),t)$ represent the present value of profits when the monopolist chooses an optimal strategy. The strategy could call for preemption only up to some date, after which the firm no longer attempts to prevent entry. The general expression for $V(A(t),t)$ is

$$(13)\quad V(A(t),t)=max\Big\{\big[\pi_p(A(t),t) +(1-\mu(A(t),t))\beta V(A(t+1),t+1) +\mu(A(t),t)\beta\pi_0/(1-\beta)\big];\pi_0/(1-\beta)\Big\}.$$

The term in the square brackets is the present value of a preemption strategy. The current return from preemption is $\pi_p(A(t),t)$; with probability $(1-\mu(A(t),t))$, no rival firm will patent and the monopolist can choose in the next period whether to continue preemption or allow entry to occur. This explains the term $(1-\mu(A(t),t))\beta V(A(t+1),t+1)$. With probability $\mu(A(t),t)$, a rival will patent and the former monopolist's profits next period, discounted to the present, are $\beta\pi_0/(1-\beta)$, which accounts for the third term in the square brackets. The last term is the present value of profits if entry occurs, and this equals the return if no attempt is made to preempt rivals.

A general solution for the monopolist's optimal policy is straightforward but cumbersome. Simplifying the dependence of the probabilities μ and σ offers insight into the determinants of the preemption decision without detailed computations. Assume the probability, μ, of a breakthrough by a competitor is constant and the expected number of new $R\&D$ paths in each period,

$$(14)\quad \bar{n}(A(t),t)=\sum_{n=0}^{\infty}\sigma(n|A(t),t)n$$

is also a constant. The present value of a preemption strategy for this case is

$$(15)\quad \bar{V}=\pi_p+(1-\mu)\beta\bar{V}+\mu\beta\pi_0/(1-\beta),$$

where $\pi_p=(1-\mu)\pi_m+\mu\pi_0-\bar{n}\pi_e/(1-\beta)$. Rearranging terms gives

$$(16)\quad \bar{V}=\frac{\pi_0}{1-\beta}+\frac{1}{1-(1-\mu)\beta}\times\left[(1-\mu)(\pi_m-\pi_0)-\frac{\bar{n}}{1-\beta}\pi_e\right].$$

Since $\pi_0/(1-\beta)$ is the present value of profits when the firm does not attempt a preemption strategy, the expected profits from preemption are positive only if

$$(17)\quad \pi_m-\pi_0>\frac{\bar{n}}{(1-\beta)(1-\mu)}\pi_e.$$

This condition is much more restrictive than the requirement that monopoly profits exceed the industry profits if entry occurs, as determined in Section I. Entrant profits in

[12] Milton Kamien and Nancy Schwartz (1978) construct a descriptive model of imitative research.

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equation (18) are multiplied by the factor $\bar{n}/(1-\beta)(1-\mu)$. The term $\bar{n}\pi_e/(1-\beta)$ is the present value cost of continued entry deterrence, and this is divided by $(1-\mu)$, the probability that deterrence is successful. Even modest prospects for new *R&D* opportunities cause a significant increase in the cost of entry deterrence. It is not difficult to see that a preemption strategy would be futile in a technologically progressive industry, where both $\bar{n}$ and μ are relatively large.

Furthermore, even if the factor $\bar{n}/(1-\beta) \cdot(1-\mu)$ is close to one, inequality (17) is not equivalent to the condition that monopoly profits exceed profits with competition because the profit, π_m, is defined to include the impacts of imitating firms. This is less than pure monopoly profits by an amount equal to the sum of the profits of imitating firms plus the losses from imitative competition. Hence, even if the monopolist could succeed in preempting all patentable substitute technologies, this does not assure that a preemptive strategy would yield a higher net return.

Although these results imply that patenting may be an ineffective means to deter entry in most industries, other strategies may be used preemptively to erect barriers to entry. A monopolist may accelerate investment in new capacity in order to accumulate a capital stock large enough to serve as an entry deterrent. The effectiveness of preemptive capacity construction depends, as Dixit (1979, 1980) has argued, on the relation between a firm's capacity level (the threat level in game-theoretic terms) and the firm's production decision after entry occurs (i.e., the credibility of the threat). With free entry, a monopolist has an incentive to preemptively build capacity to deter entry, provided the capacity will be used if entry occurs (see Spence, 1977; Williamson, 1977b; and Gilbert and Harris, 1980).

IV. Concluding Remarks

While several conditions limit the efficacy of preemptive activity, the analysis in this paper shows that in some circumstances a firm can maintain a monopoly through preemptive activity despite the potential of entry. The conclusion is in agreement with that of Williamson (1977a), but for different reasons. Williamson attributes the persistence of dominant firms at least partly to market imperfections. We do not disagree with Williamson's arguments that market imperfections contribute to the persistence of dominant firms. We do disagree with the contrafactual statement that in the absence of market imperfections potential competition would eliminate dominant firms. Our results show that without market imperfections (except for an initial monopoly), incentives exist to maintain a monopoly position. Indeed, a perfect market for *R&D* inputs gives the monopolist a credible threat that it would overtake any rival undertaking a competitive research program, which reduces the cost of preemption to nil and makes the preservation of his monopoly position costless and hence doubly attractive.

The undesirable consequences of preemptive activity are evident. A firm may sustain its monopoly power through preemption. The firm may spend resources on the development of new technologies, and then deny society the use of these technologies. Resources are expended on research and development only to produce "sleeping patents" which are withheld from use, and the firm with monopoly power maintains its monopoly position. However, prohibiting preemptive activity need not lead to an increase in economic surplus even in those extreme situations where resources are expended primarily for entry deterrence rather than for product development.

The problem that may arise is implicit in the analysis of strategic behavior in Section III. Preemptive research and development is only one of many actions which, in the language of Joe Bain, may impede the entry of rivals or at least mitigate the profit loss from competition. In the absence of preemption, alternative entry-deterring behavior could incur private and social costs that exceed the social cost of monopoly sustained by preemptive activity. Section III showed conditions where strategic capital investment is lower when combined with preemptive research and development. If preemptive activity were prohibited, strategic capital investment, with its associated costs, would

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increase and the net cost in terms of economic surplus could be larger.

Preemption would be very hard to identify in any practical situation because it is difficult to distinguish product development that is the result of superior foresight and technological capabilities from development that is motivated by entry deterrence. This may be just as well since preemption need not have adverse consequences for economic welfare. Preemption requires investment in product development with only a probability of successful entry deterrence. Society gains from the development of new technology at a pace at least as rapid as would occur with more competition, and in all but rare instances the technology would be put to use. If entry deterrence is not successful, the burden of monopoly would be removed or reduced. Since entry at some date is inevitable, to the extent that preemption does occur it is a phase in the Schumpeterian process of creative destruction.

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