Uncertain Innovation and the Persistence of Monopoly: Reply

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In my 1983 article in this *Review*, I reported results (based upon a stochastic model of invention) which were at variance with those (based upon a deterministic model of invention) reported previously in 1982 by Richard Gilbert and David Newbery (hereafter G-N).

In their comment, G-N claim that the differences in our respective results arise not due to the presence or absence of uncertainty, as I suggested, but due to (in my model) 1) a different assumption about the timing of moves in the *R&D* game, 2) the absence of free entry, and 3) assumed diseconomies in the management of the firm. The model in my paper was intentionally highly simplified, eschewing the issues of fixed costs and free entry, because the point was simple and intuitive. The point was *not* that preemption—or a weaker notion, stochastic preemption—would *never* occur. Nor did I claim that a deterministic invention process was either necessary or sufficient for preemption. My point was simply that when uncertainty is introduced into the G-N deterministic bidding model, the equilibrium outcome is quite different: in the deterministic model, the monopolist persists with probability one, while in the stochastic model, the monopolist will suffer entry—not just with positive probability—but with probability greater than one-half. Thus their conclusions regarding the likelihood of persistence are highly sensitive to the assumption of a deterministic invention process. Of course, this is not to say that their conclusions (or mine) are not equally sensitive to other modeling assumptions. In the sequel, I will examine the role of alternative assumptions regarding the order of play, free entry, and managerial diseconomies.

I. The Order of Play

There is no explicit discussion in G-N's 1982 article regarding the order of play in the game. However, indirect evidence tends to point toward simultaneous moves. For instance, "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" (p. 516). That is, monopolist and entrants alike each pick an investment level; in a sequential-move game, entrants would select a best-response function.[1]

Moreover, G-N assert that their model is formally equivalent to a particular type of auction model in which firms enter bids for the innovation; the winning bidder must then spend the amount of its bid on *R&D*. This is essentially a first-price auction with complete and perfect information. It turns out that in this framework, there is no need to specify timing conventions at all. It is easy to show that the simultaneous-move equilibrium is identical to the equilibrium specified by G-N.[2] Thus, regardless of the sequential or simultaneous nature of the bidding, the equilibrium outcome is the same. The agent with the highest valuation (in this case the incumbent monopolist) wins; however, the winner needs to pay only (a tiny bit more than) the amount of the next-highest valuation.

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[1]In a related model, Partha Dasgupta and Joseph Stiglitz explicitly assume a leader-follower structure; they state that "active firms work on the reaction function of potential entrants; i.e., entertain von Stackelberg conjectures regarding their behavior" (1980, p. 10).

[2]Technically, if we think of this as a first-price auction, then both the sequential-move and simultaneous-move equilibria are really "*epsilon*-equilibria," since there is no *minimum* winning bid.

Thus it is perfectly reasonable to compare G-N's bidding model with a stochastic invention model in which firms move simultaneously. However, in evaluating their conjectures about the effects of uncertainty on their model, it is important to keep in mind their (implicit) sequential-move assumption. I will postpone until Section IV my comments on the appropriateness of the sequential-move framework.

II. Unrestricted Entry

Gilbert and Newbery emphasize that their model includes free entry,[3] that mine doesn't, and that this is (at least in part) responsible for our differing results. The issue of free entry is a red herring. In their original paper they claim that free entry is *not* crucial to their result (and, indeed, it isn't). Immediately following their main argument, they state that "...the same 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 [free entry]" (pp. 516–17). Moreover, in their model it is only the most efficient challenger which provides any competition for the incumbent; theirs may as well be a two-firm model.

Nevertheless, consider what happens in my model if one adds fixed costs and allows unrestricted entry (obviously both must be added at once; due to the assumption of decreasing returns to investment, with no fixed costs the number of firms is infinite). The fixed cost, denoted F, does not affect equilibrium flow investment, only whether or not the challenger firm plays. Since $F=0$ implies infinitely many firms, and since the equilibrium challenger payoff with n firms can be shown to be decreasing in n (see my forthcoming paper), for any n one can find an F_n such that only the incumbent and n challengers want to play. For one challenger, this fixed cost is $F_1 = V^C(x_I^*, x_C^*)$. When n challengers play, the results are even stronger; now the incumbent firm invests less than *each* challenger. Thus its probability of persisting as a monopolist is less than $1/n$. Thus unrestricted entry can easily be accommodated without any weakening of my results.

III. Managerial Diseconomies

"Managerial diseconomies exist if the monopolist cannot conduct a research program or production plan as efficiently as any rival" (G-N, 1982, p. 518). This would not ordinarily seem to rule out decreasing returns to scale in the invention technology, as long as both incumbent and challengers alike are subject to the same decreasing returns. Actually, G-N want to say that if no managerial diseconomies exist, then the monopolist is as efficient as *all rivals put together*. Essentially, one needs to be able to run parallel $R\&D$ projects at no worse than constant returns to scale. Gilbert and Newbery "extend" my model to a number of parallel projects without including a fixed cost per project. Since this leads to an infinite number of parallel projects, they impose arbitrary upper bounds on the number of projects which may be undertaken by the incumbent and by challengers, and then discuss what happens when these bounds are differentially relaxed. In my earlier paper I reported results based on a model with parallel projects; the details of this model are available in an unpublished technical appendix. My own extension involved a fixed cost of K per project, and a flow cost, or research intensity, on each project. For simplicity, let the intensity be fixed at x, yielding hazard rate $h=h(x)$, and let n_I and n_C denote the number of parallel projects chosen by the incumbent and the challenger, respectively. The payoff functions now take the forms[4]

$$V^I(n_I, n_C) = [n_I h\Pi(c) + n_C h\pi_I(c) + R - n_I x] / [r + n_I h + n_C h] - n_I K$$

[3]I interpret the term "free entry" as meaning *unrestricted*, but not necessarily *costless*, entry.

[4]The present value of profits to a monopolist using the new technology with unit cost c are $\Pi(c)$, capitalized profits to the incumbent and entrant if the entrant

and $V^C(n_I, n_C) = [n_C h \pi_C(c) - n_C x]$

$$/ [r + n_I h + n_C h] - n_C K,$$

where it is assumed that $h\Pi(c) - x > 0$, so that the challenger has at least a chance at positive profits if the innovation is drastic. Differentiating V^i with respect to n_i, $i = I, C$ and simplifying yields the following necessary conditions at an interior Nash equilibrium (n_I^*, n_C^*).

$$(1) \quad [r + n_C^* h][h\Pi(c) - x] - h[n_C^* h \pi_I(c) + R] - KB^2 = 0$$

$$(2) \quad [r + n_I^* h][h\pi_C(c) - x] - KB^2 = 0,$$

where $B = r + n_I^* h + n_C^* h$.

PROPOSITION 1: *If the innovation is drastic and $R > 0$, then $n_I^* < n_C^*$; that is, the incumbent conducts fewer parallel projects than the challenger.*

PROOF:

If the innovation is drastic, then $\Pi(c) = \pi_C(c)$ and $\pi_I(c) = 0$. Combining equations (1) and (2) yields

$$(3) \quad (n_C^* - n_I^*)[h\Pi(c) - x] = R.$$

Since $h\Pi(c) - x > 0$, equation (3) requires that $n_I^* < n_C^*$.

Again, a simple continuity argument establishes that there is an open set of technologies which are not drastic, but for which Proposition 1 remains valid.[5]

patents the new technology are $\pi_I(c)$ and $\pi_C(c)$, respectively. Current flow revenues to the incumbent are denoted R. An innovation is *drastic* if it would drive the incumbent from the market; i.e., if $c \leq c_0$ where c_0 is the maximum level of unit cost such that $\pi_I(c) = 0$. In the interest of brevity, the reader is referred to my 1983 article for more complete definitions and the derivation of payoff functions.

[5]Assuming that success in $R\&D$ is a function of *fixed* rather than flow costs, Richard Freeman (1982) finds that a single domestic entrant will conduct more parallel projects than an incumbent foreign monopolist. Thus this result does not depend upon the fixed vs. flow specification of costs.

IV. Conclusions

Gilbert and Newbery have argued that alternative assumptions regarding the conditions of entry, economies of scale and the order of play (and not uncertainty) are responsible for the differences in our respective results concerning the persistence of monopoly. It seems clear from the above discussion that at least the first two of these alternatives can be accommodated with no effect on the results. The models outlined in my original paper and in the preceding pages herein all describe circumstances in which, *were the invention process deterministic*, the incumbent would persist as the monopolist. But in the stochastic formulation, the incumbent enjoys a lower marginal benefit to invention than does the challenger when the innovation is drastic, or nearly so. Consequently, the incumbent invests less than the challenger and, *on average*, entry occurs.

All of my analysis is based upon interior Nash equilibria; that is, ones in which the challenger actually participates. Gilbert and Newbery object to assumptions which allow for the possibility of (or even guarantee) interior equilibria, saying that one cannot examine preemption and entry deterrence in such a framework. I think this takes an extremely narrow view of preemption and entry deterrence. When it is impossible to credibly preempt or deter entry with probability one, it still makes sense to ask whether stochastic preemption or stochastic entry deterrence are prevalent features of an industry. That is, are potential entrants discouraged *on average* from participating, or do they participate to a lesser extent than they would in the absence of the incumbent's strategic behavior?

I will concede that alternative assumptions regarding the order of play will typically yield different equilibrium results (G-N's deterministic bidding model is one example in which the order of play is of no consequence). But I do question the appropriateness of G-N's assumed order of play, and the attribution of the undesirable consequences to the patent system. In their comment, G-N extend their own model to the case of uncertainty, making explicit their sequential-move assumption. They show that in equilibrium the incumbent will choose an entry-deterring level of investment. However, this investment level will not be credible without some mechanism for commitment. They remark that

> Whether preemption will occur ultimately rests on the extent to which firms can make prior entry-deterring commitments that are credible to potential competitors. We would argue that the incumbent has a natural temporal advantage since after all he is the incumbent, in which case the central issue is one of credibility. [p. 242]

That monopoly power per se should confer a first-mover advantage seems debatable at best. One could argue equally persuasively the obverse claim that the potential entrant should have the first move, since the incumbent may not be aware of its existence or intent to invest until it actually does so. The entrant's investment alerts the incumbent to its presence, and it is the incumbent who must respond.

Even if one concedes a first-mover advantage to the monopolist, there remains the issue of credibility. In their original paper, G-N state that their purpose is to determine "whether institutions such as the patent system create opportunities for firms with monopoly power to maintain their monopoly power" (p. 514). However, if the difference in our respective results is due to their assumption that the incumbent can credibly commit itself to a preemptive investment level, then the responsibility for persistent monopoly clearly does not reside with the patent system, but with the (implicit) institution which facilitates an otherwise noncredible threat.

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