Recent Developments in Oligopoly Theory

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Research in oligopoly theory has grown so rapidly that, in the space available, I can only highlight one or two important new developments. My chosen topic, like that of Franco Modigliani nearly twenty-five years ago, is entry. This is not for want of progress; quite the opposite is the case. The new work can be characterized by its recognition of the interdependent sequential decisions that the issue of entry involves, and formulation of logically consistent sets of assumptions and equilibrium concepts to replace earlier *ad hoc* methods.

It was always recognized that profitability of entry would be crucially affected by the incumbent's subsequent actions. These should be analyzed as a part of the oligopolistic interactions that would occur if entry took place. However, earlier theory postulated exogenous assumptions on the part of prospective entrants concerning incumbents' actions. Maintenance of output by incumbents was thought to be the most aggressive or unfavorable response, and the postulate that a prospective entrant would act on this assumption was called the Sylos Postulate. Maintenance of price by incumbents was held to be a very accommodating response, and according to Modigliani, such an assumption would be "a rather foolish one for the entrant to make."

The Sylos Postulate was widely adopted, and the resulting limit-price theory of entry deterrence became the textbook model of large-scale entry, albeit with accompanying warnings. Nothing in the level of pre-entry output per se argues for its continuation. Under many conditions it is undesirable or even impossible for an incumbent to maintain output after entry, and an entrant who knows this is not deterred by threats to do so. Under other conditions, the incumbent has access to actions that lend credibility to threats, but then the same actions may allow threats of response even more aggressive than output maintenance.

Recent work has split along these two lines. On one hand, we have research into strategic behavior yielding credible threats of entry deterrence. On the other, there is specification of conditions under which all such threats are empty, so that the prospect of entry exercises severe discipline on incumbents. I now examine the main features of these approaches.

I. Commitment

The classic analysis of Thomas Schelling showed how a threat could be made credible by entering into a prior commitment that made its fulfilment optimal *ex post*. The application to entry can be illustrated in an example similar to that given by Steven Salop. I develop it somewhat differently to elucidate some game-theoretic ideas that will be useful later.

Consider a two-stage game between an incumbent monopolist and a prospective entrant. The first stage is the latter's entry decision. If he stays out, the incumbent earns monopoly profits P_m. If entry occurs, the incumbent decides whether to fight a price war, with profits P_w to each, or to share the market, with profits P_d to each duopolist. This simple structure suffices for the present purpose, but it can be thought of as the reduced form of a more complex game with further continuous choices of outputs etc. Figure 1 shows the usual game tree. At each termination point the corresponding payoffs are shown, the first component being the incumbent's. It is assumed that $P_m > P_d > 0 > P_w$, that is, duopoly is profitable but not

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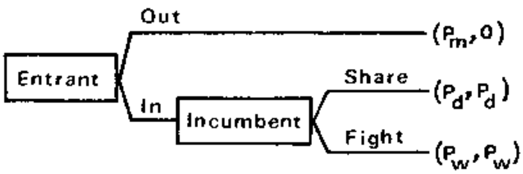

FIGURE 1

as much as monopoly, while a price war is mutually destructive.

In this sequential game, players can choose strategies, that is, complete plans specifying actions to be taken at each available turn. Each action can depend on the known history of the game up to that point, including previous actions of other players. Such strategies are called "closed-loop." The game is noncooperative, so the Nash concept of equilibrium seems natural. A pair of closed-loop strategies, one for each player, such that neither wants to change his strategy given that of the other, would then be a "closed-loop Nash equilibrium."

In my example, the strategy pair "Fight if entry" for the incumbent and "Stay out" for the entrant constitutes such an equilibrium. Given the former, the outsider wants to keep out; given the latter, the incumbent can freely plan a costly price war that is never going to occur. This is patently unrealistic. In treating the incumbent's strategy as given, the entrant is attaching credibility to a threat which the other has no *ex post* incentive to fulfill. Thus the closed-loop Nash equilibrium is not a good solution concept.

To avoid this problem, we should make it a requirement of an equilibrium strategy that each of its substrategies starting from any point of the game tree should be optimal, whether or not the contingency represented by that point actually arises in the play of the game when this strategy is confronted with the equilibrium strategy for the other player. This idea must be greatly refined for more complicated games, but the rough statement will suffice here. With the same looseness, the resulting equilibrium will be called a "perfect" or "sequential" equilibrium. Rigorous treatments are given by David Kreps and Robert Wilson, and Reinhard Selten.

In the above example, the strategy "War if entry" cannot be part of a perfect equilibrium. The entrant knows that the incumbent's optimal response to entry is sharing. Since $P_d > 0$, he stands to gain by entering. Therefore this is the outcome in the perfect equilibrium.

Now suppose the incumbent has available a prior irrevocable commitment, such as incurring cost C in readiness to fight a price war. This does not affect his payoff if a war in fact occurs, but lowers it by C otherwise. The new three-stage game tree is shown in Figure 2. An incumbent who has made this commitment will find it optimal to fight in the event of entry if $P_w > P_d - C$. An entrant, knowing this, will stay out if the incumbent is committed, and enter if he is passive. The incumbent, knowing this in turn, will make the commitment if the ultimate payoff from doing so, $P_m - C$, exceeds that from being passive, P_d. Provided there exists a commitment whose cost satisfies $P_m - P_d > C > P_d - P_w$, it allows the incumbent to employ a credible threat and deter entry to his own advantage. Incidentally, the example also shows how a sequential equilibrium has to be solved backwards.

The availability of such a commitment is a matter for each specific case. Sunk capacity is the most cited example; Curtis Eaton and Richard Lipsey summarize and extend that literature. Salop gives other examples such as brand selection and advertising. There are two essential requirements: the commitment should be made (and made known) prior to the entrant's decision, and it should be irreversible. The incumbent often has a natural advantage of the first move, although an unaware passive incumbent may find himself facing an aggressive committed entrant, when the roles are reversed and the incumbent must contemplate exit. Irreversibility is a matter of technology and institutions. For example, capacity serves the purpose only if it cannot be costlessly liquidated. Capital goods that depreciate rapidly, or ones for which an efficient resale market exists, are not useful instruments for an entry-deterring commitment.

This commitment is not costless: it lowers the incumbent's profits by C below the mo-

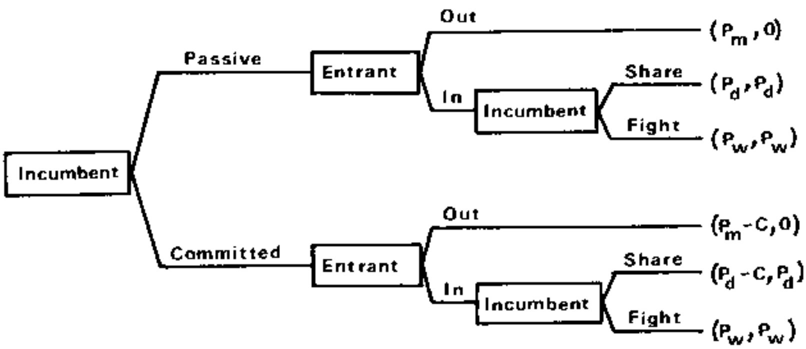

FIGURE 2

nopoly level. It is sometimes asserted that side bets are costless deterrents. Thus the incumbent might contract to pay a third party a large sum in the event of his failing to meet entry with a price war. This makes fighting the optimal *ex post* response, and the sum never has to be paid. But this does not work if the entrant has access to the same third party. He need only argue that in the outcome the incumbent will not have to pay anything, and offer the third party a small but actual sum in return for voiding the contract. In reality, "meeting competition" clauses in sale contracts come close to being costless deterrents, but may involve the cost of tipping off buyers about the existence of profits, and inducing them to drive harder bargains. Frank Easterbrook discusses several predatory strategies for both parties.

Finally, it should be noted that to the extent that commitment deters entry, it entails a twofold social cost: the loss of consumers' surplus due to continued monopoly pricing, and the resource cost of the commitment instrument.

II. Reputation

Return to the game of Figure 1. There is no commitment, and the threat of "War if entry" is empty. If the incumbent plays this game repeatedly against a succession of potential entrants, might he have an incentive to carry out the threat to obtain a reputation that will deter future entry? The idea is that short-run losses from a price war would be recouped in the form of increased profits from the subsequent monopoly.

Suppose the game is to be played a fixed finite number of times. Suppose there is complete information in the sense that the strategies and payoffs are common knowledge: each player knows them, each knows the other knows, and so on. Then in the repeated game the perfect equilibrium has entry and sharing in each round. The proof is a simple backward unravelling. In the last play sharing is optimal for the incumbent, and both know this; so there will be entry in that round, and both know this, too. Then the same applies to the penultimate round, and so on. For reputation to have a role, therefore, we need either infinite (or indefinite) repetition, or incomplete information.

In the former case things are easy, in fact too easy. Let b denote the discount factor, and suppose $(P_d - P_w) < (P_m - P_d)b/(1 - b)$, that is, relative to sharing, the one-period loss from fighting is outweighed by the present value of subsequent gains from entry prevention. Then it can be verified that there is a perfect equilibrium where the incumbent fights each entry provided he is not burdened with a history of acquiescence, and each new entrant comes in only if there has been previous sharing. Unfortunately, there are many other perfect equilibria, including the one with entry and sharing at each play. The problem is similar to that of multiple Nash equilibria in an infinitely repeated game like the prisoners' dilemma; James Friedman discusses this issue.

Next consider a fixed finite sequence of plays, but allow incomplete information. Alternative models are explored by Kreps and Wilson, and by Paul Milgrom and John Roberts. As an illustration, suppose it is not common knowledge whether a commitment instrument satisfying the conditions stated earlier exists. Then an entrant does not know whether the incumbent's payoffs are as in the top half or the bottom half of the game tree of Figure 2. Each entrant will have prior beliefs represented by subjective probabilities for the two alternatives, and will revise then in a Bayesian manner using his knowledge of the structure of the game and his observations of the incumbent's previous actions. A committed incumbent always fights, so a single episode of sharing will expose a lack of commitment. An uncommitted incumbent can hope to be mistaken for a committed one by acting as he would, that is, fighting entry. Thus an observed fighting response conveys less information. After a careful calculation of mutually consistent actions and probability revisions, we find that a perfect equilibrium can have three phases, although some may be absent in particular examples. An uncommitted incumbent will fight in the early phase, use a randomized strategy (fight with a probability that is positive but less than one) in the middle phase, and start sharing in the final phase. This accords with intuition, since the potential gains from acquiring the reputation are greater, the longer the remaining sequence of plays. In the papers cited above, if q is the prior probability of facing a committed incumbent, the equilibrium shows the fight response in all but the final n plays of the game, where n behaves like $-\log q$, that is, it increases quite slowly as q goes to zero. Thus a very small amount of incomplete information can explain a lot of reputation-building action.

Schelling stresses the practical importance of reputation in achieving credibility for threats (and promises). The rigorous formulation of this using perfect equilibria in repeated games with incomplete information is a major achievement. However, care is necessary in applying it. Given any closed-loop equilibrium with empty threats, one can construct a story of incomplete information to make it a perfect equilibrium. As an extreme example using the above model, if $qP_w+(1-q)P_d<0$, i.e., $q>P_d/(P_d-P_w)$, then even in a single play the entrant will stay out, and the incumbent who knows this will enjoy a monopoly. The issue is whether the assumed incompleteness of information is realistic. Cases where a very small q suffices are appealing, but in practice a judgment of plausibility must be made for each specific case.

The incumbent may in turn be unsure of the entrant's payoffs. Provided the same entrant plays the game repeatedly, there will be scope for aggressive actions to build his reputation as well.

The informational limitation above was exogenously imposed. But each player gains from creating such incompleteness of information if none exists initially, and the other knows it. This opens up new strategic possibilities. Predation in an entrant's test market is an example. The rationality of pretending irrationality, analyzed by Schelling, also bears on this issue. This has serious, but unclear, implications for policies that seek to increase information.

III. Contestability

The above work attempts precise formulations of post-entry oligopoly, in order to trace back the implications for strategic entry-deterrence. By contrast, the theory of perfectly contestable markets finds conditions under which post-entry oligopoly is irrelevant, and strategic entry-deterrence impossible. A detailed account of this research appears in the book by William Baumol, John Panzar, and Robert Willig.

A perfectly contestable market is defined as one where 1) all producers have access to the same technology; 2) this technology may have scale economies such as fixed costs, but must not have sunk costs; and 3) incumbents cannot change prices instantly. To these should be added; 4) consumers respond instantly to price differences. In such a market, a prospective entrant can adopt a hit-and-run tactic without considering retaliation from, or oligopolistic interaction with, the incumbent. He undercuts prevailing prices for all or some goods slightly, starts serving the whole market for them, and can always exit costlessly if and when price retaliation occurs. Such a raid will be profitable if the incumbents are not minimizing the cost of producing the market outputs, or are making positive aggregate profits, or are cross subsidizing. In an equilibrium structure of the industry, therefore, all these practices must be absent, which gives a strong social desirability to the market outcome even without classical perfect competition with many producers.

This theory has important normative features. Equilibrium in an "as if contestable" market, when one exists, provides a much better benchmark for social policy than an unrealistic "as if competitive" standard under natural monopoly or oligopoly. This serves to focus regulatory policy towards removing artificial barriers to contestability, improving contestability when the prevailing industry structure is not conducive to it, and reserving direct action for cases of "nonsustainability," that is, failure of existence of equilibrium in a contestable market.

As a positive theory of market structure, it needs careful handling. In most cases in practice, production requires some commitments that can only be liquidated gradually, consumers assimilate and respond to price changes with some delay, and firms need some time to calculate and implement price changes. Perfect contestability is the judgment that the third lag is the longest. There are instances where this can be argued, such as the passenger air traffic market between a given city pair. But the scope of validity of the theory is unclear. The traditional presumption in industrial organization is the opposite, that is, that prices can be changed more quickly than sunk capacity. Such a view underlies the literature on entry deterrence discussed above. It is also behind the rival notion of quantity sustainability advanced by William Brock and José Scheinkman. In their model, entrants act on a multiproduct extension of the Sylos Postulate. This can be justified by assuming that the incumbents' costs are all sunk so that they maintain output levels, and the market is an efficient auction market so that prices adjust immediately to absorb the additional output of the entrant. The resulting equilibrium does not have the strong socially desirable properties of the price-sustainable case.

In practice, careful empirical work in each specific context will have to be undertaken before we can say whether an industry is contestable and sustainable, and decide whether and what regulatory attention it requires.

REFERENCES

Baumol, William J., Panzar, John, C., and Willig, Robert D., *Contestable Markets and the Theory of Industry Structure*, San Diego: Harcourt Brace Jovanovich, 1982.

Brock, William A. and Scheinkman, José A., "Free Entry and the Sustainability of Natural Monopoly: Bertrand Revisited by Cournot," Workshop Series No. 8126, University of Wisconsin, Social System Research Institute, September 1981.

Easterbrook, Frank H., "Predatory Strategies and Counterstrategies," *University of Chicago Law Review*, Spring 1981, *48*, 263–337.

Eaton, B. Curtis and Lipsey, Richard G., "Capital, Commitment, and Entry Equilibrium," *Bell Journal of Economics*, Autumn 1981, *12*, 593–604.

Friedman, James W., *Oligopoly and the Theory of Games*, Amsterdam: North-Holland, 1977.

Kreps, David M. and Wilson, Robert, "Sequential Equilibria," *Econometrica*, forthcoming 1982.

______ **and** ______, "Reputation and Imperfect Information," *Journal of Economic Theory*, forthcoming.

Milgrom, Paul and Roberts, John, "Predation, Reputation and Entry Deterrence," *Journal of Economic Theory*, forthcoming.

Modigliani, Franco, "New Developments on the Oligopoly Front," *Journal of Political Economy*, June 1958, *66*, 215–32.

Salop, Steven, "Strategic Entry Deterrence," *American Economic Review Proceedings*, May 1979, *69*, 335–38.

Schelling, Thomas, *The Strategy of Conflict*, Cambridge: Harvard University Press, 1960.

Selten, Reinhard, "Re-examination of the Perfectness Concept for Equilibrium Points in Extensive Games," *International Journal of Game Theory*, January 1975, *4*, 25–55.