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New Theories of Predatory Pricing[1]

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With the approach of 1992, when EEC regulations will prevail in any Common Market member not having its own national competition policy, antitrust issues have become a subject of immediate interest in a number of European countries. At the same time, concerns with 'international competitiveness' have reinvigorated the debate over antitrust in North America and elsewhere in the industrialized world. This renewed interest in competition policy coincides with an unparalleled series of advances in economists' theoretical understanding of the competitive, strategic behaviour of firms and of the welfare implications of this behaviour. This new learning can potentially inform the formulation of policy in important ways. The purpose of this chapter is to review one aspect of this work and point out its implications for antitrust policy.

The subject at hand is predatory pricing, the temporary charging of particularly low prices in order to improve long-run profitability by inducing exit, deterring entry, or 'disciplining' rivals into accepting relatively small market shares. The idea that firms might use such pricing practices as an exclusionary device is a familiar one. Well-documented instances of this practice date back over a century, and claims of recent occurrences continue. For over three-quarters of a century, both explicit legislation and case law in the USA have condemned such temporary price cutting, at least when practised by large firms or ones that already hold significant market shares. Yet, despite the widespread belief in the existence and efficacy of predatory pricing, the logic of this alleged practice was not subjected to adequately reasoned legal or economic analysis until McGee's influential 1958 re-examination of the *Standard Oil* case.[2]

[1] The financial support of the National Science Foundation is gratefully acknowledged.

[2] *Standard Oil Company of New Jersey* v. *U.S.*, 221 U.S. 1, 47, 76 (1911).

This case was brought under Section 2 of the Sherman Antitrust Act of 1890, which forbids attempts to monopolize.[3] The claim was that the Standard Oil Trust had attempted in the period up to 1899 to obtain a monopoly position and that it had done so in part through a policy of selective price cutting aimed at rivals in particular markets. Standard Oil was supposed to have cut prices and held them low until the targeted rivals were forced to exit or agreed to sell out to Rockefeller. (Other alleged exclusionary tactics included the securing of preferential rail rates, foreclosing supplies to rivals, industrial espionage, and the selective use of dynamite on rivals' facilities.) Other well-documented instances of such apparent predation from the same era involve ocean shipping in the China–United Kingdom tea trade (see Yamey 1972, for a description based on the House of Lords investigation in the *Mogul* case) and the United States Tobacco Trust (see Burns 1986 and 1987). Based on such cases, the idea of predatory pricing became well established in legal, business, and economic thinking, and it remains so today. For example, see the recent claims of predatory pricing in the 'less-than-truckload' motor-carrier industry in the Eastern Central states in the period since trucking deregulation (Abruzzese 1987) or the recent complaints about 'dumping' (e.g. of semiconductors by Hitachi in the United States or of automobiles by Hyundai in Canada).

In this context, it is striking that McGee argued that predatory pricing was not a rational strategy for Rockefeller's firm to have adopted. Further, although various authors suggested potential difficulties with McGee's original arguments or their extension to other cases (e.g. Telser 1966; Scherer 1970; Yamey 1972; Posner 1976), even quite recently McGee was able to argue forcefully that predatory pricing was very unlikely to yield a positive return, that it would thus rarely be adopted, that the main effect of legal prohibitions would be to deter desirable price competition, and, moreover, that no satisfactory, complete economic analysis indicated otherwise (McGee 1980).

[3] This is still the usual vehicle for bringing predatory pricing cases in the US. Exceptions come in regulated industries in which specific statutes give antitrust exemption but still outlaw predatory pricing. For example, the use of 'fighting ships' is expressly condemned by the Shipping Act 1916, which otherwise gives a measure of antitrust immunity to the regulated ocean liner shipping industry. Section 86 of the Treaty of Rome appears to provide a basis for prosecuting predatory pricing in the EEC.

McGee's key arguments may be summarized as follows.[4] First, he argued that driving out rivals via predation does not prevent new entry from occurring once the predator raises its prices to enjoy its improved market position, and such entry (whether by new firms or the erstwhile prey) may in fact be made easy because the prey's production facilities will be available. Such entry means that any gains from inducing exit will be short-lived. Secondly, McGee suggested that cheaper strategies for achieving a monopoly are often available. For example, merger or acquisition would have been legal options in Rockefeller's time, and the relatively relaxed attitude of the Reagan administration on antitrust has again made concentration-increasing mergers easier. Thirdly, McGee claimed that predatory pricing ought not to be able to force exit, once the fact that the price cutting must be temporary is recognized. The prospect of long-term profitability ought to lead the prey to stay in, and ought to give its investors and lenders the incentive to finance any temporary losses.

McGee's arguments would suggest a legal doctrine that presumes that claims of predation are without merit. While economic reasoning has had an increasing impact on the thinking of lawyers and judges in the United States, few have fully accepted the implications of McGee's work. Instead, the emerging orthodoxy in United States antitrust law is based on a literature that appeared between McGee's two papers and that largely ignored his arguments. This literature continues to assume that predatory pricing is a potential problem because it might be used as an exclusionary device. It then seeks to determine legal tests that would establish that predation had been attempted. The key feature of this work is an objective of avoiding having to determine judicially the intent of the accused firm's pricing policy and, instead, of substituting mechanical examination of quantities that are presumed to be objectively observable, such as prices, costs, or output levels.

The leading contribution to this literature—both in terms of its temporal precedence and its impact on US case law—is that of Areeda and Turner (1975).[5] The Areeda–Turner test is conceptually simple: prices above (reasonably anticipated) marginal cost represent legal competitive behaviour; prices below marginal cost represent illegal predation. The apparent simplicity of this test and its connection to the theory of perfectly competitive behaviour (and, by extension, to Pareto optimality criteria) have been central to its becoming the key element of the new orthodoxy.

[4] A fuller discussion and references to development of McGee's ideas by others may be found in Milgrom (1987).

[5] See Ordover and Saloner (1987) for a presentation and extended critique of both the Areeda–Turner test and its principal competitors.

Since 1982, however, a new literature in economics has emerged that re-examines the logic of predatory pricing and of predatory or exclusionary practices more generally. This work involves strategic, game-theoretic analyses of imperfectly competitive behaviour, in contrast to the more standard (non-strategic) economic logic that is embodied in both McGee and Areeda–Turner. Significantly, this new research undermines the conclusions of both the competing branches of previous work: predatory pricing can make excellent theoretical sense, and yet the predatory prices bear no necessary relation to marginal costs.

In the remainder of this paper we briefly describe some of the major elements of this new work. We focus on models where predation arises in response to informational asymmetries and especially on ones where it manifests itself as an attempt to affect rivals' perceptions and inferences about future profits.[6] Our discussion will attempt to relate this literature to more familiar themes by accentuating the market structure assumptions in the theoretical models. A second focus is on the predictions that emerge from these models concerning the relationships between prices and costs under predatory behaviour. Finally, we offer some thoughts regarding the policy implications of this work.

1. Intertemporal Demand Linkages and Predation

Although our focus is on models of predation in which informational asymmetries are fundamental, in this section we digress briefly to discuss theories in which intertemporal linkages in demand underlie predation.

Recall McGee's argument that any gains from predation will be fleeting at best and thus that it will rarely be worth while to suffer reductions in current profits to induce exit: the predator's raising prices above costs to enjoy the increased market power that it

[6] Fuller discussions of this strand of the literature are found in Ordover and Saloner (1987) and Roberts (1987), and a critique of the methodology of games of incomplete information as it is used in these models is found in Milgrom and Roberts (1987).

bought by preying will attract new entry (or re-entry). For this argument to be valid, it must be the case that entrants will be able to compete on a more-or-less equal footing with the incumbent. Under the assumptions embodied in standard models, this is indeed the case: sales in one period have no impact on future demands or costs, so new entrants are not disadvantaged relative to established firms. If, however, these conditions fail, then McGee's argument fails too, and predation that did induce exit might well give rise to permanently increased market share and supernormal returns. For example, if there are strong experience curve effects, then late entrants will suffer a production cost disadvantage that may prevent their competing effectively, or if customers incur significant costs in changing brands, then late entrants are handicapped by their need either to compensate customers for these switching costs or to limit themselves to buyers who had not been served by the incumbent.

A number of authors have examined the dynamics of competition in the presence of such inter-temporal linkages. See, for example, Fudenberg and Tirole (1983) on learning curves and Klemperer (1986) on switching costs. However, relatively little attention has been given to the possibility of predatory practices in these contexts. An important exception is due to Farrell and Saloner (1986), who focus on situations where technological compatibility concerns create externalities in demand that provide a basis for rational predation. (See also Katz and Shapiro 1986.)

Consider a durable good whose value to any individual user is an increasing function of the number of individuals using it: a computer employing a particular operating system is a possible example. Suppose (individually infinitesimal) customers arrive at a rate $n(t)$, and that once they purchase, they are 'locked in'. Suppose too that at some date T^*, a new product appears that fills the same function as the existing product but is technologically incompatible with it. Newly arriving customers after date T^* can select either product, and the benefits that accrue at any date to a customer from having made either choice are an increasing function of the total mass of customers having made the same choice by that date.

In such a situation, it will be an equilibrium for all customers arriving after date T^* to select the new technology if the discounted present value of being the first to adopt it, assuming that all later arrivals follow suit, exceeds the discounted present value of being the last to adopt the old technology. If this inequality is reversed, then the unique equilibrium is for no one to adopt the new technology. (See Farrell and Saloner 1986 for a full characterization of equilibrium.)

Now, suppose that the new technology is competitively supplied, so that it is priced so that its vendors earn zero profits, while a monopoly exists in the existing technology, and further suppose that, under monopoly pricing of the existing technology, it is equilibrium behaviour for the new technology to supplant the old. However, suppose that the new technology is not that much superior to the old, and, in particular, that there is a non-negative price for the product embodying old technology at which, at date T^*, it is better to be the last buying this product than the first buying into the new technology, even if all later puchasers should also adopt the new technology. In this case, it is feasible for the monopolist to cut its price to this level and deter the buyers at T^* from adopting the new technology. Moreover, suppose the monopolist continues to hold its price down. Then eventually (but in finite time) a sufficient mass of customers will have purchased its product that the benefits for new buyers of having compatibility with this large installed base are sufficient that the unique equilibrium from that date on is for all new arrivals to choose the old technology, even if it is monopolistically priced. From this point on, the monopolist can keep its price at the monopoly level[7] without fear of anyone choosing the new technology. Thus, predation is feasible, and it may also be profitable if price does not have to be cut too much for too long, i.e. if the new technology is not too much better than the old.

Note that there is no reason to expect that the predatory pricing in this model would necessarily involve prices below marginal or average variable costs (either those of the monopolist or those of the competitive purveyors of the new product). Thus, such predation would not run afoul of the Areeda–Turner test. Moreover, as Farrell and Saloner suggest, it is even possible that this form of predation may be welfare-enhancing in that, absent

[7] During the predatory period, the price needed to deter adoption gradually rises to the monopoly level as the installed base grows.

predation, equilibrium might involve adoption of the new technology when the socially efficient outcome would be for the older technology to prevail.[8]

These features—that predation may be rational, that cost-based tests may fail to identify this predatory behaviour, and that the predation may be socially desirable—reappear in the information-based analyses discussed below. Meanwhile, given the frequency of complaints about predatory dumping in industries with strong experience-curve effects (e.g. DRAM semiconductor chips), and the common use of cost-based criteria to judge whether illegal pricing is being practised, it would seem valuable to see if these conclusions hold in a context where sales volume has intertemporal cost implications.

2. Predation as Driving a Rival into Bankruptcy

The standard image of predatory pricing is probably best captured by the 'long-purse' or 'deep-pockets' story: a firm with greater financial resources cuts price enough to impose losses on its weaker rivals, who eventually are forced to exit by impending or actual bankruptcy that occurs while the predator is still comfortably solvent. The predator then raises price again to enjoy its monopoly. Presumably, monopoly profits from other product or geographic markets would be a source of the war chest needed to pursue this strategy. Thus, this view of predation naturally becomes associated with the image of a large firm operating in several (product or geographic) markets preying upon a smaller one operating in few markets, even if the prey has the larger market share in the contested markets (as in the *Utah Pie*[9] case).

In fact, the basic idea behind the long-purse/deep-pocket story—that predation involves imposing losses and ultimate bankruptcy—has until very recently lacked acceptable theoretical underpinnings, despite some important attempts to build a theory involving these elements.

[8] The key externality here is that those who have already adopted the old technology are marooned when the new one supplants it, and they receive fewer benefits than they would if later purchasers' choices were to be compatible with them.

[9] *Utah Pie Co.* v. *Continental Baking Co. et al.* 386 U.S. 685, 697 (1967).

Telser (1966) was the first to show formally that differential ability to sustain losses can, indeed, make it rational to bankrupt a rival if this will yield a sufficient stream of monopoly profits (and if merger is not a cheaper alternative). However, his analysis simply assumed that one firm has a larger war chest. In particular, it does not explain why the prey cannot borrow funds to obtain a similar-sized war chest. Note that the mere availability of such funds would deter a firm's rival from ever attempting to bankrupt it through predation, and so the potential prey would never actually have to call upon its line of credit. Moreover, if such borrowing is not possible, then within the terms of Telser's model the prey should recognize its weakness and the predator's incentives and should exit before (or at least as soon as) predation is adopted, since this minimizes its losses. (This point is made very clearly by Benoit (1984).) Thus, this model predicts that actual predation ought never to be observed, except as a result of mistakes.

Later contributions sought to overcome these problems in the theory, but with only limited success. In particular, Benoit (1984) showed that assuming asymmetric information regarding the prey's commitment to the business can alter the model's predictions so as both to rationalize continued operation in the face of predation and to generate actual predatory episodes. Specifically, suppose that the potential prey alone knows how long a period of losses it can survive. Suppose too that there is some chance that the prey will stubbornly stay in until destroyed, but that the predator cannot tell if its prey is committed to this line of behaviour. Finally, assume (as in Telser's model) that re-entry after exit is not possible. Consider now a firm that is a normal profit-maximizer. When faced by predation, it could initially mimic the behaviour of the committed and stay in, despite incurring losses, in the hope that the predator will become pessimistic about the possibility of inducing exit at reasonable cost and will acquiesce to the prey's continued existence. If this continued existence is sufficiently profitable, then the prey will be willing to purchase it by suffering the losses involved in staying in the market in the face of predation. Thus, the mere threat of predation (or a single episode of unremuneratively low pricing) does not necessarily induce exit. Meanwhile, it can still be in the predator's interest to cut prices because exit can be induced, although perhaps not immediately. Thus, one would observe predatory incidents, these would be of varying lengths, and

they could end either by the prey's exiting or by the predator's giving up the fight.

While these predictions seem attractive and this general line of argument has some real appeal, the specific form of informational asymmetry assumed by Benoit is not particularly natural. Firms might well be unsure about how great their rivals' reserves are, about the losses that others will incur at different prices, or about how much each is willing to suffer to achieve a monopoly position. If informational asymmetries of these sorts alone could be shown to generate predatory episodes in equilibrium, the theory would have much more appeal than it does when it has to rely on the possibility of suicidal stubbornness or stupidity. Unfortunately, it is not obvious that these more plausible asymmetries will suffice. Moreover, Benoit's model still leaves unanswered the objection to assuming, rather than explaining, differential ability to absorb losses.

Fudenberg and Tirole (1985) have suggested a different approach that seeks the dual objective of both meeting the objection that the prey ought to be able to borrow funds to finance its defence and, at the same time, of generating an equilibrium in which actual predatory behaviour would occur. Suppose that there is a moral hazard problem with borrowers' possibly misappropriating funds. Then, results in the theory of contracts (Townsend 1979; Gale and Hellwig 1985) indicate that the amount that a firm will be able to borrow in any period under the optimal one-period contract will depend positively on the amount of its own capital that it can put up in the period. Thus, eroding a firm's reserves sufficiently by imposing losses on it may result in its losing further access to the capital market. At this point it could presumably be driven into bankruptcy by further below-cost pricing. Then, recognizing its vulnerability, it would leave.

This suggestion is interesting, but far from completely worked out. In particular, it does not allow for the possibility of the target firm's obtaining multiperiod financing arrangements under which it would retain access to additional capital even if its assets were depleted by predatory pricing. If such were available, then predation would again be ineffective, because eroding the prey's capital would not deny it access to further funding and so not put it in a position where it could be bankrupted. It is certainly plausible that contracts that would guarantee enough access to borrowing to deter predation would be unfeasible because they would be subject to such great incentives for misappropriation. However, absent a demonstration of this, the long-purse/deep-pocket story could not be considered to hold together theoretically.

Very recently, Bolton and Scharfstein (1988) have largely met these objections. They consider a situation very much like that treated by Fudenberg and Tirole. Two firms compete for two periods. One has access to internally generated funds to finance its operation while the other has no such access (in either period) and so must rely on borrowed capital. Again, a large firm operating in several markets and a small, local firm seem to provide a natural context for application. The profits of the second firm can take on one of two values ('High' or 'Low'), and their realized value is not directly observable to lenders. Thus, these profits may potentially be misappropriated by the owner/managers, who can simply claim that profits are low when they are actually high.[10] Finally, the first firm can take actions that increase the probability that the second firm's profits will be low. These are not specifically modelled (pricing is suppressed in this model), but presumably cutting price is a major candidate for this role.

Bolton and Scharfstein first consider the optimal financing contract between the capital market and the second firm under the assumption that predation will not be practised. They show that the optimal contract makes the probability of obtaining financing for the second period an increasing function of first-period announced profits, since this gives the firm an incentive not to misappropriate first-period receipts.[11] Of course, this gives an incentive for predation (provided the cost of preying is low enough), since increasing the probability of the low-profit outcome increases the likelihood that the second firm will not be active in the second period because it will be unable to gain financing.[12]

[10] The authors also suggest that their model would apply in other moral-hazard contexts, for instance, where effort that (probabilistically) increases profits is unobservable by investors and costly for managers to provide.

[11] In equilibrium, misappropriation is fully deterred, so that—assuming equilibrium behaviour—the lenders can infer that low profits are a result only of bad luck and not of managerial moral hazard. Still, the costly punishment of (probabilistically) denying credit must be inflicted in order to maintain incentives.

[12] Note that there is no way in this model to prevent misappropriation in the last period, because the firm has no assets that can be seized. Thus, if one lender cuts off credit, no other will lend (provided the low level of profits is negative). In contrast, Fudenberg and Tirole assume in their single-period model that the lowest level of profit is positive, so that there is something to seize.

Bolton and Scharfstein then calculate the optimal contract between the second firm and its lenders subject to a constraint that predation not be attractive. The effect of this constraint is straightforward: to deter predation, it is necessary to reduce the difference between the probabilities of refinancing for the second period when profits are high versus when they are low.[13] This can occur by lowering the probability of refinancing when profits are high, but may also take the form of increasing the probability of refinancing after low profits are reported.

Whether deterring predation is actually worth while depends on the value of various parameters in the model and on whether the financing contract is observed by the potential predator. Nevertheless, there are situations in which equilibrium involves predation, even when the prey has access to multiperiod financing arrangements. Of course, for costly predation to be adopted in equilibrium, it must bring a positive pay-off in terms of increased exit.

Note that the results of this modelling do not quite correspond to the usual deep-pocket story, because the predation does not have the effect of exhausting the prey's resources and thus forcing exit (as in Fudenberg and Tirole 1985); instead, the low profits it yields lead to credit being cut off. This is not *per se* a criticism of the model, since the traditional story ignores the possibility of borrowing, but it would be interesting to examine whether the original story can be made rigorous. It is also worth noting that the Bolton-Scharfstein results depend on the lenders not being able to determine that predation has been practised[14] and so on their not being more willing to refinance if low profits arise during a predatory episode than if predation has not been practised. Nevertheless, it seems likely that the broad outlines of their results would continue to be valid so long as the lenders cannot be certain that predation has occurred.

However, note that if the lenders can monitor managerial behaviour sufficiently well, they can reduce or eliminate the asymmetries of information that underlie this whole approach. These features may help explain the frequent practice of the providers of financing having a membership on corporate boards.

[13] Again, it is a property of the optimal contract that profits are correctly reported.

[14] Even though they may be able to infer that it has occurred under the assumption of equilibrium behaviour.

Moreover, venture capitalists, who provide funding to start-up firms, often take a quite active role in working with management. To the extent that monitoring may be easiest in such presumably small firms, the assumptions of this model may be less applicable here than would otherwise be the case.

The importance of these results is that the long-purse/deep-pocket story of predation is the only one in which imposing losses on a current rival—and thus below-cost pricing—plays any central, necessary role. As we shall see, modern, inference-based theories of predation involve much more subtle modes of behaviour, with the predation taking the form of using low prices to attempt to alter rivals' beliefs and expectations and thereby induce exit, deter entry, or limit their aggressiveness. The predatory behaviour in these models need not involve prices that are less than costs. However, even in the deep-pocket approach, there would seem to be no implication that price will be below *marginal* cost; all that is needed is that there be a negative cash flow. Moreover, it is the costs of the alleged prey, not those of the predator, that are relevant. The implications for the Areeda-Turner orthodoxy are clear, although we will belabour them below.

3. Predation as Pricing to Influence Expectations

A firm's decisions about entering or leaving an industry, about accepting or rejecting a merger offer, or about setting its prices or determining its output are all properly based on its expectations of the profit implications of these various choices. If a rival could influence these expectations, then it could affect the firm's decisions. For example, if an incumbent firm could cause potential entrants to believe that it would be an especially tough firm against which to compete, it might deter their entry. And if charging particularly low prices could lead to such beliefs, we would then have a theory of limit or predatory pricing. Similarly, if preying upon one entrant would deter other potential entrants because they expect to meet the same reception, then we would have another theoretical basis for predatory behaviour.

However, under the informational and behavioural assumptions that are commonly (if sometimes only implicitly) made in standard economic modelling—that all relevant information is equally well

(or poorly) observed by everyone, that agents ignore sunk costs and benefits and, in each situation, act in the fashion that is optimal from that point forward, and that optimal behaviour is uniquely identified in each situation—it turns out to be remarkably difficult to construct an equilibrium theory in which agents are able to manipulate one another's beliefs. The reason is that with symmetric information every agent can figure out what is optimal for each to do, because each knows the others' objectives, capabilities, and options as well as they do. Thus, each can predict exactly what equilibrium behaviour will be from each point forward, and with unique equilibria there is no room for non-trivial expectations that involve anything manipulable by an agent.

However, once agents are differentially informed, matters change markedly.[15] The literature in fact contains a variety of models in which asymmetric information gives rise to the use of aggressively low prices and high outputs to attempt to influence rivals' behaviour through their beliefs. Traditionally, these models have been viewed as falling into three classes—labelled 'signalling', 'signal-jamming', and 'reputation' models, respectively—and the three do in fact have some different characteristics and different implications. Nevertheless, all three are fundamentally manifestations of the same basic phenomenon, and although we will respect the traditional labels, this underlying unity should be kept in mind (see Milgrom and Roberts 1987).

We consider signalling models first. These models rely on the predator being better informed than the prey about some market characteristics that are relevant to the prey's exit and output decisions. For example, suppose a firm's costs are private information to it. Because the firm's costs are uncertain from the point of view of its current or potential rivals, even if they could accurately predict how the firm's price and output will depend on its cost (the firm's strategy)—as they can in equilibrium—they cannot predict what its actual choices will be and thus what profits they will earn

[15] One could also possibly build a theory of predatory or limit pricing without assuming asymmetric information by relaxing the uniqueness of equilibrium assumption. Specifically, low prices could possibly be a means to indicate that the prey should expect that, if it does not exit, future play will be governed by an equilibrium that is unprofitable for it rather than by another one under which it would be profitable. While no such model has yet been developed, Pearce (1982) provides a discussion of the basic idea of early moves signalling which of several equilibria will obtain in subsequent play.

from their various choices. This will give them an incentive to try to learn the firm's costs; with this knowledge they can take the actions that will be optimal given what the firm will actually do, but without it the best they can do is optimize with respect to their prior beliefs about its costs and the actions it might take. If the firm could bias this learning, it could then hope to influence its rivals' behaviour to its benefit. In particular, if a firm's believing that its rival has low costs would induce it to exit or to limit its output, then the rival would want to foster the belief that its costs are low.

One avenue for attempting to learn the firm's costs is to try to infer them from its observed behaviour: the prices or quantities it chooses. Suppose that low costs are believed to be associated with low prices. Then, by setting lower prices than would otherwise be optimal, the firm can hope to bias its rivals' inferences, causing them to think that its costs are lower than they actually are, and thereby persuade them that it will be a tougher competitor than it actually would be. Further, since the firm's optimal choice absent this signalling/inference effect will be characterized by a zero-derivative condition, at the margin it is costless (to a first approximation) to shade the price. Thus, if its rivals are trying to infer costs from price, the firm will be led to try to influence their inferences and their resulting actions by setting its price low to signal low costs.

This 'signalling game' style of reasoning was first developed in Milgrom and Roberts (1982*a*), [16] where it was used to yield a theory of limit pricing: by biasing entrants' estimates of its costs downward, an incumbent can hope to reduce entry. It has also been used by Roberts (1986) to yield a theory of predation aimed at inducing exit or, failing that, restraining a rival's future output.[17] In this model, the predator is assumed to be better informed about demand conditions than is the prey, and its incentive is to make demand appear to be weak so that the prey will decide either that continued operations are not worth while or, at least, that if it does not exit it should produce the low quantities that are appropriate when demand is weak. Saloner (1987) has developed a model of

[16] Salop and Shapiro (1980) independently advanced a model of test-market predation based on the incumbent's private information about its costs. However, the restrictions they placed on the prices that could be chosen prevented their obtaining the full richness of the results that are inherent in the problem.

[17] This model in fact involves elements of both standard signalling models and signal jamming.

predation designed to soften up a merger candidate which also uses this logic: by convincing the target that it cannot compete profitably, the firm can hope to improve the terms upon which it makes the acquisition. Finally, Mailath (1984) has employed these methods to generate a model of price wars arising in situations where several firms have private information about pay-off-relevant variables.

Equilibrium in a signalling game of predation requires three conditions to hold: that, for each possible value of its private information, the predator choose the price or quantity that is optimal given its conjecture as to how the prey will react to each possible observed choice; that the prey act optimally, given its conjecture as to how the predator's observed choices depend on its private information; and that these conjectures about one another's strategies be correct. Thus, in equilibrium, no agent's beliefs can be systematically biased, even if some other agents are acting in ways that are intended to distort the agent's inferences. In equilibrium, agents will recognize the incentives that others face to alter their behaviour so as to influence inferences and will properly make allowances for these incentives in interpreting the behaviour that is observed. If the predator's equilibrium strategy results in observables that are a one-to-one function of its private information (a separating equilibrium), then in equilibrium the prey will correctly infer the predator's private information from its actions; if the strategy is not invertible, then a precise inference is not possible, but the prey will still be able to infer that the predator's information is such as to give rise to the particular realized observation, and this inference is not biased.

This rational expectations property of equilibrium has a striking implication: the predatory pricing that is generated in these theories does not cause its target to underestimate the profitability of continued operations or to overestimate the aggressiveness of the predator's future price and output choices. These depend on the predator's private information, of which the prey forms an unbiased estimate in equilibrium by making the appropriate inferences from its observations. Consequently, there is no reason to expect that the predation will induce exit or restrain rivals' future price and output choices by influencing inferences.[18]

[18] Of course, the recognition that the predator will attempt to bias inferences by setting lower prices or expanding output relative to what would otherwise be optimal will influence the prey's price and output choices during the predatory episode. See Roberts (1986).

This last point may seem paradoxical: if the predatory pricing is not going to succeed, why should it be practised? The reason is that the prey understand the incentives to try to influence their inferences, and in equilibrium they make allowances for these. Consequently, they interpret a particular observed level of price or output in light of the incentive to charge low prices, not as if there were no such incentive. As a result, if the potential predator were to deviate from its equilibrium behaviour and charge simply the (relatively high) price that would be appropriate if there were no incentive to try to influence beliefs, its rivals, seeing only this price, would interpret it as meaning that the firm has had higher costs than it actually does. They would then be even less likely to leave, and if they stay in, they would compete more aggressively, believing the firm to be relatively weak. The resulting extra competition means that the firm would be worse off than it would have been with the lower price corresponding to equilibrium behaviour.

The fact that this form of predation does not induce exit or discipline rivals might suggest that it is innocuous, or even socially beneficial if the resulting low prices are not too far below marginal costs. However, if the prospect of facing low profits due to predation by a better-informed, established firm deters entry (even though, should entry occur, the predation will not succeed), then the welfare implications of this form of predation are ambiguous.[19] Thus, there may be some interest in considering the circumstances under which it might be expected.

The first key assumption in these models is that one of the firms, the potential predator, is better informed than the other about a variable, such as demand or costs, whose value is relevant for the latter's decisions. Such an assumption would often seem plausible if the second firm is a recent or potential entrant, if the predator has just introduced a new version of the product, or if it has opened new production facilities or adopted a new technology with which the prey is not familiar. A change in management or ownership of the predator might also suffice if it might be associated with a shift in objectives or strategy. Finally, if market conditions are changing and the one firm is known to have better market research or to have

[19] This possibility was noted by Scharfstein (1984).

access to information from other markets with which it is familiar, then the informational asymmetry assumption might again be expected to hold. To the extent that these latter characteristics are likely to be positively associated with size or multimarket operations, the traditional view of which sort of firm is likely to be the predator is supported. Of course, the better-informed firm might also be a new entrant with costs that are unobservable by the established firms.

Secondly, these models assume that there is no effective way that the better-informed firm can make its information available to the other firms directly and credibly; otherwise, given the nature of equilibrium in these models, it would do so.[20] In this context, the models usually assume that the private information is about a simple, one-dimensional variable, because this assumption greatly simplifies the formal analysis.[21] It might, on the surface, seem fairly simple to reveal such information directly: for example, perhaps the firm could bring in outsiders to observe its operations to see that its costs are not higher than it claims. Yet, in reality, it might prove very difficult to transmit credibly something like an estimate of demand, even if it were a single number, and when the private information is more complex, it might be impossible to remove the asymmetry.

A third assumption is needed in the formal model to generate predation. It is that the less-informed firm will actually attempt to infer the better-informed firm's private information from its price and output decisions and that the informed firm will recognize this and attempt to take advantage of it. Also, for the conclusion that the low prices will not distort the exit decision, it is also necessary that the prey correctly interpret the informed firm's choices in terms of its incentives. While there is some empirical and experimental support for signalling models that would suggest that at least the first two of these are not totally implausible, as we will see below, they are not strictly necessary: other formulations will generate

[20] It might seem that, for some values of its private information, the firm would not want it revealed. For example, if the equilibrium strategy pools firms with different cost levels, then high-cost firms may benefit from being pooled with those with low costs. However, the low-cost firms would freely reveal their costs if it were possible, because they would gain from being recognized as tough competitors. Thus, failure to reveal would indicate high costs. See Milgrom and Roberts (1986).

[21] Indeed, the study of multidimensional signalling is at a very early stage, and there have been few applications.

similar behaviour. Of course, if one accepts the first two assumptions and not the third, then the predation will induce exit, and it then becomes more of a matter for antitrust concern. For example, attempts to disrupt an entrant's test marketing could succeed in deterring a producer from committing itself to the whole market when the incumbent knows that it would be profitable.

Finally, although most of the models in this vein deal with only a single predator and prey, this is not crucial. In fact, demonstration effects are easily formalized in this work, and having several markets to protect can be expected to increase the incentives for predation in any one.

In any case, if one is inclined to worry about this form of predation as an antitrust issue, then it is important to recognize that the predatory prices that it generates need bear no direct relation to the predator's marginal cost. To induce exit, all that is needed is that the price should, in the long run, be expected to be below the prey's average avoidable costs—essentially, long-run average costs. And to limit future output from the prey, the predator need only convince the prey that its costs are lower than they actually are; this need not even involve prices below average costs.[22] Thus, even when the two firms have the same costs, the Areeda–Turner test would not necessarily identify this pricing as predatory. Meanwhile, if the predator faces lower costs—for example, if the issue is whether the prey should incur the costs involved in entering a previously uncontested market—then the predatory prices might well be above the predator's current average cost.

Thus, the signalling models of predation cause real problems for the conclusions of orthodox analysis. The same is true for the models based on signal jamming or reputations.

The signal-jamming approach is formally somewhat different from the signalling one in that it relies on different sorts of informational asymmetries, but it is very similar in spirit and in the conclusions it yields. The one well-developed signal-jamming model of predation is due to Fudenberg and Tirole (1986), but an earlier contribution using this logic is Riordan's (1985) model of price wars.

The essence of signal jamming is that there is again a variable that is not directly observable and whose value the prey is trying to

[22] This assumes something like Cournot competition, where equilibrium market shares are negatively related to costs.

learn because it is relevant to its future profits and thus to its price, quantity, and exit decisions. Again too, the distribution of the observable correlates of the underlying variable of interest are assumed to depend on the actions of the potential predator. Thus, the predator can hope to bias the inferences drawn by the prey by altering its own actions. However, in this set-up, there is no assumption that the predator is better informed about the variable's true value. Thus, its actions cannot depend on the value of the variable, as they do in standard signalling models. Nevertheless, there is an asymmetry of information: it is assumed that the actions of the predator that influence the values of the observed variables are themselves not observed by the prey. (Otherwise, the prey could simply net them out and there would be no possibility of influencing its inferences.) There is also a necessity of assuming an asymmetry of position between the firms which in some ways parallels the asymmetry in the signalling models of assuming that one firm is informed and the other not. Specifically, one of the firms must be assumed to be entertaining a decision to exit. This firm becomes the prey. If both were willing to consider exiting, then one would get a model of price wars, not of predation.

A context in which this sort of theory might be particularly applicable is one where the prey is test-marketing a product in a market where the predator is already active. Here the asymmetry of position and the unobservability of actions seem reasonable. By offering *sub rosa* price breaks to distributors, utilizing coupons, increasing promotions, etc., the established firm can hope to disrupt the prey's test, cause it to underestimate the profitability of its product, and thereby discourage it from entering fully.

The properties of equilibrium in signal-jamming models are essentially those with signalling. The predator cuts price to bias the prey's inferences; the prey allows for this behaviour and so is not fooled; consequently there is no effect on exit or on future price-output decisions; and yet there may be some deterrence of entry by the threat of predation, even though, should the entry occur, the predation will be 'unsuccessful'. Again too, there need be no connection between the predatory prices and marginal or average variable costs, so the relevance of the Areeda–Turner test is problematic.

A striking feature of these first two types of theories is that although the predator is aiming at driving out or disciplining a

current rival, it fails to do so, and yet the rational expectation that it will attempt to prey in order to influence inferences may deter entry. In the third class of predation models—those based on reputation arguments—the objective is explicitly to deter future entry by preying on current rivals, independent of whether the predation induces its target to exit.

The first formal reputation models of predation were developed by Kreps and Wilson (1982) and Milgrom and Roberts (1982*b*). In these models, a firm operating (or anticipating operating) in several markets preys on any early entrants, even if it is not worth while to do so in terms of the profits that are received from the entered market alone. This predation is practised in order to develop a 'reputation for toughness' that deters other potential entrants because it leads them to expect that their entry will meet the same predatory response.

The analysis depends on an informational asymmetry of the type used in the signalling models: it is private information to the predator whether it would prey in a single market absent any demonstration effects.[23] Such a willingness to prey might arise from cost considerations directly, from contracts written between owners and management that reward sales instead of profits (see Fershtman and Judd 1987), or simply from a streak of craziness. The key point is that failure to prey against a single rival implies that the incumbent is not a 'natural' predator that would fight all attempts at entry. Then, future entrants need not fear predation at all, and so all will enter.[24] In contrast, preying keeps alive the possibility that future entrants will also meet an aggressive response and, if this possibility is sufficiently unattractive to these entrants, they may be deterred. Thus, preying may be worth while, even though it is immediately costly. In fact, if a sufficient number of

[23] If there were an infinite number of markets—as might be the case if the markets were for different generations of a firm's products—then there is no need for an informational asymmetry to generate predation for reputation. However, in such contexts there will also be many non-predatory equilibria. See Roberts (1987) and Ordover and Saloner 1987.

[24] With a fixed, finite number of potential entrants, if it is common knowledge that the incumbent would not prey against a single entrant in isolation, then in the only subgame perfect equilibrium all the potential entrants do enter and the incumbent never preys. The logic is by induction. The incumbent will not prey if the last entrant comes in, and thus entry will occur at the last stage, independent of the history at previous rounds. But since preying against the second-last entrant cannot deter entry by the last one, the incumbent will not prey at the next-to-last stage, and so entry occurs then too. But now the logic applies at the third-to-last stage.

markets remain to protect, the probability that the entrants ascribe to the incumbent being a natural predator can be made arbitrarily small, and predation will still be the response to entry: although the firm actually finds predation unprofitable in isolation, it will fight if challenged, mimicking the behaviour of the natural predator, in order to maintain its reputation for toughness and deter future entry. Of course, the anticipation that the firm will fight to protect its reputation in itself serves to deter current entry attempts as well.

Easley, Masson, and Reynolds (1985) have also developed a reputation model of predation by a firm operating in a number of markets. The profitability of entry into any of these markets is unknown to the potential entrants, but it is known to be correlated across markets. Demand may possibly be low, in which case entry is unattractive, but if it is high, then entry is warranted. In equilibrium, if demand actually is strong the incumbent unobservably cuts price (as in the signal-jamming model) to generate observables that mimic those when demand is weak. It thereby develops a reputation for weakness of demand in its markets that deters or delays further entry.

These sorts of model would seem most applicable when there is a firm operating in numerous markets where what happens in one market is both observable to participants in other markets and reasonably considered as being indicative of what would happen in these other markets in similar circumstances. These markets could be geographical ones, they could be for different products at any given time, or they could be defined over time. The more such markets there are to protect—the greater are the incentives to build and maintain a reputation that deters challenges. Thus, in particular, the high-tech industries would seem particularly suited to generating such pricing.

In signalling and signal-jamming stories, predation was not socially undesirable once entry occurred, and its only negative effect was the essentially unintended one on entry. In some contrast, in the present set-up, if entry does occur then its being met by predation strengthens the predator's reputation and has a further deterrent effect. Thus, this sort of predation seems more troubling from an antitrust viewpoint. However, again it is the case that predation need not drive its target out of business to be effective, nor is it necessary to impose operating losses: it is enough that profits be sufficiently small or delayed that they do not justify

sinking the costs of entry. Again, the Areeda–Turner test is irrelevant.

4. Thoughts on Policy Implications

Traditional economic theory questions whether predation is likely to occur, and suggests that prohibitions aimed at it will be efficiency-reducing, deterring normal competitive behaviour. Despite this, business people, lawyers, industrial organization scholars, legislators, and courts have treated predation both as a real occurrence and as a problem. However, the litigation of predation has had a tendency to get into messy, expensive and ambiguous determinations of intent. At least in the United States, the response to the resulting inefficiences—both in the costs of trial and in the effects on business of being unsure of the legality of various practices—has been to attempt to lay down sharp rules for behaviour, principally defining illegal predation to be the setting of prices below some measure of costs. Of course this approach does not address the lack of an economic theory generating predation.

The more recent economic analyses discussed here suggest that firms will, in fact, attempt to exclude rivals by setting lower prices than they would find optimal if there was no hope of inducing exit, deterring entry, or persuading rivals to accept limited market shares. We have called such behaviour 'predatory', because both its form and its intent match the traditional use of this term. Yet, as we have accentuated above, it need not involve prices that are low enough to run foul of the proposed tests for predation. Moreover, a pure monopolist unconcerned with actual or potential competitors but employing a technology with strong learning effects could rationally price below (current) marginal cost. Thus, price levels that the tests would label as predatory need not be such in fact. Consequently, it would seem that there is little value to these tests. Moreover, these same failures seem sure to haunt any other attempt at a simple mechanical rule.

Beyond this, of course, is the issue of whether antitrust law ought to attack prices that are predatory in the sense used here. We have seen that this behaviour can be socially costly, not in the expected fashion of eliminating current competition but rather through an impact on future entry. Thus, could it be clearly identified and

effectively prohibited, there might be gains to doing so. But this would involve requiring firms to charge the 'right' prices—those that they would charge if the market and informational conditions gave no possibility of affecting rivals' behaviour![25] The problems of determining what these prices are are mind-boggling. Doing so would surely cost more than any efficiency gain one might realize from reducing the height of dead-weight-loss triangles. And, given the complexity of actual business decisions and the subtle nature of the behaviour and inferences involved, it is not at all clear that even determining intent can work, no matter what the costs incurred. If so, it may be best simply to give up on attempts to control predation, even if one believes that it can and does occur.

[25] This is in essence what is called for in the predation test proposed by Ordover and Willig (1981).

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