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predatory pricing. It has long been part of the popular folklore of business that firms sometimes engage in predatory actions against their competitors. For example, a firm might cut its price so low in some local market where it faces competition that neither the firm nor its competitor can earn a profit there. Such price-cutting would be called 'predatory' (by some) because it is inconsistent with short-run profit maximization by the firm and it appears to benefit the firm in the long run only by bankrupting or otherwise weakening its rival. Of course, predatory actions are not limited to pricing decisions – for example, a choice of store locations by a grocery chain too near its competitors could be predatory – but our discussion in this short note will focus on predatory pricing and the theoretical controversy surrounding it.

Theoretical interest in predatory pricing was high in the late nineteenth and early twentieth centuries. Sharp price reductions were thought to be one of the tactics used by trusts and monopolies to consolidate their power. Perhaps the most famous early allegations of predatory pricing were those made by attorneys for the United States against John D. Rockefeller's giant Standard Oil trust. In one of the first successful applications of the Sherman Antitrust Act, US government lawyers claimed that Standard Oil Company had (among other unlawful practices) cut prices to unprofitable levels in selected local markets in order to drive the local competition out of business (*US* v *Standard Oil et al.* (1911)). Then, once the competition was gone, Standard Oil raised the price again to enjoy monopoly profits. Even apart from ethical considerations, such behaviour leads to inefficient resource use: The competitors productive facilities lie idle and the monopolist's ultimate production level is inefficiently low.

After a period of dormancy, theoretical interest in predatory pricing was rekindled by an influential paper of John McGee (1958). McGee examined the court records of the Standard Oil case, and found that the evidence supporting a claim of predatory pricing was weak. More significantly, he argued on theoretical grounds that predatory tactics are unprofitable and therefore unlikely ever to be observed. So, regulations aimed at prohibiting such practices would serve only to restrict competition.

The arguments made by McGee and his followers (including Telser (1966), Areeda and Turner (1975), Bork (1978) and Easterbrook (1981)), which dominated theoretical discussions of predatory pricing until the late 1970s, can be summarized as follows. First, when a successful predator seeks to enjoy the fruits of its newly gained monopoly by raising its price, it will soon face new entry. One possibility is that the old competitor will try again once the price has been increased. Even if it has no taste for another fight, its old plant still stands, and could be bought cheaply by a new entrant. New entry is therefore inexpensive and potentially profitable, so it is likely to occur – an outcome which would make the original predatory tactic unprofitable. Second, when a firm like Standard Oil with an 80 per cent market share in a local market cuts prices substantially to drive out a firm with a 20 per cent share, it suffers a large loss of revenues in 80 per cent of the market in order to gain the profits of only 20 per cent. That is unlikely to be a worthwhile exchange. Third, the predator has better strategies available, like buying out the competitor, which removes both the competitor and its plant from the market, achieving monopoly while making new entry less likely. Fourth, there is little reason for a competitor facing a price war to give up the fight and withdraw from the market. The predator, too, is suffering losses and can be expected to restore its prices to a profitable level soon. This knowledge will bolster the competitor and its creditors and investors through a difficult, but short-lived predatory episode.

For those who accepted these seemingly cogent arguments, the unavoidable conclusion was that legal restrictions aimed at blocking predatory activities or making them unprofitable are misguided, and only serve to restrict the legitimate activities of businessmen. The threat of legal sanctions can dissuade firms that achieve cost reductions from reducing prices. This harms consumers directly and weakens incentives for cost reduction. A prohibition against reducing prices in response to entry would only deprive consumers of one of the main benefits of entry and could also encourage collusive pricing practices. In short, restrictions aimed at eliminating the non-existent problem of predatory pricing would only interfere with the normal and desirable workings of competitive markets.

Theory notwithstanding, there is good evidence that predatory tactics have sometimes been adopted by overzealous competitors. For example, early in this century, ocean shipping cartels made use of 'fighting ships' that followed competitors' ships into port and undercut their prices (US Department of Justice, 1977). Predatory intent also seems to be the best explanation of some of the price wars that have occurred in local gasoline markets as well as among US coffee distributors following entry into some regional markets, and of the fierce price cutting in the computer peripheral equipment industry in the early 1970s, to name just a few events. Clearly, some key element was missing from the theories of McGee and his followers.

When a firm considers entering a market, it must base its decision on its expectations of profit from entry. It asks: Will the incumbent firm respond aggressively? If so, by how much will prices fall when we enter? Will our firm be able to produce cheaply enough to be profitable? Will there be enough demand to support another producer? The firm's expectations – the way it answers these questions – are pivotal in determining its entry decision. Now here is the crux of the matter: An incumbent firm can, by its actions, influence the expectations of a potential entrant.

The idea that a firm with market power might try to discourage a competitor by manipulating its expectations was introduced into the modern literature of industrial organization by Milgrom and Roberts (1982), whose focus was on the problem of limit pricing. The idea was quickly adapted by Kreps and Wilson (1982) and Milgrom and Roberts (1982a) to explain episodes of predatory pricing. By responding aggressively to entry, a predator may be able to convince that entrant, or other potential entrants, that entry into its markets is unprofitable.

Thus, for example, a firm in an industry with rapid product change might cut prices sharply in answer to new entry in order to discourage the new entrant from continuing an active product development programme. Whether the entrant attributes its lack of profitability to its high costs, to weak market demand, to overcapacity in the industry, or to aggressive behaviour by its competitor, it will properly reduce its estimate of its future profits. If its capital has other good uses, this might lead it to withdraw from the industry. If not, it may nevertheless be dissuaded from making new investments in and developing mew products for the industry. At the same time, other firms may be deterred from entering the industry. If *any* of these things happens, the predator benefits.

Notice that, according to this theory, predatory activities do not have to drive the competitor from the market to be successful. And, in contrast with McGee's theory, if they do succeed in driving a competitor out, new entry will not follow inevitably when the monopolist raises its price to enjoy the fruits of its actions: potential entrants may no longer expect to profit by entry. It is not even necessary for the predator to profit directly from its price-cutting in the contested market in order for predatory pricing to be profitable. When Maxwell House resisted the introduction of Folger's brand coffee into some of its Midwestern United States markets, its payoff came from Folger's decision to delay entry into the largest Eastern markets, such as the New York city market.

The new 'expectational' theories of predatory pricing differ in several important respects from the turn-of-the-century's 'drive the competitor into bankruptcy' theories. First, expectational predatory behaviour can vary in its intensity, which makes it harder to identify than the 'bankrupt the competitor' kind of predatory act. Second, the social welfare cost of predatory pricing according to the new theories comes more from dynamic inefficiencies than static ones. To be profitable, predatory behaviour need not force the competitor's facilities to lie idle or lead to monopoly pricing in the contested market; it is sufficient to deter further investments and discourage new product development by competitors. Predation discourages innovators and entrepreneurs by leading them to expect low returns for their valuable efforts. In a growing industry or one with rapid technical change, the chilling of innovation and new investment entails even higher social costs than the static efficiency costs identified by the older theories. Third, expectational competition is not always a social bad: when two or more strong competitors battle to gain market share, demonstrating their commitment to their industry by cutting prices and introducing new products, the public benefits from vigorous competition.

The proper policy response to the threat of predatory price cutting is complex, because the facts are complex. It is true that excessive price cutting can discourage an innovative firm from making new investments, but it is also true that price cutting allows efficient firms to enjoy the benefits of their cost advantage and encourages inefficient firms to improve their efficiency or to curtail their production. The new theories do make one conclusion quite clear: Policymakers should be especially sensitive to predatory pricing in growing, technologically advanced industries, where the temptation to discourage entry is large and the costs of curtailed entry even larger.

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prediction. Any rational theory of prediction must be based upon a model. Enoch Powell expresses this view when he says, 'The prophets were not soothsayers; they were expounders.'

We shall formulate models in discrete time, so that the time variable t can be assumed to take integral values. The value of a variable x at time t will be denoted x_t. We shall frequently denote the observation taken at time t by y_t (usually vector-valued) and shall then denote the *observation history*

$$(y_t, y_{t-1}, \ldots)$$

available at time t by Y_t. The estimate of a quantity u based upon Y_t will be denoted $u^{(t)}$. Thus $x_{t+m}^{(t)}$ is, for positive m, the predictor of x_{t+m} formed at time t. The linear *linear least square* (LLS) criterion chooses $u^{(t)}$ as the linear function of Y_t that minimizes the mean square deviation $E[u - u^{(t)}]^2$ (or a matrix analogue if u is vector-valued). If all variables are jointly normally distributed (*Gaussian*, henceforth), then this $u^{(t)}$ can also be characterized as the conditional expectation $E[u \mid Y_t]$ or as the maximum likelihood (ML) estimate of u for given Y_t.

There are two techniques useful in the calculation of such estimates and predictors: *recursive methods* (associated with Markov models) and *generating function methods* (associated with cases in which structure is time-invariant and prediction errors are stationary).

If x and y are random vectors of zero mean then we shall use $\mathrm{cov}(x, y)$ to denote the cross-covariance matrix $E(xy')$, and shall write $\mathrm{cov}(x, x)$ simply as $\mathrm{cov}(x)$.

RECURSIVE METHODS: MARKOV MODELS AND THE KALMAN FILTER. Consider the dynamic equation, typical of many econometric models:

$$x_{t+1} = Ax_t + \epsilon_{t+1} \qquad (1)$$

Here the process variable x is supposed to be a vector, and so A a corresponding square matrix, and ϵ_t is assumed to be vector white noise of zero mean and with covariance matrix N. One special feature of this model is that it is linear; another is that it is Markov (at least if ϵ is Gaussian). This is, that x is a state variable which constitutes a complete description, in that all aspects of the future which can be predicted from

$$X_t = (x_t, x_{t-1}, \ldots)$$

can also be predicted from x_t.