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CAPACITY SIGNALS AND ENTRY DETERRENCE

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If potential entrant firms are well informed they will generally not believe incumbents' threats to expand output when experiencing entry. But this expectation underlies most excess capacity models. We demonstrate an asymmetric information equilibrium in which potential entrants rationally fear output expansion by oligopolists with excess capacity. Less effective collusive oligopolies may be destabilized (expanding output) upon entry. One symptom of less effective collusion is excess capacity. Hence excess capacity becomes a signal of the potential for output expansion. In a rational expectations equilibrium this signal may also be mimicked by oligopolies which would not otherwise carry excess capacity.

1. Introduction

In his pioneering work on limit pricing Bain examined a model of entry deterrence with an existing firm (or firms acting in concert) and a group of potential entrants. He described various possible equilibria, i.e., 'blockaded entry', 'effectively impeded entry', 'ineffectively impeded entry', and 'free and easy entry'. His main conclusion was that under certain conditions firms would 'limit price' to effectively impede entry.

Recently attention has turned to consider whether limit pricing is 'credible'. Should a lower pre-entry price lead a rational entrant to expect lower post-entry', 'effectively impeded entry', 'ineffectively impeded entry', and 'free and and entry problem as an imperfect information game. A potential entrant does not know the exact cost function, or some other characteristic, of the incumbent firm. Then, if there were no strategic behavior, pre-entry prices would signal post-entry equilibria. In such models strategic behavior involves some firms exploiting this price signal by limit pricing. [See Milgrom and Roberts (1982a), Saloner (1982) or Matthews and Mirman (1983).][1]

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[1]The strategic issues, especially in light of feared predation, may be found in Salop (1981). Bain (1949, 1952, 1956) recognizes that if potential entrants know the incumbents' strategy the bluff is not credible. His formulation is, hence, implicitly an imperfect information game.

Another approach was taken by Spence (1977, 1979), Williamson (1977) and Dixit (1979). In this approach potential entrants have complete information about incumbents' cost curves, reactions, etc. The incumbents have a 'first mover advantage'. They can alter their short-run cost curves, and hence expected post-entry equilibria, by altering their fixed capital stock.

In these models potential entrants conjecture that the incumbents' entry response will be to *expand output* to its short-run marginal cost curve. Incumbent firms may then install sufficient excess capacity to deter entry. Although pre-entry prices are lower due to the effects of the additional capacity on short-run cost curves, we are reluctant to refer to this as 'limit pricing'.

The logic behind using capacity changes to deter entry is that capital has an element of irreversibility while price does not. Certainly changing irreversible capital credibly changes the form of the post-entry equilibrium, whereas the reversible selection of price alone does not accomplish the same result. The credibility problem, however, remains. Why should potential entrants expect incumbents to expand output to their marginal cost curves?

In 1980 Dixit solved the credibility problem using a different capacity model. The incumbent firm adds sufficient capacity such that even were it to contract output to a post-entry Nash–Cournot equilibrium, the potential entrant could not profitably enter. Since the incumbent is doing the best it can do post entry, the capacity establishes a self enforcing mechanism and is a credible entry deterrent.

Dixit's 1980 approach has the advantage of not relying upon potential entrants believing threats of output expansion to deter entry. On the other hand, Dixit's entry deterrence strategy would only be practiced by a narrow group of firms. In the former models incumbents needed only enough extra (and costly) capital to deter an entrant which expected a significant output expansion post entry. We may think of this expanded output level as Q^*. The Dixit 1980 model can be thought of as requiring sufficient additional capital such that the potential entrant would not enter if it expected an output *contraction* to Q^*. The costs of deterring entry are much higher in this model, contracting the class of firms for which an entry deterrence policy would be optimal.

The excess capacity strategy would be relevant for an expanded class of firms if the output expansion conjecture could be resurrected. One method of doing so would be to make the threats to expand output credible by some other mechanism and then communicate why this threat is credible to potential entrants. Leaving aside the problems of reaching such a stance of credibility, the potential for antitrust prosecution would limit the desirability of this route.[2]

[2]The legal implications of such threats are threefold. First, evidence of threats can establish specific intent (a necessary ingredient for 'attempt to monopolize' cases). Second, the threats

Williamson (1977) presents a model in which firms may install excess capacity to facilitate predation. In his model a 'collusive oligopoly' may respond to entry by output expansion, however a 'loose oligopoly' may exhibit 'behavior akin to predatory pricing ... caused by breakdowns in pricing discipline ...'.

Our model follows a closely allied observation. Although we could, as Williamson, deal with collusive oligopolies which would practice predation if entered, we take a different approach. Suppose there are loose oligopolies, as in Williamson. But suppose that tight oligopolies would find predation to be unprofitable. Not withstanding this, however, the tight oligopolies may find pre-entry capacity addition, if it created entry deterrence, to be profitable. Hence we deal with only two polar types of oligopolies, 'tight' or 'loose', which are respectively 'stable' and 'unstable' in the face of entry.[3] In our model we assume that loose oligopolies would become competitive upon entry of an additional firm. Such oligopolies would naturally expand output post entry [e.g., marginal cost price as in Spence and Dixit (1979)], but they would not be carrying out a threat or violating some antitrust law. More interestingly we note that this proposition, coupled with asymmetric information, may yield a rational expectations equilibrium that entails 'partial

themselves may be deemed a 'predatory act'. Third, to establish a mechanism to make output expansion self enforcing post entry would itself generate additional independent circumstantial evidence of the actual use of such a threat. [See Salop (1979) for some examples of such mechanisms.]

Williamson proposed an antipredation rule which limited firms from expanding output in response to entry. As Williamson notes, this behavior '...can appear in loose oligopolies ... caused by breakdowns in pricing discipline...'. Ex post one may be able to distinguish which phenomenon occurred, but trying to do so may lead to many errors in practice [McGee (1980)]. Threats, on the other hand, will not be credible unless they detail why they should be taken seriously. A threat to expand output to eliminate a rival, especially if accompanied by a believable reason to expect it to be carried through, may be evidence of culpability. In the recent rational predatory pricing literature Milgrom and Roberts (1982b) and Kreps and Wilson (1982) rely upon believable threats to 'play tough' post entry. (These need not be interpreted as threats to 'prey'.) Easley, Masson and Reynolds (1985) rely upon pretending to be weak (e.g., pretending that a non-cooperative solution would emerge post entry). As in this paper, no culpability is implied in the pre-entry information disseminated by the monopolist.

[3]In fact there could be n types of oligopolies and some oligopoly of type k may be trying to appear to have the characteristics of some type $j \neq k$, where the entrant's priors on profitability of entering a type j lead to negative expected profits. Furthermore, there may be numerous such sets, e.g., k and i both trying to look like j and $k' \neq i, j, k$ trying to look like $j' \neq i, j, k$.

One could model the oligopolies which are unattractive to enter in many ways. For example, they might be Cournot–Nash rather than collusive post entry. We choose to demonstrate the principle with two polar cases which most closely resemble the conjectures used in Spence, Williamson, and Dixit (1979). We call these 'tight' and 'loose'. These correspond with Williamson's 'collusive' and 'loose' oligopolies with the exception that his collusive firms predatorily expand output after entry. As ours do not expand, we use the weaker term of 'tight' oligopoly. The breakdown in pricing discipline in loose oligopolies following entry describes a move from what Scherer (1980) calls 'stable' to 'unstable'. His discussion of the underlying factors suggests how unobservable underlying factors may affect stability and suggests how in some cases stability may be fragile and entry may catalyze breakdown of stability.

pooling'. Some stable oligopolies may mimic the (pre-entry) characteristics of loose – potentially unstable – oligopolies to portray themselves as poor prospects for entry. The actions of these oligopolies could deter entry almost exactly as if they were actually going to expand output to set marginal cost prices in response to entry. In this framework the problem of credibility is handled not by taking a credible threat per se, but by effectively feigning an inability to price in anything but a competitive fashion if entry were to occur.[4]

Given that loose oligopolies may expand output to marginal costs in response to entry, entry into a loose oligopoly with excess capacity would often be unprofitable. So if a tight oligopoly can mimic a loose oligopoly with excess capacity it may deter entry. Many have suggested that in fact excess capacity may be one of the characteristics of a loose oligopoly, so we shall simplify both the model and exposition by supposing this link exists and that looseness can only be observed indirectly through excess capacity.[5]

In section 2 we discuss the literature on the determinants of excess capacity, including that literature which relates it to loose oligopoly. Section 3, which may be read independently, develops the model and its implications.

2. Sources of excess capacity

There are many factors that may lead industries to carry temporary or chronic excess capacity. Before looking at excess capacity additions designed for entry deterrence, we look at 'natural causes of excess capacity. Chronic excess capacity has often been linked to loose oligopoly. We discuss this linkage and related natural causes in section 2.1. In section 2.2. we link excess capacity in a loose oligopoly with the potential for the breakdown of oligopolistic stability (e.g., competition) upon entry of a new firm or firms. The procedure is to first provide a link between excess capacity as a signal of 'looseness' in an oligopoly and then provide a link between such looseness and the expectation that an industry may be incapable of pricing above marginal costs were entry to occur.

In section 3 we allow firms to exploit the excess capacity signal to achieve entry deterrence. There we derive strategic use of excess capacity for entry deterrence in a rational expectations partial pooling equilibrium.

[4]The recent burgeoning policy literature on predatory pricing [see Salop (1981) or Brodley and Hay (1981) for analyses of this literature] is dealing directly with our point that it is often very hard to distinguish a predatory price from a competitive one.

[5]'Looseness', as defined here, is the condition that the addition of an entrant would lead to lost coordination, and the emergence of a Bertrand Equilibrium. One signal of 'looseness' might be periodic price wars. If such price wars [illegible] with capacity above some critical level deter entry, incumbents may exploit this. They could add both phony price wars (to signal looseness) and excess capacity (to deter entry given that looseness has been perceived). Formally the results of such a model follow directly from this model.

2.1. Some 'natural causes' of excess capacity

There are many factors such as misanticipated demand or lumpy investments which can cause excess capacity. Such temporary excess capacity may, ceteris paribus, temporarily decrease the propensity for entry.[6] There are also theories which predict chronic excess capacity in some types of oligopoly. There are at least three explanations of oligopoly behavior which suggest that looser oligopolies will tend to have chronic excess capacity.

Some theories of oligopolistic investment suggest that tight oligopolies are less likely to experience investment instability. The reasons cited are that *better* information, differentiated products, and *better* coordination each help 'call forth the proper amounts of investment by the right firms in response to demand changes' [Scherer (1969)].[7] Note that by inference, *lesser* coordinated or looser oligopolies may be less efficient in this regard. Heflebower (1961, 1967) also provides a link between oligopoly and excess capacity. He suggests that a price change tends to be more swiftly observable and easily parried with price than is the initiation of, for example, the planning for an advertising blitz. The latter 'blunt instrument' is harder to anticipate and harder to parry. Loose oligopolies may thus be able to coordinate pricing, but only tight oligopolies may have the coordination necessary to suppress these other competitive tools.[8] This suggests that firms install more capacity to take advantage of the market share gains when such blunt instruments are successful, and that firms which lose market share due to others' successes have excess capacity thrust upon them.

A third explanation follows Wallace (1937), Duesenberry (1958), and Esposito and Esposito (1974). They suggest that oligopolies which can coordinate price, but not capacity decisions, will have chronic excess capacity when demand is uncertain. The argument is that with consumer inertia, firms with excess capacity can more readily gain new consumers when there are unanticipated demand increases, and retain them through inertia (given the price coordination) thereafter. Thus, unless they can suppress capacity competition by agreement, such *firms* would carry deliberate excess capacity in equilibrium.[9]

[6]Masson and Shaanan (1985) show empirical evidence indicating for any level of entry barriers, profits and growth, excess capacity reduces industry entry. They theoretically discuss how, with imperfect information, limit pricing and excess capacity deterrence may both occur at the same time. Their test results are consistent with excess capacity entry deterrence or with the hypothesis that excess capacity is simply thrust upon firms, but that the firms can then exploit the benefits of the entry reducing effects of excess capacity through a higher limit price.

[7]See for example Scitovsky (1951) and Richardson (1960). Their argument, and a test which does not support their contentions, are in Scherer (1969).

[8]See Waldman (1983) for a discussion of essentially this point and an application to capacity theory. It should be noted that there will be rents from price coordination without suppression of non-price competition as long as the tools for non-price competition are slow (quasi rents) or have decreasing returns (permanent rents if entry is not free, quasi rents if it is free).

[9]Esposito and Esposito test this theory and find support for it. Mann, Meehan and Ramsay (1979) criticize their study and, using a different test, arrive at more agnostic conclusions.

From each of these literatures there is a link flowing from loose oligopoly to the expectation of excess capacity. In the next section a link between excess capacity and loose oligopoly is noted.

2.2. Excess capacity and stability

The conventional wisdom is that excess capacity leads to less stable (or less profitable) oligopoly. For example, if there is no excess capacity and $LRAC$ curves are horizontal at $LRAC^*$ in the relevant range then in equilibrium $SRMC = LRAC = LRAC^* = SRAC$. If there is excess capacity then in equilibrium $SRMC < LRAC^* < SRAC$. Thus for any given price the true price–cost margin $(P - SRMC)/P$ is enhanced. This leads to incentives to expand the use of non-price competitive weapons or to cheat on price agreements. Accordingly, if all other things are equal, we should expect oligopolies with excess capacity to generally be looser or less stable.

2.3. Capacity, stability and entry

Although excess capacity is a factor leading to reduced oligopolistic stability, there are many such 'stability factors'. After reviewing the literature on oligopolistic stability Scherer (1980, p. 227) concludes:

> 'To summarize, cooperation to hold prices above the competitive level is less likely to be successful, the less concentrated an industry is; the larger the competitive fringe is; the more heterogeneous, complex and changing the products supplied are; the higher the ratio of fixed or overhead to total costs is; the more depressed business conditions are; the more dependent the industry is on large infrequent orders; the more opportunities there are for under-the-counter price shading; and the more relations among company executives are marred by distrust and animosity.'

Clearly several of these factors are related to excess capacity. Depressed business conditions; large and infrequent orders; and the overhead costs arguments are excess capacity arguments.

The next question involves how these measures might relate to entry. Entry can perturb these measures. It must directly raise the ratio of fixed costs to total costs at any given price level (increase excess capacity). It may also raise the fringe size, lower concentration, raise heterogeneity, or add a new player whose actions cannot be predicted/trusted.[10]

If we can conceive of an unstable oligopoly with these prevailing charac-

[10]Fellner (1965) discusses how entrants may move into new niches which may lead to asymmetries in demands or costs and reduce coordination. Similarly new firms with different past market experiences raise the possibility of discordant conjectures.

teristics, then we should be able to conceive of a potentially unstable oligopoly as an oligopoly which has levels of these variables which almost lead it to be unstable. The oligopoly would be potentially unstable in the sense that an increase in one of these variables would lead to instability. This is our 'loose oligopoly'. Holding all other market parameters constant, entrants would be less likely to enter industries with greater excess capacity even if no 'retaliation' were ever expected by firms. In other words, potential entrants may anticipate an expansion of output that would occur were they to enter, not because of a threat, but because the industry might become unstable. Masson and Shaanan (1985) lend some support to these theories by empirically demonstrating that, holding profits, growth and barriers to entry constant, then higher excess capacity leads to less entry.

These theories suggest that looser oligopoly may be associated with excess capacity and that looser oligopoly may become unstable with entry. The final question is whether a tight oligopoly is readily observable, or whether it may have the opportunity to feign being a loose oligopoly.

One generally non-observable factor of course stands out – conspiracy. In the context of Scherer's discussion this level of 'cooperation' is linked to 'trust'. As noted by Hay (1982), price fixing is not enforceable by law, so it can only be based upon 'trust'. If this level of 'trust' were observable it would be eliminated by antitrust action. The rest of these conditions are also hard to quantify. For example, the definitions of the relevant market and concentration levels are frequently not agreed upon within the literature or the courts. How variable is the capital structure and how observable is that over each time period from the outside? As Scherer (1980, p. 227) discusses the elements of stability he goes on to state:

> 'None of these links is strictly deterministic, all reflect central tendencies subject to random deviation. It is in part because of this complexity and randomness that oligopoly poses such difficult problems for the economic analyst.'

This lack of certainty explains why economists cannot perfectly predict industry profits using industry structure and why entrants often err in their entry decisions. We see this lack of certainty manifested by the high incidence of ex post unprofitable entry [see, for example, Biggadike's (1979) study of the new entry outcomes for leading firms on the *Fortune* list]. It is this uncertainty which oligopolists will exploit in the model.

It is signaling of looseness, and the ability to send false signals, which will drive our model. We shall concentrate our modeling on a signal which we will assume is measurable – capacity. Clearly the uncertainty about entry outcomes given any set of observable industry characteristics might be exploited by industries which have the ability to do so. It is this basic uncertainty which we use in the following sections.

3. The model

In section 3.1. we develop the theory of the firm and show a set of equilibrium conditions. In 3.2 we examine an equilibrating process and we examine some alternatives in 3.3.

3.1. Firms and equilibrium

As noted earlier, we abstract by assuming there are only two general types of oligopoly. We assume that a tight oligopoly can achieve higher profits and lower excess capacity than a loose oligopoly. We further assume that potential entrants can observe all excess capacity in the economy. This describes an extensive form of the game which has two stages: (1) a stage in which all oligopolies select capacity levels, followed by (2) a stage in which entrants can observe all capacity levels and make entry decisions. These entry decisions lead to payouts for this two stage game. These payouts themselves are determined by the outcome of a post-game game in which loose oligopolies, when entered, are forced to marginal costs, causing entry into these industries to be unprofitable. Tight oligopolies are assumed to be profitable to enter. The form of this post-game game need not be specified as long as the present value of entry to loose oligopolies is negative, and that to tight oligopolies is positive.[11]

Finally, we assume that strategic behavior would be profitable for at least some tight oligopolies. This condition is that the profits to be earned from adding excess capacity to feign being a loose oligopoly, and hence avoiding entry, are greater than the profits to be earned without the excess capacity, but with entry.

In what follows firms have complete information: knowing exactly the number of each type of player. Specifically, potential entrants will know the exact number of tight/stable oligopolies which have added excess capacity to appear like loose/potentially unstable oligopolies.[12] However, information will remain imperfect in the sense that potential entrants cannot discern

[11]Output expansion to marginal cost is clearly not required for loose oligopolies. This special case is only relevant for developing a condition under which the conjecture in the Spence and Dixit (1979) models may be correct.

[12]In many games with complete but imperfect information one knows only the number (distribution) of players who would play as each type. In such models the normal approach is to analyze the case of a single player drawn from this distribution. In this model the complete sample is drawn. All players are playing, and can be observed, but entrants are still imperfectly informed as to the identity of each. Often single draw models require imposing arbitrary conjectures on firms to select between potential equilibria [as in Milgrom and Roberts (1982a)], the use of sequential equilibria [e.g., Kreps and Wilson (1982)], or adding a large component of exogenous noise to the model to achieve uniqueness [as in Matthews and Mirman (1983)].

Using the complete draw of all players avoids these difficulties and leads to an anlytically far simpler model structure capturing many of the essential effects of imperfect information. We note later that for a wide class of equilibria the results are unaltered if a single draw is used instead.

which specific industries with excess capacity are tight/stable oligopolies and which are loose/potentially unstable oligopolies. Now we can formalize these relationships.

Denote the total number of industries as n, the number of tight oligopolies as n_t and the number of loose oligopolies as n_l. Index the n oligopolies such that the hth oligopoly is unstable if $h \in [1, \ldots, n_l\}$ and is stable if $h \in \{(n_l+1), \ldots, n\}$.

The profits of the incumbent firms in oligopoly h are $\Pi_h = \Pi_h(K, E)$, where K is the level of capacity in the industry and E is zero if there is no entry and one if there is entry. Let $K = K^*$ be the profit maximizing level of capacity chosen by any tight oligopoly which is not purposely setting capacity to deter entry. Further let $K = K^* + X$ be the excess capacity solution which arises in all loose oligopolies.[13] Only $K = K^*$ or $K = K^* + X$ will be chosen by tight oligopolies since selecting a value of $K = K^* + Y$, $Y \neq X$ shows additional coordinating abilities and hence would signal that the industry was a tight oligopoly. Since entry would be profitable into such an industry, if $K^* + X$ is not selected, then K^* must maximize industry profits.

We next specify the profitability of each type of industry. The loose oligopolies cannot jointly control capacity. Their profitability is given by $\Pi_h = \Pi_h(K^* + X, E)$. (Economic profits, as in real situations, may be only imperfectly estimated by industry outsiders.) In the tight/stable oligopolies, $h \in \{(n_l+1), \ldots, n\}$, each industry will face the following maximization problem:

$$\max_K \Pi_h(K, E) \quad \text{given} \quad E = \mathrm{E}(K, s),$$

where s will be the number of tight oligopolies which select to add excess capacity. The derivation of the equilibrium level of s and why it is in the entry function will become clear presently.

The entry function is derived from the profitability of entry. The profits from entry into h are $\pi_h = \pi(K, h)$ (using lower case π to distinguish entrant profits from incumbent profits of upper case Π). These are given by

$$\begin{aligned} \pi_h &= \bar{\pi} \quad \text{for} \quad h \in (1, \ldots, n_l\}, \\ &= \hat{\pi} \quad \text{for} \quad K = K^* \quad \text{and} \quad h \in \{(n_l+1), \ldots, n\}, \\ &= \pi^* \quad \text{for} \quad K = K^* + X \quad \text{and} \quad h \in \{(n_l+1), \ldots, n\}, \end{aligned}$$

where $\hat{\pi} > \pi^* > 0 > \bar{\pi}$.[14]

[13] We might assume that loose oligopolies cannot coordinate to add yet further excess capacity to avoid the tight oligopolies freeriding the excess capacity signal. It will become apparent, however, that for pure strategy equilibria they do not have any incentive to do so even if they had the ability.

[14] By profits we mean the present value of entry. If there are sunk costs, flow profits might be positive, inducing no exit, but profits may be negative in the sense the term is used here. We

It follows that potential entrants will enter all tight oligopolies for which $K=K^*$. Potential entrants will not wish to enter loose oligopolies.

If entrants were to regard excess capacity as a perfect signal of a loose oligopoly they would only enter tight oligopolies with $K=K^*$. If tight oligopolies were to recognize this then all tight oligopolies for which $\Pi_h(K^*+X,0)>\Pi_h(K^*,1)$ would select K^*+X, exploiting the excess capacity signal and deterring all entry. Hence if entrants naively believe that excess capacity is always a perfect signal of looseness, then incumbents in tight oligopolies can add excess capacity to deter new entry. Furthermore, since no industries with $K=K^*+X$ would ever be entered, $\pi^*>0$ would never be observed. The entrants would never learn that their conjectures were naive.

The self-fulfilling expectations equilibrium described in this example is based upon unsophisticated entrant conjectures. There is no reason to expect potential entrants to be less sophisticated than established firms. Both groups could recognize that tight oligopolies may generate excess capacity to mimic being loose. In this event, if there is a pooling outcome (all tight oligopolies setting $K=K^*+X$) or partial pooling outcome (some tight oligopolies setting $K=K^*+X$), the signal has the potential to become saturated: used to an extent that it is no longer a reliable signal of negative expected profits following entry. If both potential entrants and existing firms are sophisticated the problem changes and the equilibrium number of tight oligopolies that choose excess capacity may change. In a pooling or a partial pooling equilibrium, potential entrants will again enter all industries with $K=K^*$ but in some cases they would additionally enter industries with $K=K^*+X$. Such entry to industries with excess capacity would occur if the expected profits from entry were positive. If a high enough proportion of industries with excess capacity were tight oligopolies, into which entry would lead to $\pi^*>0$, then this could outweigh the possible penalties of entering loose oligopolies with $\bar{\pi}<0$.

Specifically, if s of the stable industries select excess capacity then the expected profits from entry into a pool comprising (n_1+s) industries with excess capacity will be

$$\mathrm{E}[\pi|s]=\left(\frac{s}{n_1+s}\right)\pi^*+\left(\frac{n_1}{n_1+s}\right)\bar{\pi}. \tag{1}$$

could also let entrant profits vary within categories, but this only complicates the analysis and adds no further insights. For example, $\bar{\pi}$ could be the expected value of entering a randomly drawn loose oligopoly. There could even be some profitability to entering some loose oligopolies as long as expected profits from entering this class of firms are negative. Furthermore note, were we to assume $\pi^*<0$, we would be assuming that the excess capacity addition was a credible entry deterrent even if entrants knew this was a tight oligopoly. This fits one of three cases: (1) the Dixit (1980) case, (2) a credible predation case, or (3) a case in which the tight oligopoly deliberately puts itself in a position with sufficient excess capacity that it would be forced to become unstable upon entry.

The entry function is thus

$$\begin{aligned}\mathrm{E}(K,s)&=0 \quad \text{if} \quad K=K^*+X \quad \text{and} \quad \mathrm{E}[\pi\,|\,s]<0,\\ &=1 \quad \text{if} \quad K=K^*, \quad \text{or}\\ &=1 \quad \text{if} \quad K=K^*+X \quad \text{and} \quad \mathrm{E}[\pi\,|\,s]\geqq 0.\end{aligned}$$

It will be this entry function over which the tight oligopolies will select their profit maximizing levels of K.

Now we can describe how the hth industry's choice of excess capacity depends on the extent that other oligopolies choose this strategy. To do this we allow the excess capacity decision stage of the game to be sequenced: each oligopoly in turn selects capacity given information on the capacity choices of each previous player. (We deal with simultaneous moves later.)

If $s-1$ other tight oligopolies have selected $K=K^*+X$ then the hth industry, *if it assumes that it would be the sole additional industry which would select* $K=K^*+X$, would do so if $\Pi_h(K^*+X,\mathrm{E}(K^*+X,s))>\Pi_h(K^*,1)$ and would choose $K=K^*$ otherwise. Clearly if $\mathrm{E}[\pi\,|\,s]\geqq 0$ there will be entry into the excess capacity group. In this case since $\mathrm{E}(K^*+X,s)=1$, $K=K^*$ will be chosen by the hth industry as $\Pi_h(K^*+X,1)<\Pi_h(K^*,1)$. If $\mathrm{E}[\pi\,|\,s]<0$ then industry h will select $K=K^*+X$ if $\Pi_h(K^*+X,0)>\Pi_h(K^*,1)$.[15]

This decision rule is based on the assumption that the hth industry assumes that it will be the sole additional industry to add excess capacity. The decision is based upon whether becoming the sth industry to add excess capacity causes $\mathrm{E}(K^*+X,s)$ to become positive. Clearly the decision rule is unchanged if after $s-1$ other tight oligopolies have selected $K=K^*+X$, industry h conjectures that Δ other tight oligopolies will also select $K=K^*+X$ and $\mathrm{E}[\pi\,|\,s+\Delta]<0$ so $\mathrm{E}(K^*+X,\ s+\Delta)=0$. This observation will simplify the derivation of rational expectations equilibria.

Various rational expectations equilibria are possible in this model. These include no deterrence, $s=0$; pervasive deterrence, $s=n_t$; and some deterrence, $0<s<n_t$, equilibria. Two general types of partial pooling equilibria exist. The technically simplest equilibria occur when there are only a few tight oligopolies that find it cost effective to choose excess capacity. If entry is not profitable when all tight oligopolies for which $\Pi_h(K^*+X,0)>\Pi_h(K^*,1)$ have selected $K=K^*+X$ then the signal will not become saturated. This equilibrium requires no structure in addition to our current model structure. It is

[15]Note that formally our model requires somewhat more excess capacity than a strict Spence model. Spence finds the residual demand curve defined by market demand net of the monopolist's shortrun marginal cost curve. Then capacity is set such that entry profits are $\varepsilon<0$ but $\varepsilon\to 0$. For $\mathrm{E}[\pi\,|\,s]<0$ for integer values of $s>0$ we must assume that at K^*+X, the residual demand is finitely below the entrant's cost curve.

trivially defined by $s=s'$ where

$$s' = \#\{h \in \{n_{1+1},\dots,n\}: \Pi_h(K^*+X,0) > \Pi_h(K^*,1)\},$$

$$E[\pi \mid s'] < 0 \quad \text{for all} \quad h \quad \text{with} \quad K=K^*+X, \quad \text{so}$$

$$E(K^*+X, s') = 0.$$

Analytically more interesting partial pooling equilibria occur when the number of tight oligopolies which would like to deter entry by selecting $K=K^*+X$ exceeds the number which would saturate the signal, i.e., if all of them installed excess capacity, random entry to industries with $K=K^*+X$ would yield positive expected profits. In this case to attain an equilibrium number of firms with $K=K^*+X$ that is consistent with entry deterrence requires that a sufficient number of tight oligopolies 'self-select' to choose $K=K^*$. These equilibria will require some additional structure. To build this structure we first describe a sequencing model in which some exogenous source sets the sequence of plays in the capacity decision stage of the same. We then generalize the model to allow for endogenous sequencing or simultaneous decision making.

3.2. One equilibration process

A sequential equilibrium will be used as a building block for later analysis. As will be clear from the analysis, we could sequence the plays of the tight oligopolists in any order [e.g., sequenced in order of random draws from $\{(n_1+1),\dots,n\}$]. We shall instead choose a special case for our sequencing. This special case simplifies the exposition and has an economic interpretation for a class of Nash equilibria which we consider later.

Let us order the tight oligopolies in order of their potential gains from installing excess capacity to deter entry. This is, for all h and h' in $\{n_1+1,\dots,n\}$, if $h<h'$, then

$$[\Pi_h(K^*+X,0) - \Pi_h(K^*,1)] \geqq [\Pi_{h'}(K^*+X,0) - \Pi_{h'}(K^*,1)].$$

For the sequential equilibrium we assume that the n_1 loose oligopolies move first, each one selecting $K=K^*+X$. Then we allow industry n_1+1 to be the first tight oligopoly to select K, industry n_1+2 to be the second to select K, etc. continuing until all n_t of the tight oligopolies have selected K.[16]

Tight oligopoly s knows that if $s-1$ tight oligopolies already have $K=K^*+X$ and if $E[\pi \mid s] \geqq 0$ then its optimal level of K is K^*. This applies for any

[16]Note that the definition of $E[\pi \mid s]$ relies on random entry of industries with $K=K^*+X$. Thus potential entrants must not observe the sequence of decisions in the first stage of the game.

tight oligopoly, s. Furthermore each industry is aware that all other industries operate knowing this relationship. Thus each tight oligopoly, s, in turn knows that no future industry $s+\Delta$ will select K^*+X if this will cause $\mathrm{E}[\pi \mid s+\Delta] \geqq 0$. Accordingly each industry in turn need only consider whether: (a) deterrence would be profitable if it were feasible, and (b) whether deterrence is feasible in the sense that were it to select K^*+X, the signal would not be saturated so that expected profits to entry would remain negative. Thus the industries in order will select $K=K^*+X$ only until s^*, where either $s^*=n_t$ or one of the following conditions is satisfied:

(a) $\Pi_{n_l+s^*+1}(K^*+X,0) \leqq \Pi_{n_l+s^*+1}(K^*,1)$, or

(b) $\mathrm{E}[\pi \mid s^*+1]=\left(\dfrac{s^*+1}{n_l+s^*+1}\right)\pi^*+\left(\dfrac{n_l}{n_l+s^*+1}\right)\bar{\pi} \geqq 0.$

Formally the equilibrium can now be defined as

(i) K^*+X for all $h \in \{1,\ldots,n_l\}$,

(ii) K^*+X for all $h \in \{n_{l+1},\ldots,n_{l+s^*}\}$,

(iii) K^* for all $h \in \{n_{l+s^*+1},\ldots,n\}$,

where $s^*=\min\{s',s''\}$, with

(a) $s' \equiv \min\limits_{\text{integer}} s \in [0,n_t]$, such that

(1) $\Pi_{n_l+s}(K^*+X,0) > \Pi_{n_l+s}(K^*,1)$, and

(2) $\Pi_{n_l+s+1}(K^*+X,0) \leqq \Pi_{n_l+s+1}(K^*,1)$

[given the mathematical convention $\Pi_{n+1}(K^*+X,0) \leqq \Pi_{n+1}(K^*,1)$].

(b) $s'' \equiv \min\limits_{\text{integer}} s \in [0,n_t]$, such that

$$\mathrm{E}[\pi \mid s] < 0 \leqq \mathrm{E}[\pi \mid s+1]$$

(given the mathematical convention that $\mathrm{E}[\pi \mid n_t+1] \geqq 0$).

The industries in group (i) are loose oligopolies with excess capacity thrust upon them, the industries in group (ii) (if that set is non-empty) are tight oligopolies which exploit the excess capacity signal, and the industries in group (iii) (if that set is non-empty) are tight oligopolies which do not install excess capacity. If $s^*=s'$ then all industries which would find deterrence to be profitable will deter entry. If $s^*=s''<s'$ then the equilibrium is determined by some tight oligopolies not adding excess capacity because to do so would saturate the signal. This equilibrium, based on exogenously sequenced moves, has been described in some detail and it will be shown to be equivalent to the Nash equilibrium for one specification of a model in which sequencing is not exogenously imposed.

3.3. Some alternative equilibration processes

In this section we present some other equilibration processes in a non-rigorous discussion. We first note that any exogenous sequencing, through historical accident etc., would yield an equilibrium with $s^*=\min\{s',s''\}$ tight oligopolies installing excess capacity. Then, as before, there would be $\max\{0,s'-s''\}$ industries which would have liked to install excess capacity to deter entry which would not do so due to impending signal saturation. If $s^*=s'$ it will be the same industries in equilibrium with $K=K^*+X$ as above. If $s^*=s''<s'$ then the industries with excess capacity are determined by their order in sequence.

Second we note that if $s^*=s'$, then even without any sequencing in the capacity decision stage of the game, simultaneous capacity moves trivially retaining s' as the equilibrium. Furthermore, if the technical structure determined an equilibrium of s', the sequencing underlying the two stages of the game is not necessitated in the sense that potential entrants would need to know only the capacity selected in a single industry to decide whether to enter that industry. The only hard cases involve $s'>s''$ with no exogenous sequencing.

We next present two Nash equilibrium processes for dealing with cases for which $s^*=s''<s'$ and there is no exogenous sequencing in the capacity stage of the game. The first approach yields simple pure strategy equilibria identical to those above in section 3.2. The second approach uses game theoretic mixed strategy equilibria. Both approaches yield natural equilibria which are symmetric in strategy space, albeit not in actions.[17] The latter approach further necessitates a discussion of possible strategic moves by loose oligopolies.

[17]The two approaches which follow can be characterized by symmetric strategy functions. If the net gain from deterring entry to industry i is $\Delta\Pi_i$, the first approach solves for a symmetric capacity addition function $X(\Delta\Pi_i)=X_i$ such that $X(\Delta\Pi_i)=\{X$, if $\Delta\Pi_i>\Delta\Pi^*$; 0, otherwise$\}$. The symmetric Nash equilibrium function $X(\cdot)$ will determine the $\Delta\Pi^*$ corresponding with $s^*=\min\{s',s''\}$ in section 3.2.

The second approach involves solving for the symmetric probability function $p(\Delta\Pi_i)=p_i\in[0,1]$ where p_i is the probability industry i assigns to playing $X_i=X$, and $(1-p_i)$ is assigned to playing $X_i=0$, in a mixed strategy game.

Although the functions, $X(\cdot)$, $p(\cdot)$, are symmetric, their outcomes, X_i, p_i, are clearly not.

For the first approach we assume $s' > s''$ and that tight oligopolies have strict differentials in the sense that the net gains from entry deterrence, $[\Pi_h(K^* + X, 0) - \Pi_h(K^*, 1)]$, are different for h than for h' for all $h' \neq h$. Next assume each tight oligopoly knows its ordering in this distribution.[18] Now consider the following conjectures: 'Were I to decide to add excess capacity, I would certainly expect any industry with greater gains from deterrence to do likewise.' Then, all industries will have the conjecture that if h wishes to add excess capacity then all more advantaged industries $h' < h$, will add excess capacity. Then $s^* = s''$ is a Nash equilibrium in a simultaneous capacity decision game. Although industries $h \in \{n_{1+s''+1}, \dots, n_{1+s'}\}$ would desire to add excess capacity if it would deter entry, they would not do so because they would expect that the s'' industries with greater gains from excess capacity would certainly do so if any of them were willing to do so. Hence it is not optimal for any of them to add excess capacity as that would saturate the signal and hence not deter entry whatsoever.

This seems to be a natural solution to the game. There is, however, another natural solution from treating the capacity decision stage as a mixed strategy game.

A mixed strategy equilibrium exists in which all of the s' industries which would find $K = K^* + X$ profitable were it to deter entry would select whether or not to add excess capacity by use of an optimally selected random draw. For each of these industries the probability assigned to adding X will be non-zero.

This class of equilibria obviously exists and could be readily solved for under the assumption that loose oligopoly behavior is exogenous. We note, however, in the mixed strategy case loose oligopoly optimal behavior *may* be altered. This is because the entry decisions are made in the second stage, after the information on how many industries have installed excess capacity is revealed. The entry rule remains the pure strategy rule, $E(K, s)$, where K and s are known. *In all of the pure strategy equilibria above, entry to loose oligopolies was always zero. Thus loose oligopolies had no incentive to sort themselves from those tight oligopolies which have added excess capacity.* Now, however, if $s' > s''$ then there is a finite probability that the first stage of the game will determine some $s > s''$ tight oligopolies with excess capacity. Hence any loose oligopoly with $K = K^* + X$ then faces a finite probability of entry. Unlike the earlier cases, now the loose oligopolies can lose profits due to entry. Thus they have an incentive to sort themselves from tight oligopolies with excess capacity.

[18] Of course potential entrants cannot know this ordering. It is reasonable to believe that industry insiders could know their own relative profit levels without others being privy to this information. If they are also aware of the form of the distribution of these differences, the[illegible]h may know their place in the distribution while no industry outsiders know the location [illegible] any industry in the distribution.

If the loose oligopolies could add higher levels of excess capacity[19] this would make it more expensive for tight oligopolies to feign being loose oligopolies. This would lower s' and would reduce the probability of entry and could even reduce it to zero (if the new level of s' were at or below the new level of s''). But by hypothesis the firms in a loose oligopoly may not be able to coordinate to expand capacity. If we assume that this means that loose oligopolies must inherently have $K=K^*+X$ we need go no further. But each *firm* is a strategic player. If at the decision time each firm in the loose oligopoly is free to expand capacity then they may do so to deter entry. Any increase in excess capacity would be the combination of the individual firm optimal levels of additional capacity. Loose oligopolies would then have excess capacity of $X'>X$. This would raise the costs to tight oligopolies of mimicking of loose oligopolies. This in turn may lower s' and must lower the mixed strategy equilibrium cumulative probability of entry to industries with $K=K^*+X'$ as loose oligopoly sorting behavior raises capacity by $(X'-X)$.

Other possibilities abound. For one thing, the sequencing of the stages of the game may be relaxed. For example, individual entrants may know only the capacity decisions of a single industry, a single draw imperfect information game in which entrants might also employ mixed strategies if $s'>s''$. Or alternatively, one could add the potential for alternative or additional signals. For example, the gains to tight oligopolies of pretending to be loose oligopolies will be lower if to pretend to be loose requires periodic price wars in addition to the excess capacity. If the equilibrium is not a pure strategy equilibrium then loose oligopolies wish to sort themselves. Being unable to influence capacity, they may sort themselves by lowering price, leading to a lower s'. Price reductions have the property that in many cases *a single firm* can impose a lower industry price by lowering its own price. So a firm in a loose oligopoly with $s'>s''$ may uniltareally act to lower s' even if coordination to affect capacity levels is not possible.

Although we cannot say definitively which solution concept is best, we do know the form of the equilibrium if $s'\leq s''$ (that $s^*=s'$) for any reasonable equilibrium concept. The hard cases are those in which $s'>s''$. If historical factors do not determine a sequencing of moves, then the nature of equilibrium depends upon the nature of the solution concept employed. Under some solution concepts our model explains an entry deterrence equilibrium. For other solution concepts it can further be used to lay the foundations explaining loose oligopoly sorting behavior.

[19]The 'tight' oligopolies are, by hypothesis, tight enough to collude upon capacity. As Waldman (1983) points out, excess capacity agreements may be particularly difficult to achieve.

4. Conclusion

We have developed a stylized model in which a partial pooling rational expectations equilibrium exists with entry deterring excess capacity generation. The model has industries selecting excess capacity at levels which would deter entry if potential entrants expected output expansion post entry. However these industries do not threaten to expand output post entry and would not do so if they experienced entry. Potential entrants recognize that some such industries exist, but being unable to assess all factors which determine inherent industry stability, they do not enter some industries which feign being potentially unstable. The 'credibility problem' is solved not by a credible threat, but by feigning potential instability.

This result is significant for several reasons relating to the motives for excess capacity generation. What if the Dixit (1980) credible deterrence argument is accepted? Then massive, and hence very costly, excess capacity may be needed to deter entry. In this case few, if any, oligopolies may choose to do so. In models by Spence (1977, 1979) and Dixit (1979), monopolists need less excess capacity to deter entry, so they more frequently would choose to do so. However these models do not present a convincing story for why entrants would fear these excess capacity levels. Rational entrants should not expect the post entry output expansion which drives these models. What we demonstrate is that even if rational behavior implies that monopolists would desire to contract output post entry, there exist equilibria in which the fear of output expansion can deter rational potential entrants. From this it follows that entry deterrence with the more modest levels of excess capacity as in Spence (1977, 1979), Williamson (1977) and in Dixit (1979) may deter entry, expanding the demonstrated class of rational equilibria in which entry deterrence may be optimal.

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