Queen's Economics Department Working Paper No. 837

Entry Deterrence

Roger Ware

Department of Economics
Queen's University
94 University Avenue
Kingston, Ontario, Canada
K7L 3N6

10-1991

DISCUSSION PAPER #837

Entry Deterrence

by

Roger Ware
Queen's University*

October 1991

* Chapter written for the volume, *The New Industrial Economics*, edited by George Norman and Manfredi La Manna. Mailing address of author: Department of Economics, Queen's University, Kingston, Ontario, K7L 3N6

This paper surveys the recent literature on strategic entry deterrence. Particular attention is paid to limit pricing, entry deterrence models using a two-stage framework, incomplete information treatments of entry deterrence and entry deterrence as a framework for modelling the determination of market structure. In addition there is some discussion of antitrust issues.

INTRODUCTION

A traditional textbook in Industrial Organization would list "Entry Barriers" as a structural variable, and a major determinant of the ability of industry incumbents to earn supernormal profits. An achievement of the past two decades of research in the field is a solid recognition of the fact that entry barriers, and other industry characteristics such as technology, are not exogenous, but rather the endogenous result of competition in, and for, the industry. Entry barriers can be created strategically to maintain the profits of a monopoly incumbent. In a similar way the struggle for cost reducing innovations clearly determines the configuration of industry technology. Both of these examples involve aspects of industry conduct feeding back on, and determining, the structure of the industry. The ultimate goal of this research agenda is a theory of industry performance in which only tastes, behaviour, and some basic conditions of the industry are exogenous: market structure is to be explained as an outcome of more primitive conditions.

Fundamental to the notion of a conduct driven theory of industrial organization is a theory of strategic behaviour. My goal in this chapter is to survey the study of strategic behaviour in one important area: that of strategic behaviour towards entry. The idea that incumbent firms may attempt to restrict access to their markets is certainly not new, and of course it extends widely to many labour markets as well as those for consumer goods. Nevertheless, important new insights have been gained from work on strategic behaviour in the past decade and a half, and it is on these insights that I focus in this chapter.

Several other recently published and excellent surveys overlap with the subject matter of this chapter. In particular Gilbert (1989) and Tirole (1988) discuss many of the issues that I cover. Space limitations have prevented me from discussing empirical investigations of the ideas which are surveyed here: the reader is referred to Geroski, Gilbert and Jacquemin (1990) for an excellent survey.

1.1 Limit Pricing

The origins of modern approaches to the analysis of entry deterrence are to be found in the theory of *limit pricing*. This concept originated in the work of Bain (1956), Sylos-Labini (1962) and Modigliani (1958). The essence of the argument is as follows. Given a technology with increasing returns to scale, an incumbent monopolist can deter entry by lowering price below the monopoly price so as to reduce the market available to the entrant; A sufficiently low price will deter entry altogether. More precisely, the incumbent monopolist chooses a quantity sufficiently large that a potential entrant, computing potential profits from the *residual demand*, would be unable to earn positive profits. Formally, we can define the *limit output* (LO) as follows. Let $\hat{x}_e(x_i) = \text{argmax}\ \pi(x_e,x_i)$, where $\pi(\cdot)$ is the entrant's profit function, and x_e, x_i are the outputs produced by entrant and incumbent respectively. Then LO is the solution to $\pi(\hat{x}(\text{LO}),\text{LO}) = 0$. The *limit price* (LP) is given by $\text{LP} = f(\text{LO})$ where $f(\cdot)$ is the inverse demand function.

dynamic limit pricing: the Gaskins model

Gaskins' (1971) model has also had a significant impact on the development of ideas about strategic entry deterrence and limit pricing. A dominant firm chooses an intertemporal price path (p_t) to maximize

$$\pi(t_0) = \int_{t_0}^{\infty} (p_t - c)(D(p_t) - x_t) e^{-r(t - t_0)} dt \tag{1}$$

where $D(p_t)$ is total demand at price p_t, x_t is the total supply from competing firms, c is the dominant firm's average cost of production (taken to be constant), and r is the discount rate. It is assumed that the rate of entry, $\partial x/\partial t$, is an increasing function of the price set by the dominant firm. In the absence of cost advantages in favour of the dominant firm, the only equilibrium limit price is the price that is equal to average (and marginal) cost. It follows, from the formal solution to the model, that the dominant firm must disappear, i.e. its limiting market share as t approaches infinity is zero.

There are obvious problems with the specification of dynamic limit pricing. First, it is not clear why the dominant firm should be a price leader, particularly after its share of the market has been significantly eroded by entry. Second, the dynamics of the entry process are specified exogenously, rather than derived from the optimizing behaviour of entrants. In particular, the dominant firm and entrants do not engage in the kind of strategic interaction which we review in this chapter.

1.3 Lack of Credibility (Perfection) in the Static Limit Pricing Model

The static limit pricing model has rightly been criticized on the grounds that the monopolist's implied threat to continue producing the pre-entry quantity *after* entry, is not credible; with most specifications of demand and costs, the incumbent monopolist would have an incentive to reduce output in response to entry. In the language of dynamic games, the original limit pricing solution is not a sub-game perfect equilibrium. This point can be illustrated simply with the aid of the game tree shown in Figure 1. In this

[Figure 1 should be placed about here]

"generic" entry game the entrant chooses either to enter or to stay out, and the incumbent responds to entry either by accommodating the entrant, "the share strategy' or by being aggressive "the fight strategy". There are two Nash equilibria to the game: "Fight, if Entry; Stay Out" and "Share, if Entry; Enter". Only the latter is sub-game perfect, however. The former equilibrium is sustained by an incredible threats: faced with the *fact* of entry, the incumbent would benefit from sharing the market. In game theoretic terms, the threat to fight by the incumbent is not a Nash equilibrium strategy to the entry sub-game.

2. ENTRY DETERRENCE IN THE TWO-STAGE FRAMEWORK

The development of models of credible threats to deter entry owes much to the work of Thomas Schelling. In his book *The Strategy of Conflict* (1960) Schelling defines a strategic move as "one that influences the other person's choice in a manner favourable to oneself by affecting the other person's expectations of how oneself will behave". More recently strategic behaviour has been modelled within the framework of two stage and multi-stage games. All of these models conform to the following general structure: In the initial period, one or more of the firms has the opportunity to take some action that will have real economic consequences for the state of competition in the second period. The first period may consist of sequential moves of perfect information by all the agents, for example, such as investments in capacity, or in a production technology. These first period actions are the "strategic" ones. In the second period, some simple Nash equilibrium emerges, given the conditions inherited from the initial period. Subgame perfection requires that these second-period actions form a (static) Nash equilibrium in the second period sub-game.

It is important to realize the essential role of sunk costs in a dynamic, strategic environment. The essence of these entry deterrence models is that firms can make commitments at early dates that influence the competition to follow. But no action is a commitment if it is swiftly and costlessly reversible. It is the sunkness - at least the partial sunkness - of investments that qualifies them as strategic decisions.

The entry process is an intrinsically asymmetrical one, in that incumbent firms already have their capital in place before entry, whereas the entrant must sink capital on *entering*. Although two period models can be symmetric (e.g. Brander and Spencer (1983)) the asymmetric two period game in which incumbent firms make sunk investments before entry, has proved very fruitful in its application to the analysis of strategic entry deterrence.

2.1 The Basic Two-firm Two Stage Entry Game

An important analysis of the two period entry game is Dixit (1980). The following exposition follows Ware (1984) more closely, because the treatment of sunk investments is more satisfactory in the later model. In Dixit's model, only the incumbent is able to commit sunk investment before the production period. However, since this investment takes the form of capacity which is necessary for production, then production by the entrant must also be preceded by investment in sunk capacity. The entrant's ability to commit, albeit after the incumbent but before production, is a valuable asset that has a significant impact on the equilibrium to the entry game. Moreover, the entrant has no choice: if he is to enter, he has to make an investment in sunk capacity in exactly the same way as the incumbent.

Both incumbent monopolist and the potential entrant produce with a technology described by the cost function:

$$C^i(q_i,k_i) = (1 - \alpha)q_i + \alpha k_i + F_i$$

where q_i is quantity produced, k_i is investment in capacity, and $q_i < k_i$. F_i is the fixed cost of entering the industry. Thus, the production technology is Leontief. Further, the parameter α, where $0 < \alpha < 1$, measures the proportion of unit costs (whose total is set equal to one), which takes the form of sunk capacity.[1] Each firm is capable of producing an undifferentiated product with inverse demand given by $p = f(X)$, where X is aggregate output. The function f(X) is twice differentiable, and for $f(X) > 0$, $f'(X) < 0$. Further,

[1]Note that the meaning of α here is equivalent to $1 - \alpha$ in Ware (1984).

assume that demand satisfies the *Hahn-Novshek condition*: $f'(X) + x_i f''(X) < 0$, for all $x_i < X$, where x_i is the output of firm i[2]. This condition ensures that reaction functions are downward sloping. In the model under review, the significance of the Hahn-Novshek condition is that the response of an incumbent firm to entry can never be to increase output. The incumbent firm would never hold excess capacity as a barrier to entry, because it follows that none of this excess capacity would be used after entry. At a more formal level, it can be shown that perfect equilibria to this game and all games with this structure, will not involve excess capacity (see Eaton and Ware (1987)).

The structure of the game is as follows: firm one chooses a level k_1 of investment in sunk capacity. Firm two then makes an entry decision, which if positive, also involves a choice of a level k_2 of investment in sunk capacity. In the second period of the game either one or both firms produce quantities so as to maximize profits, conditioned on their investments in period one. The game is thus a dynamic game of almost perfect information, and the appropriate equilibrium concept is that of the perfect Nash equilibrium. Effectively, the incumbent firm, as first mover, computes the equilibrium response to his actions, and makes an investment choice with foresight about the final period equilibrium.

The entry game is perhaps best analyzed by first describing the final period equilibrium. Equilibrium can be thought of as "constrained Cournot", in that $x_i = \min(k_i, Z(x_j))$, $i,j = 1,2$ where

---

[2]Roughly, this requires that demand be not too convex, and is satisfied by linear demand, but not by constant elasticity demand.

$$Z(x_j) \equiv \underset{x_i}{\mathrm{argmax}}\, x_i f(x_i + x_j) - (1 - \alpha)x_i$$

i.e. the Cournot reaction function. If firm 2 stays out, then of course, its second period output is zero.

Figure 2 illustrates the solution to the quantity game. There are four regions in the figure: in I, both firms are unconstrained by their capacities; in II both are constrained; in III(IV) , one (two) is constrained and two (one) is unconstrained. The boundary between regions II and IV is $Z(x_2)$ and the boundary between II and III is $Z(x_1)$.

[Figure 2 should appear approximately here]

To understand firm one's period one investment choice, it is useful to construct firm two's reaction function in k_1, k_2 space. This is illustrated in Figure 3. To the left of point A, two's response to one's investment is given by its full cost reaction function, defined as $\underset{k_2}{\mathrm{argmax}}\ k_2 f(k_1 + k_2) - k_2$. At point A, firm two is indifferent between the choice given by the above equation $\tilde{k}_2$ and $\bar{k}_2$, in which it exercises a kind of limited Stackelberg leadership by picking the best point T along firm ones variable cost reaction function, implying excess capacity for firm one. For all capacity choices $k_1 > \bar{k}_1$, firm two will make the same choice $\bar{k}_2$, since increasing capacity only adds to excess capacity for firm one, but has no effect on the second period equilibrium.

[Figure 3 should appear approximately here]

It is clear that firm one would not invest $k_1 > \bar{k}_1$ in the perfect equilibrium. Its choice will be dictated by a comparison of the best choice given entry of two, with a choice of k_1 which deters entry, if deterrence is possible. Whether deterrence is possible depends on firm two's profits at point A - if they are positive, then firm one is unable to deter entry, and the perfect equilibrium will involve entry with quantities given by the best point for firm one on BA.

Given entry, the perfect equilibrium choice of k_1 is min $(k_1^S, \bar{k}_1)$ where k_1^S is the Stackelberg choice of capacity for one, defined by $k_1^S = \underset{k_1}{\text{argmax}}\ k_1(k_1 + Z(k_2)) - k_1$ and k_2 in perfect equilibrium is given by the corresponding point on BA, firm 2's reaction function.

Let x_1^D denote the quantity produced by firm one which would just drive firm twos profits to zero in a post entry game, and deter entry. Also, let k_1^M denote the monopoly choice of k_1, unconstrained by threat of entry. Then four qualitatively different perfect equilibria to the entry game are possible.

(1) *blockaded entry* $(k_1^M > k_1^D)$ The incumbent firm does not face a credible threat of entry at all, because simply by investing in its profit maximizing choice of capacity, unconstrained by entry, entry will be rendered unprofitable.

(2) *strategic deterrence* $(k_1^M < k_1^D)$ The incumbent is able to deter, and deterrence is more profitable than a strategy of accommodation towards the entrant.

(3) *strategic accommodation* $(k_1^M < k_1^D)$. The same conditions as above hold, but in this case a strategy of allowing entry is more profitable for firm one than that of deterrence.

(4) *unimpeded entry* $(k_1^D > \bar{k}_1)$. Firm one is unable to credibly install sufficient capacity to deter the entrant, and so must be content with choosing its best point on BA, as described above.

Several broad conclusions can be drawn from the above two firm entry game.

(i) *limit pricing can be resurrected in a game theoretic framework, and may be an important feature of entry deterrence models.* The original limit output model suffered from the defect that the threat to produce the limit output *after entry*, was not credible. In the above model, by sinking part of his costs prior to entry, the incumbent is sometimes able to make the limit output credible, and thus deter entry. Exactly as Schelling described, the sinking of part of the incumbent's costs prior to the production period, lowers his avoidable costs, and gives him an incentive to produce a larger quantity in response to any quantity produced by an entrant. Knowing this, the entrant may choose not to enter.

(ii) *excess capacity is not a barrier to entry in this model.* Wenders (1971) and Spence (1977) argued that incumbent firms would hold excess capacity as a threat to expand output in the event of entry. Such a threat to expand output, however, is generally not credible in the actual event of entry. This might be regarded as a disturbing feature of these models, because there is some evidence that excess capacity is used as a barrier to entry by incumbent firms. A model which does exhibit excess capacity in equilibrium is Barham and Ware (1990).

(iii) *Strategic Entry Deterrence may be Welfare Improving* The market described by the model of this section is a Natural Monopoly. To the extent that Strategic entry deterrence leads to an outcome with larger output and lower price than say a monopoly unthreatened by potential entrants, aggregate net surplus is increased.

(iv) *The greater the proportion of costs which can be sunk by the first mover, the greater is the strategic advantage enjoyed.* In this model the advantage is only apparent when entry is accommodated. If entry is accommodated, strategic advantage takes the form of higher profits for the first mover relative to the second mover. The incumbent firm obtains its strategic advantage from incurring production costs before its rival(s), so that in the final period when production and sales take place variable costs per unit of production are low, and the incumbent will be guaranteed a large market share in the final equilibrium.

2.2 Other examples in a similar framework

Strategic Holding of Inventory by Incumbents

Sinking costs "up front" is embodied in its purest form by production for inventory, to be stockpiled until a later period. Rival firms who hold no inventory and who must produce for sale must incur the full production costs for each unit, whereas sales of inventory incur no variable costs. If the stockpile of inventory is sufficiently large, entry may be deterred and the threat to "dump" the stockpiled inventory on the market is never exercised. The strategic advantage embodied in inventory in this way is discussed in Ware (1985), and Arvan (1986).

Raising Rivals' Costs

Salop and Scheffman (1983, 1986) argue that an established firm may be able to invest to raise industry costs, either for new entrants alone or for the whole industry. If costs are raised sufficiently, entry will be deterred. Two examples are the buying up of low extraction cost resource deposits, which raises extraction costs for new entrants (the classic example is the allegation against the Alcoa Corporation); and Williamson's (1968) observation that efforts to increase union wages in coal mining could benefit incumbent firms by making entry more difficult.

To demonstrate this argument requires no more than a presentation of the *basic pre-emption paradigm*, a result which demonstrates that any incumbent monopolist will be willing to outbid a potential entrant for a scarce industry resource, whether it is ore deposits, an industry patent, or unionized labour. The result depends only on industry profits declining as a result of entry, which would occur with any post-entry game short of perfect collusion. Suppose that an entrant was prepared to bid for the resource up to a price w which would just drive its post-entry profits to zero. Post entry profits would then be

$$\pi_i(w) + \pi_e(w) < \pi_i(w+\varepsilon)$$

where a wage of $w+\varepsilon$ on the right hand side implies that the incumbent has pre-empted the resource and entry has been deterred. Given that $\pi_e(w)=0$ it follows that:

$$\pi_i(w) < \pi_i(w+\varepsilon)$$

and the incumbent monopolist will prefer to deter entry. In words, given that its monopoly profits will always exceed total industry profits after entry, the incumbent will always be prepared to bid a little more than w, and the entrant will be excluded.

The pre-emption paradigm crops up repeatedly in the entry deterrence literature. Eaton and Lipsey (1979) in an early formalisation of the issue, argued that an incentive exists for *spatial pre-emption*, i.e. for a monopolist to build plants in new locations (in a growing market) just before it would be profitable for a rival firm to enter those same markets. West (1982) found weak evidence to support the existence of spatial preemption in supermarket locations. Gilbert and Newbery (1982) show that for the same reason an incumbent monopolist has an incentive to acquire an industry patent before a new entrant, thus preserving the monopoly.

Learning Economies

There is considerable evidence that cumulative experience in a given production process lowers unit costs. The strategic implication of this is clear: an early entrant can gain an advantage over future rivals by pushing down the learning curve with high levels of production. Production today (prior to entry) has two benefits: profits are created today, but also future costs are lowered and hence the incumbent's market share in any future post-entry game will be increased. If early, pre-entry production is large enough, entry may be made unattractive. The properties of strategic investment in learning are thus very similar to that of strategic investment in a cost reducing technology.

The foregoing assumes that the benefits of learning by a pioneer firm do not diffuse to rival firms, without their having to undertake the same production levels. Lieberman (1984) found that the diffusion of learning is fairly common. However, to the extent that firms are able to retain some of the cost advantages of experience, strategic learning effects will still occur.

Competition between Networks

Networks are goods with demand side complementarities. These can be direct, as in the case of telephone service (each person added to the network increases the value to existing subscribers); or indirect, for example the case of home video movies, where the larger selection available in a compatible format increases the value of VCRs. The work of Farrell and Saloner ((1985),(1986a),(1986b)) and Katz and Shapiro ((1985),(1986)) has advanced considerably the understanding of network phenomena, and its implications for entry deterrence.

One effect of network externalities is similar to that of learning, or any other cost reducing sunk investment. Early investment by incumbents to build up the network can increase market share in any post entry game with rivals (for the same *current period* production); A sufficiently large expansion of the network prior to entry may deter entry altogether.

A second feature of networks is novel, however. Today's consumers form expectations about *future* adoption of the technology. A consumer will be more willing to invest in a particular standard today the larger he expects the network to become in the future. The worst outcome would be the possibility of "stranding", where a new standard is adopted, and "software" for the old standard will not be provided in future. Owners of Betamax VCRs, and of eight track tape players, are examples of stranded consumers. With the possibility of competing standards, anything the incumbent can do to convince current consumers to stay on his network, rather than defect to another, will make entry more difficult. Farrell and Saloner (1986) show that a product preannouncement by an incumbent may prevent consumers from making a switch to a socially desirable competing technology.

Strategic Investment and the Durability of Capital

We have emphasised that the commitment value of capital depends on the sunk nature of the investment. It is important to investigate how this strategic interaction depends on the *durability* of the capital, and whether the strategic advantage of first movers can be expected to persist over the long term. Eaton and Lipsey (1980, 1981) investigated the effect of depreciating capital on simple two-stage capital commitment models of entry deterrence, and found that, while in general a recognition that capital depreciates tends to reduce the advantage of the first mover, more general conclusions were difficult to draw. To quote their conclusion,

> This review demonstrates that the properties of entry equilibrium are dependent upon the nature of Product Specific Capital and apparently minor changes in the nature of Products Specific Capital can produce dramatic changes in the properties of equilibrium. As a corollary, knowledge of the nature of Product Specific Capital is necessary to determine whether entry deterrence is possible, is profitable, and is socially wasteful. (Eaton and Lipsey, 1980)

2.3 Top Dogs, the Fat Cat Effect, the Puppy Dog Ploy and the Lean and Hungry Look:

a more general framework for analysing two-stage competition.

The title of this section is drawn from Fudenberg and Tirole (1984), who proposed a framework for analysing two stage competition, which helps to draw together much of the earlier work, including that on two-stage models of entry deterrence.

Consider a general model of two-stage competition with two firms. Firm 1 has the opportunity to make a sunk investment K in the first period, which alters the costs (or demand) faced by firm 1 during the second period, but does not affect firm 2's costs (or demand). In the second period a non-cooperative equlibrium is reached, $x_1(K),x_2(K)$. Firm 1's profits can thus be written $\pi^1(x_1(K),x_2(K),K)$, and the profit maximizing choice of capital is obtained by differentiating:

$$\frac{d\pi_1}{dK} = \frac{\partial\pi_1}{\partial x_1}\frac{dx_1}{dK} + \frac{\partial\pi_1}{\partial x_2}\frac{dx_2}{dK} + \frac{\partial\pi_1}{\partial K} = 0 \qquad (2)$$

Equation (2) may be called the fundamental equation of strategic two-stage competition. The first term vanishes by the envelope theorem (x_1 is optimally chosen in period two). The second term, captures the *strategic effect* of marginal investment. The final term is simply the direct or non-strategic effect of marginal investment on profits. In a non-strategic, or open loop, problem, only this last term would appear. Thus, the sign of the second term (together with the concavity of π_1 in K) determines whether firm 1 will overinvest or underinvest relative to a non-strategic equilibrium. By working through the comparative statics, the strategic term can be evaluated as:

$$\frac{\partial \pi_1}{\partial x_2}\frac{dx_2}{dK} = \frac{\pi^1_{x_2}\,\pi^2_{x_2 x_1}\,\pi^1_{x_1 K}}{|M|} \tag{3}$$

The second derivatives on the right hand side are to be interpreted in the obvious way, and $|M|$ is the determinant of the matrix of second derivatives. Consider a standard entry deterrence game of the sort discussed in section II.A.1. If in the equilibrium firm 1 chooses to (or has no choice but to) accommodate entry, then an equation with the structure of equation (2) determines the equilibrium choice of investment. The Fudenberg and Tirole classification combines the first and third terms on the right hand side of (3) in the following way.

$\pi^1_{x_2}\pi^1_{x_1 K} < 0$: investment makes you "tough". The effect of marginal investment by firm 1 is to lower the rival firm's profits, by inducing firm 1 to be more aggressive in the second period game.

$\pi^1_{x_2}\pi^1_{x_1 K} > 0$: investment makes you "soft". The effect of marginal investment by firm 1 increases the rival firms profits, by inducing firm 1 to be less aggressive in the second period game.

Finally, the centre term $\pi^2_{x_2x_1}$ determines whether the strategy choices x_1 and x_2, are strategic complements or strategic substitutes.

$$\pi^2_{x_2x_1} > 0: \quad \text{strategic complements}$$

$$\pi^2_{x_1x_2} < 0: \quad \text{strategic substitutes}$$

A classification of the possibilities for equilibrium investment is given in the table below.

Investment Strategies under Two Stage Competition
where Entry Accommodation is optimal

Investment makes you:

	"TOUGH"	"SOFT"
Strategic Complements	Underinvestment PUPPY DOG	Overinvestment FAT CAT
Strategic Substitutes	Overinvestment TOP DOG	Underinvestment LEAN AND HUNGRY LOOK

If firm 1 is able to deter the entry of firm 2, and finds this more profitable than the strategy of accommodation, the analysis is slightly different. Firm 1 know chooses K to maximize profits subject to the constraint of keeping the *post entry* profits of firm 2 non-positive. The constrained optimization can thus be written:

$$\max_K \quad \pi_1(x_1,K) + \lambda\pi_2(x_1(K),x_2(K))$$

where λ is a lagrange multiplier. The first order condition is:

$$\frac{\partial\pi_1}{\partial K} + \lambda\left[\frac{\partial\pi_2}{\partial x_1}\frac{dx_1}{dK} + \frac{\partial\pi_2}{\partial x_2}\frac{dx_2}{dK}\right] = 0 \qquad \textbf{(4)}$$

The last term vanishes from the envelope theorem. The first term inside the brackets is now the strategic term, i.e. the term capturing the strategic impact of investment, as compared to the non strategic effect of investment, captured by the first term. By working through the comparative statics once again, the second term can be rewritten:

$$-\lambda\pi^2_{x_1}\pi^2_{x_2x_2}\pi^1_{x_1K}$$

The first and third terms in the above expression are the same as in the accommodation case, but the second term is always negative. We can now classify outcomes in terms of investment in the deterrence case in the following table.

Investment Strategies under Two Stage Competition
where Entry Deterrence is optimal

Investment makes you:

	"TOUGH"	"SOFT"
Strategic Complements	Overinvestment TOP DOG	Underinvestment LEAN AND HUNGRY LOOK
Strategic Substitutes	Overinvestment TOP DOG	Underinvestment LEAN AND HUNGRY LOOK

The advantage of the Fudenberg-Tirole framework is that most of the simple two stage models of entry deterrence can be accommodated into it. For example, the capital commitment models of Dixit (1980) and Ware (1984), and the inventory model of Ware (1985) are all examples of top dog games (for equilibria involving both deterrence and accommodation). However, suppose that investment lowers *marginal costs* and second period competition is in prices (which are strategic complements); the type of equilibrium strategy depends on whether accommodation or deterrence is optimal. Deterrence still calls for the "top dog" strategy, because investment makes deterrence easier. If firm 2 is to be accommodated, however, firm 1 should underinvest (play a "puppy dog" strategy) because investment leads to a lower price for firm 1, and a response of a lower price from firm 2, which hurts firm 1.

Tirole[3] presents several interesting applications. For example, a simple model of entry in a differentiated market modelled on a line, can be thought of as a puppy dog game. Firms choose to locate as far apart as possible (this is underinvestment in location relative to locating at the centre of the product space) because this reduces the severity of price competition between them.

2.4 Entry Deterrence in Models with Incomplete Information

In the models we have described, sunk capital creates a link between the current actions of the incumbent and future actions in response to entry. i.e. sunk capital solves the Sylos paradox, of why pre-entry choices should mean anything to the entrant, and hence the incumbent, unable to influence the entrant's choice, will pursue short run profit maximization until entry actually occurs.

A second way of creating the link between today's actions and the profitability of entry is through *incomplete information*. The basic idea here is that the entrant may be less well informed than the incumbent about the industry environment, in some way which would influence the entrant's calculation of post-entry profits. Examples would be the incumbent's costs, the level of demand, even the elasticity of demand. The entrant may, however, attempt to infer the incumbent's cost level from his *pre-entry price*. This is

[3] Tirole (1988), pp. 328-336

the environment of a signalling model, where the incumbent knows that his pre-entry price will be a signal of his true costs, and hence of the profitability of entry. The natural equilibrium concept to use here is that of Bayesian Equilibrium, in which players update their prior beliefs according to Bayes' Law, and in equilibrium beliefs have to be consistent.

The classic paper here is Milgrom and Roberts (1982). In it they show that a monopolist facing the threat of entry, where both firm's costs are private information, will choose a price below the monopoly price corresponding to his actual costs. In effect, the monopoly attempts to signal a lower level of costs than he actually possesses, to encourage the entrant to revise downwards his estimate of post-entry profits. In a sense, their model, like the capital commitment style models, reintroduces a kind of limit pricing behaviour by the incumbent, in a rigorously specified model of equilibrium behaviour. To see that the full information monopoly price cannot be an equilibrium for the monopolist, consider a choice of p just below the monopoly price, ie the monopolist chooses $M(p) - \varepsilon$. From the envelope theorem we know that this will have no first order effect on the incumbent's profits, but the entrant will revise down his assessment of the incumbent's costs, which in turn will lower the probability of entry and the incumbent's profits by an amount which does not vanish to first order. Hence the incumbent will always pick a price below the monopoly price, which demonstrates, heuristically, the limit price result.[4]

Note also that under some circumstances the incumbent may wish to signal by

[4]Note this the equilibrium price in this model is not the Bain-Sylos-Modigliani Limit Price.

raising price. Two examples that have been examined are the case where a high elasticity of demand encourages entry, so that the incumbent will signal a low elasticity by raising price (Salop(1982)), and the case where the entrant does not know his own costs, in which case the incumbent will signal high costs with a high price.

3 MULTIPLE ENTRANTS, MODELS OF ENDOGENOUS MARKET STRUCTURE

The goal of a theory of entry deterrence is to increase our understanding of market structure. That is, strategic entry deterrence is an aspect of industry conduct which may be a determinant of market structure. The models of entry deterrence which we have discussed above restricted attention to the strategic interaction between a monopoly incumbent (or at least a collusive oligopoly) and a single entrant. Although this literature has generated considerable insight into strategic behaviour towards entry, the framework is very restrictive as a theory of market structure. First, the methodology is applicable only to markets containing at most two firms. Second, the assumption of a single potential entrant is quite artificial, and gives rise to misleading results. While a monopolist may choose to accommodate a single entrant rather than incur the costs of deterrence, accommodation is much less likely if further entry is possible. A principle similar to the pre-emption principle (discussed in section II.A.2) is at work here. If allowing entry simply leads to an equilibrium in which the former monopolist shares the market with one or more entrants, but the equilibrium price is the same as if the monopolist had deterred all entry, then the latter strategy is likely to be more profitable.

Only if entry deterrence is costly, and the costs can be shared with other entrants, would a monopolist voluntarily accommodate entry when it could be deterred.

In a framework of possible multiple entry, *market structure* becomes an endogenous property of the model, determined by interaction of strategic behaviour with the basic conditions of demand and technology. An interesting feature of equilibria with multiple entrants is that they tend to exhibit a *limit pricing* property not unlike the BSM model. To see this, consider a model in which firms enter in some arbitrary sequence and commit to quantities. Any configuration of entry production which deters further entry must involve a total production by the industry no smaller than the BSM limit output, otherwise entry would continue to occur. Thus, the equilibrium price can be no larger than the BSM limit price.

The sequential entry models offer some insight into market structure. In Eaton and Ware (1987), the equilibrium number firms is the smallest number that can deter the entry of an additional firm. While this is a fairly compelling idea, the result is driven by the assumption of Leontief costs, which implies that entry deterrence is not costly. In the models of Schwartz and Baumann (1988) and McClain and Riordan (1989), entry deterrence is costly, and the equilibrium may involve more than the minimum number of firms. Essentially, earlier entrants prefer to *delegate* the costs of entry deterrence to later entrants, even to the point of allowing more entry than is strictly necessary. In all of these models, profits typically decline with the order of entry i.e. the early entrants capture rents.[5]

In contrast to the two-firm game, investment in entry deterrence has a public good aspect in a multiple firm framework. Each firm's investment in entry deterrence will benefit all incumbent firms equally, but the costs must be incurred privately. Two features of this non-cooperative nature of investment in entry deterrence which have been discussed in other work are *delegation* and *underinvestment*.[6] Delegation refers to the incentive of early entrants in the sequence of investment not to do their full share of entry deterrence in the knowledge that later entrants will be forced to pick up the slack, because these later entrants have a strong incentive to deter further entry. Underinvestment occurs when this process of coordination breaks down, in a classic prisoner's dilemma fashion. As a result, the collective entry deterrence efforts of the incumbent firms, acting individually and non-cooperatively, amount to less than a jointly optimal amount of investment, based on cooperative investment decisions. Gilbert and Vives (1986) and Waldman (1989) have shown that whether or not underinvestment occurs depends on the discrete nature of the investment requirement for entry deterrence, as well as on the importance of the positioning aspect of investment.

[5]Although Eaton and Ware show that exceptions are possible, because the last entrant can credibly threaten earlier entrants with a sharply lower price if they try to increase their market share (Eaton and Ware (1987) pp 12-13)

[6]See Gilbert and Vives(1986), Maclean and Riordan (1989), Waldman (1985) and (1989), and Tirole(1988).

IV. CONTRACTS AS A BARRIER TO ENTRY

Not all entry deterrence requires a real investment to make it credible. The signing of a *long term contract* can have the effect of excluding entry. Aghion and Bolton (1987) offer an interesting example of a contract between a monopoly supplier and a single customer, which excludes a low cost entrant in a way which is socially inefficient. The incumbent's costs equal ½, whereas the entrant's are unknown to the consumer and supplier at the time of contract signing, but both have a common prior distribution which is uniform on [0,1]. Clearly, efficiency requires that the entrant produce whenever its realised costs are less than ½. Aghion and Bolton show that it is in the interest of the incumbent and customer to sign a contract of the form (P,P_O), where P is the price if the customer buys, and P_O is a penalty for breach, if the customer chooses to buy from the entrant. Suppose $(P,P_O) = (3/4, 1/2)$. The entrant can only compete with a cost realisation less than $1/4$, but it is easy to show that the incumbent is better off, and the customer no worse off, with this contract than with no contract, in which case the entrant would enter with costs less than or equal to $1/2$, but Bertrand pricing would keep the price equal to $1/2$.

Aghion and Bolton refer to the Brown Shoe case in U.S. antitrust law, and the commentary of Bork (1978), who argued that customers would never sign contracts which excluded low cost entry, if it were not in there own interest. Although this model does have a somewhat contrived structure (negotiation between the entrant and customer is precluded, for example) it does serve as a reminder that, with imperfect competition, there is no particular reason to expect private contracts to be socially efficient.

V. CONCLUSIONS

Parallel to the development of more sophisticated theories of strategic behaviour and market performance over the past two decades, has been a lively debate about the meaning and importance of the concept of entry barriers. The debate has ranged from a somewhat semantic discussion of the appropriate definition of entry barriers Bain (1968), Stigler(1968), Von Wiezsacker (1980)) to a more fundamental debate as to whether the concept is useful at all (Demsetz (1982), Gilbert (1989), Dick and Lott(1990)).

At the risk of misinterpretation, the extreme Chicago position, (which is held vociferously, perhaps only by scholars at UCLA) seems to be that the only entry barriers are those that are created by government regulation. The total costs of any firm in an industry, including those with unique *production* advantages, are the same if the asset which confers the advantage is properly capitalized into costs. These costs are also shared identically by any potential entrant who can always contemplate purchasing an incumbent firm.

While this debate is important, it deflects attention from the issues which are most relevant for policy. In short - when is market structure efficient, and when is it inefficient? None of the protagonists in these definitional debates would deny that strategic behaviour could potentially have adverse efficiency consequences (although they would differ widely as to the magnitude of the effects). An answer to this question requires a positive analysis of the development of market structure, together with a normative interpretation, and a further analysis of the scope for policy. The study of strategic entry deterrence, which I have surveyed in this chapter, is an important plank in this research agenda.

REFERENCES

Aghion, P. and Bolton, P. (1987) "Contracts as a barrier to entry", *American Economic Review*, 77:388-401

Arvan, L. (1985) "Some examples of dynamic Cournot duopoly with inventory", *The Rand Journal of Economics*, 16:569-578.

Bain, J. (1949) "A note on pricing in monopoly and oligopoly", *American Economic Review*, 39:448-464

Bain, J. (1956) *Barriers to new competition*, Cambridge: Harvard University Press.

Bain, J. (1968) *Industrial Organization*, New York: Wiley.

Barham, B. and Ware, R. (1990) "Excess Capacity, Entry Deterrence, and Market Structure: A Note", mimeo, University of Toronto.

Brander, J.A. and Spencer, B. (1983) "Strategic commitment with R&D: The symmetric case", *Bell Journal of Economics*, 14:225-235.

Dick, A.R. and Lott, J. (1990) "The role of potential competition in industrial organization: comment", *Journal of Economic Perspectives*, 4:213-215.

Demsetz, H. (1982) "Barriers to Entry", *American Economic Review*, 72:47-57.

Dixit, A.K. (1980) "The role of investment in entry deterrence", *Economic Journal*, 90:95 -106.

Eaton, B.C. and Lipsey R.G. (1979) "The theory of market preemption: The persistence of excess capacity and minopoly in growing spatial markets", *Economica*, 46:149-158.

Eaton, B..C. and Lipsey, R.G. (1980) "Exit barriers are entry barriers: The durability of capital as a barrier to entry", *Bell Journal of Economics and Management Science*, 11:721-729.

Eaton, B.C. and Lipsey, R.G. (1981) "Captial, commitment and entry equilibrium", *Bell Journal of Economics and Management Science*, 12:593-604.

Eaton B.C., and Ware, R. (1987) "A theory of market structure with sequential entry", *Rand Journal of Economics*, 18:1-16.

Farrell, J. and Saloner, G. (1985) "Standardization, compatibility and innovation", *The Rand Journal of Economics*, 16:70-83.

Farrell, J. and Saloner, G. (1986a) "Standardization and Variety", *Economic Letters*, 20:71-74.

Farrell, J. and Saloner, G. (1986b) "Installed Base and Compatibility: Innovation, Product Preannouncements, and Predation", *American Economic Review*, 76:940-955.

Fudenberg, D. and Tirole, J. (1984) "The fat-cat effect, the puppy-dog ploy, and the lean and hungry look", *American Economic Review Papers and Proceedings*, 74:361-366.

Gaskins, D. (1971) "Dynamic limit pricing: Optimal pricing under threat of entry", *Journal of Economic Theory*, 2:306-322.

Geroski, P., Gilbert, R. and Jacquemin, A. "Barriers to entry and strategic competition", in: J. Lesourne and H. Sonnenschein, eds., *Fundamentals of pure and applied economics*. New York: Harwood.

Gilbert, R. (1989) "Mobility barriers and the value of incumbency", in H. Sonnenschein and R. Willig, eds. *Handbook of Industrial Organization*. New York: North Holland.

Gilbert, R. (1989) "The role of potential competition in industrial organization", *Journal of Economic Perspectives*

Gilbert, R. and Newbery, D. (1982) "Preempting patenting and the persistence of monopoly", *American Economic Review*, 72:514-526.

Gilbert, R., and Vives, X. (1986). "Entry deterrence and the free rider problem." *Review of Economic Studies*, 53:71-83.

Katz, M. and Shapiro, C. (1985) "Network externalities, Competition, and Compatibility", *American Economic Review*, 75:424-440.

Katz, M. and Shapiro, C. (1986), "Technology adoption in the presence of network externalities", *Journal of Political Economy*, 94:822-841.

Lieberman, M. (1984) "The learning curve and pricing in the chemical processing industries", *The Rand Journal of Economics*, 15:213:228.

McLean, R., and Riordan, M. (1989). "Equilibrium industry Structure with sequential Technology Choice, *Journal of Economic Theory.*

Milgrom, P. and Roberts, J. "Limit pricing and entry under incomplete information: an equilibrium analysis", *Econometrica*, 50:443-459.

Modigliani, F. (1958) "New developments on the oligopoly front", *Journal of Political Economy*, 66:215-232

Salop, S. and Scheffman, D. (1983) "Raising rivals' costs", *American Economic Review*, 73:267-271.

Salop, S. and Scheffman, D. (1986) "Cost-raising strategies", working paper no. 146, Federal Trade Commission, Bureau of Economics.

Schelling, T. (1960) *The strategy of conflict*. Cambridge, Mass.: Harvard University Press

Schwartz, M., and Baumann, M. (1986). "Entry-deterrence externalities and relative firm size." *International Journal of Industrial Organization*, 6:181-197.

Spence, A.M. (1977) "Entry, capacity, investment and oligopolistic pricing", *Bell Journal of Economics*, 8:534-544.

Stigler, G. (1968) *The organization of industry*, Homewood, Ill.:Richard D. Irwin, Inc.

Sylos-Labini, P. (1962) *Oligopoly and technical progress*. Cambridge, Mass.: Harvard University Press

Tirole, J. (1988) *The theory of industrial organization*, Cambridge: MIT press.

Von Weizacker, C. (1980) "A welfare analysis of barriers to entry", *Bell Journal of Economics and Management Science*, 11:399-420.

Waldman, M., (1987). "Non-Cooperative Entry Deterrence, Uncertainty and the Free Rider Problem." *Review of Economic Studies*, 51:301-310.

Ware, R. (1984) "Sunk costs and strategic commitment: a proposed three stage equilibrium", *Economic Journal* 94:370-378.

Ware, R. (1985) "Inventory holding as a strategic weapon to deter entry" *Economica*, 52:93-102.

Wenders, J. (1971) "Excess capacity as a barrier to entry", *Journal of Industrial Economics*, 20:14-19

West, D. (1982) "Testing for market preemption using sequential location data", *Bell Journal of Economics and Management Science*, 12:129-43.

Williamson, O. (1968) ""'Wage rates as barriers to entry: The Pennington case in perspective", *Quarterly Journal of Economics*, 85:85-116.

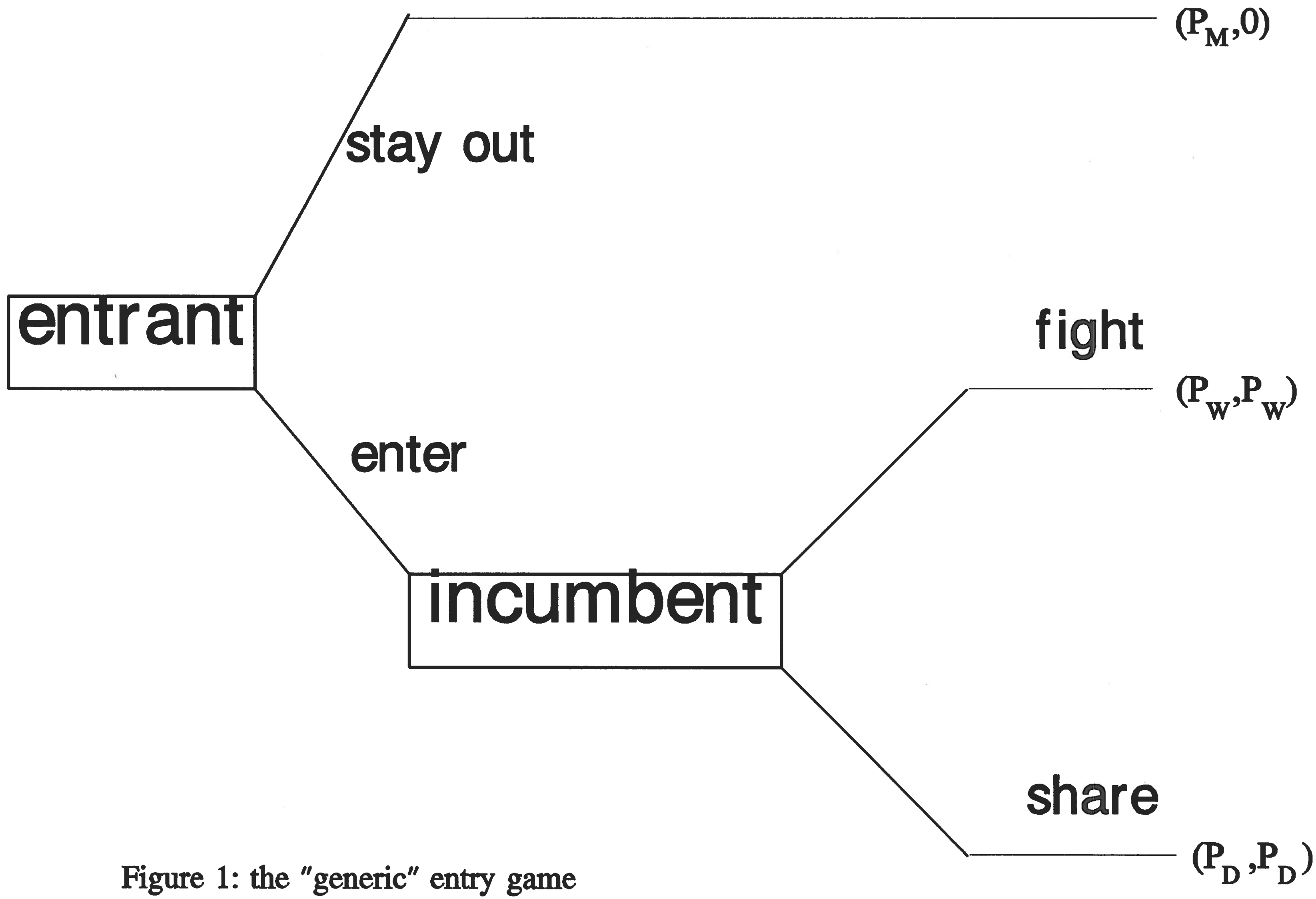

Figure 1: the "generic" entry game

Payoffs: (incumbent, entrant) where $P_M > P_D > 0 > P_W$

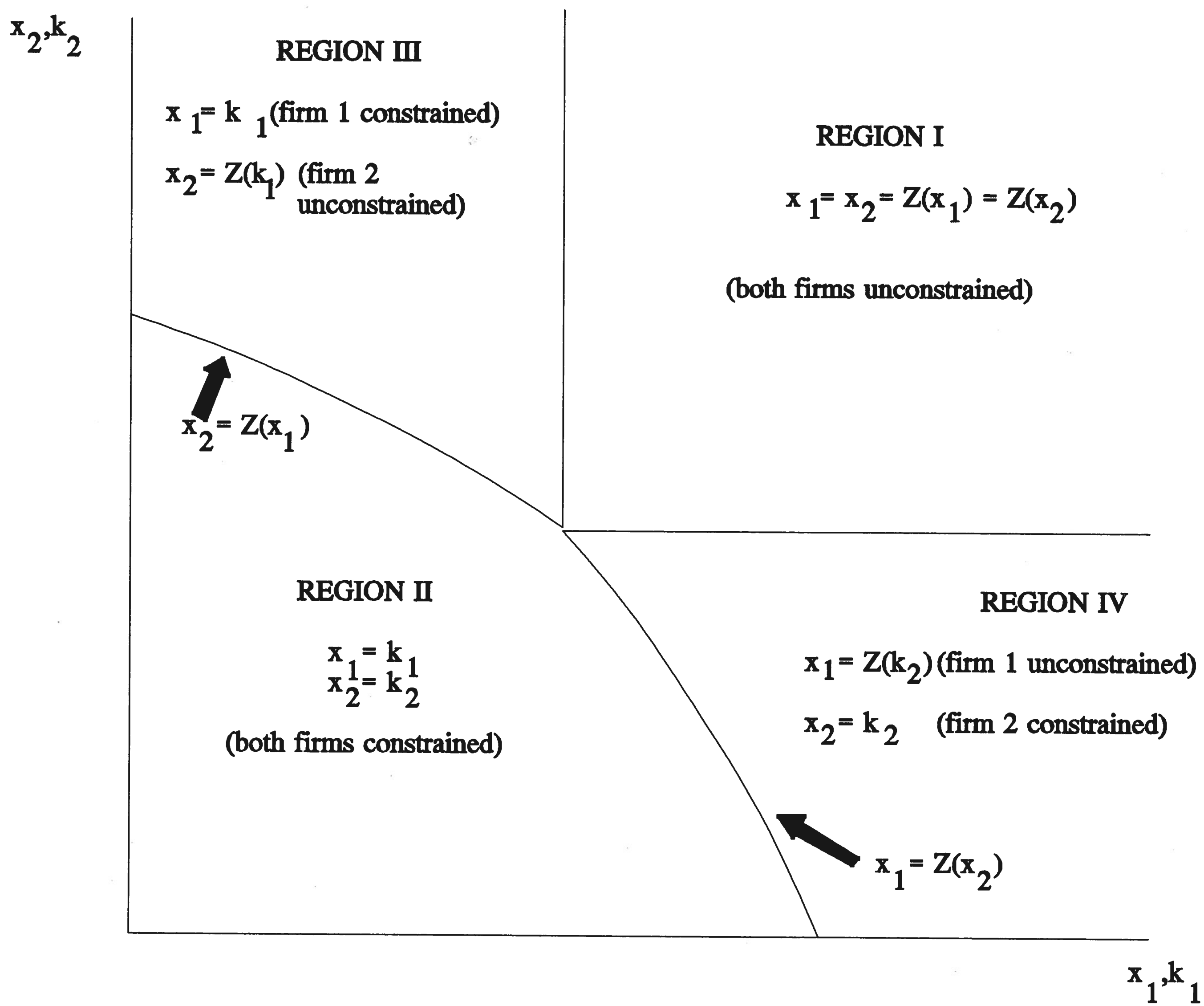

Figure 2: The four phases of constrained cournot equlibrium for duopoly

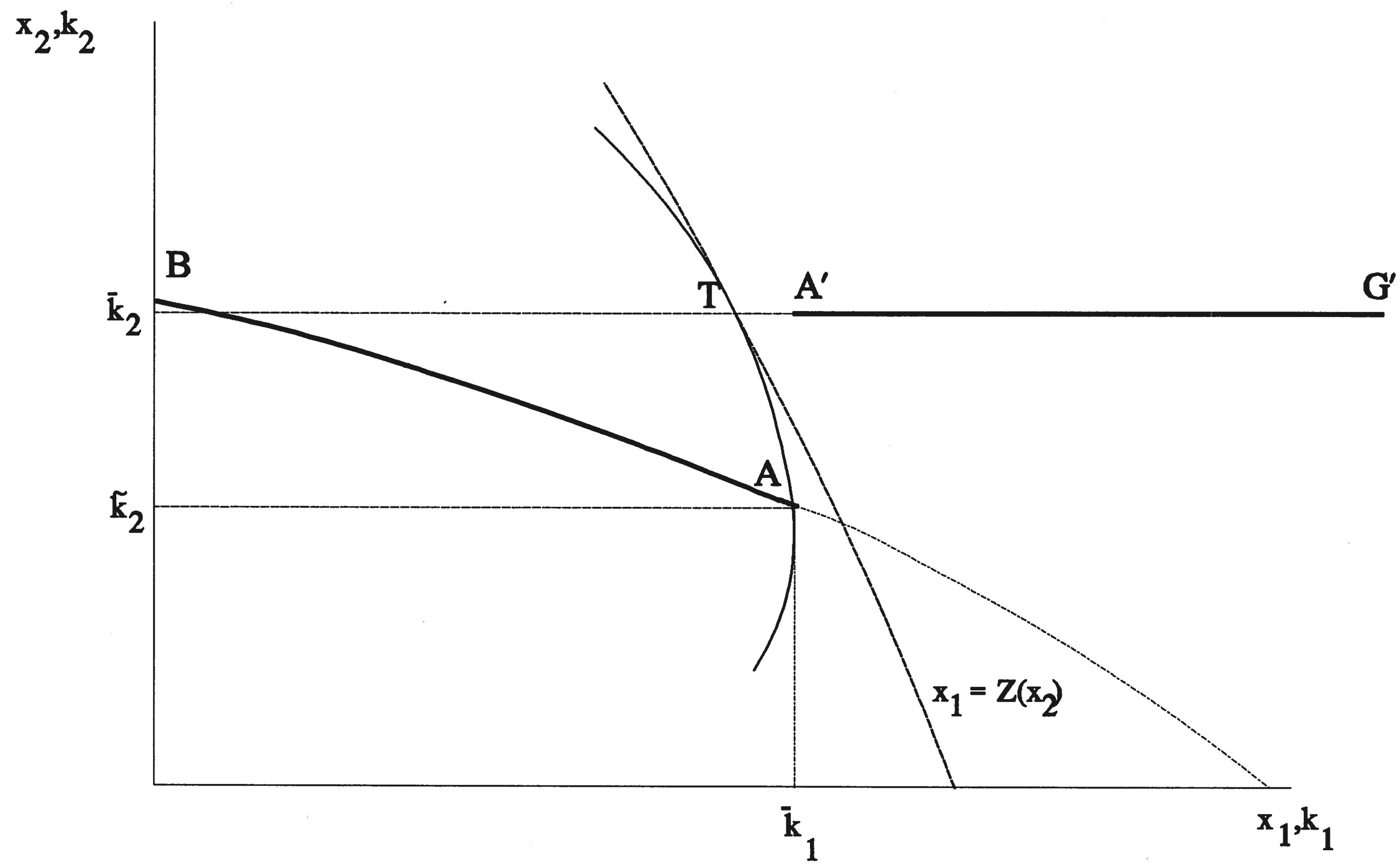

Figure 3: Firm 2's reaction correspondence