Exit barriers are entry barriers: the durability of capital as a barrier to entry

B. Curtis Eaton*

and

Richard G. Lipsey**

We argue that the effectiveness of capital as an entry barrier depends critically on its durability and that this aspect of capital has been largely ignored. We examine strategic decisions with respect to capital durability in two models. In a broad range of cases an active policy with respect to durability and replacement of capital is necessary to maintain a position of market power. Such policies will result in capital that is "too durable" or "too soon replaced" or "too well maintained" relative to the cost minimizing solution (for a given time path of output).

1. Introduction

■ In his seminal essay on bargaining, Thomas Schelling (1956) distinguishes threats and commitments. Both are designed to influence a competitor by impressing him with the consequences of his actions. Both take the same form: "If you take action X, I shall take action Y, which will make you regret X." The distinguishing characteristic of a threat is that the actor has no incentive to carry out action Y either before or after action X. The distinguishing characteristic of a commitment is that, X having occurred, it is in the actor's self-interest to take action Y. A fanatic may carry out a threat, and may thus make "credible threats." A maximizer would not carry out his threats and thus cannot make his threats credible. There would seem, therefore, to be little place for threats in maximizing models.

In this paper we examine the use of product-specific capital goods as vehicles for entry-deterring *commitments*. It may seem surprising that there is anything left to say on this subject in view of such works as Caves and Porter (1977), Dixit (1979, 1980), Eaton and Lipsey (1978, 1979), Schmalensee (1978), and Spence (1977, 1979). These papers deal, however, with what may be called the atemporal aspect of capital as a barrier to entry: a monopolist strategically commits a quantity of capital which is sufficient to produce a negative *flow* of profits to a new entrant. This may be called a *type-A artificial monopoly* (*A*

---

* University of British Columbia and Yale University.

** Queen's University and Yale University.

This is a shortened version of Eaton and Lipsey (1980), in which proofs may be found of results asserted in the present article. We are indebted to G. C. Archibald, Y. Kanemoto, and J. Roemer for comments and suggestions.

for "atemporal"). *Type-A natural monopoly* occurs when nonstrategic profit-maximizing behavior commits enough capital to produce a negative flow of profits to an entrant. Capital indivisibilities and decreasing costs are at the heart of this analysis. One firm can profitably serve such a market but two cannot.

The point of this paper is that it is not indivisibilities and decreasing costs *per se* which create barriers to entry. Rather, it is the intertemporal commitment of specific capital to a market, in combination with decreasing costs which creates an entry barrier. We thus focus on the durability of capital in the creation of entry barriers. We define a *type-T natural monopoly* (T for "temporal") to be one in which *cost minimizing* decisions with respect to durability, replacement, and maintenance of capital imply that there is no point in time at which entry is profitable, and a *type-T artificial monopoly* to be one in which *strategic decisions* with respect to capital prevent there being any point in time at which entry is profitable.

To see the potential importance of durability as an entry barrier, first consider two extreme cases under static demand and cost conditions. At one extreme is a type-A natural monopolist who has no sunk costs. (This would arise, for example, if capital were not product-specific and could be bought, sold, and rented on perfect markets.) Although only one firm can serve this market profitably, there exists no vehicle for commitment to the market. With no sunk costs the market is "up for grabs" at each instant. The absence of capital fixity and associated fixed costs thus seems to imply chaos. At the other extreme, the durability of capital (plant) is exogenous and infinite. Now a type-A natural monopolist has a permanent commitment to the market: as long as he can cover his avoidable costs he will remain in the market. As a result, he need never consider the possibility of the entry of new firms.

Second, consider the intermediate case in which a type-A natural monopolist's plant has an exogenous and finite durability, $0 < H < \infty$. When unconcerned about entry, the monopolist replaces his plant every H years. But a potential new entrant could establish plant just as the monopolist was about to renew his plant. The market would then belong to the new entrant. But foreseeing that strategy, the existing monopolist would renew his plant a little sooner. But foreseeing this, a potential new entrant would establish his plant sooner yet, and so on. In this case it is clear that the type-A natural monopolist must concern himself with the threat of entry; he is not a type-T natural monopolist.

In this article we study the strategic use of capital to create a type-T artificial monopoly. It is useful in analytical studies to separate strategic decisions with respect to the creation of the two types of monopoly. To isolate the creation of type-A artificial monopoly, it is convenient to assume type-T *natural* monopoly by letting the durability of capital be infinite (Spence, 1979; Dixit, 1980). Similarly, to isolate the creation of type-T artificial monopoly, it is convenient in this article to assume a type-A *natural* monopoly. (Our results extend in a fairly obvious way to a firm that has erected entry barriers to create a type-A artificial monopoly as well as to oligopolists who wish to maintain their place in the market.)

Our analysis shows that the textbook, type-A natural monopoly is not necessarily a type-T natural monopoly and that it is impossible for the monopolist to separate cost-minimizing decisions from profit-maximizing ones.

This results because capital produces a revenue to the firm by acting both as a factor of production and as a barrier to entry.

2. Model 1: one-hoss shay capital

■ The basic assumptions of model 1 are as follows. There is an indivisible, product-specific capital good, called plant, which is large enough that a monopolist would require only one unit of it. There are constant returns to the variable factor up to plant capacity.

If there were two firms in the market, each with one unit of plant, their common capacity and common short-run marginal costs would imply a symmetric resolution of the duopoly problem. The symmetric resolution might be Cournot-Nash, or it might be based on some conjectural-variation formulation. Indeed any symmetric resolution will allow us to define what we require: R_1 *is the rate of flow of revenues over variable costs when one firm serves the market;* R_2 *is the rate of flow of revenues over variable costs for either firm when two firms serve the market*. We assume that R_1 and R_2 are time invariant, that firms know them with certainty, and that $R_1 > 2R_2 > 0$. These inequalities imply that the resolution of the duopoly pricing problem is not joint profit maximizing and that duopolists cover variable costs.

In model 1 plant of durability H costs $C(H)$ and requires no maintenance. We assume that

$$\lim_{H\to 0} C(H) > 0, \qquad C'(H) > 0, \qquad \text{and} \qquad C''(H) \geq 0 \text{ for } H > \hat{H}. \tag{1}$$

These restrictions guarantee that H will always be chosen to be positive and finite. The deterioration of this "one-hoss shay" capital depends on its age and is independent of intensity of use. Since R_2 is positive, a firm which has plant is committed (in Schelling's sense of the word) to stay in the market until its plant expires.

If a monopolist replaced plant of durability H every $H - \Delta$ periods, its minimum commitment to the market would be Δ. The discounted present value of this policy to a monopolist would be

$$V(\Delta,H) = \frac{R_1}{r} - \frac{C(H)}{1 - \exp[-r(H - \Delta)]} . \tag{2}$$

It is, of course, Δ that is the deterrent to entry and, given Δ, H will be chosen to maximize profits. Define

$$\tilde{V}(\Delta) = \frac{R_1}{r} - \frac{C(h(\Delta))}{1 - \exp[-r(h(\Delta) - \Delta)]} , \tag{3}$$

where $h(\Delta)$ is the profit-maximizing (or cost-minimizing) value of H, given Δ. It can be shown that $h'(\Delta) > 0$. Let $\bar{H} = h(0)$. Type-A natural monopoly requires that

$$\tilde{V}(0) = \frac{R_1}{r} - \frac{C(\bar{H})}{1 - \exp[-r\bar{H}]} > 0 > \frac{R_1}{2r} - \frac{C(\bar{H})}{1 - \exp[-r\bar{H}]} . \tag{4}$$

The first inequality implies that one firm could more than cover costs and the second implies that two could not.

We assume that entry will occur if and only if the discounted present value of an entrant's profits is greater than zero, and thus we adopt the following definitions. An entry-preventing policy (EPP) is a policy such that the discounted present value of an entrant's profits is always less than or equal to zero. An optimal, entry-preventing policy (OEPP) is an EPP that maximizes the monopolist's present value evaluated at any point in time when he is replacing his plant.

To provide an intuitive explanation of the problem we *assume* that an OEPP exists, denoted by Δ^*, and that potential entrants consider only this policy. Subsequently we show directly the existence of an OEPP with $0 < \Delta^* < h(\Delta^*)/2$. The present value of an entrant's pursuing policy Δ^* is

$$E(\delta,\Delta^*) = -C(h(\Delta^*)) + R_2 \int_0^{\delta} \exp[-rt]dt + R_1 \int_{\delta}^{h(\Delta^*)-\Delta^*} \exp[-rt]dt + V(\Delta^*) \exp[-r(h(\Delta^*) - \Delta^*)],$$

where δ is the length of time until the sitting monopolist's plant expires. To interpret this expression let the origin in time be the time of entry. The entrant's initial plant would cost $C(h(\Delta^*))$ and he would earn R_2 from time 0 to δ. Since Δ^* is, by assumption, an EPP, the sitting monopolist would not renew plant and entry would be deterred at all future times. Thus the entrant would earn R_1 from δ to $h(\Delta^*) - \Delta^*$ at which time he would renew his plant and his present value would be $V(\Delta^*)$. $E(\delta,\Delta^*)$ can be rewritten as

$$E(\delta,\Delta^*) = \tilde{V}(\Delta^*) - (R_1 - R_2) \int_0^{\delta} \exp[-rt]dt. \tag{5}$$

The second term is the new entrant's "price of admission": the difference between profits when the market is served by two firms rather than one firm for the length of time until the sitting monopolist exits. This is also, of course, the measure of the barrier to entry at any point in time. Let Δ be the sitting monopolist's policy. Then

$$E(\Delta,\Delta^*) = \max_{\delta} E(\delta,\Delta^*) = \tilde{V}(\Delta^*) - (R_1 - R_2) \int_0^{\Delta} \exp[-rt]dt, \tag{6}$$

which is the maximum present value of an entrant.

Thus the monopolist's problem is

$$\left.\begin{aligned} &\max_{\Delta} \tilde{V}(\Delta) \\ \text{subject to} \quad &E(\Delta,\Delta^*) \leq 0. \end{aligned}\right\} \tag{7}$$

Both $\tilde{V}(\Delta)$ and $E(\Delta,\Delta^*)$ are decreasing in Δ, and thus the maximization problem posed in (7) is solved by finding $\bar{\Delta}$ such that $E(\bar{\Delta},\Delta^*) = 0$. But Δ^* is an OEPP by assumption and thus $\bar{\Delta} = \Delta^*$. So, if it exists, Δ^* must satisfy $E(\Delta^*,\Delta^*) = 0$. $E(0,0) = \tilde{V}(0)$, which is positive by the first inequality in (4). $E(\Delta,\Delta)$ is decreasing in Δ and goes to $-\infty$ as Δ goes to ∞. Thus, there exists a unique $\Delta^* > 0$ such that $E(\Delta^*,\Delta^*) = 0$. It can be shown that the second inequality in (4) implies that $\Delta^* < h(\Delta^*)/2$. Intuitively, if Δ^* were greater than $h(\Delta^*)/2$, costs of plant would exceed the costs of having two units of plant in the market at all times, which could not be profitable, given our definition of natural monopoly.

At the outset we assumed existence of Δ^*, and thus the argument above is only an intuitive argument. We can however use the result that Δ^* is the unique value of Δ such that $E(\Delta,\Delta)$ is equal to zero to show directly that Δ^* is the unique OEPP. Note first that $E(\Delta_m,\Delta_e)$ is the maximum present value of an entrant with policy Δ_e, if Δ_e is an EPP, when the sitting monopolist's policy is Δ_m. Note that the first derivatives of E with respect to Δ_m and Δ_e are negative. We use a proof by contradiction to demonstrate that Δ^* is the unique OEPP.

Proof: (i) Assume $\Delta_1 < \Delta^*$ is an EPP and that the sitting monopolist's policy is Δ_1. Then, since Δ_1 is an EPP, $E(\Delta_1,\Delta_1) \leq 0$, otherwise an entrant adopting policy Δ_1 would not be deterred. But we have shown that for $\Delta_1 < \Delta^*, E(\Delta_1,\Delta_1) > 0$, which contradicts our assumption that Δ_1 is an EPP. Thus $\Delta_1 < \Delta^*$ is not an EPP. (ii) Now assume that Δ^* is not an EPP and that the sitting monopolist's policy is Δ^*. Since Δ^* is not an EPP, there exists an EPP, Δ_2, such that $E(\Delta^*,\Delta_2) > 0$. But since $E(\Delta^*,\Delta^*) = 0$ and E is decreasing in its second argument, $\Delta_2 < \Delta^*$. But, by the argument in (i), $\Delta_2 < \Delta^*$ cannot be an EPP, a contradiction. Thus Δ^* is an EPP.[1] (iii) The argument in (ii) implies that any policy, $\Delta > \Delta^*$, is an EPP. But since $\tilde{V}(\Delta)$ is decreasing in Δ, Δ^* is the unique OEPP. *Q.E.D.*

For completeness we must show that the monopolist prefers the OEPP to the policy of "graceful exit": allowing entry to occur and then exiting when his plant expires. In the absence of entry prevention, entry would occur $\Delta^* - \epsilon$ periods before the sitting monopolist's plant expired, where ϵ is arbitrarily small. As ϵ goes to zero, the present value of graceful exit approaches

$$G(\Delta^*) = R_2 \int_0^{\Delta^*} \exp[-rt]dt > 0. \tag{8}$$

Note that

$$\tilde{V}(\Delta^*) - E(\Delta^*,\Delta^*) = (R_1 - R_2) \int_0^{\Delta^*} \exp[-rt]dt.$$

But since $E(\Delta^*,\Delta^*) = 0$, we have

$$\tilde{V}(\Delta^*) = (R_1 - R_2) \int_0^{\Delta^*} \exp[-rt]dt, \tag{9}$$

and since $R_1 > 2R_2$, we have $V(\Delta^*) > G(\Delta^*) > 0$.

We have shown in model 1 that an active policy of entry prevention is necessary—that type-*A* natural monopoly does not imply type-*T* natural monopoly—and that this strategy is profitable. Protecting this monopoly position involves the dissipation of monopoly rents and is wasteful of scarce resources, since the monopolist replaces plant before it is economically obsolete. The dissipation of monopoly rents through early replacement of capital and the resulting resource waste will be smaller the stronger is duopoly price competition, and the smaller are the monopoly profits (*ceteris paribus* the smaller is

[1] This argument assumes that the entrant considers only entry-preventing policies. We show in Eaton and Lipsey (1980), footnote 2, that nonentry-preventing strategies are never profitable.

R_2 or R_1). Regulation that reduces monopoly profits may thus reduce the social waste analyzed in this paper.

Since $\Delta^* > 0$ and $h'(\Delta) > 0$, it follows that $h(\Delta^*) > \bar{H}$. In other words, the strategy of entry deterrence leads the monopolist to choose plant which is more durable than the cost-minimizing durability. This result does not reflect an additional burden since, given Δ^*, durability is chosen to minimize costs.

3. Model 2: maintaining plant

■ In model 2 we assume that plant costs K, $K > 0$, and that maintenance costs, m, are a convex function of age of plant, a:

$$m = g(a), \qquad g'(a) > 0, \qquad g''(a) \geq 0. \tag{10}$$

Notice that we have three categories of costs in this model: sunk costs of plant; costs of maintaining plant which are avoidable only by not producing and which are invariant with respect to output; and the constant marginal costs of production. Define $C(S)$ to be the discounted present cost of a new plant over a service life of S periods. Then

$$C(S) = K + \int_0^S g(a) \exp[-ra]da. \tag{11}$$

The restrictions on $g(a)$ imply that $C'(S) > 0$ and $C''(S) > 0$.

$C(S)$ satisfies the restrictions on the cost function in model 1, and it follows immediately that the monopolist could create a minimum commitment to the market, Δ, by replacing plant, *with a prepaid maintenance contract of S periods*, every $S - \Delta$ periods. By analogy with model 1 there exists a Δ^* which maximizes profits, subject to entry's being unprofitable. Further, it is easily demonstrated that the optimal service life associated with Δ^* is less than the cost-minimizing service life, so that plant is replaced before its economic life is over.

Our purpose in model 2 is to explore another entry-preventing strategy when plant is maintainable. Accordingly, define S to be the policy of replacing plant every S periods. The present value to a monopolist of this policy is

$$V(S) = \frac{R_1}{r} - \frac{C(S)}{1 - \exp[-rS]}. \tag{12}$$

$V(S)$ is pseudoconcave in S, decreases without bound as S goes to zero and as S goes to infinity, and therefore has a unique maximum.[2] Let $\bar{S}$ be the value of S which maximizes $V(S)$.

We wish to argue that, in the event of entry, the sitting monopolist would stay in the market until his maintenance costs rose to R_2. We argue as follows: if $g(a)$ were less than R_2, and if the monopolist paid $g(a)$, then he and the entrant would face identical avoidable costs, the resolution of the duopoly problem would be symmetric, and the monopolist would enjoy the flow R_2; therefore, the monopolist will incur the maintenance costs if and only if $g(a) \leq R_2$. Alternatively, in the event of entry the monopolist could sign a binding maintenance contract with a third party, and his avoidable costs would then be just

[2] Pseudoconcavity of $V(S)$ requires that when $V'(S) = 0$, $V''(S) < 0$, which is easily verified. See Diewert, Avriel, and Zang (1977) for a useful taxonomy of concavity.

the marginal costs of production. An optimal maintenance contract would run until $g(a) = R_2$.

Let A be the age of plant such that $g(A) = R_2$. Then if the monopolist chooses a policy $S \leq A$, his minimum commitment to the market is $A - S$. If he chooses $S > A$, his minimum commitment to the market is zero.

Then we seek the existence of a policy S^* which solves

$$\left.\begin{aligned} &\max_S V(S) \\ \text{subject to} \quad & \\ &E(S,S^*) \leq 0, \end{aligned}\right\} \tag{13}$$

where

$$E(S,S^*) = \begin{cases} V(S^*) - (R_1 - R_2) \displaystyle\int_0^{A-S} \exp[-rt]dt, & \text{if} \quad S \leq A, \\ V(S^*), & \text{if} \quad S > A. \end{cases} \tag{14}$$

$E(S,S^*)$ is interpreted as the present value of an entrant's pursuing policy S^* when the monopolist's policy is S.

Several cases require attention. First, suppose the monopolist adopts policy $\bar{S}$. It is clear from (14) that if A is large enough relative to $\bar{S}$, the monopolist need not pursue an active policy of entry prevention. Let $\bar{A}$ be the value of A in (14) such that $E(\bar{S},\bar{S}) = 0$. Then, if $A \geq \bar{A}$, $S^* = \bar{S}$, and entry prevention is costless. This is a case of type-T natural monopoly.

Denote by S_1 and S_2 the minimum and maximum values of S such that $V(S) = 0$. Pseudoconcavity of $V(S)$ then implies that $V(S) > 0$ in the open interval (S_1,S_2) and $V(S) < 0$ for $S < S_1$ and for $S > S_2$. When $A \leq S_1$, the constraint in (13) cannot be satisfied in the profitable range of production. Thus $S^* = S_1$ and $S^* = S_2$ are the only solutions to the problem posed in (13) and $V(S^*) = 0$. In this case it is clear that the use of a prepaid maintenance contract to deter entry is the preferred strategy.

Finally, consider the case when $S_1 < A < \bar{A}$. $E(S_1,S_1) < 0$, since $S_1 < A$, and $E(\bar{S},\bar{S}) > 0$, since $A < \bar{A}$. Both $V(S)$ and $E(S,S^*)$ are increasing in S when $S_1 < S < \bar{S}$, and thus S^* must satisfy $E(S^*,S^*) = 0$. Since $E(S,S)$ is increasing in S in this interval, there exists a unique S^*, $S_1 < S^* < \bar{S}$ such that $E(S^*,S^*) = 0$. An argument parallel to that in model 1 shows that S^* is the unique OEPP. Since $S^* < \bar{S}$, plant is replaced before its economically useful life is over.

We have shown that when plant is maintainable, there exist circumstances where entry deterrence is costless, the case of type-T natural monopoly. When an active policy of entry deterrence is necessary, the monopolist has two options, both of which require the replacement of plant before its economically useful life is over. Since a potential entrant has the same options, the monopolist must choose the more profitable option.

4. Conclusions

■ Our analysis suggests a need for revision of the concept of natural monopoly. A fully insulated natural monopoly must have both type-A and type-T natural monopoly. If it has only the former, it may be able to use specific capital to create a type-T artificial monopoly.

Profit maximization does not imply cost minimization in our models. Thus, when one is considering the creation of artificial barriers to entry, taking minimized costs as a primitive can be misleading. Product-specific capital is a natural vehicle for commitment, and firms who so use it will violate cost minimization.

It may be useful to consider the argument that a successful entry-preventing strategy must be based on commitment, not threat, in the context of the creation of a type-T monopoly. To make an entry-deterring threat in model 1, the sitting monopolist must threaten that in the event of entry, he will stay in the market *long enough* that the entrant's present value at time of entry will be nonpositive. "Long enough" is Δ^* periods. If the sitting monopolist's plant has at least Δ^* periods of remaining economic life, then the threat is a commitment, because the sitting monopolist's plant can more than cover its variable costs. If his plant has less than Δ^* periods of remaining economic life, the threat is not a commitment: fulfilling it would require building new plant at a time when it promises a negative present value. Δ^* can be interpreted as the monopolist's minimum commitment to the market or as the minimum *barrier to his exit*. It is in this sense that barriers to exit are barriers to entry.

The intuitive appeal of our results suggests to us that they will survive generalization of our assumptions with respect to capital. Two obvious possibilities are capital that decays exponentially or capital that decays only with use. Specific capital is a natural vehicle for commitment to the market, and commitment is valuable to the firm, since it inhibits entry. Accordingly a profit-maximizing firm will choose the specifications of specific capital (its durability and/or time of replacement and/or level of maintenance, etc.), so that marginal cost is equal to a positive marginal value in inhibiting entry. This choice will often result in specific capital that is "too durable" or "too soon replaced" or "too well maintained" relative to the unconstrained cost-minimizing solution.

The entry-deterring strategies that we have analyzed would be relatively easy to detect in a world of static demand and technology. They would, however, be much harder to detect in the real world of changing demand and technology. The entry-preventing firm may then appear as the "alert" firm, establishing capacity to meet growing demand, and as the "progressive" firm, investing early in new technologies.

Application to policy is clearly premature. The purpose of this article is to reveal a gap in our present theories of natural and artificial monopoly. To do this we use stark concepts of capital. At a minimum, analysis of more "realistic" assumptions with respect to capital and corroborating empirical work are necessary before the social waste that occurs in our models can be held to be likely and/or significant. In this context it is important to note that although waste of capital always occurs in model 1, it may be unnecessary in model 2.[3]

References

Caves, R.E. and Porter, M.E. "Barriers to Exit" in R.T. Masson and P.D. Qualls, eds., *Essays on Industrial Organization in Honor of Joe S. Bain*, Cambridge: Ballinger, 1976.

——— and ———. "From Entry Barriers to Mobility Barriers: Conjectural Decisions and Contrived Deterrence to New Competition." *Quarterly Journal of Economics* (May 1977), pp. 241–261.

[3] Since writing this paper, our attention has been drawn to Caves and Porter (1976), in which the issues discussed in this paper are foreshadowed. See especially their pages 44–45.

DIEWERT, W.E., AVRIEL, M., AND ZANG, I. "Nine Kinds of Quasi Concavity and Concavity." Discussion Paper 77-31, University of British Columbia, 1977.

DIXIT, A. "A Model of Duopoly Suggesting a Theory of Entry Barriers." *Bell Journal of Economics* (Spring 1979), pp. 20–32.

———. "The Role of Investment in Entry Deterrence." *Economic Journal* (March 1980), pp. 95–106.

EATON, B.C. AND LIPSEY, R.G. "The Theory of Market Preemption: The Persistence of Excess Capacity and Monopoly in Growing Spatial Markets." *Economica* (May 1977).

——— AND ———. "Freedom of Entry and the Existence of Pure Profit." *Economic Journal* (September 1978), pp. 455–469.

——— AND ———. "Exit Barriers Are Entry Barriers." University of British Columbia Discussion Paper No. 80-3, February 1980.

SCHELLING, T.C. "An Essay on Bargaining." *American Economic Review* (June 1956), pp. 281–306.

SCHMALENSEE, R. "Entry Deterrence in the Ready-to-Eat Breakfast Cereal Industry." *Bell Journal of Economics* (Autumn 1978), pp. 305–327.

SPENCE, A.M. "Entry, Capacity, Investment, and Oligopolistic Pricing." *Bell Journal of Economics* (Autumn 1977), pp. 534–544.

———. "Investment Strategy and Growth in a New Market." *Bell Journal of Economics* (Spring 1979), pp. 1–19.