Are Sunk Costs a Barrier to Entry?

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Abstract

The received wisdom is that sunk costs create a barrier to entry—if entry fails, then the entrant, unable to recover sunk costs, incurs greater losses. In a strategic context where an incumbent may prey on the entrant, sunk entry costs have a countervailing effect: they may effectively commit the entrant to stay in the market. By providing the entrant with commitment power, sunk investments may soften the reactions of incumbents. The net effect may imply that entry is more profitable when sunk costs are greater.

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1 Introduction

The role of sunk costs in the persistence of competitive advantage has been an important question in modern strategy thinking. Research in the area has generally taken one of two approaches toward modeling the importance of sunk costs: the structural approach, which views sunkness as a factor which increases the height of entry barriers; and the behavioral approach, which emphasizes sunkness as a form of commitment.

Consider first the structural approach. Borrowing from the industrial organization literature and work in antitrust economics, sunk costs have been shown to create barriers to entry for new firms into profitable industries, thus protecting incumbents and their profits. The sunk investments that give rise to these barriers may be largely exogenous (for example, the need for purpose-built production facilities with little value in alternative uses); or endogenous (for example, expensive brand-building activities such as advertising). In either case, sunk costs will represent investments put at risk by an entrant uncertain of its ability to successfully establish itself in the market. The greater the sunk investment required for entry, the riskier entry becomes and the less likely it is that incumbents will be challenged.[1]

In contrast to the structural approach, the behavioral approach derives from the strategy literature on commitment. As argued by, for example, Ghemawat (1991), commitment to the right strategies can influence the play of other actors in ways beneficial to players able to commit.[2] Competitors can be persuaded to compete less aggressively or not at all, suppliers can be convinced to make important relationship-specific investments, and customers' loyalty can be cultivated — in other words, the ability to make the right kind of commitment can be the source of a firm's competitive advantage.[3] The

[1]See, for example, the contestability literature, which considers the profitability of hit-and-run entry in which sunk costs play a central role, e.g. Baumol et al (1982). See also Ross (2004). Related treatments of sunk costs as a barrier to entry can be found in a variety of strategy and industrial organization texts (e.g. Church and Ware, 2000, and Spulber, 2004) and in merger enforcement guidelines of a number of antitrust agencies, e.g. Canada (2004, paragraphs 6.10 to 6.14), European Commission (2004, paragraphs 69 and 73) and United States (1997, Section 3).

[2]Many strategy texts have now picked up on this theme. See, e.g. Besanko et al. (2004, Chapter 7).

[3]The value of commitment goes beyond competition in the market, as those familiar with the famous examples of generals burning bridges and ships to commit their soldiers to fierce military engagements will recognize. These military examples are often repeated in strategy texts, e.g. Dixit and Skeath (1999, p. 309), Dixit and Nalebuff (1991, p. 156) and Besanko et al. (2004, p. 234).

challenge for firms seeking competitive advantage through commitment lies in finding ways to make those commitments — that is, to take important irreversible actions that change other players' best responses in the right way. As sunk costs represent, by definition, irreversible investments, they are a natural candidate for such strategic behavior.

Past work on strategic approaches to sunk costs has studied the ability of incumbents to protect monopoly positions through sunk investment in large capacity production facilities. Large sunk capacity in these models (e.g. Dixit, 1980; Spence, 1977) serves to commit the incumbent to higher output rates, and this lowers post-entry price and profits for prospective entrants. If it lowers profits enough, there will be no entry.[4] In this way, sunk costs are seen, as under the structural approach, as barriers to entry.

Our interest here is also in the strategic use of sunk costs as commitment devices. However, we believe the entry barrier view of sunk costs is incomplete in an important sense. Through its focus on sunk investments by incumbents, it misses the potential for entrants to use sunk investments to commit to entry and thereby influence the behavior of their incumbent rivals.[5] If an entrant, who would otherwise anticipate an aggressive response by the incumbent (in an effort to chase the entrant from the market), can commit itself irreversibly to that entry, it can defeat the purpose of the incumbent's retaliation. In this view, high levels of sunk investment may actually facilitate entry if they serve to commit entrants to staying in the market and thereby induce the incumbent to adopt a more accommodating strategy.[6]

When Archer Daniels Midland (ADM) decided to enter the lysine market in July 1989, it invested heavily in the construction of the world's largest manufacturing facility in Decatur, Illinois — a plant three times the size of the next largest facility in the world. ADM used the excess capacity (a largely irreversible investment) to influence its rivals, specifically persuading them to enter into a price-fixing agreement (until caught and successfully prosecuted

[4]See also, Porter (1980, p. 100), Saloner et al (2001, p. 229), Tirole (1989, pp. 314–323), Geroski et al. (2000, pp. 26–27) and Church and Ware (2000, p. 123).

[5]The idea that sunk costs can strengthen an entrant's position is recognized in at least one strategy text, though we are unaware of any formal modeling on this point. See Saloner et al. (2001, p. 229).

[6]Bagwell and Ramey (1996) adapt the Dixit model by allowing the incumbent to have avoidable fixed costs and show that if they are large enough the entrant may be able to persuade the incumbent to leave the market after entry. As in our present work, their focus in on strategies available to entrants to elicit accommodating responses from incumbents. The key in their model, however, lies in the split between sunk and avoidable costs of the incumbent, while here our focus is on the entrant's cost structure.

by the Antitrust Division of the U.S. Department of Justice).[7] Bagwell and Ramey (1996, p. 662) cite other examples that support the notion that large investments by entrants may serve to discourage aggressive post-entry behavior by incumbents.

By contrast, the airline industry, frequently presented as a paradigm of low sunk costs, is a frequent source of failed entry attempts, frequently due to, at least in part, the aggressive and possibly even predatory responses by incumbents.[8] In summary, anecdotal evidence shows that higher sunk costs do not necessarily mean more difficult or less likely successful entry.

In this paper, we consider a model of rational predation to see if the degree of sunkness of entry costs can alter the incumbent's incentives to predate. We show there exists an equilibrium with rational entry, possible predation by the incumbent and exit by the entrant. We then consider equilibrium comparative statics and show there are cases when the entrant benefits (in terms of ex-ante expected payoff) from higher sunk costs.

Our model builds on a simple Dixit-type framework in which an entrant and incumbent play a two stage game. In the first stage the entrant decides whether or not to enter, and if entry is the choice, makes the necessary fixed cost investments, a fraction of which is sunk. In the second stage the players select output levels in the Stackelberg fashion with the incumbent moving first. The incumbent then must choose between a predation strategy that involves setting a large output in an effort to encourage the entrant to leave the market (reclaiming its non-sunk fixed costs), and a strategy of accommodation that concedes some market share to its new rival.[9] In this model, a higher proportion of fixed costs that are sunk means that exit will be less profitable

[7]See Connor (2001, p. 170).

[8]We do not mean to suggest that every failure of a small airline (and there were many) was due to predatory actions undertaken by incumbent carriers - it is well recognized that many were undercapitalized and strategically unprepared for the markets they were entering. As pointed out by a referee, many new airlines were also severely restricted in their access to key support facilities such as gate facilities and landing slots. This said, there is also considerable evidence that a number of new carriers were compelled to exit through the very aggressive (and possibly predatory) actions of incumbents. On the experience in many countries see Forsythe et al. (2005) and Bolton et al. (2000). The set of airlines accused of predatory reactions to entry includes American Airlines, Northwest Airlines, Lufthansa and Air Canada.

[9]The predation strategy will not in general involve prices below cost (without a recoupment period after exit it cannot be profitable for the incumbent to sell below cost) and so may not satisfy some cost-based definitions of predation. However, as a strategy that is only profitable because it induces the exit of a rival, it will satisfy the well-known Ordover-Willig (1981) definition of predation. See also Cabral and Riordan (1994).

for the entrant; this will make the predation strategy more costly for the incumbent.

Our key result is that increasing the fraction of fixed costs that are sunk makes the entrant locally worse off, almost everywhere. However, there will be a critical level of sunkness such that for higher levels the incumbent cannot induce exit and the entry will not be resisted. In this way, our model illustrates how sunk costs can, in some cases, deter entry, while in others facilitate it.

2 A quantity setting model

Consider an industry with two potential firms, 1 and 2, which compete in the market for a homogeneous product with demand $p = 1 - q_1 - q_2$, where p is price and q_i is firm i's output level. Firm 1 is committed to remaining active. Firm 2 must initially decide whether to enter. If firm 2 enters, it pays an entry cost K and Nature generates its marginal cost. For simplicity, we assume that firm 2's marginal cost can either be equal to c, with probability θ, or zero, with probability $1 - \theta$.[10] Firm 1's marginal cost, in turn, is equal to zero.[11]

Upon observing firm 2's entry decision and its cost, firm 1 chooses its output. Firm 2 must then decide whether to be active or to exit; if active, firm 2 must also choose its output level. Finally, if firm 2 decides to exit, then it recovers $\phi \equiv (1 - s) K$ from its initial investment, where s is the degree of entry cost sunkness.

Having a particular example in mind may help in following the model. Consider the case of airline competition. An entry cost will include, among other things, buying (or leasing) an aircraft fleet (cost K). Once the incumbent airline learns that a new airline plans to enter a particular market, the incumbent decides how many flights it wants to schedule in that market (output q_1). The entrant then decides whether it wants to remain active and, if so, how many flights it wants to schedule in the market (output q_2). Finally, equilibrium fares, $p_1 = p_2 = p$, result from the total number of available flights: $p = 1 - q_1 - q_2$.[12]

The assumption that the incumbent chooses output before the entrant is important for our analysis. In the spirit of Lipman and Wang (2000) and

[10] Similar qualitative results would be obtained if firm 2's cost were drawn from a continuous probability distribution on an interval.

[11] Frequently, entrants have lower marginal cost than incumbents. Our assumption that the incumbent has zero marginal cost is made for simplicity and does not change the qualitative nature of our results.

[12] See Kreps and Sheinkman (1983) for a justification of this reduced-form approach.

Table 1: Model timing.

1. Firm 2 decides whether to enter; if so, it pays entry cost K.
2. Nature generates firm 2's cost level (c with probability θ, zero with probability $1-\theta$).
3. Firm 1, with zero marginal cost, chooses output level, q_1.
4. Firm 2 chooses output level q_2 or exits. If it exits, it recovers $(1-s)K$.

Caruana and Einav (2006), we propose the Stackelberg assumption as the reduced form of a repeated quantity setting game where the incumbent has a greater switching cost than the entrant. This seems a reasonable assumption given that the incumbent has been in the market for some time.

Essentially what we need in our model is the feature that after a new firm enters, the incumbent has the opportunity to take some aggressive action, after which the entrant can choose to exit. We believe our model is reasonable and that it is about the simplest we could construct that allows for this sequence of meaningful decisions. Of course this could be also be accomplished with a model in which firms make simultaneous moves over a sequence of periods, but this would complicate the model by forcing us to analyze other decisions that are not really relevant to the possibilities we wish to explore here.

The timing of the game is described in Table 1. We assume that both the prior distribution of firm 2's marginal cost and its actual realization are common knowledge. So, while there is uncertainty in our model we do not assume any information asymmetry across firms.

In order to focus on the relevant parameter range, we make the following assumptions regarding the values of K and c:

Assumption 1 $K < \frac{1}{16}$.

Assumption 1 ensures that we are not in a situation of "natural monopoly," in which firm 2 decides never to enter.

Assumption 2 $K > \frac{\frac{3}{2}-\sqrt{2}}{16}$.

Assumption 2 is a sufficient condition for there to be cases when the incumbent has an incentive to induce the entrant to exit. If the value of K is very small, then regardless of the degree of cost sunkness the incumbent prefers not to fight entry. Notice that $\frac{3}{2}-\sqrt{2}$ is less than 1, so the lower bound on K implied by Assumption 2 is lower than the upper bound implied by Assumption 1.

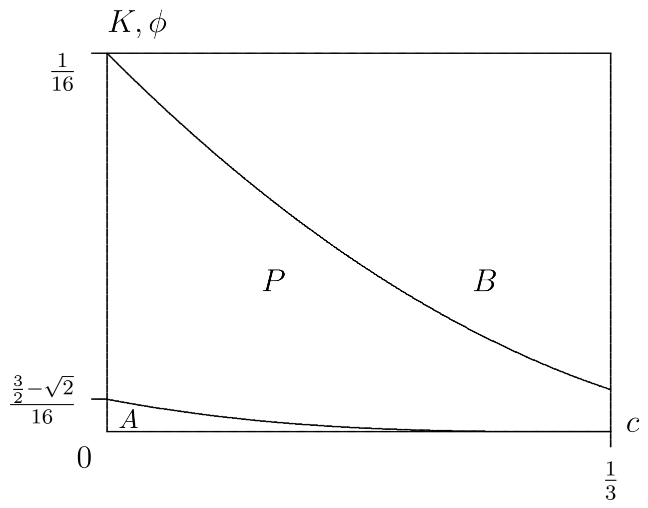

Figure 1: Relevant regions of parameter values.

Assumption 3 $c < \frac{1}{3}$.

Assumption 3 ensures that in the standard Stackelberg outcome with firm 1 as the leader and 2 as the follower firm 2 chooses a strictly positive output rate. A higher value of c leads to a corner solution whereby firm 2 is shut out of the market.

Figure 1 illustrates the set induced by Assumptions 1–3. The upper limits of the box marked in the (c, K) space are the values in Assumption 2 and 3. The lower bound in Assumption 2 is the vertical intercept of the curve closer to the c axis. We note that Assumption 2 is a sufficient condition. A necessary and sufficient condition for the interior-solution results we present below is that the value of K lie outside of region A in Figure 1.[13]

The rest of the analysis is organized as follows. First, in Section 3 we look at the post-entry game. That is, we assume firm 2 has entered and look at firm 1's output decision and firm 2's response (which is either an output level or the decision to exit). As we will see, the answer depends on the particular values of K, c and s. Next, in Section 4 we consider the comparative statics with respect to s. This will lead to the main results in the paper, namely, the impact of s on firm 2's entry and exit decisions, as well as its ex-ante expected value.

[13] This corresponds to the condition (explained below) that $K > K'$, where K' is implicitly given by:

$$\left(c + 2\sqrt{K'}\right)\left(1 - c - 2\sqrt{K'}\right) = \frac{1}{8}(1 + c)^2.$$

3 The post-entry subgame

Suppose that firm 2 enters. First we note that, since a (partially) sunk entry decision has been made, firm 2's effective opportunity cost of entry is now given by $\phi = (1-s)\,K$. Since s is a scalar in the unit interval, ϕ lives in the same space as K. However, while the upper bound of ϕ is the same as K (that is, $\frac{1}{16}$, by Assumption 1), the lower bound is zero. In terms of Figure 1, while pairs (c, K) must be in regions B or P, (by Assumptions 1–3), pairs (c, ϕ) may also occupy region A.

In the analysis that follows, we will consider three possible cases, corresponding to regions B, P and A in Figure 1. We will first consider the case when firm 2's cost is given by the positive value c. The case when firm 2's cost is zero can simply be solved for by substituting 0 for c.

Firm 1's expected payoff is given by $(1-q_1-q_2)\,q_1$. Firm 2's continuation payoff, in turn, is given by $(1-q_1-q_2-c)\,q_2$ if it remains active and ϕ if it exits.[14] If firm 2 is to remain active, then its optimal output level is $q_2^* = \frac{1}{2}(1-q_1-c)$. This gives firm 2 an optimal response profit of

$$\pi_2^* = \frac{1}{4}\,(1-q_1-c)^2, \tag{1}$$

conditional on being active.

If firm 2 is to remain active, then we have the conventional Stackelberg case. Output levels are given by $q_1^S = \frac{1}{2}(1+c)$ and $q_2^S = \frac{1}{4}(1-3\,c)$, where the superscript S stands for Stackelberg. This leads to equilibrium continuation profits of $\pi_1^S = \frac{1}{8}(1+c)^2$ and $\pi_2^S = \frac{1}{16}(1-3\,c)^2$.

When will firm 2 choose to exit? First, we consider the case of blockaded entry, that is, the case when firm 2 exits even if firm 1 selects monopoly output. Straightforward computation shows that monopoly output is given by $q_1^M = \frac{1}{2}$. Substituting into (1) and equating to the opportunity cost of entry we get

$$\phi = \frac{1}{16}\,(1-2\,c)^2. \tag{2}$$

Equation (2) defines the lower boundary of region B in Figure 1. For values of ϕ to the NE of this boundary, entry is blockaded, that is, firm 2 exits even though firm 1 sets the monopoly price.

For points to the SW of the boundary defined by (2), firm 2 exits only if firm 1 sets a high enough output. To determine this output level, we equate

[14]Throughout the paper, we refer to continuation profit or continuation payoff as firm 2's profit excluding the entry cost.

the right-hand side of (1) to the opportunity cost of entry:

$$\phi = \frac{1}{4}\,(1 - q_1 - c)^2,$$

or simply

$$q_1^P = 1 - c - 2\sqrt{\phi},$$

where the superscript P stands for predation. At this output level, and considering firm 2 exits the market, firm 1's profit is given by

$$\pi_1^P = (1 - q_1^P)\, q_1^P = \left(c + 2\sqrt{\phi}\right)\left(1 - c - 2\sqrt{\phi}\right).$$

Firm 1 has the option of setting the Stackelberg output and receiving a profit of $\pi_1^S = \frac{1}{8}(1+c)^2$. The condition for predation to be an optimal strategy is thus given by

$$\left(c + 2\sqrt{\phi}\right)\left(1 - c - 2\sqrt{\phi}\right) \geq \frac{1}{8}\,(1+c)^2. \qquad (3)$$

Computation establishes that

$$\frac{1}{8}\,(1+c)^2 = c\,(1-c) + \frac{1}{8}\,(1-3\,c)^2.$$

This implies that, if $\phi = 0$, then the left-hand side of (3) is strictly lower than the right-hand side of (3). Let ϕ' be the value of ϕ that solves (3) as an equality. Since output is decreasing in ϕ and firm 1's profit is decreasing in output, the left-hand side is increasing in ϕ. Since moreover the left-hand side is lower than the right-hand side for $\phi = 0$, it follows that ϕ' is strictly positive (for all c in the $[0, \frac{1}{3})$ interval).

The critical value ϕ', which is a function of c, defines the upper bound of region A in Figure 1. Recall that the left-hand side of (3) is increasing in ϕ. It follows that firm 1 is better off by predating for values of ϕ above the boundary (region P), and better off accommodating entry for values of ϕ lower than the boundary (region A).

We summarize the analysis of this section with the following result

Proposition 1 *Consider the subgame following entry by firm 2.*

- *If* $(c, \phi) \in B$, *then* $q_1 = q_1^M = \frac{1}{2}$ *and firm 2 exits (blockaded entry).*
- *If* $(c, \phi) \in P$, *then* $q_1 = q_1^P = 1 - c - 2\sqrt{\phi}$ *and firm 2 exits (predation).*
- *If* $(c, \phi) \in A$, *then* $q_1 = q_1^S = \frac{1}{2}(1+c)$, $q_2 = q_2^S = \frac{1}{4}(1-3\,c)$ *(accommodated entry).*

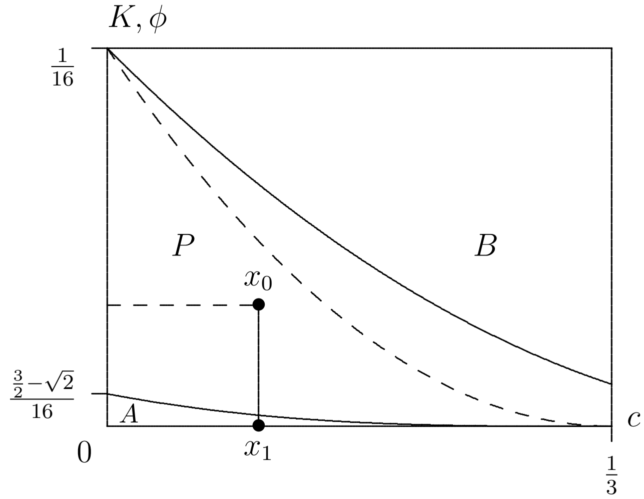

Figure 2: Effect of varying s from 0 to 1. For given values of (c, K), as s changes from 0 to 1, the pair (c, ϕ) moves from x_0 (outside of A) to x_1 (inside of A).

4 Sunk costs, entry, and exit

We now explore the comparative statics with respect to s implied by the results in the previous section. First, we note that firm 1's optimal strategy implies a discontinuity in firm 2's subgame profit with respect to the value of s. To see this, notice that, for a given K, different values of s imply different values of ϕ, ranging from K to zero as s varies from 0 to 1. This is illustrated in Figure 2. For given values of (c, K), as s changes from 0 to 1, the pair (c, ϕ) moves from x_0 (outside of A) to x_1 (inside of A).

Notice that, by Assumption 2, $K > \frac{\frac{3}{2}-\sqrt{2}}{16}$, which implies that point x_0 must lie outside of region A. In fact, for $s = 0$, $\phi = K$. Depending on the particular values of (s, K), x_0 may lie in region P or in region B. Whichever, is the case, x_0 lies in a region where the subgame calls for firm 2 to exit. As to x_1, it always falls in region A. In fact, the upper boundary of region A is strictly above the horizontal axis for any value $c \in [0, \frac{1}{3})$.

If firm 2 exits, then its continuation payoff is given by ϕ. If firm 2 does not exit (region A), then its continuation payoff is given by $\pi_2^S = \frac{1}{16}(1 - 3\,c)^2$. The condition $\phi = \pi_2^S = \frac{1}{16}(1 - 3\,c)^2$, that is, the condition that a Stackelberg follower is indifferent with respect to exiting or not, is given by the dashed line in Figure 2. If follows that, for points in region A, all of which are below the dashed line, firm 2 strictly prefers to be a Stackelberg follower than to exit.

This implies that, as s shifts from 0 to 1, (s, ϕ) eventually crosses the

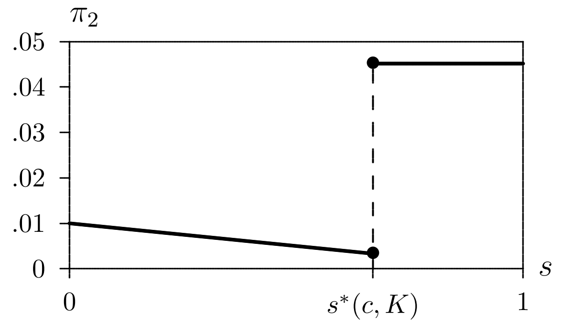

Figure 3: Firm 2's continuation profit as a function of entry cost sunkness ($K = .01,\ c = .05$).

boundary from the P region to the A region, and at that point firm 2's payoff discontinuously increases. On the other hand, while we are in the P region, firm 2's payoff, which is given by $\phi = (1 - s)\,K$, is decreasing in s.

We summarize our analysis in the following result:

Proposition 2 *There exists an $s^*(c, K)$ such that $d\,\pi_2\,/\,d\,s < 0$ for $s < s^*(c)$ and $\lim_{s\uparrow s^*(c)} \pi_2(s) < \lim_{s\downarrow s^*(c)} \pi_2(s)$.*

Figure 3 illustrates Proposition 2. It depicts the value of firm 2's continuation profit for particular values of K and c. Notice that π_2 is weakly decreasing almost everywhere (and strictly decreasing for all $s < s^*$). In other words, for almost every value of s (that is, except for a set of measure zero), a small increase in s implies (weakly) a decrease in π_2. This result corresponds to the "conventional wisdom" that entry cost sunkness creates a barrier to entry.

A second important property of the equilibrium π_2 map is that it discontinuously increases as s crosses the $s^*(c)$ threshold. The reason for this is that a higher value of s implies a shift from the predation regime to the no-predation regime. Past this threshold we remain in a "no predation and no exit" regime in which the degree of sunkness of the fixed costs is irrelevant. We thus conclude that increasing the degree of cost sunkness has two opposing effects.

To summarize the analysis so far: given that firm 2 has entered, firm 2 may be better off or worse off with $s = s_2$ than with $s = s_1 < s_2$. If s_1 and s_2 lead to points in the P region, then firm 2 is better off with the lower s value. If s_1 belongs to the P region and s_2 belongs to the A region, then firm 2 is better off with the higher value of s.

Our next step in the analysis is to close the model by considering the entry decision as well. As explained in Section 2, firm 2 is ex-ante uncertain about its marginal costs, which is equal to c with probability θ and 0 with probability $1 - \theta$. Pre-entry uncertainty about entry costs is important for two reasons. First, it leads to a natural model where predation occurs not only in the equilibrium, as we have already established, but also along the equilibrium path.[15] Second, as a result of predation along the equilibrium path, the entry with uncertainty model highlights the two main effects of entry cost sunkness: the negative effect (in case of exit sunk costs are bad for the entrant) and the positive effect (sunk costs increase the entrant's commitment to remain active, which softens the incumbent).

The analysis underlying Figure 3 was conducted for a particular value of c. The same analysis applies for the case when $c = 0$, with the difference that points x_0, x_1 lie on the vertical axis. This implies that, if $c = 0$, then there exists a threshold value s_1 such that, as s crosses s_1 we move from the P region into the A region; and if $c > 0$, then there exists a threshold value $s_2 > s_1$ with the same properties, that is, as s crosses s_2 we move from the P region into the A region. Notice that $s_2 > s_1$ follows from the fact that the boundary separating regions P and A is decreasing in c.

Consider now firm 2's prospects upon deciding whether to enter. If it does so and c equals zero, then it will remain active if and only if $s > s_1$. If c is positive, however, it will remain active if and only if $s > s_2$. So, if $s < s_1$ firm 2 will exit regardless of the value of marginal cost. If $s > s_2$, then firm 2 will not exit, regardless of the value of marginal cost. Finally, for intermediate values of s, $s_1 < s < s_2$, firm 2 exits if and only if its marginal cost is positive.

When should firm 2 enter? Clearly, if $s < s_1$ then firm 2 never enters, since it anticipates it will always exit. For higher values of s, the answer depends on the particular values of c and K. If (c, K) is below the dashed line in Figure 2, then Stackelberg follower profits are greater than K, and the firm is better off by entering. Notice however that $(0, K)$ falls below the dashed line. This means that a sufficient condition for entry when $s > s_1$ is that θ be close to zero. We thus have the following result characterizing the overall entry and exit equilibrium:

[15] We have established that, for some parameter values, predation takes place in the post-entry game. However, we have not established that entry takes place in equilibrium (for the relevant parameter values). So while predation occurs in a subgame, that subgame may not be visited in equilibrium. In other words, predation may simply be a threat, not an actual event.

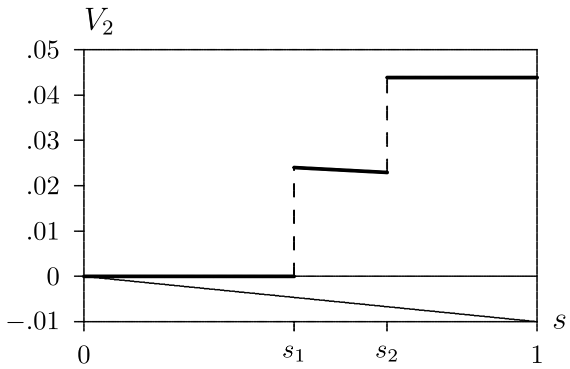

Figure 4: Firm 2's value as a function of entry cost sunkness ($K = .01, c = .05, \theta = .5$). The thick line represents firm value. The thin, negatively-sloped line corresponds to payoff in case the firm exits (that is, $-s\,K$).

Proposition 3 *Suppose θ is close to zero. There exist values $0 < s_1 < s_2 < 1$ such that*

(a) Entry takes place if and only if $s > s_1$.

(b) If $s_1 < s < s_2$, then firm 2's ex-ante expected payoff is strictly decreasing in s; if $s < s_1$ or $s > s_2$, then ex-ante expected payoff is independent of s.

In other words, if θ is close to zero then the equilibrium has firm 2 entering if and only if entry costs are sufficiently sunk; and, given that firm 2 enters, its expected payoff is decreasing in the degree of entry cost sunkness.

Figure 4 illustrates Proposition 3. On the vertical axis, we measure firm 2's ex-ante expected profit, V_2. (Recall that π_2, introduced earlier, denotes firm 2's *continuation* payoff.) For $s < s_1$, firm 2 correctly anticipates that, no matter what its costs, firm 1 will prey it out of the market. It follows that the expected payoff from entry is $-s\,K$, the measure of entry sunk costs. Since expected payoff from entry is negative, firm 2 does not enter and $V_2 = 0$. If $s > s_2$, then firm 2 anticipates that, no matter what its costs, firm 1 will accommodate entry. Since θ is close to zero and a zero cost Stackelberg follower's profits are greater than entry cost, firm 2 enters. Moreover, since firm 2 does not exit, its payoff is independent of s.

Suppose now that $s_1 < s < s_2$. In this region, a low cost firm 2 would be met by an accommodating incumbent, but a high cost firm 2 would be met by a predating incumbent. Since θ is close to zero, firm 2's expected profit is positive, and its optimal strategy is to enter. Since there is a positive probability of exit (marginal cost is high with probability θ) and profits are decreasing in s when exit takes place, it follows that V_2 is decreasing in s. In other words, from an ex-ante point of view firm 2's expected profit is the Stackelberg follower profit with probability $1 - \theta$ and $\phi - K = -s\,K$ with probability θ. Since the former does not depend on s, the expected value is decreasing in s.

In summary, as s moves past s_1 or past s_2 firm 2 receives a (discontinuous) increase in V_2. However, within the interval $[s_1, s_2]$, V_2 is decreasing in s. We thus have the two effects of entry cost sunkness: the commitment value effect, which implies the increasing portion of V_2; and the uncertain entry effect, which corresponds to the decreasing portion of V_2.

The condition that θ be close to zero is sufficient to obtain the qualitative pattern described by Figure 4. Notice that, for $s_1 < s < s_2$, payoff conditional on entry is a convex combination of continuation payoff when cost is zero (positive continuation payoff, independent of s) and continuation payoff when cost is c (negative continuation payoff, decreasing in s). If θ is close to zero, then the resulting convex combination leads to a positive continuation payoff, decreasing in s. If θ is close to 1, then continuation payoff is still decreasing in s, but eventually becomes negative. In this case, V_2 is zero up to s_2, positive afterwards. In other words, there is no decreasing portion of V_2.

Finally, note that, for intermediate values of θ, the mid portion of the continuation payoff map may cross the horizontal axis at $s' \in (s_1, s_2)$. Specifically, there is an intermediate set $[\theta', \theta'']$ of values of θ such that this happens, where $0 < \theta' < \theta'' < 1$. (This follows from the intermediate value theorem and the fact that continuation payoff is continuous in θ.) This intermediate case is a little more complicated than that of Proposition 3. First, the entry decision is non-monotonic: it takes place if and only if $s \in [s_1, s']$ or $s \in [s_2, 1]$. Second, ex-ante payoff is strictly decreasing in s if and only if $s \in [s_1, s']$.[16]

5 Conclusion

The idea that sunk costs serve to deter entry has been supported by at least two sets of theories. The first sees sunk costs as investments put at risk when entry may be followed by a quick exit, whether that exit is deliberate (as in hit-and-run entry) or not. The greater is this potential loss, the less attractive entry will seem. The second set of theories views sunk investments — in

[16] This unusual configuration is probably a reflection of our simple model of uncertainty.

capacity, for example — as means through which first-mover incumbents can commit to rates of output so large as to not leave enough room for profitable entry.

In this paper, we have argued that by largely ignoring the potential for sunk investments to provide a vehicle for entrant commitment, the literature has missed the possibility that sunk investments might actually facilitate entry. We have illustrated this potential with a model in which an entrant making a large enough sunk investment can alter the behavior of the incumbent. By rendering exit so unattractive for the entrant (as the recoverable share of entry costs is so low), the incumbent's predation strategy becomes unprofitable. When ADM invested so much money in the world's largest (by far) lysine facility, none of its rivals could have reasonably expected that ADM could be persuaded to exit; accordingly, their rational response was accommodation. On the other hand, with exit relatively easy, poorly capitalized new-entrant airlines have frequently been the target of very aggressive pricing responses from their incumbent rivals.

We consider a specific model of entry and predation. However, we believe the intuition that sunk costs may help an entrant is more general. In a previous version of our paper, we developed an alternative model along the lines of Bolton and Sharfstein (1990) "deep pockets" model of predatory pricing. Here the entrant needs continued financing from a bank that will only offer second period financing if the first period's loan is repaid in full. In the first period, predatory actions by the incumbent can increase the chance of low profits for the entrant, but the entrant can invest resources to resist predation and will be more inclined to do so if it has little to claim (little non-sunk investments) on exit. As in the model developed in Section 2, the degree of sunkness of the entrant's investments affects the entrant's incentive to take actions to resist predation.

While our main objective here has been to integrate two different strands of the strategy/industrial organization literature to provide a more complete treatment of the effects of sunk costs on entry, we recognize that our results have potentially important implications for antitrust policy. Ease of entry into the relevant markets is a critical element in the review of most competition cases and the analysis provided here suggests that in some circumstances the ability of entrants to make commitments to entry via sunk investments may in fact facilitate entry. The flip side of this, however, is that when sunk costs are low (but not zero), incumbents may have an easier time expelling entrants through predatory actions.

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