

# The Effects of Irreversible Investment in Durable Capacity on the Incentive for Horizontal Merger\*

MYONG-HUN CHANG  
*Cleveland State University*  
*Cleveland, Ohio*

JOSEPH E. HARRINGTON, JR.  
*The Johns Hopkins University*  
*Baltimore, Maryland*

## I. Introduction

Until recently, the literature on horizontal merger had been almost exclusively concerned with two issues. The first issue, which has long historical roots, is the timing of merger activity. Of particular interest has been to understand the causes of the great merger wave. Lamoreaux [5] represents the most recent addition to this literature and provides a very good review of past work. The second issue is the welfare implications of horizontal merger of which Williamson [12] is a case in point. With the exception of Stigler [8], what had generally not been at issue in this literature was the private incentives for horizontal merger. This was true in spite of the insight provided by Stigler that the non-participants of a merger are typically made better off by a merger than are the participants. Since the firms which engage in merger reduce supply, all firms benefit from the resulting higher price but the non-merging firms benefit most because they receive a higher price without having had to reduce supply. There is then the potential for a free-rider effect in merger activity as each firm wishes it to be the other firms which merge.

The first suggestion that the private incentives for horizontal merger may not only be weak but that merger may be simply unprofitable arose in a numerical example by Szidarovszky and Yakowitz [9] in which they show in a three-firm Cournot model that a merger between two firms is unprofitable. Then a study by Salant, Switzer, and Reynolds [7], hereafter S-S-R, examined this issue in considerable detail and found very weak incentives for firms to merge together unless there are considerable savings in terms of fixed costs. Using the standard linear Cournot model, S-S-R show that only merger for monopoly, or close-to-monopoly, is privately optimal when there are zero fixed costs. The basis for this surprising result is that when the merged firm reduces output below the combined level of its pre-merger supply, the non-merged firms react by expanding output. Though price goes up in response to the merger, the market share of the merged firm declines. The latter effect can dominate so that the firms are made worse off by merging.

In response to this result, Perry and Porter [6] argue that the standard Cournot model is inappropriate for analyzing the incentive to merge as mergers are not well-defined. Since firms do

\*The first author performed this research during his graduate studies at The Johns Hopkins University

not hold capital, a merger between identical firms results in a single firm which has the same cost function as that of the firms prior to merger and, therefore, the same as that of a non-merged firm. In the post-merger environment, a symmetric equilibrium is then achieved in which the merged firm has the same output rate as that of a non-merged firm. In contrast, Perry and Porter analyze a model in which firms hold capital that impacts the firm cost function. Under the assumption that investment cannot take place in response to merger, a merged firm then faces a lower marginal cost function than the non-merged firms due to differential capital stocks. In this setting, Perry and Porter find much stronger incentives for horizontal merger than derived in S-S-R.

In contrast to the literature thus far described, Deneckere and Davidson [3] investigate the profitability of horizontal merger in a price-setting model in which firms have differentiated products.<sup>1</sup> Since there is no capital, their model is the price game analogue to that of S-S-R. Contrary to that found for quantity-setting models, however, they show that the response of the non-merged firms to a merger actually tends to raise the value of that merger to the merging firms. Since reaction functions are generally upward-sloping in price games then, when the firms merge and raise price, the non-merged firms respond by also raising price which increases the demand and profits of the merged firm. In this setting, Deneckere and Davidson show that a merger of any size is profitable to the merging firms. Similar though weaker results are found for a homogeneous goods price-setting model in which firms meet all demand subject to capacity constraints [2]. There it is shown that mergers are never unprofitable though they need not always be profitable. In any event, the price-setting models suggest much stronger incentives for merger than do the quantity-setting models of S-S-R and Perry and Porter.

It is clear that Davidson and Deneckere have made a notable point in showing that a quantity game may tend to underestimate the value of merger for the merging firms. On the other hand, Perry and Porter have shown that a quantity game with capital can still provide adequate incentives for merger. This suggests that such a framework is useful in assessing the profitability of horizontal merger activity.

The objective of the current study is to pursue the direction of Perry and Porter by investigating the role of capital in determining the profitability of merger in a quantity-setting model. However, there are two important distinctions between our model and that of Perry and Porter. First, we insert irreversible investment into the Cournot model in the form of durable production capacity. This would seem to offer the simplest way for mergers to be well-defined in the Cournot model. At the time of merger, firms will hold capacity which represents a sunk cost. A merger between two firms with equal capacity will then result in a merged firm which is "twice as large" in the sense of having twice the capacity. The second key distinction is that we do not maintain the assumption of Perry and Porter that capital stocks are fixed. Instead, firms will be allowed to invest in capacity in response to merger.

Our purpose in investigating this particular model is several-fold. Since it maintains all of the assumptions of the Cournot model, it will provide the most straightforward test of how introducing capital affects the results of S-S-R. A second objective is to determine whether the conclusions of Perry and Porter are robust to the way in which capital enters the model and to their fixed capital stocks assumption. Finally, our hope is that by analyzing different models, we can gain a better understanding of the incentive for horizontal merger.

To summarize our results, we find that the profitability of merger is reduced when firms hold

1. For an empirical estimation of the profitability of a horizontal merger between firms with differentiated products, see Baker and Bresnahan [1].

durable capital. Our analysis reveals that while durable capital does give the merged firm a cost advantage over non-merged firms, durable capital also raises the amount of costs which are sunk. An increase in the degree of costs which are sunk reduces the potential cost savings from merger relative to when firms do not hold capital. When capital stocks are allowed to adjust in response to merger, we find that the effect of reduced cost savings dominates so that the holding of durable capital reduces the profitability of merger.

**II. The Model**

At the pre-merger stage, the industry is occupied by  $n$  firms which are assumed to offer homogeneous products. Inverse market demand takes the form

$$P(Q) = a - bQ \tag{1}$$

where  $Q$  is the industry output rate. Each firm has access to the same production technology which yields constant marginal cost up to capacity. Letting  $K_i$  denote the initial capacity level of firm  $i$ , the cost function of firm  $i$  is then

$$C(q_i; K_i) = \begin{cases} \beta K_i + \alpha q_i & \text{if } 0 \leq q_i \leq K_i, \\ (\alpha + \beta)q_i & \text{if } K_i < q_i. \end{cases} \tag{2}$$

$\beta$  is the per unit cost of capacity so that  $\beta K_i$  measures the level of sunk costs.<sup>2</sup> If firm  $i$  has excess capacity, marginal cost is  $\alpha$ . To produce above  $K_i$ , firm  $i$  must add capacity so that marginal cost is then  $(\alpha + \beta)$ . This formulation of the cost function is originally due to Dixit [4]. The S-S-R model is derived as a special case by letting  $K_i = 0$  for all  $i$  so that all costs are variable.<sup>3</sup>

There are two critical features of capital which will prove to be important in our analysis. First is that investment is irreversible so that capital costs are sunk. Second, capital is durable so that firms hold capital stocks at the time of merger. For the sake of simplicity, capital is assumed not to depreciate so that the same capital stocks exist immediately after merger though firms will be able to add to their capital stocks in response to merger. Our results are robust to the assumption of zero depreciation.

Given these cost and demand conditions, the profit function of firm  $i$  takes the form:

$$\pi(q_i, Q_{-i}; K_i) = \begin{cases} |a - b(q_i + Q_{-i}) - \alpha|q_i - \beta K_i & \text{if } 0 \leq q_i \leq K_i, \\ |a - b(q_i + Q_{-i}) - \alpha - \beta|q_i & \text{if } K_i < q_i, \end{cases} \tag{3}$$

where  $q_i$  is the output rate of firm  $i$  and  $Q_{-i} = \sum_{j \neq i} q_j$ . Firms are assumed to play the Cournot game where the payoff function of firm  $i$  is the expression in (3).<sup>4</sup>

2. Since  $\beta K_i$  is sunk, it is no longer an opportunity cost of production so that it does not actually belong in the cost function. For expositional purposes, we have chosen to leave it there so as to remind the reader of the initial level of capacity and sunk costs.

3. In other words, the S-S-R model can be interpreted as when capacity is not durable so that zero capacity is carried over from the previous period.

4. We are assuming a one-stage game where firms make simultaneous capacity and output decisions. Ware [11]

At the start of the game, it is assumed the industry is at an  $n$ -firm Nash equilibrium. It is straightforward to show that the  $n$ -firm Nash equilibrium entails a firm capacity level of  $\bar{K}$  where  $\bar{K} \equiv [(a - \alpha - \beta)/b(n + 1)]$ .<sup>5</sup> Thus, prior to merger, the initial capacity stock of each firm is  $\bar{K}$ . In the event that no merger takes place, firms will then optimally produce at full capacity and earn profits equal to  $[(a - \alpha - \beta)^2/b(n + 1)^2]$ .

In specifying the initial capacity stocks of firms, we are making the common step in the literature which is to supplant the explicit derivation of the pre-merger path of the industry with some initial condition. While it may not be a reasonable assumption in all instances, we feel there are many situations for which it is plausible that firms would be at an equilibrium based upon the current market structure rather than some anticipated future market structure. Such an assumption is especially apt when there is an unexpected and exogenous opportunity for merger made available to firms. In this event, prior to merger firms would have settled in at an equilibrium based upon the pre-merger structure of the industry.<sup>6</sup> While an explicit analysis of the pre-merger path would certainly provide more generality, we feel substituting an initial condition for the derivation of the pre-merger path will still provide considerable insight into the profitability of merger and do so with much simpler analysis.

### III. Post-Merger Equilibrium

As specified in S-S-R, we will consider the set of  $m$ -firm mergers where  $m \in \{1, 2, \dots, n\}$  ( $m = 1$  represents the no-merger case). The outcome of an  $m$ -firm merger is assumed to be the Nash equilibrium for the  $(n - m + 1)$ -firm quantity game where firm  $j$  ( $j = 1, \dots, n - m$ ) has an initial capacity level of  $\bar{K}$  ( $\equiv [(a - \alpha - \beta)/b(n + 1)]$ ) and firm  $M$ , the merged firm, has capacity  $m\bar{K}$ .

As an intermediate step to solving for the Nash equilibrium, let us derive the reaction function for firm  $i$  where  $i \in \{1, \dots, n - m, M\}$ . Maximizing the profit function in (3) with respect to  $q_i$ , one derives

$$\psi(Q_{-i}; K_i) = \begin{cases} [(a - \alpha - \beta)/2b] - (1/2)Q_{-i} & \text{if } 0 \leq Q_{-i} \leq [(a - \alpha - \beta)/b] - 2K_i, \\ K_i & \text{if } [(a - \alpha - \beta)/b] - 2K_i \leq Q_{-i} \leq [(a - \alpha)/b] - 2K_i, \\ [(a - \alpha)/2b] - (1/2)Q_{-i} & \text{if } [(a - \alpha)/b] - 2K_i \leq Q_{-i} \leq [(a - \alpha)/b], \\ 0 & \text{if } [(a - \alpha)/b] \leq Q_{-i}; \end{cases} \quad (4)$$

makes the valid point that it is more reasonable to model it as a two-stage game where capacity is chosen in stage 1 and output in stage 2. We chose the one-stage game because using a two-stage game would introduce additional complexity without seeming to add to the analysis. Ware's criticism is in the context of a first-mover advantage game for which a two-stage game would seem to affect the analysis. It is interesting to note, however, that Figure 1 in [11] shows that he did allow firms to simultaneously add capacity and output in stage 2.

5. This does require that  $a > \alpha + \beta$  which is assumed to be true.

6. The most likely source of an unexpected opportunity for merger is a sudden and unexpected loosening up of antitrust policy, as has taken place in the U.S. under the Reagan administration [10]. Horizontal mergers are currently being allowed in the U.S. which had effectively been prohibited since the Celler-Kefauver Act in 1950. As a case in point, the recent merger between General Electric and RCA would have most likely been prohibited prior to the current administration's laissez-faire policy because of the fact that each firm has a substantial market share of the home entertainment industry. It seems most plausible that, prior to merger, General Electric and RCA were at an equilibrium based upon the current market structure and not one based upon the anticipation of a different market structure due to merger.

where  $K_i = \bar{K}$  for  $i = 1, \dots, n - m$  and  $K_M = m\bar{K}$ . If the other firms produce sufficiently low (that is,  $Q_{-i} < [(a - \alpha - \beta)/b] - 2K_i$ ), firm  $i$  optimally adds capacity while if  $Q_{-i}$  is sufficiently large (that is,  $Q_{-i} > [(a - \alpha)/b] - 2K_i$ ) then firm  $i$  produces with excess capacity. In an intermediate range, the initial capacity constraint is binding at firm  $i$ 's optimal output rate.

A symmetric Nash equilibrium is defined by output rates  $q_M$  and  $\hat{q}$ , where  $q_j = \hat{q}$  for  $j = 1, \dots, n - m$ , which satisfy (5) and (6):

$$q_M = \psi((n - m)\hat{q}; m\bar{K}), \tag{5}$$

$$\hat{q} = \psi((n - m - 1)\hat{q} + q_M; \bar{K}). \tag{6}$$

Let  $\theta$  measure the relative cost of capacity:  $\theta \equiv (\beta/(a - \alpha))$ .

**PROPOSITION 1.** *If  $\theta \in [0, ((m - 1)/(m + n))]$ , the unique symmetric Nash equilibrium is*

$$q_M = [(a - \alpha + (n - m)\beta)/b(n - m + 2)], \quad \hat{q} = [(a - \alpha - 2\beta)/b(n - m + 2)]. \tag{7}$$

*Proof.* Let us first show that there can be at most one symmetric Nash equilibrium. By substituting (5) into (6), a Nash equilibrium is defined by a fixed point to the function  $f(\hat{q})$  where

$$f(\hat{q}) \equiv \psi((n - m - 1)\hat{q} + \psi((n - m)\hat{q}; m\bar{K}); \bar{K}). \tag{8}$$

Since

$$f'(\hat{q}) = \psi'(\cdot; \bar{K})[(n - m - 1) + \psi'(\cdot; m\bar{K})(n - m)] \tag{9}$$

and  $\psi'(\cdot; \cdot) \in \{0, -1/2\}$ , it is straightforward to show that  $f'(\hat{q}) \leq 0$ . Given  $f(\hat{q})$  is continuous, there is then at most one fixed point to  $f(\hat{q})$ . Therefore, there is at most one symmetric Nash equilibrium.

Recall that if firms do not merge then each firm possesses the equilibrium level of capacity and will optimally produce at full capacity. Therefore, since the purpose of merger is to reduce supply below what would be produced otherwise, let us conjecture that the merged firm has excess capacity in equilibrium.  $q_M$  will then be determined by

$$q_M = [(a - \alpha)/2b] - (1/2)(n - m)\hat{q}. \tag{10}$$

In response to the merged firm setting output below the no-merger level, we will conjecture that the non-merged firms expand output and add capacity so that

$$\hat{q} = [(a - \alpha - \beta)/2b] - (1/2)[(n - m - 1)\hat{q} + q_M]. \tag{11}$$

Solving (10) and (11), we derive the values in (7). To complete this proof, we need to show that our conjectures are correct in equilibrium; that is, the merged firm produces with excess capacity and the non-merged firms add capacity. It is easy to show that

$$[(a - \alpha + (n - m)\beta)/b(n - m + 2)] < m\bar{K} \text{ and } [(a - \alpha - 2\beta)/b(n - m + 2)] > \bar{K} \tag{12}$$

iff  $\theta < ((m - 1)/(m + n))$ . Q.E.D.

**PROPOSITION 2.** *If  $\theta \in [((m - 1)/(m + n)), 1]$ , the unique symmetric Nash equilibrium is*

$$q_M = m\bar{K}, \quad \hat{q} = \bar{K}. \tag{13}$$

*Proof.* Since  $\bar{K} \equiv ((a - \alpha - \beta)/b(n + 1))$  then if  $Q_{-j} = (n - 1)\bar{K}$  it is obvious that  $\bar{K}$  is a best reply for firm  $j$ . Now suppose  $Q_{-M} = (n - m)\bar{K}$ . Substituting  $(n - m + 1)((a - \alpha - \beta)/b(n + 1))$  for  $Q_{-M}$  in the reaction function in (4),  $m\bar{K}$  is a best reply for the merged firm iff

$$\begin{aligned} [(a - \alpha - \beta)/b] - [2m(a - \alpha - \beta)/b(n + 1)] &\leq [(n - m)(a - \alpha - \beta)/b(n + 1)] \\ &\leq [(a - \alpha)/b] - [2m(a - \alpha - \beta)/b(n + 1)]. \end{aligned} \tag{14}$$

The first inequality always holds while the second is true iff  $\theta \geq ((m - 1)/(m + n))$ . Q.E.D.

In contrast to S-S-R, we find that  $q_M > \hat{q}$  for all  $\theta \in (0, 1)$  so that the merged firm always produces a greater amount than a non-merged firm. This is directly due to the greater capacity level of the merged firm. Figure 1 provides a graphical exposition of the post-merger equilibrium. Let  $MR'$  represent the marginal revenue curve of firm  $i$  in the pre-merger stage given  $Q_{-i} = (n - 1)\bar{K}$  (that is, the other firms are at their no-merger equilibrium output rates). Merger causes the marginal revenue curve to move up and the vertical segment to the marginal cost curve to shift out to  $m\bar{K}$  for the merged firm. If  $\theta < ((m - 1)/(m + n))$  then the new curve,  $MR''$ , intersects the marginal cost curve below full capacity,  $m\bar{K}$ . Thus, if  $Q_{-M} = (n - m)\bar{K}$ , the merged firm has an incentive to produce below capacity. In response to the reduced supply, the non-merged firms will expand capacity and output beyond  $\bar{K}$ . When  $\theta < ((m - 1)/(m + n))$ , the post-merger equilibrium then entails  $q_M < m\bar{K}$  and  $\hat{q} > \bar{K}$ .

When  $\theta \geq ((m - 1)/(m + n))$ , the marginal revenue curve for the merged firm is instead  $MR'''$  which intersects the marginal cost curve at capacity. Merger does not affect the supply decision of the firms as they choose to produce at full capacity. Similarly, the non-merged firms will then supply at capacity. Thus, merger does not affect the equilibrium output rates when the relative cost of capacity is sufficiently high (that is,  $\theta \geq ((m - 1)/(m + n))$ ). The intuition is that when  $\theta$  is high, the initial capacity level is relatively low so that the merged firm finds it optimal not to produce below capacity.

Given Propositions 1 and 2, we can calculate the profit rates associated with the post-merger equilibrium:

$$\hat{\pi}_M(n, m) = \begin{cases} [(a - \alpha + (n - m)\beta)^2/b(n - m + 2)^2] - [\beta m(a - \alpha - \beta)/b(n + 1)] & \text{if } \theta < [(m - 1)/(m + n)], \\ [m(a - \alpha - \beta)^2/b(n + 1)^2] & \text{if } \theta \geq [(m - 1)/(m + n)], \end{cases} \tag{15}$$

$$\hat{\pi}_j(n, m) = \begin{cases} [(a - \alpha - 2\beta)^2/b(n - m + 2)^2] & \text{if } \theta < [(m - 1)/(m + n)], \\ [(a - \alpha - \beta)^2/b(n + 1)^2] & \text{if } \theta \geq [(m - 1)/(m + n)], \end{cases} \tag{16}$$

where  $j = 1, \dots, n - m$ .

#### IV. Profitability of Merger

Let  $g(n, m)$  represent the gain to  $m$  firms from merging. As defined previously in the literature,  $g(n, m)$  equals the profits earned by the merged firm at the post-merger equilibrium less the sum

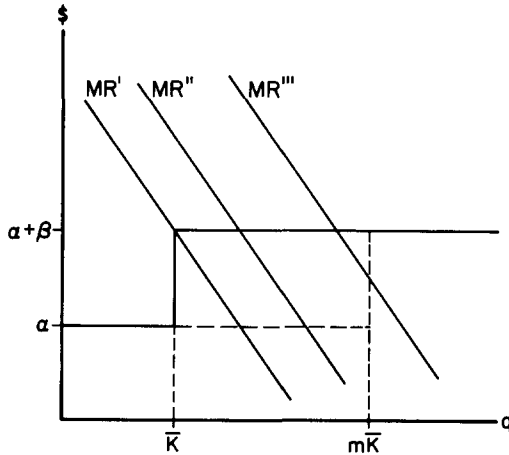


Figure 1

of the profits earned by the  $m$  firms at the no-merger equilibrium. Using the analysis of the preceding sections, it takes the explicit form:

$$g(n, m) = \begin{cases} \{ [(a - \alpha + (n - m)\beta)^2/b(n - m + 2)^2] - [m\beta(a - \alpha - \beta)^2/b(n + 1)^2] \} \\ - [m(a - \alpha - \beta)^2/b(n + 1)^2] & \text{if } \theta < [(m - 1)/(m + n)] \\ 0 & \text{if } \theta \geq [(m - 1)/(m + n)]. \end{cases} \quad (17)$$

We can now present our main result.

**THEOREM.**  $g(n, m) > 0$  if and only if  $\theta < \phi(n, m)$  where

$$\phi(n, m) = [-n^2 + 2(m - 1)n - m^2 + 3m - 1]/[n^3 - 2(m - 1)n^2 + (m - 1)^2n + m]. \quad (18)$$

*Proof.* Working through the algebra, it is straightforward to show that when  $\theta \leq ((m - 1)/(m + n))$  then  $g(n, m) > 0$  if and only if  $\theta < \phi(n, m)$ . Thus, we need only show that  $\phi(n, m) \leq ((m - 1)/(m + n))$ . Once again, working through the tedious algebra yields

$$\text{sign} \{ [(m - 1)/(m + n)] - \phi(n, m) \} = \text{sign} \{ (n - m)[n(n - m) + 3n - m + 2] \}. \quad (19)$$

The r.h.s. expression is positive (zero) if  $n$  exceeds (equals)  $m$ . Q.E.D.

To assess the restrictiveness of this condition, let us compare it to the condition derived by S-S-R. As mentioned previously, the S-S-R model is the case when  $K_i = 0$  for all  $i$ . Define  $\tilde{g}(n, m)$  as the associated gain from an  $m$ -firm merger when  $K_i = 0$  for all  $i$ :

$$\tilde{g}(n, m) = [(a - \alpha - \beta)^2/b(n - m + 2)^2] - [m(a - \alpha - \beta)^2/b(n + 1)^2]. \quad (20)$$

It is straightforward to show that  $\tilde{g}(n, m) > 0$  if and only if  $\phi(n, m) > 0$ .<sup>7</sup>

Quite contrary to our prior expectations, we find that introducing irreversible investment in durable capacity into the S-S-R model makes merger less likely to be profitable. With durable

7. It can be shown that  $\phi(n, m) > 0$  if and only if  $m + m^{1/2} - 1 > n$ . Thus, in the standard linear Cournot model, merger is profitable if and only if  $m + m^{1/2} - 1 > n$ .

**Table I.** Minimum Value of  $n$  for Which  $g(n, m) > 0$  (x indicates that  $g(n, m) < 0$  for all  $n$ )

| $\theta$ | $m = n - 1$ | $m = n - 2$ |
|----------|-------------|-------------|
| 0        | 6           | 12          |
| .01      | 6           | 13          |
| .02      | 6           | 14          |
| .03      | 6           | 16          |
| .04      | 6           | 19          |
| .05      | 7           | 22          |
| .075     | 8           | 44          |
| .10      | 10          | x           |
| .15      | 20          | x           |
| .20      | x           | x           |

capacity, an  $m$ -firm merger is profitable if and only if  $\phi(n, m) > \theta$  while it is profitable in the S-S-R model if and only if  $\phi(n, m) > 0$ . The condition for merger to be profitable with durable capacity then converges to the condition derived by S-S-R as capacity cost goes to zero.

Table I describes the effect of capacity cost on the profitability of  $n - 1$ -firm and  $n - 2$ -firm mergers. For different values of  $\theta$ , the minimum value of  $n$  is shown for which an  $m$ -firm merger is profitable. As the relative cost of capacity increases, it takes a greater number of firms for an  $n - 1$ -firm or an  $n - 2$ -firm merger to be profitable. Thus, higher values of  $\theta$  require a higher percentage of firms in the industry to merge for merger to be profitable. For example, an  $n - 1$ -firm merger is profitable in the S-S-R model as long as  $n \geq 6$ . However when capacity is durable and  $\theta = .1$ ,  $n - 1$  firms will have an incentive to merge if and only if  $n \geq 10$ . For  $\theta = .15$ , an  $n - 1$ -firm merger will only take place if  $n \geq 20$  while such a merger is never profitable if  $\theta \geq .20$ .

Since this result is in contrast to our prior beliefs as well as the results derived by Perry and Porter, it is essential to understand the underlying forces behind it. Towards this end, let us compare the gains from merger with and without durable capacity.

$$\begin{aligned}
 g(n, m) - \tilde{g}(n, m) = & \{[(a - \alpha + (n - m)\beta)^2/b(n - m + 2)^2] \\
 & - [(a - \alpha + (n - m + 1)\beta)(a - \alpha - \beta)/b(n - m + 2)^2]\} \\
 & - \beta\{[m(a - \alpha - \beta)/b(n + 1)] - [(a - \alpha - \beta)/b(n - m + 2)]\} \\
 & \text{if } \theta < [(m - 1)/(m + n)].
 \end{aligned}
 \tag{21}$$

The first of the two expressions is the difference in post-merger profits net of capacity costs. This expression is positive indicating that durability of capital increases the variable profit gain from merger. It is this effect which we expected to observe because the merged firm possesses greater capacity and, therefore, effectively faces a lower marginal cost than the non-merged firms. Since the merged firm has excess capacity, its marginal cost is then  $\alpha$  while non-merged firms face marginal cost of  $(\alpha + \beta)$  given they are expanding capacity. This effect becomes more pronounced as the relative cost of capacity increases. In response to a higher value of  $\theta$ , a non-merged firm will supply less at the post-merger equilibrium while the merged firm will supply more:

$$\partial q_M / \partial \theta = [(n - m)(a - \alpha)/b(n - m + 2)] > 0,
 \tag{22}$$

$$\partial \hat{q} / \partial \theta = -[2(a - \alpha)/b(n - m + 2)] < 0.
 \tag{23}$$



Perry and Porter found a similar effect as merger resulted in the marginal cost function shifting down in their model.

It is the negativity of the second term in (21) which accounts for our result that durable capital makes merger less likely to be profitable. This expression represents capital cost savings from merger which are realized only when capacity is not durable. In the S-S-R model, the merged firm reduces supply, relative to the no-merger equilibrium, and saves  $(\alpha + \beta)$  on each unit since all costs are variable. However, when firms hold an initial stock of capacity, it implies that some costs are nonrecoverable. Thus, the merged firm only saves  $\alpha$  per unit as its capacity costs are sunk. The second term in (21) is then the savings in capacity costs from merger when capacity is not durable. The durability of capital (and the fact that capital costs are sunk) then implies that the merged firm does not hold the optimal level of capacity but rather has excess capacity. This reduces the amount of cost savings from merger and makes it less profitable for firms to merge.

## V. Relationship to Literature

Our finding that irreversible investment in durable capacity makes merger less profitable is in stark contrast to the conclusion of Perry and Porter [6]. They found that merger is at least as profitable in their model as in the S-S-R model and that, generally, merger is more profitable. A detailed comparison of our model and that of Perry and Porter will now be provided in order to determine the source of the conflicting results.

Perry and Porter model the firm cost function as:

$$C(q; K) = gK + dq + (e/2K)q^2; \quad (24)$$

where  $K$  is the firm capital stock (not necessarily capacity) and  $g, d, e > 0$ . Since capital stocks are fixed, the pre-merger and post-merger capital stocks of a non-merged firm are identical while the capital stock of the merged firm is the sum of the pre-merger capital stocks of the merger participants. Hence, if firms  $1, \dots, m$  merge then the cost function of the merged firm is as specified in (24) where  $K = \sum_{i=1}^m K_i$ .

The common elements in our model and that of Perry and Porter are that firms choose quantity, capital is durable and cost-reducing, and capital costs are sunk so that there are no cost savings in terms of lower fixed costs. Since capital has the same features in Perry and Porter's model as in ours, the same two effects of irreversible investment in durable capital should arise in their analysis. Recall that these two effects are: 1) capital gives the merged firm lower marginal cost than the non-merged firms; and 2) capital costs are sunk so that the saving in terms of capital costs from merger are reduced. In terms of differences in the two models, Perry and Porter assume marginal cost is strictly increasing and that the marginal cost function of the merged firm is shifted down due to merger. In contrast, we assume that marginal cost is constant though there is an additional cost for capacity. Nevertheless, assuming constant marginal cost as opposed to rising marginal cost will generally result in greater output expansion by the non-merged firms. This will tend to make merger less profitable in our model and should partially explain the conflicting findings.

However, the key distinction in the two models which we believe is the underlying source of the sharply different conclusions is that Perry and Porter assume capital stocks are fixed so that firms cannot invest in additional capital in response to merger. In contrast, firms in our model

are allowed to adjust their capital stocks after merger occurs. Under the assumption that firms are able to invest in capital in response to a merger, it was observed that the non-merged firms expand capacity (and, therefore, output) and by doing so reduce the value of the merger to the merging firms. It is important to note that if firms were not allowed to adjust their capacity stocks than merger would always be profitable in our model as the non-merged firms would be constrained by their existing capacity levels to produce at the same level as when merger does not take place. Under this assumption, the merged firm could reduce supply without inducing the non-merged firms to raise output.

Finally, let us relate our results to those derived by Davidson and Deneckere [2] who examine a homogeneous goods model in which firms choose price and meet all demand subject to a capacity constraint. Thus, capital enters their model in the same way it does in ours; as production capacity. In contrast to our findings, they show that merger is never unprofitable. The source of this difference in results is very much the same as that with Perry and Porter. Davidson and Deneckere do not allow firms to expand capacity in response to merger. Thus, non-merged firms are limited in terms of their output response to merger. Of course, the fact that it is a price game is also an important source of difference in our results. This is highlighted by the fact that if initial capacity levels are sufficiently great, the equilibrium in their model is the perfectly competitive outcome whether merger takes place or not.

## **VI. Concluding Remarks**

Since the model we analyze is rather special, it would be unwise to place much emphasis on the particular finding that irreversible investment in durable capacity makes merger less likely to be profitable. The value of the model rests instead in pointing out two countervailing effects emanating from durable capital. The first effect, which was recognized by Perry and Porter, is that the merged firm will have a larger capital base than the non-merged firms and this will lead to lower marginal cost. In our model, this took the form of a non-merged firm facing higher marginal cost because of its desire to expand capacity. The impact of this effect is to reduce the expansion of output by the non-merged firms in response to merger and, therefore, raise the profitability of merger. A second, and previously unrecognized, effect that arose from our analysis is that the sunk capital costs resulting from irreversible investment reduce the amount of cost savings achieved by merging and lowering supply. The essential point is that the merged firm is unlikely to hold the optimal level of capital because its capital stock is based upon the pre-merger market structure and capital depreciates slowly over time. The most likely event is that the merged firm will hold excess capacity as the result of its desire to restrict supply relative to the pre-merger situation. As long as it has some excess capacity and capital costs are sunk, the cost savings from merger will be reduced relative to when capital is not durable. This effect should arise in all models with sunk capital costs regardless of whether firms choose quantity or price.

The main criticism to the model of S-S-R was that mergers were not well-defined because firms did not hold durable capital stocks. It was furthermore generally inferred that allowing for durable capital would make mergers more profitable than indicated by the results of S-S-R. Our analysis shows that allowing for irreversible investment in durable capital introduces several effects which do not necessarily make merger more profitable and can certainly make it less profitable. This suggests that there are still many questions yet to be answered about horizontal mergers.

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