R&D and Merger Profitability

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This paper analyzes the interaction between R&D and merger profitability. The industry is composed of symmetric firms who undertake cost-reducing R&D and compete in output. A subgroup of firms merge, and all firms adjust their R&D investments to the new market structure. It is found that in most cases R&D has a negligible impact on merger profitability, and does not change the critical number of firms required to make a merger profitable. However, when firms are indifferent toward a merger in the absence of R&D, R&D has an effect on merger profitability. Noncooperative R&D makes such mergers profitable for low and high levels of spillovers, and unprofitable for intermediate levels of spillovers; moreover, the range of spillovers such that a merger is unprofitable due to R&D increases with concentration. Cooperative R&D without information sharing makes such mergers profitable for low spillovers, but unprofitable for high spillovers. Cooperative R&D with information sharing makes such mergers unprofitable.

Keywords: Mergers, Merger paradox, R&D, R&D cooperation, R&D spillovers

JEL Classification: D43, L13, O33

I. Introduction

On the one hand, R&D investment is known to be a major engine of growth and economic and technological progress. On the other hand, mergers are known to have deep effects on the performance of markets, and often involve a tradeoff between allowing firms to enhance their market power and allowing them - and consumers - to

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benefit from increased efficiencies or network externalities. Yet, the interaction between mergers and R&D is not well understood. What is the impact of mergers on R&D investments? And what is the impact of R&D on the private and social profitability of mergers? This interaction, and the double causality between R&D and merger profitability, are the subject of the present paper.

There exist large separate literatures on mergers and on R&D. On the theoretical side, there is a large literature on mergers. Of particular relevance to the current paper is the work related to merger profitability. Unless there are special circumstances or efficiency gains obtained by the merger, mergers by Cournot firms are often unprofitable, unless they include a large proportion of firms in the industry.[1] The current paper will show how R&D contributes to this debate.

The theoretical literature on R&D has addressed the effect of mergers, and has compared R&D cooperation with mergers (which entail cooperation at both the output and R&D stages). Brod and Shivakumar (1997) analyze R&D cooperation with and without output cooperation, with both R&D cooperation and collusion considered as exogenous. However, in their model R&D cooperation and output collusion involve all firms in the industry, leaving out the issue of the impact of R&D on merger profitability. Choi *et al.* (2003) analyze integration in a systems market and find that integration by the producer of a monopolized component into the competitive complementary component market may reduce R&D. Moreover, they analyze the incentives for integration, and find that the private incentives may exceed the social incentives when R&D investment is in an intermediate range. However, the issue of merger profitability is addressed.

[1] Different mechanisms have been proposed through which firms can evade the merger paradox: Access to scarce capital (Perry and Porter 1985); product differentiation with Bertrand competition (Deneckere and Davidson 1985); non-Cournot behavior (Kwoka 1989); capacity constraints (Baik 1995); properties of the demand function (Fauli-Oller 1997; Hennessy 2000); the short run *vs.* the long run (Polasky and Mason 1998); choice of product range (Lommerud and Sørgard 1997); dynamic Cournot competition (Dockner and Gaunersdorfer 2001); open-loop *vs.* closed-loop strategies (Benchekroun 2003); improved information flows inside the merged entity (Huck *et al.* 2004); intra-firm coordination (Higl and Welzel 2005); and setting competition between the internal divisions of the merged firm (Creane and Davidson 2004).

The empirical literature has focused on the effect of mergers on R&D. The evidence on the impact of mergers on R&D investments is mixed. Mergers improved technological performance in the American computer industry (Hagedoorn and Duysters 2000) and in the chemical industry (Arora *et al.* 2000). However, Bertrand and Zuniga (2004) find that in OECD countries, domestic mergers tend to depress R&D investments, while cross-border mergers have a positive effect on R&D. Cassiman *et al.* (2005) find that mergers involving rivals reduce R&D, while mergers involving non-rivals boost R&D. Blonigen and Taylor (2000) find that in the U.S. electronic and electric equipment sector, there is a negative relationship between R&D intensity and the propensity to merge. The effect in the other direction, from R&D (and spillovers) to merger profitability, is not addressed in either the theoretical or empirical literatures.

To analyze the interaction between mergers and R&D, we set up a model of Cournot competition where firms invest in cost-reducing R&D, and where R&D spillovers are present. In a two-stage framework, firms invest in R&D in the first stage and compete in output in the second stage. Any mergers, if they take place, occur prior to the R&D stage. The focus of the paper is on how the presence of R&D affects merger profitability. That is, does the presence of R&D investments make mergers more or less profitable, compared to a market where R&D is not present. Three types of interactions in R&D are considered: R&D competition, R&D cooperation without information sharing, and R&D cooperation with information sharing.

Regarding the effect of mergers on R&D, it is found that mergers tend to reduce R&D investments and realized cost reduction by the merged entity. When spillovers are high, however, the merger may increase R&D investment by the merging firms. As for the effect of R&D on merger profitability, in most cases, surprisingly, R&D has no effect on merger profitability. That is, for most possible mergers, if a merger is profitable (unprofitable) in a market without R&D, it will also be profitable (unprofitable) in a market with R&D. This is due to the fact that for most mergers, R&D effects are negligible relative to output effects. Hence, whether they reinforce them or mitigate them, they do not change whether the merger is profitable or not.

An interesting result obtains concerning the mergers which were neither profitable nor unprofitable in the absence of R&D: Mergers which made firms indifferent between undertaking them or not. For all such mergers, it is shown that with noncooperative R&D present,

those mergers become strictly profitable when spillovers are low or high, and strictly unprofitable when spillovers are intermediate. The intuition behind this result is that the profitability of a merger in the presence of R&D depends, through marginal costs and outputs, on how the merger affects R&D investments. While in all such mergers the merged entity contracts its R&D and outsiders expand their R&D, the impact of these changes in R&D investments on firms' competitive positions depends on spillovers. The expansion of R&D investments by outsiders hurts the merged entity when spillovers are low, but benefits it when spillovers are high. At the same time, even though the merged entity reduces its R&D investment, the spillover rate is perfect within the firm, hence, for a given R&D investment, the realized cost reduction is higher. And even though the realized cost reduction is lower than before the merger, the firm's output is lower, hence it is rational to invest less in R&D and achieve less cost reduction. This results in the following effects on the merged entity. When spillovers are low, the gain from this improved diffusion is important, and the contraction in R&D benefits the merged entity. When spillovers are high, the benefit from this improved diffusion is lower, and the contraction hurts the merged entity. Moreover, the range of spillovers where mergers are unprofitable is larger, the more concentrated the market is.

This results in three spillover ranges: Profitable mergers for low spillovers, where the positive effect of improved diffusion dominates the loss from the R&D expansion by outsiders; unprofitable mergers with intermediate spillovers, where the negative effect of contraction dominates the positive effect obtained through the R&D expansion by outsiders; and profitable mergers with high spillovers, where the benefit from outsiders' R&D expansion dominates the loss from R&D contraction by the merged entity.

The model is also extended to cooperative R&D. It is shown that cooperative R&D without information sharing makes mergers (toward which firms are indifferent in the absence of R&D) profitable for low spillovers, but unprofitable for high spillovers. On the other hand, cooperative R&D with information sharing makes such mergers unprofitable.

The next section presents and solves the model. Section III analyzes the effects of mergers on R&D, effective cost reduction, and welfare. Section IV, which constitutes the core of the paper, presents the results on merger profitability under noncooperative and cooperative

R&D. Some extensions of the model are discussed in section V. Section VI concludes and discusses the implications of the results.

II. The Model

$n>2$ firms producing a homogeneous good compete a la Cournot. Demand is given by $p=A-bY$, where Y denotes total industry output. The game has two stages. In the first stage, firms invest in cost-reducing R&D. In the second stage, firms produce and sell their output. The number of firms is exogenous.

The marginal production cost of firm i is given by

$$c_i=\alpha-\sqrt{\frac{x_i+\beta\sum_{j\neq i}x_j}{\gamma}} \tag{1}$$

where x_i denotes the R&D investment of firm i. Firm i benefits from R&D investments of other firms through the spillover rate $\beta\in[0,1]$. γ is an R&D efficiency parameter: The higher γ, the less efficient is R&D, and the harder it is to reduce marginal costs. Profits are given by

$$\pi_i=(p-c_i)y_i-x_i \tag{2}$$

Solving the output stage yields the output of firm i for a given marginal cost:

$$y_i=\frac{A-nc_i+\sum_{j\neq i}c_j}{b(n+1)} \tag{3}$$

Substituting this output into (2) and solving for the symmetric equilibrium in R&D yields the R&D investment of each firm:

$$x_i=\frac{(A-\alpha)(n(1-\beta)+\beta)}{\beta^2+b\gamma+\beta(b\gamma-1)+n[2b\gamma+2\beta(b\gamma+1)-2\beta^2-1]+n^2[b\gamma+\beta(b\gamma-1)+\beta^2]} \tag{4}$$

Obviously, the R&D investment of each firm depends on n, and

mergers, by changing n, will affect R&D.

Let $m \leq n$ firms merge and form one firm. The number of active firms following the merger is $n-m+1$. Hence, after the merger, each active firm will produce output and invest in R&D based on (3) and (4), but with n replaced by $n-m+1$.

Let $\pi_i(z)$ represent the profit of firm i when there are z firms in the market. Before the merger, each firm was making $\pi_i(n)$. After the merger, each firm is making $\pi_i(n-m+1)$. This is because when m firms merge and form one firm, the number of firms in the industry is reduced by $m-1$. The profits made by the merging firms prior to the merger are $m\pi_i(n)$. The merger is profitable iff

$$m\pi(n) \leq \pi(n-m+1) \tag{5}$$

where the subscript i is dropped for notational convenience. The complexity of the analytical solutions for R&D and profits makes it impossible to analyze merger profitability analytically. Hence, the paper will rely on numerical simulations.[2] None of the results depend on the specific parameter values used. The crucial parameters for the analysis are n, m, and β.

III. The Effect of Mergers

In this section the effect of mergers on R&D, realized cost reduction and welfare is analyzed. The goal of this section is to prepare the ground for section IV. Hence the results do not necessarily hold for all market structures nor for all possible mergers.

Consider first how the merger affects R&D investments. Consider the merger with $n=5$ and $m=4$.[3] Figure 1 illustrates the R&D investment of each firm before and after the merger. Each firm invests more in R&D, because concentration has increased and the size of each firm has increased. As Figure 2 illustrates, this results in less total R&D investment[4] for low/intermediate spillovers, but higher

[2] The following parametrization is used throughout the paper: $A=2000$, $b=1$, $\alpha=75$, $\gamma=30$.

[3] The relevance of this merger will become clear in the next section.

[4] Total R&D investment is given by $X=\sum_i x_i$, where the sum is over all active firms.

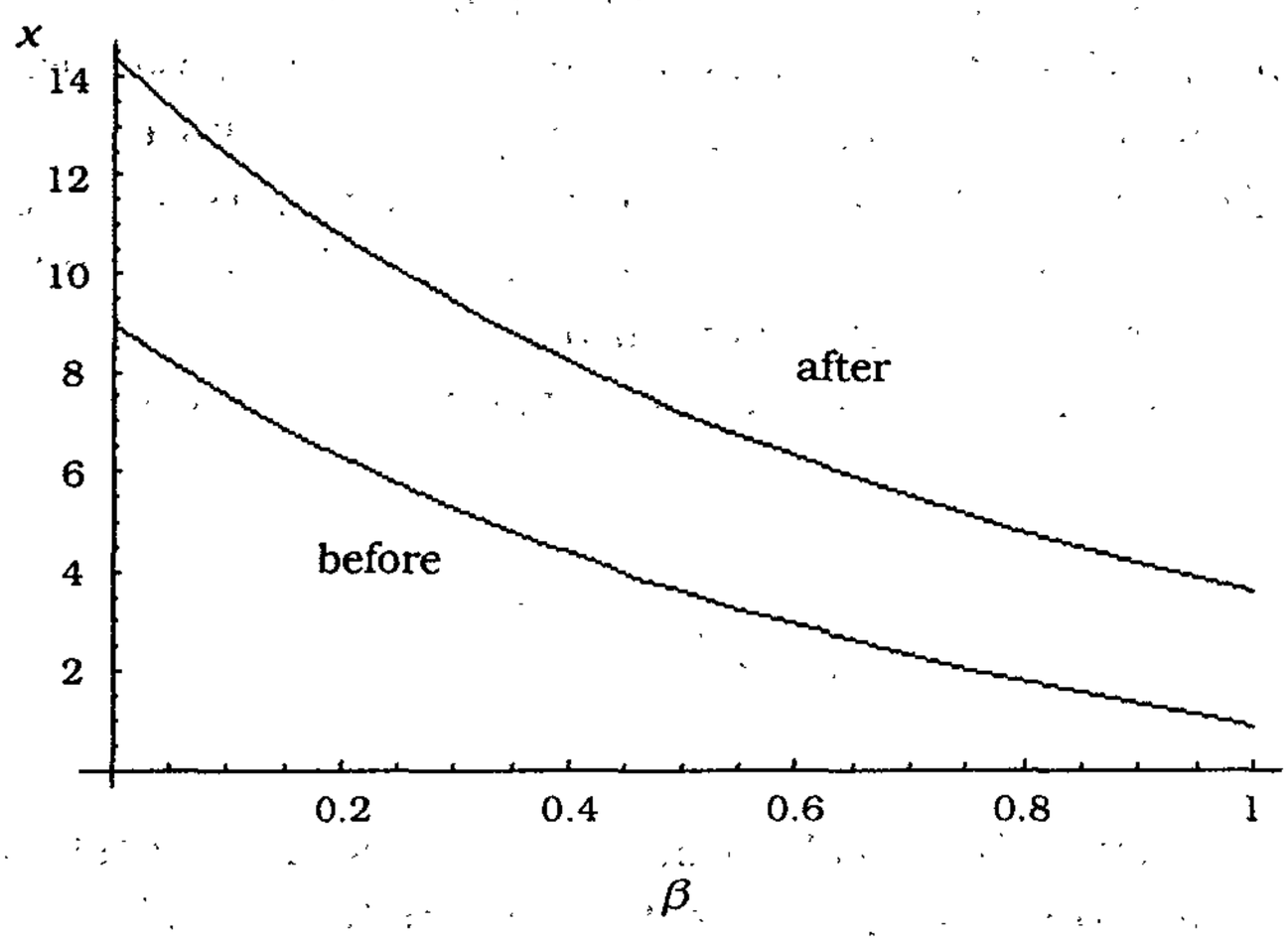

FIGURE 1
R&D INVESTMENT PER FIRM
($n=5$, $m=4$)

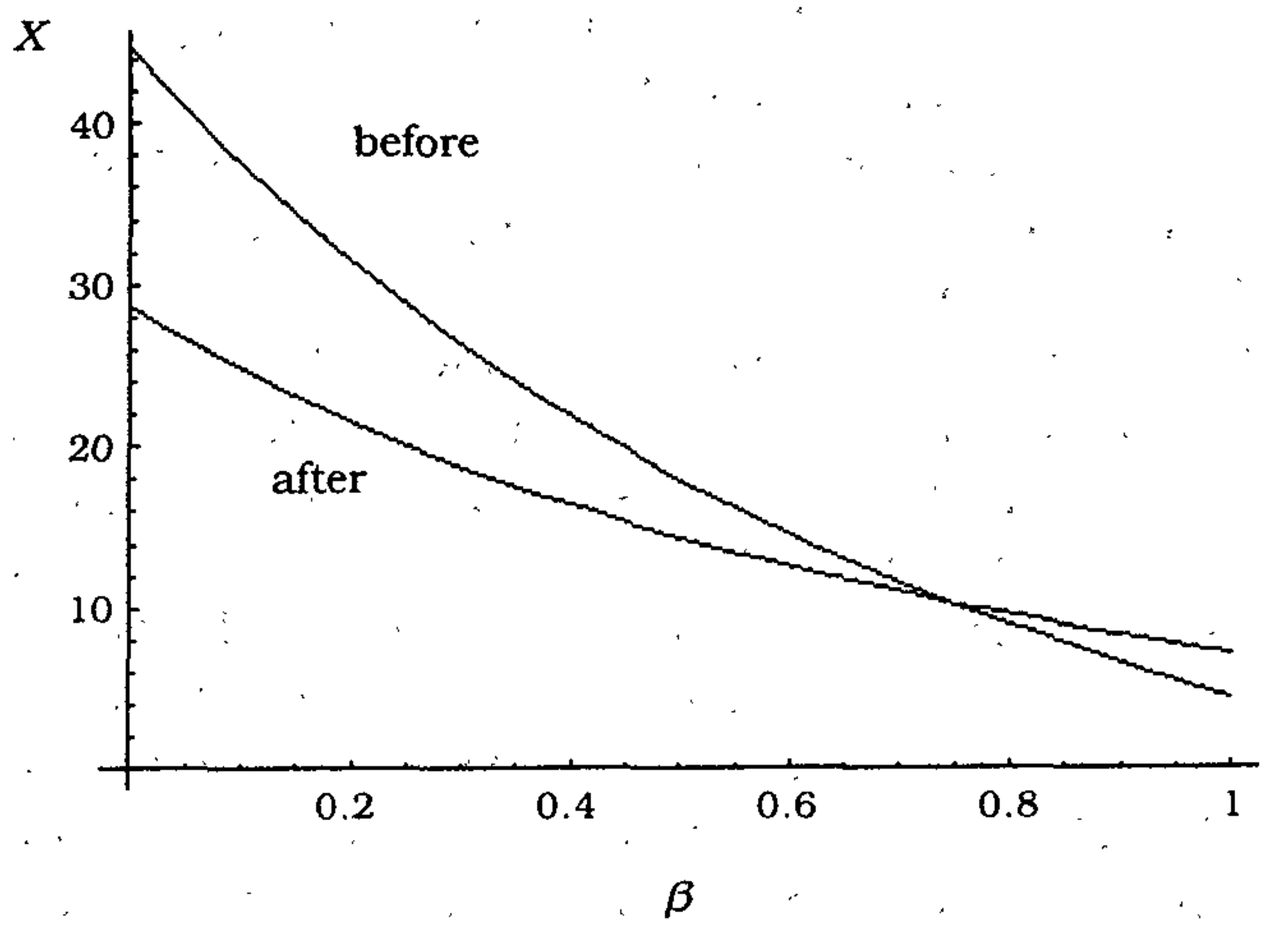

FIGURE 2
TOTAL R&D INVESTMENT
($n=5$, $m=4$)

total R&D investment for high spillovers. Intuitively, spillovers have more negative incentive effects on innovation in a noncooperative environment when the number of competitors is large. Hence total R&D investment declines more steeply with spillovers before the merger than after. This explains why the merger reduces total R&D investment for low spillovers, but increases it for high spillovers.

Effective cost reduction per firm, which represents the dollar amount by which the marginal production cost is reduced, is defined as

$$q_i = \sqrt{\frac{x_i + \beta \sum_{j \neq i} x_j}{\gamma}} \tag{6}$$

Figure 3 shows that each firm now enjoys more cost reduction, because the firm is larger, invests more in R&D, and benefits from the higher R&D investments of the other firms. This means that the industry is now operating with lower marginal costs, albeit at a higher degree of concentration. However, as Figure 4 shows, there is less total cost reduction[5] in the industry: The increase in per firm R&D and effective cost reduction does not compensate for the fact that there are less firms in the industry. As Figure 5 shows, total welfare[6] is reduced by the merger. It is easy to verify that consumer surplus is also reduced.

Until now comparisons have been made between variables concerning one firm prior to the merger and one firm after the merger. However, the relevant comparison for performance and profitability is between the investments and performance of the group of merging firms prior to the merger, with the investments and performance of the firm that results from the merger. Figure 6 compares R&D investments by the merged firms before and after. Total R&D investments of the merged firms are lower before than after the merger, except for high spillovers. There is now less R&D competition, and the output of the merged firms has declined, hence the optimal level of R&D is lower for most levels of spillovers. For very high spillovers, however, R&D was low initially because of the large number of firms prior to the merger and the strong disincentive from

[5] Total cost reduction is given by $Q = \sum_i q_i$.

[6] Total welfare is defined as $W = CS + \sum_i \pi_i$, *where* $CS = bY^2/2$ is consumer surplus.

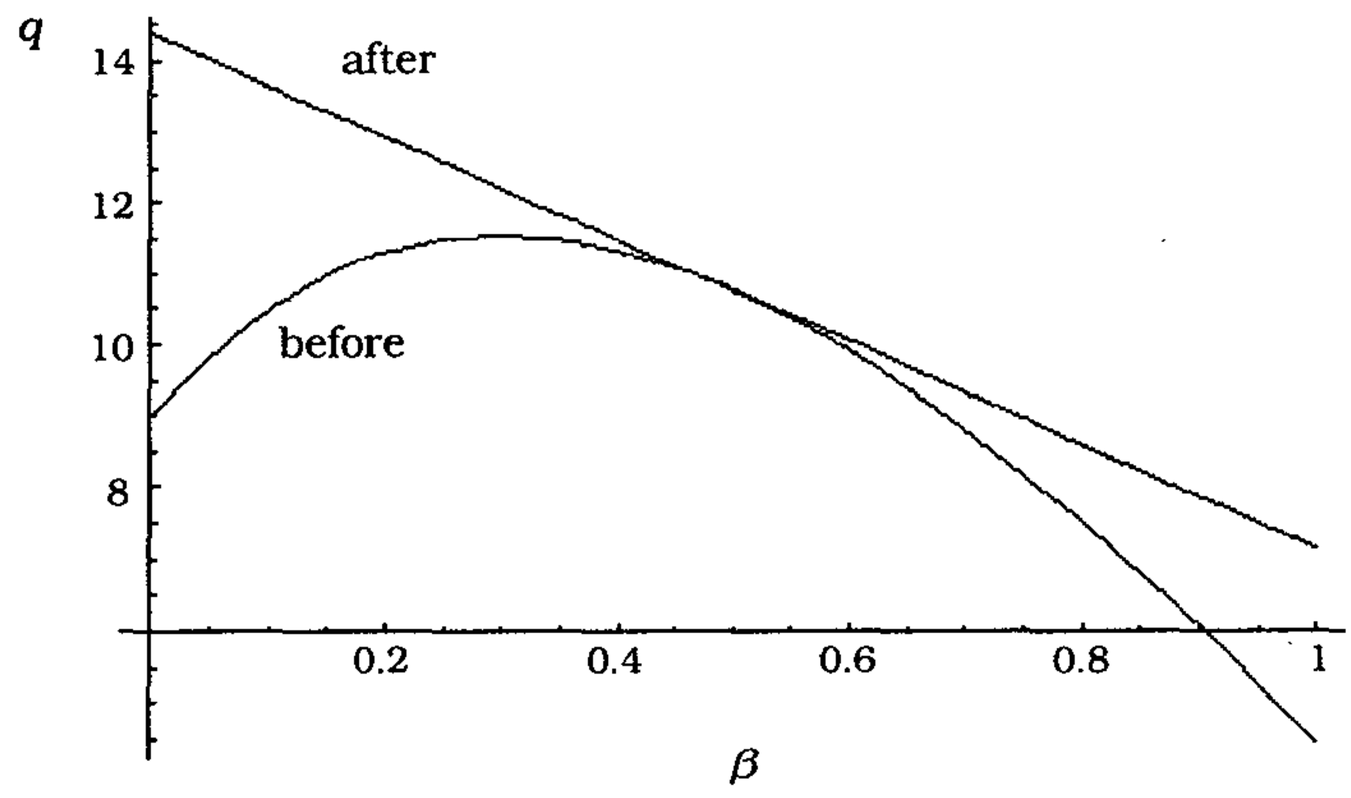

FIGURE 3
EFFECTIVE COST REDUCTION PER FIRM
($n=5$, $m=4$)

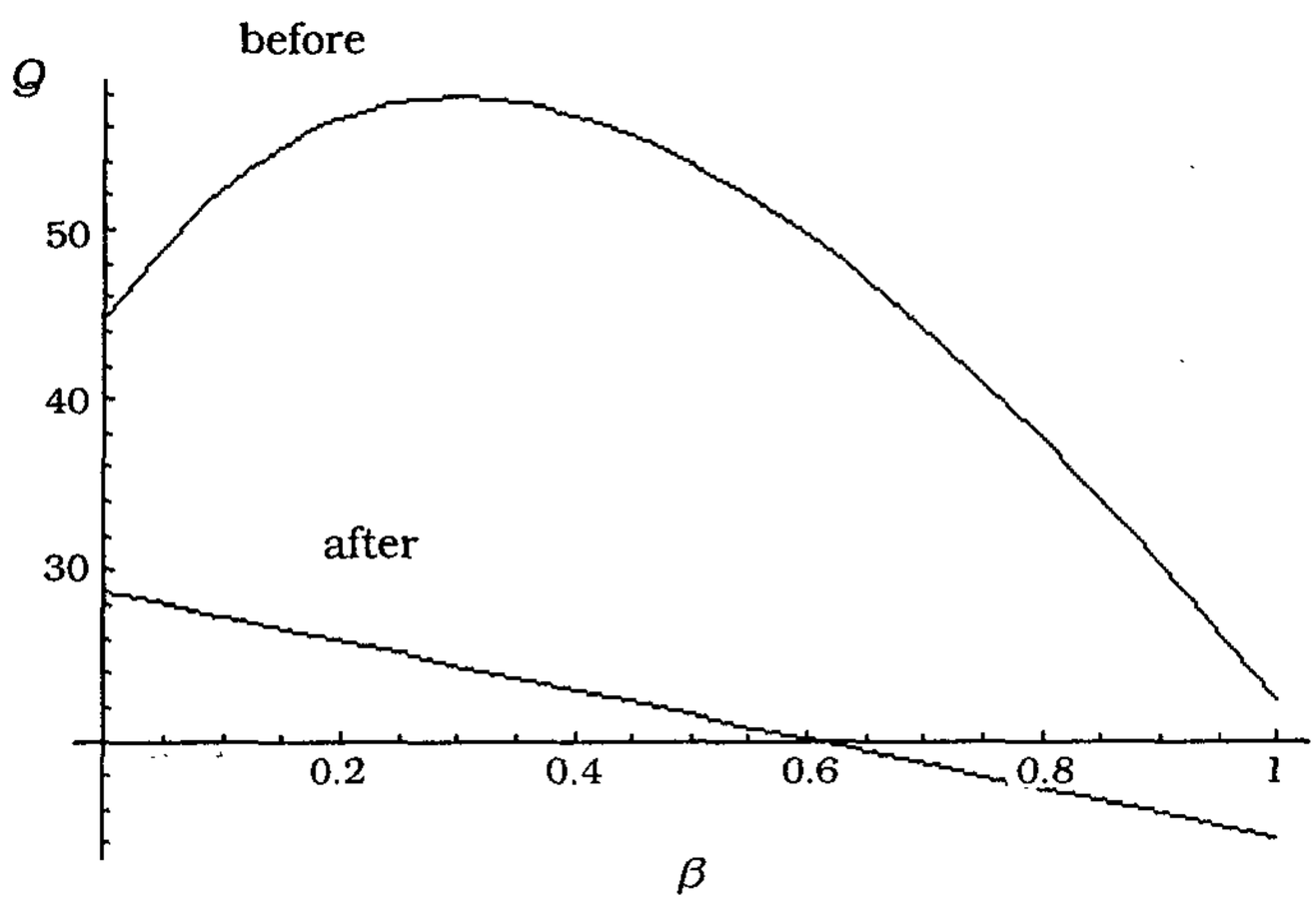

FIGURE 4
TOTAL EFFECTIVE COST REDUCTION
($n=5$, $m=4$)

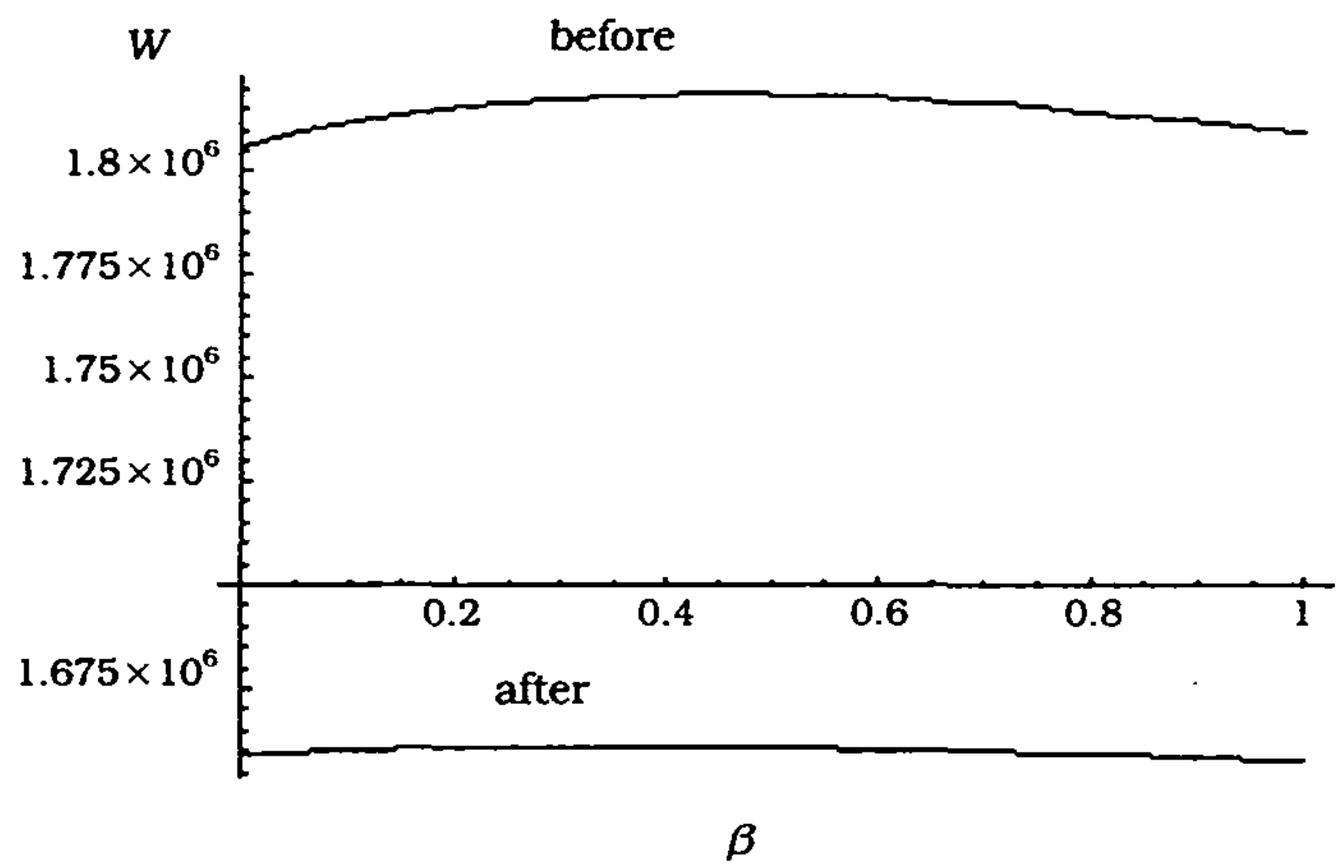

FIGURE 5
WELFARE
($n=5$, $m=4$)

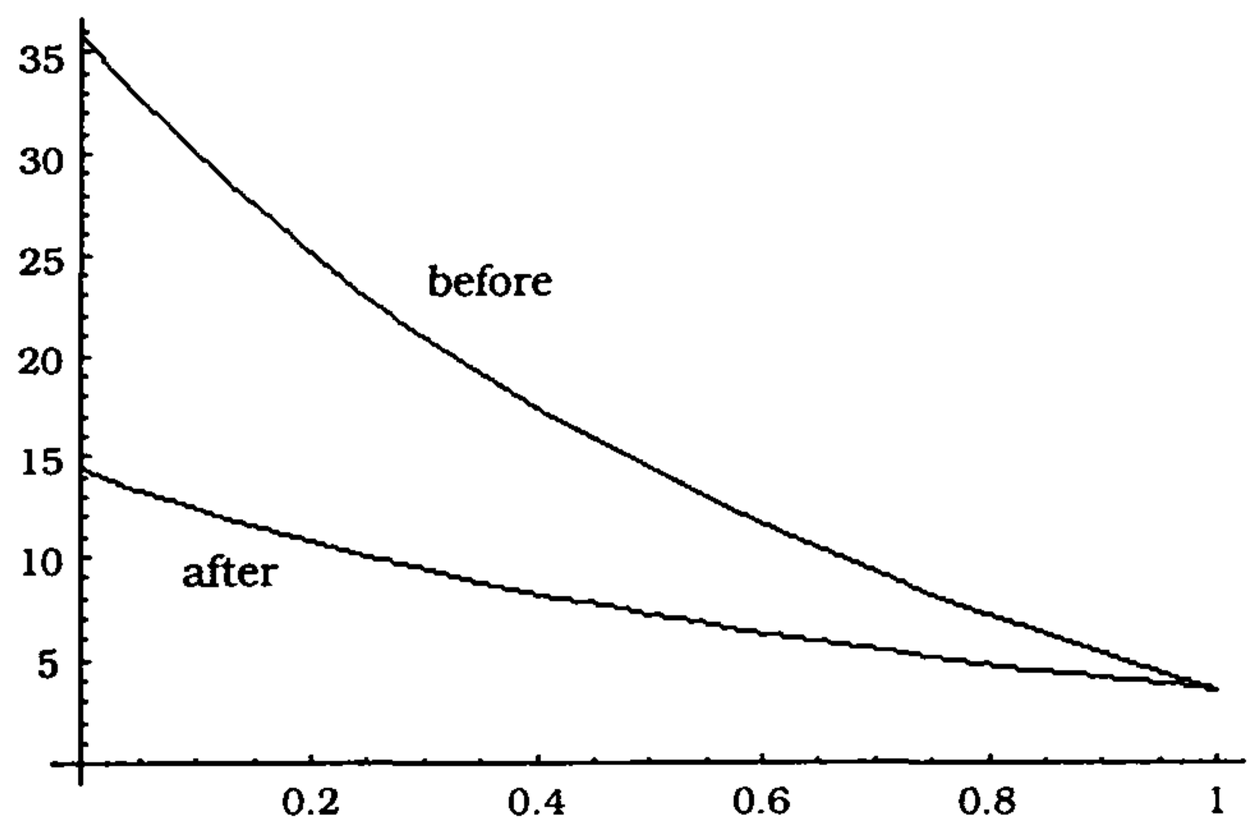

FIGURE 6
R&D INVESTMENT OF MERGING FIRMS
($n=5$, $m=4$)

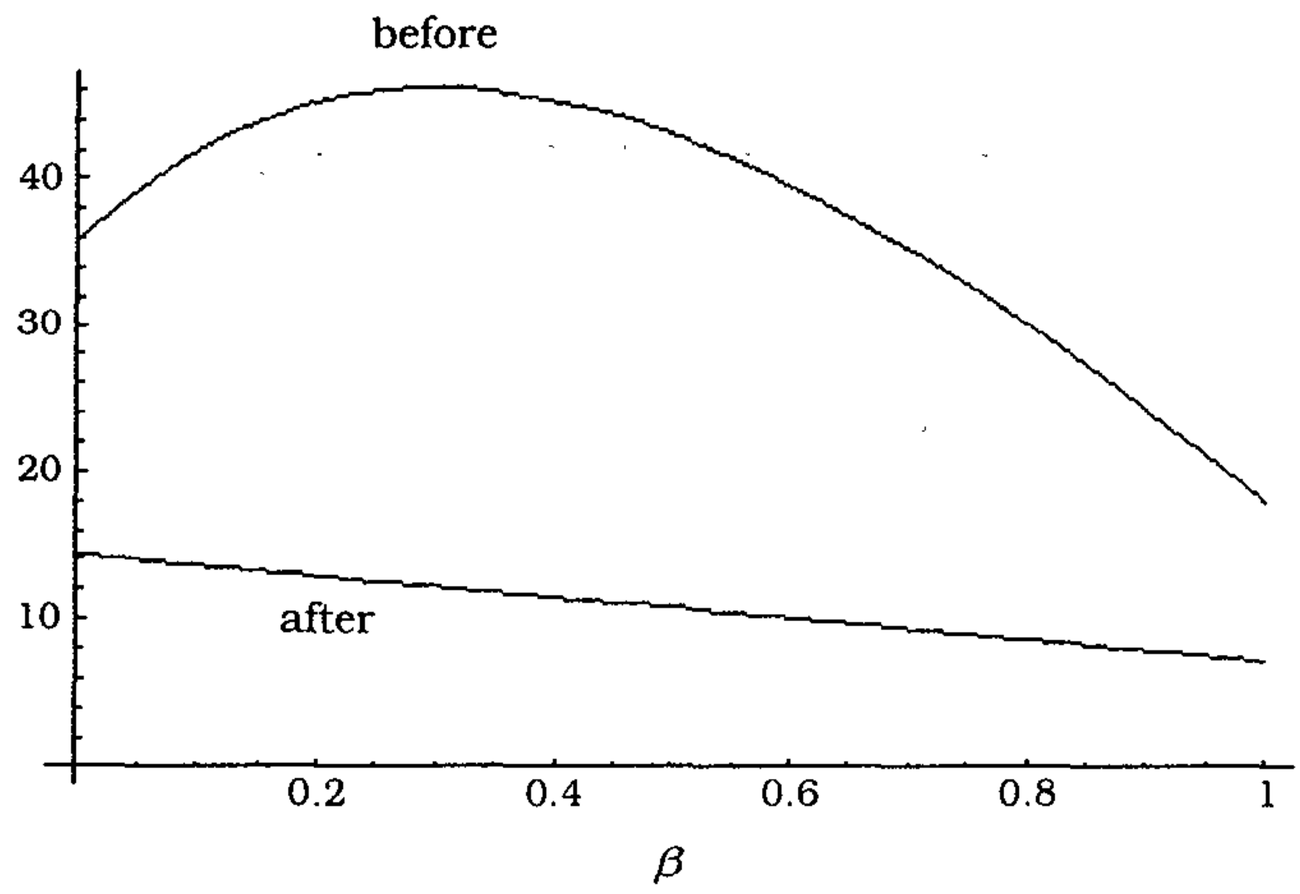

FIGURE 7
EFFECTIVE COST REDUCTION OF MERGING FIRMS
($n=5$, $m=4$)

high spillovers, hence R&D increases with the merger. Figure 7 shows that the merging firm enjoys less cost reduction after than before the merger.

IV. The Profitability of Mergers

We are now ready to analyze the profitability of mergers. In the absence of R&D, Salant *et al.* (1983) have shown that m must be large enough relative to n (at least 80%) for a merger to be profitable. Here we want to inquire how the presence of R&D affects this threshold. We first consider noncooperative R&D, and then analyze the effect of cooperative R&D on merger profitability.

A. R&D Competition

It turns out that in most cases, the presence of R&D has no effect on the critical profitability threshold. That is, for most market structures and for most mergers, a merger that is profitable (unprofitable) in the absence of R&D will also be profitable (unprofitable) in the presence of R&D.

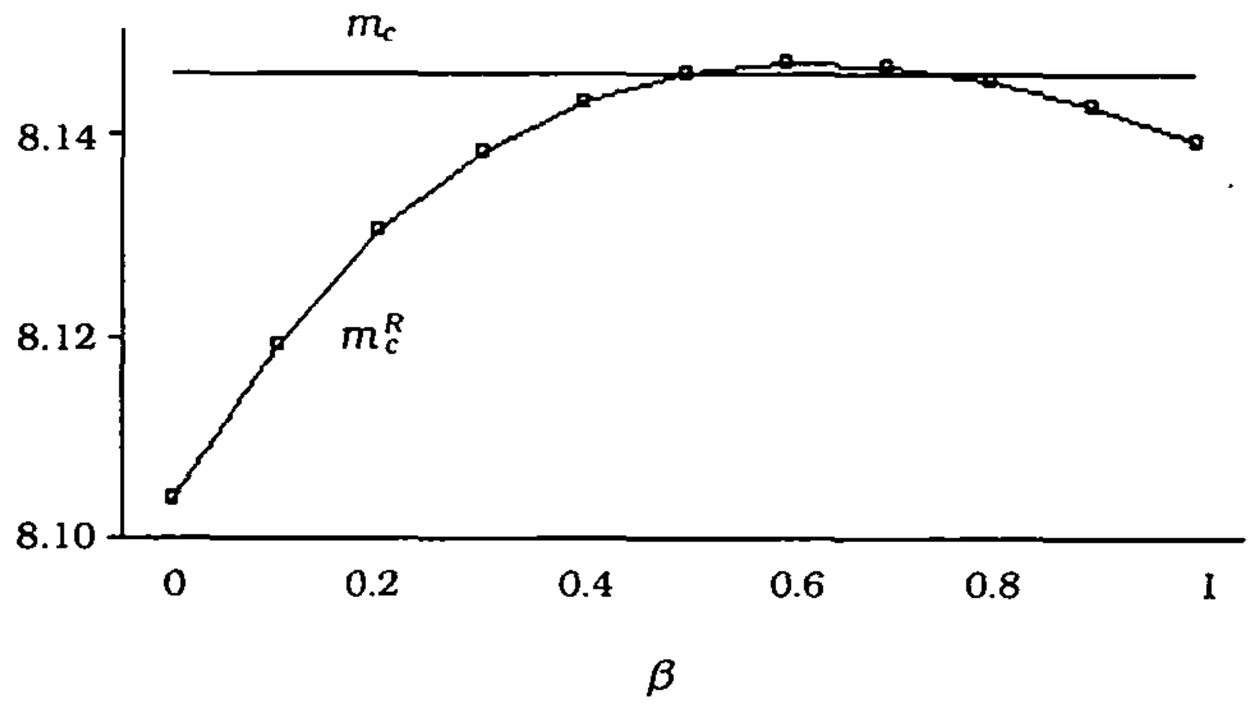

FIGURE 8
CRITICAL THRESHOLDS WITH AND WITHOUT R&D
($n=10$)

To illustrate this result, consider the market structure $n=10$. Let m_c represent the critical threshold for profitability in the absence of R&D, and let m_c^R represent the critical threshold with R&D present. In the absence of R&D, we have that (see Salant *et al.* (1983))

$$m_c=\frac{2n+3-\sqrt{4n+5}}{2} \tag{7}$$

We now wish to compare m_c with m_c^R. It is not possible to solve explicitly for m_c^R. Rather, we parametrize the model and plot is as a function of β. Figure 8 illustrates both m_c and m_c^R when $n=10$. It is clear that the presence of R&D does not affect merger profitability. While R&D affects the critical threshold, that is, $m_c \neq m_c^R$, because n has to be an integer, this change is of no consequence. Hence, in the absence of R&D, 8.2 firms are required to make a merger profitable. With R&D present, slightly less (more) firms are required when spillovers are low or high (intermediate). The reason for this will become clear shortly. However, the change in the critical threshold is of second order, and hence the integer threshold has not really changed: A merger between 8 or less firms

is not profitable, while a merger between 9 or more firms is profitable. In that sense, in a case like this, while technically the presence of R&D changes the critical threshold, the result is economically the same as without R&D.

The reason why in most cases R&D does not change the conditions for merger profitability is that the change in profits due to R&D is too small relative to the change in profits due to changes in output. For instance, when $m_c^R < m_c$, R&D enhances the profitability of the merger slightly (because now less firms are needed to make the merger profitable). Similarly, when $m_c^R > m_c$, R&D reduces the profitability of the merger. But these changes are too small to affect the sign of the inequality in (5). When the (integer) threshold is unchanged by the presence of R&D, this means that the magnitude of the net effect, irrespective of its sign, is too small to reverse merger profitability/unprofitability.

The only cases where the presence of R&D will have an effect on merger profitability is when, in the absence of R&D, firms were indifferent between merging and not merging, that is, when

$$m\pi(n) = \pi(n-m+1) \tag{8}$$

In that case, even a slight change in the critical threshold, due to the presence of R&D, can make the merger profitable or unprofitable. In such cases, we can say that R&D affects the profitability of mergers.

Table 1 illustrates the initial number of firms such that m_c is an integer. For instance, with $n=5$, a merger between 4 firms does not change the profits of the merged firms when there is no R&D. This applies to all other mergers in the table. The last column of Table 1 will be discussed below.

To analyze how R&D affects the profitability of such mergers, we focus on the merger of 4 firms when $n=5$. The analysis applies to all other mergers illustrated in Table 1. Figure 9 illustrates the critical thresholds with and without R&D when $n=5$. The presence of R&D lowers the threshold when spillovers are low or high, but raises it when spillovers are intermediate. This means that a merger of 4 firms becomes strictly profitable for low or high spillovers, and strictly unprofitable for intermediate spillovers. Figure 10 illustrates the pre and post-merger profits with $n=5$ and $m=4$. The merger is profitable iff $\beta \leq 0.5$ or $\beta \geq 0.83$.

TABLE 1
MERGERS WHICH DO NOT CHANGE PROFITABILITY IN THE ABSENCE OF R&D ($n<100$)

n	m	Range of unprofitability when R&D is present $\beta\in(0.5, \beta_c)$
5	4	$\beta\in(0.5, 0.833)$
11	9	$\beta\in(0.5, 0.750)$
19	16	$\beta\in(0.5, 0.722)$
29	25	$\beta\in(0.5, 0.708)$
41	36	$\beta\in(0.5, 0.700)$
55	49	$\beta\in(0.5, 0.694)$
71	64	$\beta\in(0.5, 0.690)$
89	81	$\beta\in(0.5, 0.687)$

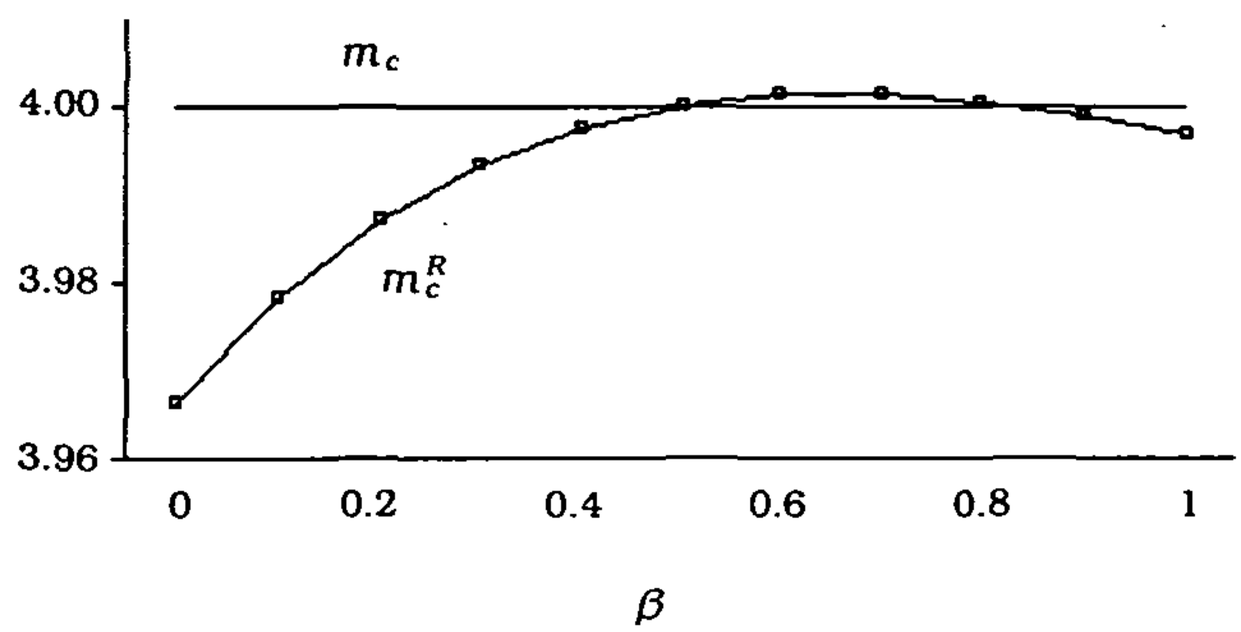

FIGURE 9
CRITICAL THRESHOLDS WITH AND WITHOUT R&D
($n=5$)

We decompose the change in profitability into two effects. Let x_b^M represent total R&D investment of the merged firms before the merger, and x_a^M represent total R&D investment of the merged firms after the merger. Similarly, let x_b^N represent total R&D investment of the non-merged firms before the merger, and x_a^N represent total R&D investment of the non-merged firms after the merger. The change in profits can be written as

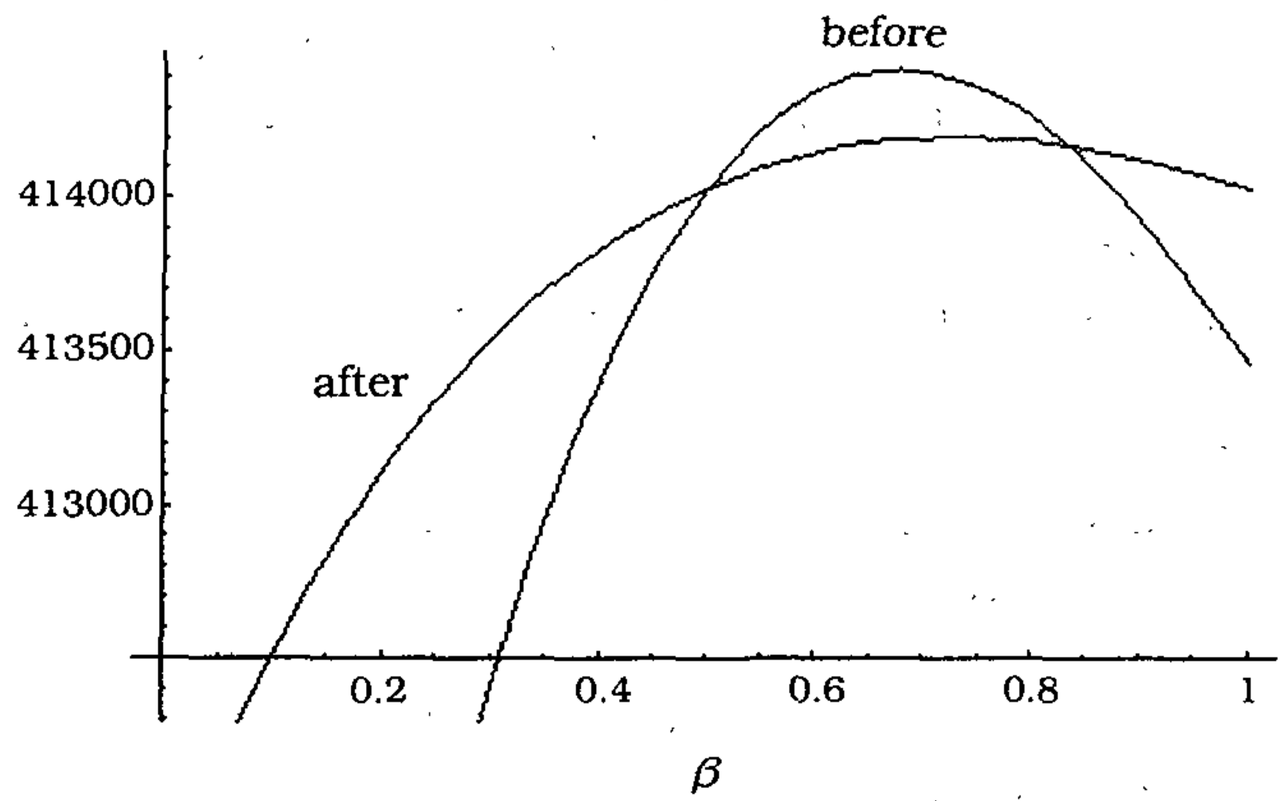

FIGURE 10
PROFITS OF MERGING FIRMS
($n=5$, $m=4$)

$$\begin{aligned}\Delta\pi &= \pi(x_a^M, x_a^N) - m\,\pi(x_b^M, x_b^N)\\ &= [\pi(x_a^M, x_a^N) - \pi(x_a^M, x_b^N)] + [\pi(x_a^M, x_b^N) - m\,\pi(x_b^M, x_b^N)] \qquad (9)\\ &= E_N + E_M\end{aligned}$$

First, there is the effect of the change in R&D by the merged firms, holding the R&D of outsiders constant. This effect is given by $E_M = \pi(x_a^M, x_b^N) - m\,\pi(x_b^M, x_b^N)$. Second, there is the effect of the increase in R&D of outsiders on the profits of the merged firms. This effect is given by E_N. Figure 11 plots E_M, E_N and their sum (which represents the change in profits of the merged firms) in the case $n=5$, $m=4$. Consistent with Figure 10, Figure 11 shows that this merger is profitable when $\beta \leq 0.5$ or $\beta \geq 0.83$, and is unprofitable in the range $\beta \in (0.5, 0.83)$. Hence, the merger is profitable for low or high spillovers, but unprofitable for intermediate spillovers.

To understand this result, we look at the decomposition of the change in profits. Consider first E_M. Figure 11 shows that E_M first declines and then increases with spillovers. Moreover, $E_M > 0$ for $\beta < 0.5$ and $E_M < 0$ for $\beta > 0.5$.

To understand this effect, note that the contraction in R&D affects the profits of the merged firms through three channels. First, it has a direct negative effect on profits, since the reduction increases their marginal cost. Second, the merger implies that the spillover rate inside the merged entity is perfect; hence, for a given level of R&D, the merger increases the effective cost reduction of the merged firms. This effect increases profits, and is more important when spillovers are low, because in this case the change in the internal spillover rate is most significant. Third, the contraction in R&D by the merged firms increases the production cost of outsiders, since they benefit less from diffusion of the R&D of the merged firms, for a given spillover rate. This third effect is most significant when spillovers are high, because it is in this case that the reduction in R&D by the merged firms hurts outsiders most. When β is close to 1, the merged entity actually expands its R&D (see Figure 6), but expansion in this case is not very beneficial, because it benefits outsiders considerably.

E_M declines with spillovers up to $\beta=0.802$ because in this range the benefit from the increase in the internal spillover rate (the first effect) is reduced; it increases with spillovers when $\beta>0.802$ (even though it is negative in this range) because in this range the benefit from the increase in the production cost of outsiders increases with spillovers.

More importantly, $E_M>0$ for $\beta<0.5$. In this range, the reduction in R&D by the merged firms actually benefits them. Remember that the merged entity is smaller than the sum of the firms prior to the merger, hence the optimal level of R&D for it has declined. In this range, the benefit from adjusting the size of R&D, and from the increase in the internal spillover rate, makes the reduction in R&D profitable. When $\beta>0.5$, however, $E_M<0$. In this range, the benefit from the increase in the internal spillover rate is less important, and the loss from R&D contraction dominates.

Consider next the effect of the increase in R&D by outsiders, E_N. As Figure 11 shows, this effect always increases with spillovers: The merged entity benefits more from this expansion, the higher is β. Moreover, $E_N<0$ for $\beta<0.5$ and $E_N>0$ for $\beta>0.5$. Hence the effect on insiders is positive when spillovers are sufficiently high.

The total change in the profitability of the merger (remember that in the absence of R&D this merger induced a zero change in the profits of the merged firms) is given by the sum $\Delta\pi=E_M+E_N$, and is shown in Figure 11. When $\beta<0.5$, the net effect is positive; in this range

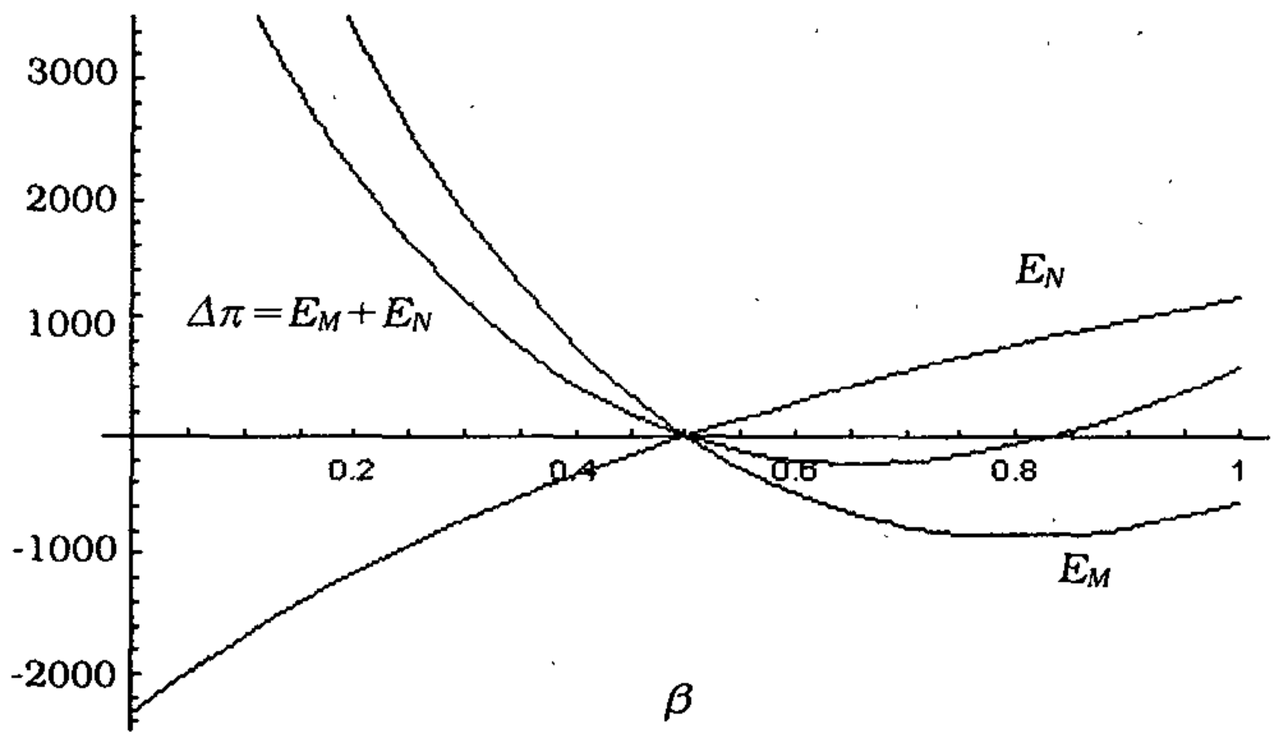

FIGURE 11
DECOMPOSITION OF THE CHANGE IN THE PROFITS OF THE MERGING FIRMS
($n=5$, $m=4$)

$E_M>0$ and $E_N<0$; hence E_M dominates: The benefit from adjusting R&D and increasing the internal spillover rate dominates the loss from the expansion of R&D by outsiders. When $\beta\in(0.5, 0.83)$, the net effect is negative. In this range $E_M<0$ but $E_N>0$: The loss from own R&D reduction dominates the gain from the R&D expansion by outsiders. Finally, when $\beta>0.83$, the net effect is positive. In this range, even though $E_M<0$ and $E_N>0$, the effect of E_N dominates: The benefit from the R&D expansion by outsiders dominates the loss from the reduction of own R&D (or the loss from R&D expansion when β is close to 1).

The last column of Table 1 illustrates the range of unprofitability for all mergers affected by R&D, for $n<100$. The lower bound is always $\beta=0.5$, and the upper bound declines with competition. As the number of firms in the industry increases (prior to the merger), E_N, the benefit from the expansion of R&D by outsiders - positive when spillovers are high -, increases, making the merger profitable for a wider range of spillovers, *i.e.* pushing the upper bound of the unprofitability range to the left.

The following proposition summarizes the effect of noncooperative R&D on merger profitability.

Proposition 1

Consider an industry composed of n firms, where the merger of m firms leaves the profits of the merged firms unchanged in the absence of R&D, with m an integer. Then, in the presence of R&D, this merger becomes strictly profitable when $\beta<0.5$ or $\beta>\beta_c$, and strictly unprofitable for $\beta\in(0.5,\beta_c)$, with $\beta_c\in(0.5,1)$. Moreover, β_c declines with n. (See Table 1 for exact values of β_c for $n<100$).

B. R&D Cartelization

Consider now how the presence of cooperative R&D affects merger profitability. Everything is as above, except that now R&D expenditures are determined cooperatively, whether there is a merger or not. For now we focus on R&D cartelization, where firms choose R&D expenditures to maximize joint profits but the spillover rate is unaffected by R&D cooperation. Moreover, even when a group of firms merge, the new entity continues to cooperate with outsiders. The impact of relaxing this assumption will be discussed later.

Under cooperation, R&D is given by

$$x_i^c=\frac{(A-\alpha)((n-1)\beta+1)}{(n+1)^2(b\gamma-\beta^2)+\beta[b\gamma(n^2+1)+2n(b\gamma-1)+2]-1} \tag{10}$$

It turns out that even with cooperative R&D, in most cases the profitability of mergers is not affected by the presence of R&D: A merger that is strictly (un)profitable without R&D remains so in the presence of cooperative R&D. What is of interest, as in the previous section, is how mergers toward which firms are indifferent in the absence of R&D, are affected by the presence of cooperative R&D. Given that a partial list of such mergers is given in Table 1, here we focus the analysis on the case where $n=5$ and $m=4$. The same analysis can be applied to all other mergers in Table 1.

Figure 12 illustrates the impact of such a merger on R&D investment of the merging firms. The merger reduces R&D investment by those firms, and the reduction increases with spillovers. When spillovers are low, the reduction in R&D is smaller because the merging firms gain from the increased spillover rate between them, and this effect is important in spite of the reduction of the size of the merged firms and their output. With high spillovers, however, the

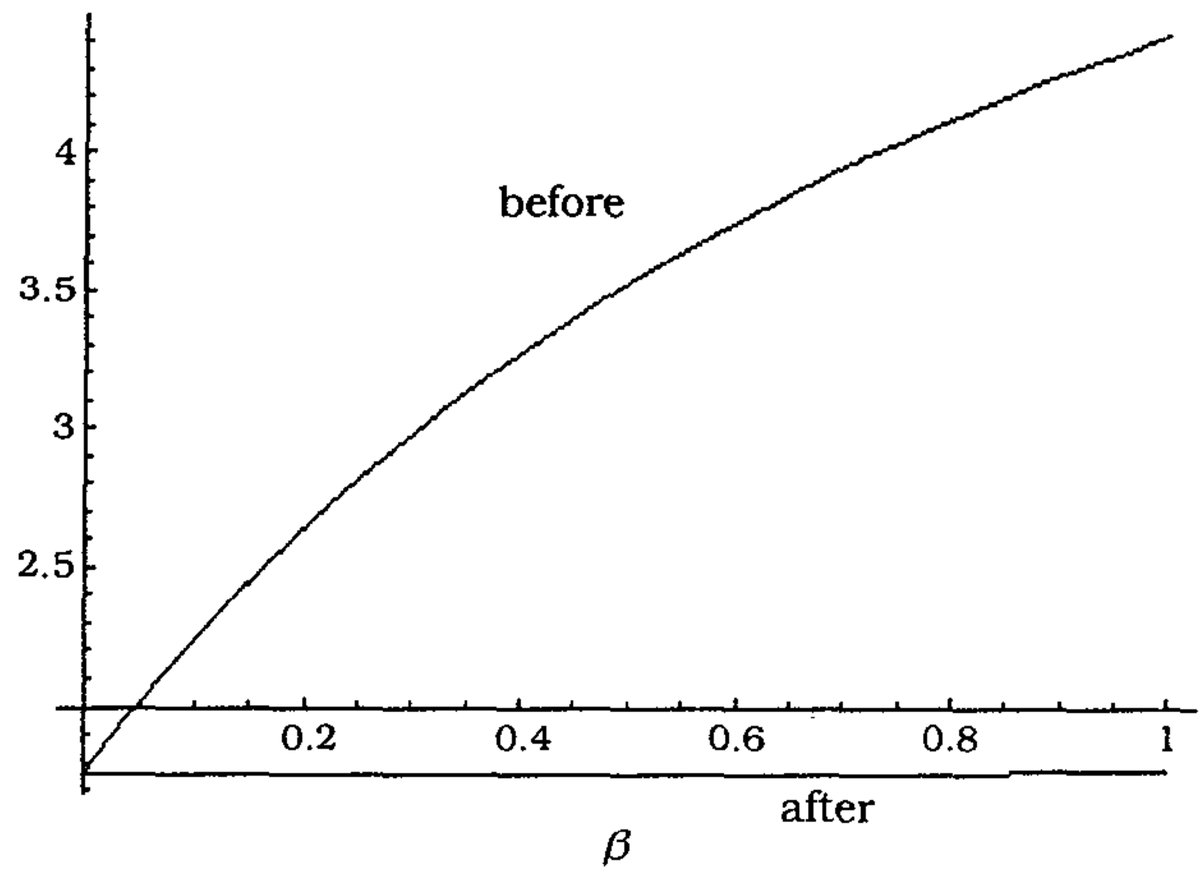

FIGURE 12
R&D INVESTMENT OF MERGING FIRMS - R&D CARTELIZATION
($n=5$, $m=4$)

value of this increased internal spillover rate is reduced, hence R&D declines more sharply.

Figure 13 shows the effect of the merger on the R&D of the outsider.[7] The outsider increases its R&D, and this increase is most substantial when spillovers are low. Note that cooperative R&D is hardly sensitive to spillovers when $n=2$, and very sensitive to spillovers at $n=5$. In fact, the sensitivity of cooperative R&D to spillovers is non-monotonic in n: It starts very low at $n=2$, reaches a peak at $n=5$, and declines afterwards (see Figure 14). The sensitivity is initially low because a low n means limited benefits from diffusion. As the number of firms increases, the benefits of diffusion increase, hence $\partial x/\partial\beta$ increases. As n increases further, however, the size of each firm is reduced, and the benefits of diffusion are more limited, hence the cooperative R&D of each firm increases less steeply with spillovers. In consequence, (going back to Figure 13) the increase in R&D is most important when spillovers are low; as spillovers increase, R&D increases less steeply after the merger than before the

[7] There is only one outsider left when $n=5$ and $m=4$.

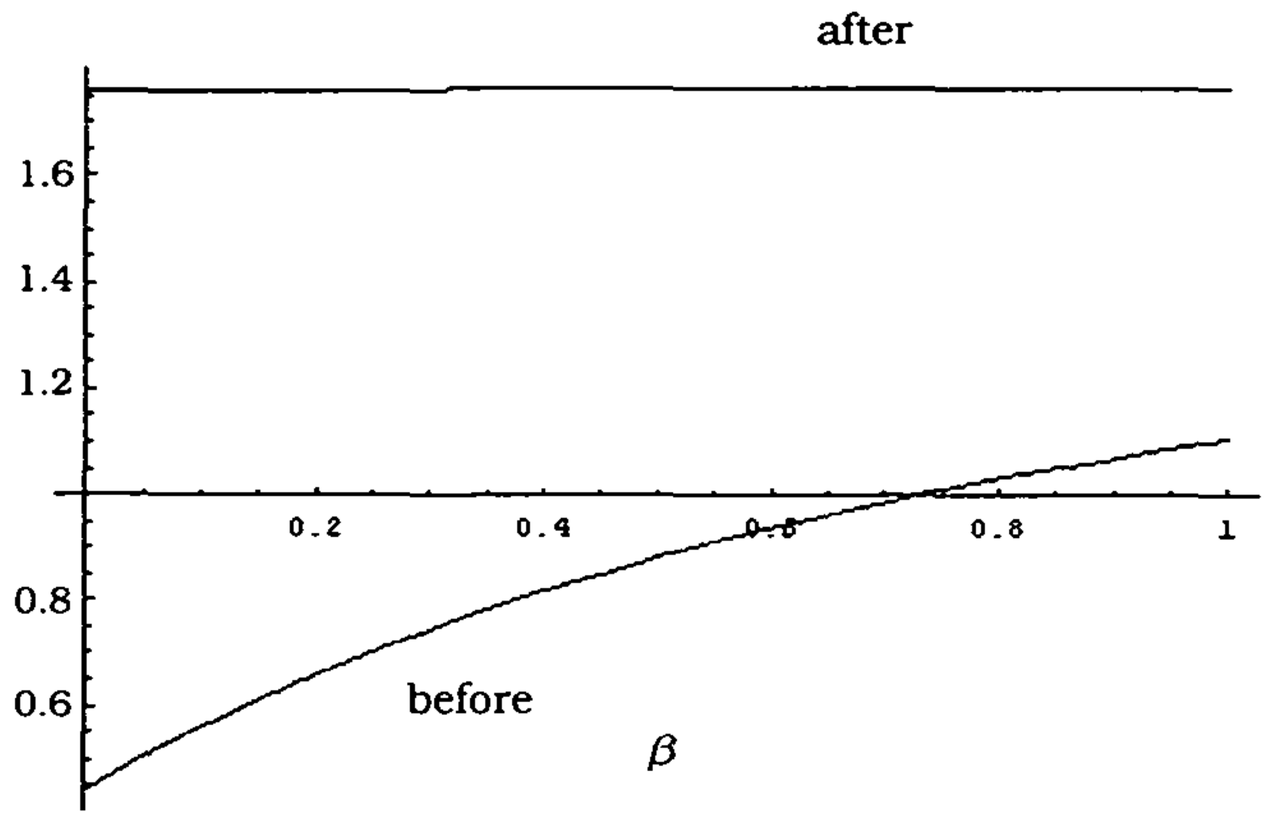

FIGURE 13

R&D INVESTMENT OF OUTSIDER - R&D CARTELIZATION

($n=5$, $m=4$)

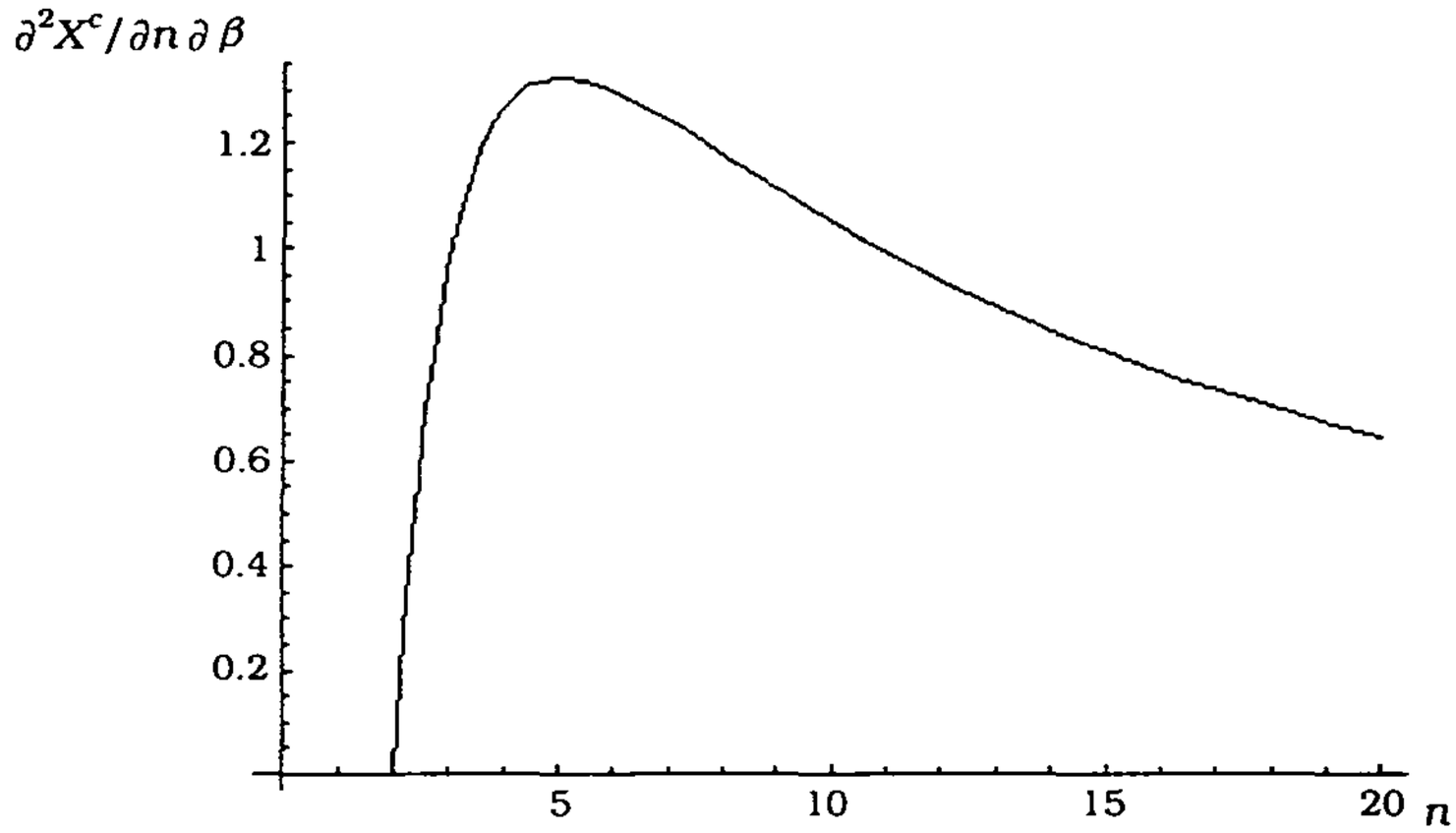

FIGURE 14

SENSITIVITY OF THE R&D - SPILLOVER RELATIONSHIP TO MARKET STRUCTURE

R&D CARTELIZATION

merger, hence the increase is less important for high spillovers. A similar explanation can also be used to explain the change in R&D by insiders illustrated in Figure 12.

The result that the decline in R&D by the merged firms increases with spillovers holds for any market structure in Table 1. However, the result that the increase in R&D by outsiders decreases with spillovers is less robust: It is reversed for very high values of m and n in Table 1. However, all the other results, in particular merger profitability, continue to hold. The reason is, as we will see, is that the effects - on merger profitability - of the change in own R&D dominate the effects of the change in the R&D of outsiders.

Consider now the effect of the merger on the profits of the merged firms. As Figure 15 illustrates, the merger of 4 firms in a 5-firm industry performing cooperative R&D both before and after the merger is strictly profitable for $\beta<0.5$ and strictly unprofitable for $\beta>0.5$. To understand this result, the same decomposition that was used for noncooperative R&D is applied to cooperative R&D (see Equation (9) above). Figure 16 illustrates the decomposition for cooperative R&D. E_M represents the effect of the change in R&D of the merged firms on profits, holding the outsiders' R&D constant. This effect is positive for $\beta<0.5$, and negative for $\beta>0.5$. Remember that the merged firms reduce their R&D following the merger. This in itself has a negative effect on their profits. However, even though there is no information sharing, the merged firms now use a single research lab, hence the implicit spillover rate within the firm is 1. For low enough spillovers, the gain from this improved internal spillovers dominates the loss from the reduction in R&D, and $E_M>0$. Moreover, the reduction in R&D by the merged firms is at its lowest when spillovers are low (see Figure 12), hence the direct loss from this reduction is also negligible. For $\beta>0.5$, however, the gain from improved internal spillovers is less important, and the merged firms lose from the reduction of their R&D, hence $E_M<0$. Moreover, the reduction in the merged firms' R&D is largest when spillovers are high, which reinforces this loss.

As for the effect of the R&D expansion by outsiders on the merged firms, it is negative ($E_N<0$) when $\beta<0.5$, because the merged firms do not benefit sufficiently from this expansion. Moreover, this expansion is at its highest when spillovers are low, which hurts the merged firms even more. For high spillovers ($\beta>0.5$), however, the gain to the merged firms is substantial, and hence $E_N>0$. Moreover, the expansion of R&D by the outsider decreases with spillovers.

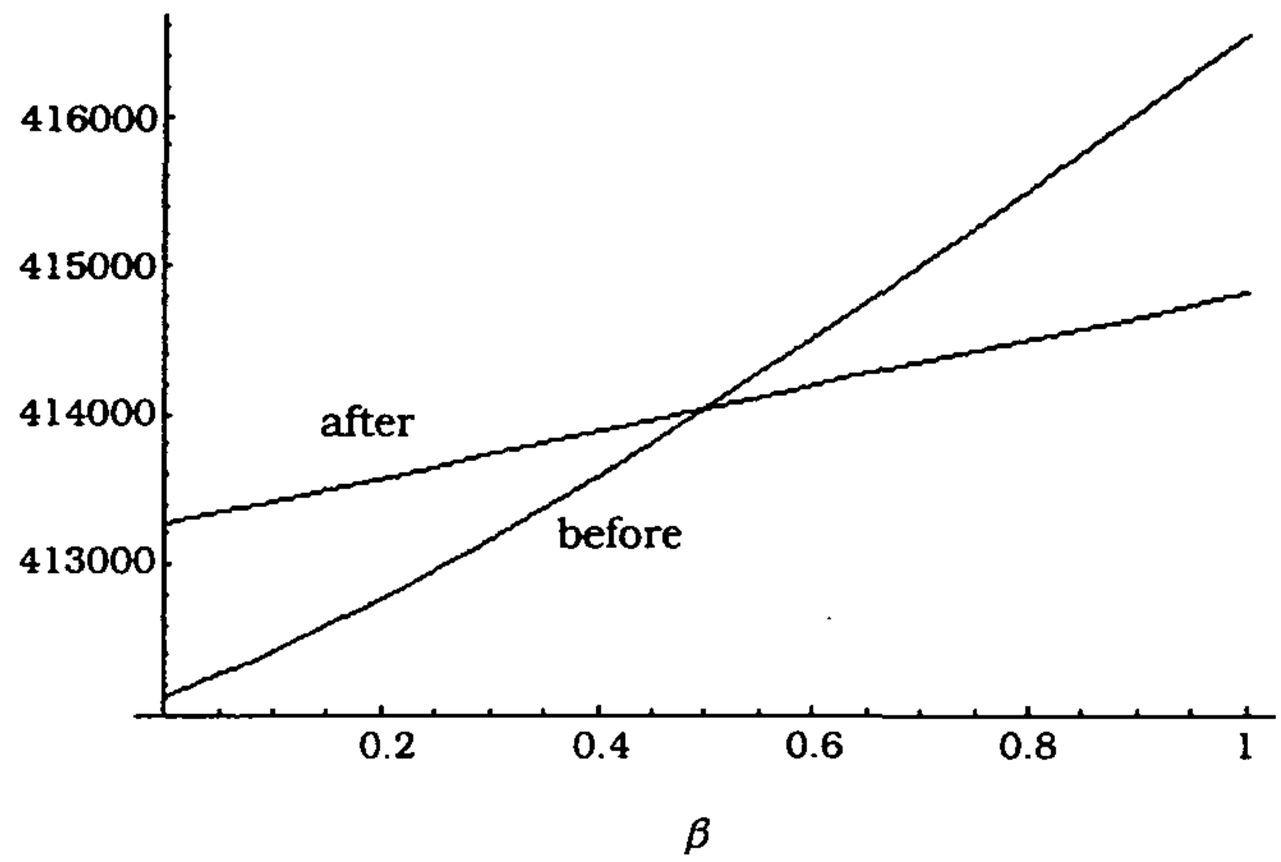

FIGURE 15

PROFITS OF MERGING FIRMS - R&D CARTELIZATION

($n=5$, $m=4$)

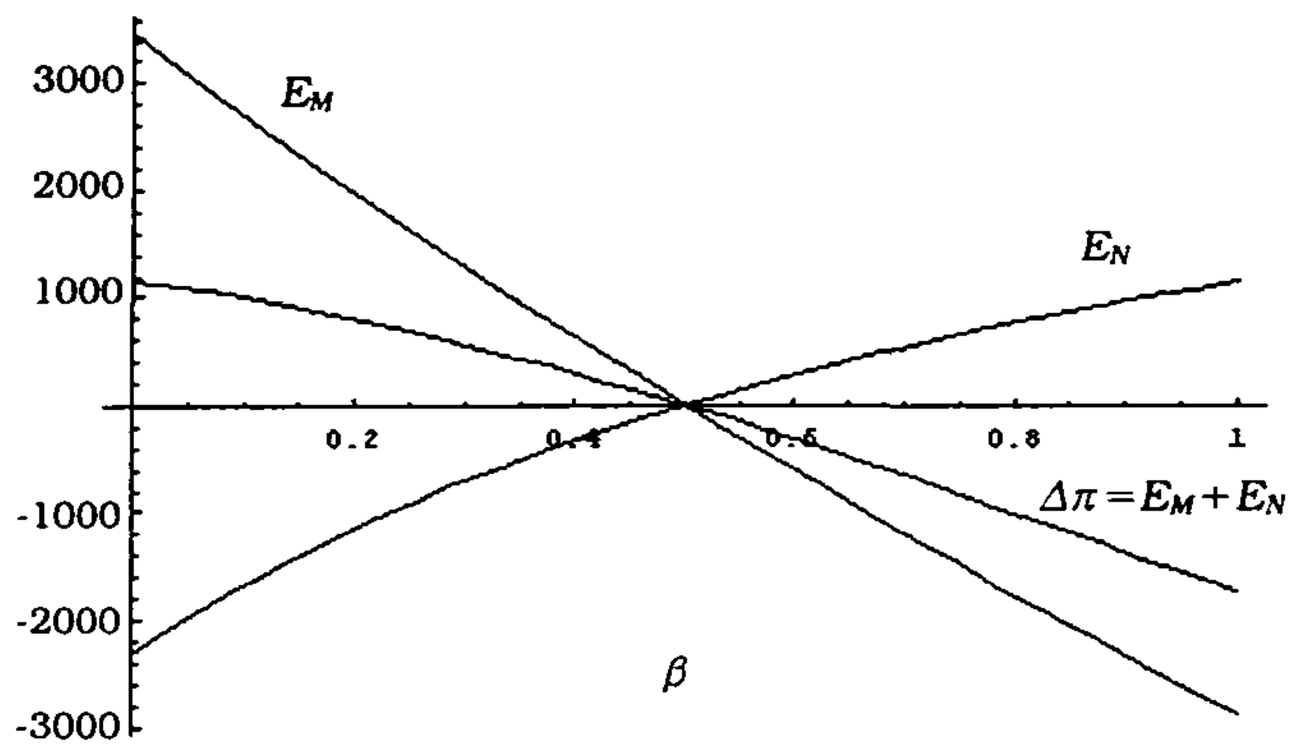

FIGURE 16

DECOMPOSITION OF THE CHANGE IN THE PROFITS OF THE MERGING FIRMS

R&D CARTELIZATION ($n=5$, $m=4$)

The net effect on profits depends on the magnitudes of these two effects. As Figure 16 shows, $|E_M| \geq |E_N|$ for all β, hence the own-effect dominates, and $sign\, \Delta\pi = sign\, E_M$.

Proposition 2

Consider an industry composed of n firms, where the merger of m firms leaves the profits of the merged firms unchanged in the absence of R&D, with m an integer. Then, in the presence of R&D cartelization, this merger becomes strictly profitable when $\beta < 0.5$ and strictly unprofitable when $\beta > 0.5$.

Compared with noncooperative R&D, R&D cartelization actually makes mergers unprofitable more often. Both cooperative and noncooperative R&D have in common that they make mergers profitable for $\beta < 0.5$, and unprofitable in the range $\beta \in (0.5, \beta_c)$. However, whereas noncooperative R&D makes mergers profitable in the range $\beta \in [\beta_c, 1]$, in this range cooperative R&D makes mergers unprofitable.

C. RJV Cartelization

Consider now the case of another major type of R&D cooperation, RJV cartelization, where firms fully share their research results, in addition to coordinating their R&D expenditures. The R&D investments in this case are obtained by substituting $\beta = 1$ into (10). Hence, RJV cartelization is equivalent to R&D cartelization with perfect spillovers. But above it was shown that a merger toward which firms are indifferent in the absence of R&D is strictly unprofitable in the presence of R&D cartelization for $\beta > 0.5$. Hence such a merger becomes strictly unprofitable under RJV cartelization. Such a merger is unprofitable because it induces a decline in R&D by the merged firms without any improvement in the internal spillover rate (because all research results were shared even before the merger). This effect dominates the gain from the expansion of R&D by outsiders (*i.e.* $|E_M| > |E_N|$ at $\beta = 1$; see Figure 16).

Proposition 3

Consider an industry composed of n firms, where the merger of m firms leaves the profits of the merged firms unchanged in the absence of R&D, with m an integer. Then, in the presence of RJV cartelization, this merger is unprofitable.

Comparing the effect of cooperative *vs.* noncooperative R&D on merger profitability, we can see that the range of spillovers (which depends on β^c) determining (un)profitability depends on market structure for noncooperative R&D, but is independent of market structure for cooperative R&D (both under R&D cartelization and RJV cartelization).

V. Extensions

It is useful to test how the results derived above would respond to different assumptions about the type of R&D cooperation and about firm behavior. In this section we briefly consider three extensions: The behavior of the merged entity following the merger, the combination of cooperative and noncooperative R&D, and efficiency gains.

A. Non-Cooperation by Merged Entity

In some cases, the merged firms may prefer to stop cooperating with outsider(s) following the merger. That is, they may now have the skills and resources necessary for them to perform R&D independently. But according to the model above, such behavior will reduce, and cannot increase, merger profitability. This is because adopting a noncooperative behavior following the merger will reduce the post-merger profits, because R&D cooperation always increases profits when firms are symmetric, which is the case here. Hence, such behavior will make the merger even more unprofitable for $\beta>0.5$, and will create a range with low spillovers such that the merger becomes strictly unprofitable (while it was strictly profitable in the presence of R&D cartelization before and after the merger).

B. Simultaneous Investment in Cooperative and Noncooperative R&D

Firms perform both cooperative and noncooperative R&D simultaneously (see Atallah (2004), Goyal *et al.* (2004)). The question is: How would the presence of both types of R&D - before and after the merger - alter the results derived above?

The model provides us with enough information to determine how the results would change in the presence of both noncooperative and

cooperative R&D for most spillover levels. Assume that cooperative R&D takes the form of R&D cartelization (no information sharing). For $\beta<0.5$, both cooperative and noncooperative R&D contribute to making the merger profitable; hence the merger becomes profitable with both types of R&D present. For $\beta\in(0.5,\beta_c)$, both types of R&D contribute to making the merger unprofitable, hence the merger would be unprofitable in this spillover range. For $\beta>\beta_c$, noncooperative R&D makes the merger profitable, while cooperative R&D has the opposite effect. The net impact on merger profitability depends on which effect dominates. If cooperative and noncooperative R&D were of approximately equal magnitudes, the change in profits given by Figures 11 and 16 would give the correct magnitudes of changes in profits. From those figures we can see that the loss from the presence of cooperative R&D is larger than the gain from the presence of noncooperative R&D. Hence the merger should become unprofitable in the range $\beta\in(\beta_c,1]$ with both types of R&D present. However, there is no guarantee that investments in both types of R&D will be of equal magnitudes. Atallah (2004) analyzes a model where firms invest simultaneously in both types of R&D, and finds that the share of cooperative R&D in total R&D increases with spillovers, hence we can expect the level of cooperative R&D to be higher than the level of noncooperative R&D in the range $\beta\in(\beta_c,1]$. This asymmetry contributes even more strongly to the unprofitability of the merger in this spillover range, as the negative effect of cooperative R&D on merger profitability will dominate even more.

The impact of R&D on merger profitability is more difficult to predict without explicitly writing the model when firms perform both types of R&D and R&D cooperation takes the form of RJV cartelization (R&D coordination combined with information sharing). Remember that RJV cartelization always contributes negatively to merger profitability. For $\beta<0.5$, noncooperative R&D contributes positively, and the net effect is ambiguous. For $\beta\in(0.5,\beta_c)$, both types of R&D make the merger unprofitable, and hence the net effect on merger profitability will be negative. Finally, for $\beta\in(\beta_c,1]$, the two types of R&D affect profitability in opposite directions, and the net effect is ambiguous (although Figures 11 and 16 suggest that the negative effect of cooperative R&D is larger than the positive effect of noncooperative R&D).

C. Efficiency Gains

In some cases mergers may induce efficiency gains,[8] which increase their profitability. In such cases the mergers induce[9] an expansion rather than a contraction of the output of the merged firms. This expansion in output would be paralleled by an increase in R&D. The merger would then have two benefits: The "exogenous" efficiency effect, and the endogenous change in R&D (in addition to the increase in the implicit internal spillover rate). When output and R&D expenditures are strategic substitutes between firms, and the efficiency gain is sufficiently important to the output and R&D of insiders, this should induce an output contraction and a reduction in the R&D of outsiders. In this case, the presence of R&D - either cooperative or non-cooperative - is expected to increase merger profitability.

VI. Conclusions

This paper has analyzed the effect of R&D on merger profitability. It was shown that in most cases R&D has no effect on merger profitability. For a few mergers, however, which made firms indifferent in the absence of R&D, R&D has an effect on merger profitability. Noncooperative R&D makes such mergers strictly profitable when spillovers are low or high, and strictly unprofitable when spillovers are intermediate. This is due to the interplay of the effect of changes in R&D by insiders and outsiders on the profits of the merged firms. Cooperative R&D without information sharing makes such mergers profitable for low spillovers, but unprofitable for high spillovers. As for cooperative R&D with information sharing, it was shown to make such mergers unprofitable.

The results of this paper enrich the large literature on merger profitability. Most of the contributions to this literature have introduced factors which make mergers profitable more often. Here it is shown that R&D has a complex effect on merger profitability. In most cases R&D does not affect merger profitability. And in the few cases where it does affect it, it can affect it either way, even for a given market structure and a given number of merged firms, depending on

[8] See Perry and Porter (1985).
[9] When the efficiency gain is important enough.

the spillover rate and the type of interaction in R&D.

The prediction of the model of a negative impact of mergers on R&D - except for high spillovers - is, at a general level, consistent with the empirical evidence presented by Bertrand and Zuniga (2004), who find that domestic mergers tend to depress R&D, and Cassiman *et al.* (2005), who find that mergers involving rivals have the same effect. The mergers studied in this paper are domestic, and involve rivals.

Should mergers in high-tech industries receive a special antitrust treatment? This paper does not suggest that mergers in high-tech industries, where R&D is more prevalent, deserve a more lenient treatment than those in more traditional industries. Even with the increase in the internal spillover rate, which was present in this paper and which represents a reduction in duplication and an increase in R&D efficiency, mergers were found to be socially harmful. The answer may well be different in industries characterized by network effects or system markets, and this issue has been addressed elsewhere.[10] But the simple presence of R&D in a market does not make mergers socially beneficial. Interestingly, these mergers may become privately profitable due to the presence of R&D even though they are not efficiency enhancing, and are often even efficiency decreasing. Any such merger proposal would have to document the presence of efficiency gains in production or in research costs to be achieved by the merger. Otherwise, the welfare effects of such mergers are very similar to those obtained in more traditional markets.

While in the current model R&D affects merger profitability only in the few cases where firms are indifferent between merging or not in the absence of R&D, R&D may turn out to be relevant for merger profitability in a much larger number of cases. On the one hand, there may be efficiency gains related to research productivity, in which case R&D will obviously enhance merger profitability. On the other hand, there may be other factors which increase the number of mergers such that firms are indifferent in the absence of R&D; for instance, fixed merger costs may make otherwise profitable Cournot mergers unprofitable at the margin, leaving a role for R&D in determining merger profitability; or, there may be efficiency gains related to production which make otherwise unprofitable Cournot mergers profitable, again increasing the importance of R&D in

[10] See, for example, Economides and White (1994) and Choi *et al.* (2003).

determining merger profitability at the margin.

Many questions remain unanswered by the model which should be seen as opportunities for future research. The use of more general cost and demand functions would allow us to verify that the results hold in more general settings. Above it was assumed that only one coalition of merging firms forms; more generally, several coalitions of merging firms may form, with each coalition consolidating the R&D activities of its members. Finally, firms may be engaged in different types of R&D activities (product innovation, process innovation, basic research, *etc.*) simultaneously, in which case a merger will affect the composition, as well as the total level, of R&D investments.

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References

Arora, A., Ceccagnoli, M., and Da Rin, M. Corporate Restructuring and R&D: A Panel Data Analysis for the Chemical Industry. Working Paper No. 173, IGIER, Bocconi University, 2000.

Atallah, G. "The Allocation of Resources to Cooperative and Noncooperative R&D." *Australian Economic Papers* 43 (No. 4 2004): 435-47.

Baik, K. H. "Horizontal Mergers of Price-Setting Firms with Sunk Capacity Costs." *The Quarterly Review of Economics and Finance* 35 (No. 3 1995): 245-56.

Benchekroun, H. "The Closed-Loop Effect and the Profitability of Horizontal Mergers." *Canadian Journal of Economics* 36 (No. 3 2003): 546-65.

Bertrand, O., and Zuniga, P. R&D and M&A: Are Cross-Border M&A Different? An Investigation on OECD Countries. Manuscript, 2004.

Blonigen, B. A., and Taylor, C. T. "R&D Intensity and Acquisitions in High-Technology Industries: Evidence from the US Electronic and Electrical Equipment Industries." *The Journal of Industrial Economics* 48 (No. 1 2000): 47-70.

Brod, A., and Shivakumar, R. "R&D Cooperation and the Joint Exploitation of R&D." *Canadian Journal of Economics* 30 (No. 3 1997): 673-84.

Cassiman, B., Colombo, M., Garrone, P., and Veugelers, R. "The

Impact of M&A on the R&D Process: An Empirical Analysis of the Role of Technological - and Market - Relatedness." *Research Policy* 34 (No. 2 2005): 195-220.

Choi, J. P., Lee, G., and Stefanadis, C. "The Effects of Integration on R&D Incentives in Systems Markets." *Netnomics* 5 (No. 1 2003): 21-32.

Creane, A., and Davidson, C. "Multidivisional Firms, Internal Competition, and the Merger Paradox." *Canadian Journal of Economics* 37 (No. 4 2004): 951-77.

Deneckere, R., and Davidson, C. "Incentives to from Coalitions with Bertrand Competition." *Rand Journal of Economics* 16 (No. 4 1985): 473-86.

Dockner, E. J., and Gaunersdorfer, A. "On the Profitability of Horizontal Mergers in Industries with Dynamic Competition." *Japan and the World Economy* 13 (No. 3 2001): 195-216.

Economides, N., and White, L. "Networks and Compatibility: Implications for Antitrust." *European Economic Review* 38 (Nos. 3-4 1994): 651-62.

Fauli-Oller, R. "On Merger Profitability in a Cournot Setting." *Economics Letters* 54 (No. 1 1997): 75-9.

Goyal, S., Konovalov, A., and Moraga-Gonzalez, J. L. Hybrid R&D. Manuscript, 2004.

Hagedoorn, J., and Duysters, G. The Effects of Mergers and Acquisitions on the Technological Performance of Companies in a High Tech Environment. Manuscript, 2000.

Hennessy, D. A. "Cournot Oligopoly Conditions under Which Any Horizontal Merger Is Profitable." *Review of Industrial Organization* 17 (No. 3 2000): 277-84.

Higl, M., and Welzel, P. Intra-Firm Coordination and Horizontal Merger. Working Paper No. 269, Institut für Volkswirtschaftslehre, University of Augsburg, 2005.

Huck, S., Konrad, K. A., and Müller, W. "Profitable Horizontal Mergers without Cost Advantages: The Role of Internal Organization, Information and Market Structure." *Economica* 71 (No. 284 2004): 575-87.

Kwoka, J. E. "The Private Profitability of Horizontal Mergers with Non-Cournot and Maverick Behavior." *International Journal of Industrial Organization* 7 (No. 3 1989): 403-11.

Lommerud, K. E., and Sørgard, L. "Merger and Product Range Rivalry." *International Journal of Industrial Organization* 16

(No. 1 1997): 21-42.

Perry, M., and Porter, R. "Oligopoly and the Incentive for Horizontal Merger." *American Economic Review* 75 (No. 1 1985): 219-27.

Polasky, S., and Mason, C. F. "On the Welfare Effects of Mergers: Short Run *vs.* Long Run." *The Quarterly Review of Economics and Finance* 38 (No. 1 1998): 1-24.

Salant, S. W., Switzer, S., and Reynolds, R. J. "Losses from Horizontal Merger: The Effect of an Exogenous Change in Industry Structure on Cournot-Nash Equilibrium." *Quarterly Journal of Economics* 98 (No. 2 1983): 185-99.