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A new model of mergers and innovation

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Abstract

This paper reexamines the impact of merger on innovation. Unlike as in Federico et al (2017), it considers the scenario where merged firms combine their research labs. It shows that, in equilibrium, each firm chooses a higher R&D effort after the merger, while industry effort may rise or fall due to the merger. Furthermore, it shows that given a sufficient condition, profits of the merged firm falls and consumer surplus rises in the post merger scenario. These results are in sharp contrast to the findings of Federico et al (2017).

Keywords: Innovation, R&D, Mergers

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1 Introduction

The centrepiece of neoclassical growth theory is technological advancement which determines the long run growth rate of an economy. Critical to technological advancement is the innovation effort and expenditure undertaken by firms. In this context, it becomes interesting to study the effect mergers have on innovation. Do firms increase innovation effort post merger? Does the overall industry level effort increase or decrease after a merger? Does the profit of a merged firm increase? Are consumers better off or worse off after a merger? These are some important questions that have been addressed in the recent paper Federico et al., (2017). The aforementioned paper uses a two-stage game to model the effort level decision of firms before and after merger and analyze its consequences, by considering a scenario in which the merged firm does not combine pre-merger labs and the paper attempts to justify such behaviour of the merged firm by assuming that there is decreasing returns to R&D effort.

When there is decreasing returns to R&D effort, there is a cost disadvantage of combining labs. However, in the presence of R&D synergy effect, there is a benefit of combining the R&D labs. This benefits arises because the probability of successful innovation is greater when an effort level is employed to a single lab rather than splitting it into multiple labs. In the scenario in which the gain from the R&D synergy effect dominates the cost disadvantage due to decreasing returns to effort, it is optimal to combine research labs. To illustrate this further, suppose there is a monopoly firm with two research labs. The cost function of the firm is $C(w_1, w_2) = C(w_1) + C(w_2)$, where the cost function is characterized by $C' > 0, C'' > 0, C'(0) = 0, lim_{w_i->1}C(w_i) = \infty$ and $w_i \in [0, 1)$ is the effort level in lab $i, (i = 1, 2)$. If R&D is successful, the firm receives a normalized payoff of 1; otherwise it receives 0. The probability of success is $w_1w_2+w_1(1-w_2)+w_2(1-w_1) = w_1+w_2-w_1w_2$. The firm's profit maximization problem is $\max_{w_1w_2} \Pi = w_1 + w_2 - w_1w_2 - C(w_1) - C(w_2)$ and its optimal effort level in each lab is given by $1 - w_i^D = C'(w_i^D)$, for $i = 1, 2$. On the other hand, if the firm has only one lab and effort level w, its probability of success is w and the final R&D effort level, w^S, is given by $1 = C'(w^S)$. Suppose $C(w) = cw + (d/2)w^2$, $c > 0$ and $1 - c < d < 1$, then $w^S = (1 - c)/d$ and $w^D = (1 - c)^2/(1 + d)$. Firm's profit with one lab $\Pi^S = [(1 - c)^2/2d] > [(1-c)^2/(1+d)] = \Pi^D$, where Π^D is the profit of the firm with two labs. Clearly, it is quite plausible to have a scenario in which it is profitable for merged firms to combine their research labs, despite having decreasing returns to R&D effort. This paper considers such a scenario, unlike as in Federico et al. (2017), and analyses the effect of merger on R&D when merged firm combine research labs instead of keeping its labs separate.

The model by Federico et al., (2017) is based on stochastic product innovation which is not cost reducing. Moreover, there are no pre-existing profits that can be cannibalized by innovation expenditure. The same assumptions have been incorporated into the model presented here. However, where the two models differ is with respect to the number of research labs of each firm as already mentioned above. In their case there is a price coordination effect, i.e., benefits of a successful innovation by either lab accrues to the firm as a whole. Such a scenario doesn't arise in this model as the labs have been combined. Unlike the results of Federico et al (2017), each firm's equilibrium effort in the post-merger scenario is higher than that in the pre-merger case. However, since merger leads to a reduction in the total number of firms and research labs in the industry, total industry R&D effort may rise or fall due to the merger. This paper derives the condition under which industry effort will also rise following the merger. Furthermore, this paper demonstrates that, given a sufficient condition, profits of merged firm falls whereas consumer surplus rises. These results are in sharp contrast to the findings of Federico et al (2017).

This paper is structured as follows. The next section gives the outline of the model with the specific assumptions about number of firms, effort level, cost of effort and payoff structure. Model description is followed by results (Propositions 1 to 4) which answer the questions posited above. The paper ends with a conclusion.

2 The model

The basic structure of the model is the same as the one proposed by Federico et al., (2017). There are $n > 2$ symmetric firms. Each firm has a single research lab before the merger. To innovate, firms expend effort $w_i \in [0, 1)$. This effort is costly and the cost of effort is expressed as $C(w_i)$. The cost function has the following structure:

$$C(0) = 0, C' > 0, C'' > 0, C'(0) = 0, lim_{w_i -> 1} C(w_i) = \infty$$

The effort level, w_i, determines the probability of successful innovation, i.e., higher the effort level, higher is the probability of innovation. All the firms in the industry are innovating a homogeneous product. Probabilities of discovery are independently and identically distributed across the n labs. Since a lab can either succeed or fail, there are 2^n possible outcomes of discovery.

The firms participate in a two-stage game. In the second stage firms observe outcomes of the first stage (success or failure at innovation) and receive payoffs. If a firm does not discover the homogeneous product, it receives zero payoff. If it is the sole innovator in the industry, then it receives the complete payoff (normalized to 1). If two competing firms successfully discover the product, each gets a payoff of $\delta << 1$. If three or more competing firms discover the product, then the competition in the product market is so strong that all get a payoff equal to zero.

2.1 Pre-merger

The game is solved using backward induction. In the second stage, payoffs are dependent on the number of successful innovators. Given this outcome, the objective function of a profit maximizing firm, $i \neq j$, in the first stage can be written as follows:

$$\max_{w_i} \Pi_i = w_i[(1-w_j)^{n-1}.1 + (n-1)w_j(1-w_j)^{n-2}.\delta] - C(w_i) \tag{1}$$

Equation 1 says that firm i gets the complete payoff, 1, when it is the only successful innovator. It gets payoff δ if there is only one rival in the product market. There are $n-1$ such combinations possible. The FOC is

$$(1-w_j)^{n-1} + (n-1)w_j(1-w_j)^{n-2}\delta = C'(w_i)$$

and the SOC is $-C''(w_i) < 0$ and therefore, always satisfied. Since all the $n > 2$ are symmetric, the equilibrium condition given by the FOC will apply to all the firms. With $w_i = w_j = w^*$, the symmetric equilibrium is

$$(1-w^*)^{n-1} + (n-1)w^*(1-w^*)^{n-2}\delta = C'(w^*) \tag{2}$$

The RHS of 2 is the increasing marginal cost of effort, whereas the LHS can be interpreted as the marginal returns to effort. Marginal cost is, by assumption, strictly increasing from 0 to ∞. RHS is strictly decreasing from a finite value to 0 in w^*. Thus, we obtain a unique equilibrium w^*. Moreover, by totally differentiating 2, we can see that w^* increases as δ increases from 0.

$$\left.\frac{\partial w^*}{\partial \delta}\right|_{\delta=0} = \frac{(n-1)w^*}{n-1+(1-w^*)^{2-n}C''(w^*)} > 0 \tag{3}$$

2.2 Merger

Assume without loss of generality that two firms, 1 and 2, merge their research labs and form a new firm denoted by M. Herein, we depart from the model given by Federico et. al (2017). We assume that the merged firms now have a single lab and thus, there are $n-1$ labs in the industry. Assuming, by the symmetry argument, that all firms besides the merged firm M behave identically, the objective function to be maximized by firm M is

$$\max_{w_M} \Pi_M = w_M[(1-w_j)^{n-2}.1 + (n-2)w_j(1-w_j)^{n-3}.\delta] - C(w_M) \tag{4}$$

The FOC with respect to w_M is

$$(1-w_j)^{n-2} + (n-2)w_j(1-w_j)^{n-3}\delta = C'(w_M) \tag{5}$$

Next we analyze the profit maximizing decision of the single $n-2$ firms in the industry. For firm $i \neq M$, the expression of the profit, given that all firms $j \neq M$ behave symmetrically, is now

$$\max_{w_i} \Pi_i = w_i[(1-w_M)(1-w_j)^{n-3}.1 + w_M(1-w_j)^{n-3}\delta + (n-3)w_j(1-w_M)(1-w_j)^{n-4}.\delta] - C(w_i) \tag{6}$$

The corresponding FOC is

$$(1-w_M)(1-w_j)^{n-3} + w_M(1-w_j)^{n-3}\delta + (n-3)w_j(1-w_M)(1-w_j)^{n-4}\delta = C'(w_i) \tag{7}$$

In equilibrium, all firms $j \neq M$ will behave symmetrically as firm i. Therefore, we define

$$FOC_i \equiv (1-w_M)(1-w_i)^{n-3} + w_M(1-w_i)^{n-3}\delta + (n-3)w_i(1-w_M)(1-w_i)^{n-4}\delta = C'(w_i) \tag{8}$$

Upon observing 5 and 8, we see that by symmetry of firms, or more specifically, $n-1$ labs, the FOC of both the maximization problems collapse to the same equation. We can now write a general post merger FOC for all firms, whether merged or single, as follows

$$FOC_{w_M^*} \equiv (1-w_M^*)^{n-2} + (n-2)w_M^*(1-w_M^*)^{n-3}\delta = C'(w_M^*) \tag{9}$$

Note that the SOC of the above maximization problems are < 0. By totally differentiating 9, we can see that w_M^* increases as δ increases from 0.

$$\left.\frac{\partial w^*}{\partial \delta}\right|_{\delta=0} = \frac{(n-2)w_M^*}{n-2+(1-w_M^*)^{3-n}C''(w_M^*)} > 0 \tag{10}$$

Proposition 1. *All firms, including the merged firm, increase equilibrium effort level after merger* $\forall\ \delta$.

Proof. We can evaluate 9 at the pre-merger equilibrium given by 2. If $w_M^* = w^*$, then subtracting equation 2 from equation 9 gives us

$$w^*(1-w^*)^{n-2} + (n-1)(w^*)^2(1-w^*)^{n-3}\delta > 0$$

Hence, $w_M^* > w^*\ \forall\ \delta$.

The result derived in Federico et al., (2017) is that post-merger, due to price coordination effect, the effort level of the merged firm falls $\forall\ \delta > 0$. However, since we are considering the case where the two labs are merged together, the probability of success increases (probability of success is i.i.d across n firms). Moreover, the effort level of the merged firm and the other single firms post merger are strategic substitutes in the first case. Since the maximization problem of both type of firms becomes equivalent in the case under consideration, the strategic effect is not present.

Corollary 1. *There is no* δ *such that* $w^* = w_M^*$

Proof. Evaluating equation 2 and equation 9 at $w^* = w_M^*$ to calculate δ where $w^* = w_M^*$ gives

$$\delta = \frac{1-w^*}{1+w^*-nw^*}$$

Since $\delta \in [0,1)$, critical assumption of $n > 2$ is violated with the δ value given above. Therefore, there exists no δ such that $w^* = w_M^*$.

Proposition 2. *Total industry effort increases after merger iff effort differential of* $n-1$ *firms after merger and pre-merger is greater than effort of the nth firm before merger.*

Proof. Pre-merger total industry effort is $Eff_{pre} = nC(w^*)$. Post-merger total industry effort is $Eff_{post} = (n-1)C(w_M^*)$. For total industry effort to be greater post merger, we need $(n-1)C(w_M^*) > nC(w^*)$. We know from equations 3 and 10 that for small value of δ, effort is rising in δ. From Proposition 1 we already know that $w_M^* > w^*\ \forall\ \delta$. Moreover, FOC conditions in equations 2 and 9 give us unique effort levels. Therefore, $C(w_M^*) > C(w^*)\ \forall\ \delta$. We can then write

$$(n-1)C(w_M^*) > nC(w^*) \Rightarrow (n-1)[C(w_M^*) - C(w^*)] > C(w^*)$$

Proposition 3. *If $(n-k+2)(1-w^*)^{n-k+1} > (n-k+1)(1-w_M^*)^{n-k}$, then merger between firm 1 and 2 is unprofitable.*

Proof. To evaluate the profitability of the merged firm, we need analyze the expression $2\Pi^* - \Pi_M^*$. Given the sufficiency condition, $(n-k+2)(1-w^*)^{n-k+1} > (n-k+1)(1-w_M^*)^{n-k}$, if we can show that $\Pi^* - \Pi_M^* > 0$ holds, then $2\Pi^* - \Pi_M^*$ is also strictly greater than zero.

$$\begin{aligned}\Pi^* - \Pi_M^* =& w^*(1-w^*)^{n-1} - w_M^*(1-w_M^*)^{n-1} + (n-1)(w^*)^2(1-w^*)^{n-2}\delta - \\ & (n-2)(w_M^*)^2(1-w_M^*)^{n-3}\delta + [C(w_M^*) - C(w^*)]\end{aligned} \tag{11}$$

Now, we know that $C(w_M^*) > C(w^*)\ \forall\ \delta$. Thus, the last term in equation 11 is strictly positive. Moreover, if $(n-k+2)(1-w^*)^{n-k+1} > (n-k+1)(1-w_M^*)^{n-k}$ is satisfied, then the whole equation 11 is > 0.

Proposition 4. *If $(n-k+2)(1-w^*)^{n-k+1} > (n-k+1)(1-w_M^*)^{n-k}$, then consumer surplus is higher post merger.*

Proof. Let us denote CS_k as the consumer surplus in state k, where $k = 0, 1, 2, 3+$ denotes the number of firms that independently introduce innovations into product market. It is reasonable to assume $CS_0 = 0$ since without any innovation there will not be a market for consumers. When one firm successfully innovates, price competition is the weakest. The price competition rises with a rise in the number of successful innovators. Since payoff is zero when there are ≥ 3 successful innovators, we club these cases under $k = 3+$. Thus, it is reasonable to assume $CS_1 < CS_2 < CS_{3+}$.

Now, to analyze the consumer surplus in pre-merger and post-merger scenario we use the following two equations,

$$CS_{pre} = \sum_{k}^{2^n} \binom{n}{k} Pr(k) CS_k$$

$$CS_{post} = \sum_{k}^{2^{n-1}} \binom{n-1}{k} Pr(k) CS_k$$

where $Pr(k)$ is the probability of state k occurring.

$$\begin{aligned} CS_{pre} =& (1-w^*)^n CS_0 + nw^*(1-w^*)^{n-1} CS_1 + \frac{n(n-1)}{2} \\ & (w^*)^2(1-w^*)^{n-2} CS_2 + [1 - Pr(0) - Pr(1) - Pr(2)] CS_{3+} \end{aligned} \tag{12}$$

$$\begin{aligned} CS_{post} =& (1-w_M^*)^{n-1} CS_0 + (n-1)w_M^*(1-w_M^*)^{n-2} CS_1 + \frac{(n-1)(n-2)}{2} \\ & (w_M^*)^2(1-w_M^*)^{n-3} CS_2 + [1 - Pr^M(0) - Pr^M(1) - Pr^M(2)] CS_{3+} \end{aligned} \tag{13}$$

where $Pr^M(k)$ is the probability of state k occurring post merger.

By subtracting equation 12 from equation 13, we get

$$\begin{aligned} CS_{post} - CS_{pre} =& [Pr^M(0) - Pr(0)][CS_0 - CS_{3+}] + [Pr^M(1) - Pr(1)] \\ & [CS_1 - CS_{3+}] + [Pr^M(2) - Pr(2)][CS_2 - CS_{3+}] \end{aligned} \tag{14}$$

If $(n-k+2)(1-w^*)^{n-k+1} > (n-k+1)(1-w_M^*)^{n-k}$, then the three terms with $Pr^M(k) - Pr(k)$ in equation 14 is < 0. Moreover, we know that $CS_1 < CS_2 < CS_{3+}$ and therefore, $CS_{post} - CS_{pre}$ > 0. Thus, merger is beneficial for consumers.

Federico et al., (2017) note that, from a total welfare perspective, the merger creates inefficiency in the allocation of effort. Starting from an efficient, symmetric distribution of efforts among firms, the merger provides asymmetric incentives to exert effort between merged firms and single firms after merger. However, this does not hold true in this case. Although the effort level of merged firms increases after merger, yet it is unclear whether the merger will necessarily be profitable. If the condition on effort levels, $(n-k+2)(1-w^*)^{n-k+1} > (n-k+1)(1-w_M^*)^{n-k}$, holds then it is possible to comment on the profitability and consumer welfare. But the two results are opposing. Under the sufficient condition, merged firms are not profitable, but consumer surplus is positive.

Thus, at a firm level, the decision to not merge may be logical, but from the point of view of a social planner, merger may be beneficial if the loss to the firm is offset by gain to society.

3 Conclusion

Using this simple model, we were able to comment on how a merger would affect the innovation effort level of a firm, total industry effort, profitability of merged firm and consumer surplus outcome post merger. An alteration of how a merger affects the number of research labs changed the outcomes in the following ways: the effort level of the merged firm rises for all payoffs instead of falling; the total industry effort is no more a function of the number of firms in the industry, but dependent exclusively on the cost structure; the profitability and consumer surplus is not certain anymore.

This paper points out that the assumption- whether following the merger of two firms, each of whom have independent research labs, the merged firm combines the two labs (as considered in this paper) or not (as in Federico et al(2017))- plays a very crucial role in determining impacts of a merger. It seems interesting to examine whether it is optimal for the merged firms to combine pre-merger research labs or to keep two independent research labs. If it is optimal for the merged firm to keep both pre-merger labs and induce those labs to compete against each other, what is the optimal number of competing research labs a firm should have? What is the optimal divisionalization of research labs, in the sense of Baye et al (1996). Does that differ from social optimality? We leave these questions for future research.

4 Appendix

Proof of Proposition 1.

$$FOC_{w^*} \equiv (1-w^*)^{n-1} + (n-1)w^*(1-w^*)^{n-2}\delta = C'(w^*)$$

$$FOC_{w_M^*} \equiv (1-w_M^*)^{n-2} + (n-2)w_M^*(1-w_M^*)^{n-3}\delta = C'(w_M^*)$$

Subtracting the two first order conditions and evaluating at $w^* = w_M^*$, we get

$$\Rightarrow w^*(1-w^*)^{n-2} + n(w^*)^2(1-w^*)^{m-3}\delta - (w^*)^2(1-w^*)^{m-3}\delta = 0$$

$$\Rightarrow w^*(1-w^*)^{n-2} + (n-1)(w^*)^2(1-w^*)^{m-3}\delta > 0 \quad \forall\, \delta \in [0,1) \tag{15}$$

Hence, $w_M^* > w^* \; \forall \; \delta$.

5 Reference

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