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Merger and process innovation ☆

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ABSTRACT

Denicolò and Polo (2018) show that the result of Federico et al. (2017), i.e., horizontal mergers reduce R&D investments of the merged firms compared to non-cooperation, holds provided the probability of failure in R&D is log-convex in R&D investments. We provide a different reason for innovation raising merger. We show that if firms invest in process innovation, merger may increase R&D investments even if the probability of failure in R&D is log-convex in R&D investments as considered in Federico et al. (2017). We also show that merger may increase expected consumer surplus and expected welfare compared to non-cooperation. Our results are important for antitrust policies.

1. Introduction

In an interesting paper, Federico et al. (2017) show that mergers always reduce R&D investments of the merged firms compared to non-cooperation. Denicolò and Polo (2018) show that the result of Federico et al. (2017) holds provided the probability of failure in innovation is log-convex in R&D investments, which allows the merged firm to spread out its total R&D expenditure evenly across its research units. If the probability of failure in innovation is log-concave in R&D investments, the merged firm will operate one research lab, and merger may increase R&D investments.

We provide a new perspective to this debate. We show that if firms invest in process innovation, merger may increase R&D investments even if the merged firm spreads out its total R&D expenditure evenly across its research units, as considered in Federico et al. (2017). We also show that merger may increase expected consumer surplus and expected welfare.

The innovation raising merger in our analysis depends neither on the internalisation of knowledge spillover by the merged entities and the R&D synergy created by merger (Federico et al., 2018) nor on demand expansion due to increased market coverage (Bourreau and Jullien, 2018).

Using deterministic R&D, López and Vives (2019) show that an increase in overlapping ownership, which increases collusive behaviour, decreases investments in process innovation in the absence of knowledge spillover. We show that collusive behaviour may increase investments in process innovation in the absence of knowledge spillover under a stochastic R&D process.

Like Denicolò and Polo (2018), our results cast doubts on the robustness of the "innovation theory of harm" that is articulated in Federico et al. (2017) and played a major role in the European Commission's decision on the *Dow-DuPont* case and might be used in other cases in the future. Hence, the antitrust authorities need to be more cautious when taking decisions on mergers based on their effects on innovation.

2. The model and the results

To get sharper results, like Denicolò and Polo (2018), we consider a duopoly model with no knowledge spillover and no R&D synergy in merger, as Shapiro (2012) argues that a merger is most likely to diminish innovative activity when only two firms pursue a specific line of research to serve a particular need in the absence of appropriability or R&D synergy in the merger.

Consider two risk-neutral firms, firm 1 and firm 2, which compete in the product market with horizontally differentiated

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products. Assume that the firms face the same constant marginal cost of production, $\bar{c}$, at the beginning. Each firm invests in R&D to reduce its marginal cost of production to c, which is assumed to be zero, for simplicity. The R&D process is uncertain and firm i succeeds in R&D with an unconditional probability z_i where the probability of success depends on firm i's R&D investment, x_i, with $z_i'(x_i) > 0$, $z_i''(x_i) < 0$, $z_i'(0) = \infty$ and $z_i'(\infty) = 0$ for $i = 1, 2$. We assume that both firms face identical probability functions, i.e., $z_i(x) = z_j(x) = z(x)$.

To avoid the effects of knowledge spillover and synergy in merger shown in Federico et al. (2018), we consider no knowledge spillover from R&D and no synergy in merger. To avoid the demand expansion effect shown in Bourreau and Jullien (2018), we assume that both products will always be produced irrespective of the R&D outcomes.

We consider a two-stage game. At stage 1, both firms invest in R&D simultaneously and the outcomes of R&D are realised. At stage 2, the firms choose their product market strategies simultaneously to maximise respective profits. We solve the game through backward induction.

We consider two different market scenarios.

Non-cooperation: Where the firms maximise their profits by choosing their R&D investments and their product market strategies non-cooperatively.

Merger: Where the firms merge and the merged firm chooses the R&D investments and the product market strategy to maximise the profit of the merged firm.

2.1. Non-cooperation

As the firms are symmetric in nature, without any loss of generality, we look at the problem of firm i. Under non-cooperation, given the equilibrium profits in the product market, the expected profit of firm i at the R&D stage is

$$\begin{aligned}\Pi_i^{nc} &= z(x_i)\, z(x_j)\, \pi_i(0,0) + z(x_i)\left[1 - z(x_j)\right]\pi_i(0,\bar{c}) \\ &\quad + \left[1 - z(x_i)\right] z(x_j)\, \pi_i(\bar{c},0) \\ &\quad + \left[1 - z(x_i)\right]\left[1 - z(x_j)\right]\pi_i(\bar{c},\bar{c}) - x_i\end{aligned}, \qquad (1)$$

where $i, j = 1, 2$ and $i \neq j$. The first (second) argument in the equilibrium profit function $\pi_i(.,.)$ shows the marginal cost of production of firm i (firm j).

The equilibrium R&D investment of the ith firm satisfies the following expression:

$$\begin{aligned}&z'(x_i)\, z(x_j)\, \pi_i(0,0) + z'(x_i)\left[1 - z(x_j)\right]\pi_i(0,\bar{c}) \\ &- z'(x_i)\, z(x_j)\, \pi_i(\bar{c},0) \\ &- z'(x_i)\left[1 - z(x_j)\right]\pi_i(\bar{c},\bar{c}) = 1.\end{aligned} \qquad (2)$$

The second order condition for maximisation is assumed to hold. The equilibrium R&D investments, $\hat{x}_i^{nc}$ and $\hat{x}_j^{nc}$ can be found by solving the reaction functions of the firms. Symmetry of the firms implies that the firms have the same equilibrium R&D investments, $\hat{x}_i^{nc} = \hat{x}_j^{nc} = \hat{x}^{nc}$. We assume throughout the paper that the probability functions are such that we have unique equilibrium R&D investments. We further assume that the equilibrium probabilities lie between 0 and 1, since the corner solutions do not add new insights to our analysis.

2.2. Merger

As success in R&D is uncertain, it is not immediate whether it is better for the merged firm to use a single research lab or to operate two research labs. In line with Federico et al. (2017), we assume that the probability of failure in innovation is log-convex in R&D investments and the merged firm operates both research labs. Hence, we assume $[1-z(x)]$ is log-convex, implying $z''(x)[1 - z(x)] + [z'(x)]^2 < 0$.

Since the merged firm runs two research labs, the R&D investment in the ith lab, $i, j = 1, 2, i \neq j$, i.e., x_i, is determined to maximise the following profit function of the merged firm:

$$\begin{aligned}\Pi^m &= z(x_i)\, z(x_j)\, \pi(0) + z(x_i)\left[1 - z(x_j)\right]\pi(0) \\ &\quad + \left[1 - z(x_i)\right] z(x_j)\, \pi(0) \\ &\quad + \left[1 - z(x_i)\right]\left[1 - z(x_j)\right]\pi(\bar{c}) - \sum_{i=1}^{2} x_i\end{aligned} \qquad (3)$$

where $\pi(0)$ and $\pi(\bar{c})$ denote the total equilibrium profits of the merged firm ex-post R&D under successful and unsuccessful innovations respectively. Note that the merged firm produces both products as a monopolist.

The equilibrium R&D investment in the ith lab satisfies the following expression:

$$z'(x_i)\left[1 - z(x_j)\right]\left[\pi(0) - \pi(\bar{c})\right] = 1. \qquad (4)$$

The second order condition is satisfied with $z''(x)[1 - z(x)] + [z'(x)]^2 < 0$. Define the symmetric equilibrium R&D investment in each lab under merger by $\hat{x}_i^m = \hat{x}_j^m = \hat{x}^m$.

2.3. Comparison of the R&D investments

If we evaluate (4) at $\hat{x}^{nc}$, we get that the LHS of (2) is greater than, less than or equal to the LHS of (4) if

$$\begin{aligned}&z\left(\hat{x}^{nc}\right)\left[\pi_i(0,0) - \pi_i(\bar{c},0)\right] \\ &- \left[1 - z\left(\hat{x}^{nc}\right)\right]\left[\left(\pi_i(0,\bar{c}) - \pi_i(\bar{c},\bar{c})\right) - \left(\pi(0) - \pi(\bar{c})\right)\right] \gtreqless 0.\end{aligned} \qquad (5)$$

If $z\left(\hat{x}^{nc}\right) \to 1$, LHS of (5) tends to $\left[\pi_i(0,0) - \pi_i(\bar{c},0)\right] > 0$ but if $z\left(\hat{x}^{nc}\right) \to 0$, LHS of (5) tends to $\left[\left(\pi_i(0,\bar{c}) - \pi_i(\bar{c},\bar{c})\right) - \left(\pi(0) - \pi(\bar{c})\right)\right] \gtreqless 0$, since $\left(\pi_i(0,\bar{c}) - \pi_i(\bar{c},\bar{c})\right) > 0$ and $\left(\pi(0) - \pi(\bar{c})\right) > 0$, implying that the R&D investments can be higher under merger compared to non-cooperation.

For a better understanding, we consider a specific example with the inverse demand function for the ith firm as $P_i = 1 - q_i - \gamma q_j$, where $i, j = 1, 2$, $i \neq j$, and $\gamma \in [0, 1]$ shows the degree of product differentiation; $\gamma = 0$ implies isolated products and $\gamma = 1$ implies homogeneous products. Also assume that the firms compete in quantities under non-cooperation, the probability of success in R&D is $z(x_i) = \sqrt{x_i}$, and $\bar{c} \in (0, 0.5)$, which ensures that both firms always produce positive outputs irrespective of the R&D outcomes.

The equilibrium R&D investments under non-cooperation and under merger can be found as $\hat{x}^{nc} = \frac{4\bar{c}^2(2-\bar{c}-\gamma+\bar{c}\gamma)^2}{\left(2\bar{c}^2\gamma+(4-\gamma^2)^2\right)^2}$ and $\hat{x}^m = \frac{(2-\bar{c})^2\bar{c}^2}{((2-\bar{c})\bar{c}+4(1+\gamma))^2}$ respectively. Plotting $(\hat{x}^{nc} - \hat{x}^m)$ in Fig. 1, we find that the shaded (white) area in Fig. 1 shows the combinations of γ and c where $\hat{x}^{nc} < (>) \hat{x}^m$.[1]

In Fig. 1, merger reduces the R&D investments compared to non-cooperation if both c and γ are high. This result can be explained in the following way.

In our example, the R&D investments and the probability of success in R&D under non-cooperation are small, implying $z\left(\hat{x}^{nc}\right) \to 0$ and the sign of the LHS of (5) mainly depends on

[1] Note that $z''(x)(1 - z(x)) + (z'(x))^2 < 0$ for $\hat{x}^m = \frac{(2-\bar{c})^2\bar{c}^2}{((2-\bar{c})\bar{c}+4(1+\gamma))^2}$ and $\bar{c} \in (0, 0.5)$.

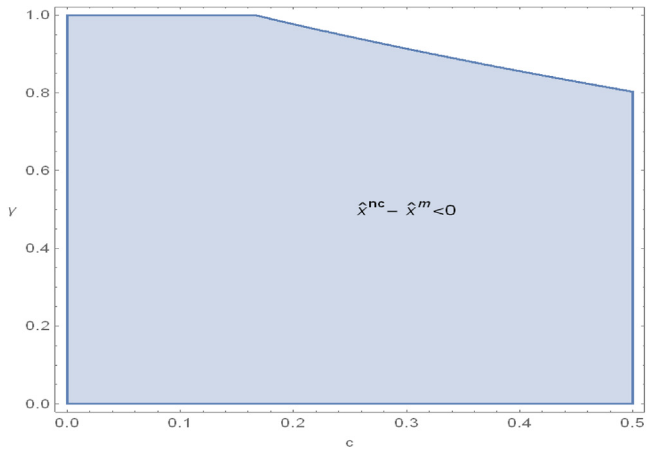

Fig. 1. $\hat{x}^{nc} < (>) \hat{x}^{m}$.

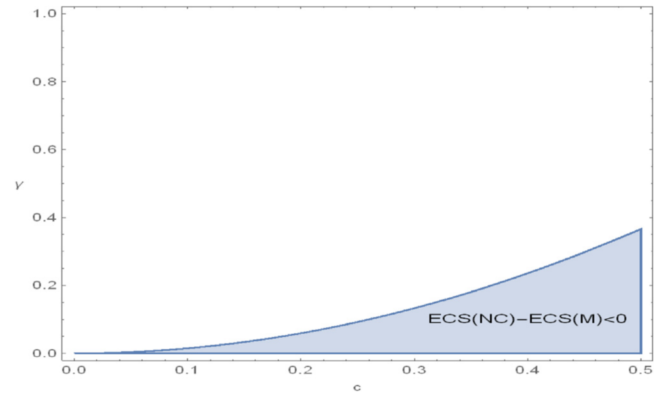

Fig. 2. $(ECS(NC) - ECS(M))$.

$[(\pi_i(0,\bar{c}) - \pi_i(\bar{c},\bar{c})) - (\pi(0) - \pi(\bar{c}))]$.[2] The difference $(\pi(0) - \pi(\bar{c}))$ shows the merged firm's benefit from innovation compared to no innovation, while $(\pi_i(0,\bar{c}) - \pi_i(\bar{c},\bar{c}))$ shows the winning firm's benefit from unilateral success in R&D under non-cooperation. The net effect depends on the relative strengths of these two differences.

If the cost reduction through R&D is large (i.e., c is high) and competition is intense (i.e., γ is high), the benefit from a successful innovation is higher under non-cooperation compared to merger, since the winning firm under non-cooperation can steal a significantly large market share from its competitor due to its significant cost efficiency and intense competition, while the monopolist's benefit from innovation is relatively less as it just replaces itself with a lower cost technology. Hence, higher R&D investments under non-cooperation compared to merger for large values of c and γ is due to the replacement effect of Arrow (1962).

On the other hand if either c is small or γ is small, the winning firm's benefit from innovation under non-cooperation is not significant as small cost reduction from innovation or mild competition does not help the winning firm under the unilateral success in R&D to steal significant market share from the competitor. In this situation, a higher market concentration under merger allows the merged firm to gain more from innovation compared to non-cooperation, thus creating higher R&D investments under merger compered to non-cooperation. This is like the Schumpeterian argument where lower competition increases innovation (Schumpeter, 1943).

The following result follows from the above discussion.

Proposition 1. *If the firms invest in process innovation, the R&D investments may be higher under merger compared to non-cooperation.*

2.4. The implications on consumer surplus and welfare

We use an example similar to Section 2.3 to show the implications on consumer surplus and welfare. Hence, consider $P_i = 1 - q_i - \gamma q_j$, where $i,j = 1,2$, $i \neq j$, $z(x_i) = \sqrt{x_i}$, quantity competition under non-cooperation, and $\bar{c} \in (0, 0.5)$.

The expected equilibrium consumer surplus under non-cooperation and under merger are respectively

$$ECS(NC) = \left[z\left(\hat{x}^{nc}\right)\right]^2 CS(0,0) + 2z\left(\hat{x}^{nc}\right)\left[1 - z\left(\hat{x}^{nc}\right)\right] CS(0,\bar{c}) + \left[1 - z\left(\hat{x}^{nc}\right)\right]^2 CS(\bar{c},\bar{c}) \quad (6)$$

$$ECS(M) = \left[z\left(\hat{x}^{m}\right)\right]^2 CS(0) + 2z\left(\hat{x}^{m}\right)\left[1 - z\left(\hat{x}^{m}\right)\right] CS(0) + \left[1 - z\left(\hat{x}^{m}\right)\right]^2 CS(\bar{c}). \quad (7)$$

We plot $(ECS(NC) - ECS(M))$ in Fig. 2 for the example considered here. The shaded (white) area in Fig. 2 shows that $ECS(NC) < (>) ECS(M)$.

Although merger makes the product market more concentrated compared to non-cooperation, higher R&D investments under merger may make the expected consumer surplus higher under merger compared to non-cooperation.

We also find that the expected profit of the merged firm is higher than the expected total profits of the firms under non-cooperation for our example, i.e., merger is profitable.

Since the expected total profits are higher under merger compared to non-cooperation and the expected consumer surplus can be higher under merger compared to non-cooperation, it is immediate that the expected welfare, which is the summation of expected total profits and expected consumer surplus, can be higher under merger compared to non-cooperation.

The following result follows from the above discussion.

Proposition 2. *Expected consumer surplus and expected welfare can be higher under merger compared to non-cooperation.*

3. Conclusion

Federico et al. (2017) show that mergers always reduce the merged firms' R&D investments compared to non-cooperation. Denicolò and Polo (2018) show that the result of Federico et al. (2017) does not hold and merger may increase innovation if the probability of failure in R&D is not log-convex in R&D investments.

We provide a different reason for innovation raising merger. We show that merger may increase R&D investments if the firms invest in process innovation, even if the probability of failure in R&D is log-convex in R&D investments as considered in Federico et al. (2017). We also show that merger may increase expected consumer surplus and expected welfare. Thus, our results cast doubts on the robustness of the "innovation theory of harm".

[2] Although the first term in the LHS of (5), i.e., $z\left(\hat{x}^{nc}\right)[\pi_i(0,0) - \pi_i(\bar{c},0)]$, is positive, the small value of $z\left(\hat{x}^{nc}\right)$ makes it small, and the second term in the LHS of (5), i.e., $\left[1 - z\left(\hat{x}^{nc}\right)\right][-\pi(0) + \pi_i(0,\bar{c}) + \pi(\bar{c}) - \pi(\bar{c},\bar{c})]$, dominates and makes the LHS of (5) negative when either c or γ is low.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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