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Abstract

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Duplicative research, mergers and innovation*

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Abstract

We show that in the model of Federico, Langus and Valletti (2017) [A simple model of mergers and innovation, *Economics Letters*, 157, 136-140] horizontal mergers may actually spur innovation by preventing duplication of R&D efforts. This possibility is more likely, the greater is the value of innovations, the less rapidly diminishing are the returns to R&D, and the more highly correlated are the R&D projects of different firms. Federico, Langus and Valletti (2017) do not obtain this result because they focus only on the case in which the merged firm spreads total R&D expenditure evenly across the individual research units of the merging firms – a strategy which is optimal, however, only if the returns to R&D diminish sufficiently rapidly.

1 Introduction

Antitrust authorities have long been concerned that horizontal mergers may create not only static inefficiencies, increasing prices and decreasing output levels, but also dynamic inefficiencies, reducing firms' incentives to invest in R&D. Such "innovation theory of harm" has been articulated analytically in two influential papers by Federico, Langus and Valletti (2017, 2017a) (henceforth, FLV), and it has played a major role in the recent decision of the European Commission in the Dow-DuPont case.

In the FLV model, horizontal mergers impact innovative activity in two ways. On the one hand, mergers increase the market power of the merged entity, allowing the merging firms to coordinate their pricing strategies and hence to capture a higher share of the value of the innovations. This increases

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their incentive to engage in R&D. On the other hand, mergers reduce rivalry in research.

FLV claim that this latter effect decreases the merged entity's incentives to innovate. They also claim that the negative effect of reduced rivalry prevails over the positive effect of increased appropriablity, and that, as a result, mergers always decrease innovative activity. The policy implication would be that in highly innovative industries, horizontal mergers are more likely to be socially harmful than in mature ones.

However, FLV focus only on the case in which the merged entity spreads total R&D expenditure evenly across the individual research units of the merging firms. In fact, even if R&D investments exhibit decreasing returns, it may be optimal, after the merger, to operate equally efficient research departments at different levels of intensity. This possibility arises because of the convexities created by the fact that different departments may replicate the same discovery, or find innovations that are close substitutes.

We show that this can overturn the result that mergers impact innovative activity negatively. Even if the merged entity decreases R&D investment in some units, it may increase investment in others to such an extent that the probability of invention increases. In this case, horizontal mergers are good for innovation (and possibly also for consumers' welfare). This outcome is more likely, the greater is the value of innovations, the less rapidly diminishing are the returns to R&D, and the more highly correlated are the R&D projects of different firms.

2 The model

We consider a single, radical innovation, such as for instance the invention of a new product. The private value of the innovation, i.e., the discounted value of future profits accruing to a successful innovator, is denoted by V. We assume that the social benefits from the innovation exceed the private benefits V, so that more innovation is socially desirable.

To discover the new technology, n ex-ante symmetric firms invest in independent R&D projects. A firm i that makes an R&D expenditure of $R_i = C(x_i)$ achieves the innovation with probability x_i. The function $C(x_i)$ is assumed to be strictly increasing and convex, with $C(0) = 0$.

To get sharper results, we focus on the case $n = 2$. Furthermore, we abstract from synergies by assuming that the merger does not affect the R&D technology: all the merged entity can do is to reallocate aggregate R&D expenditure across the merging firms' research units efficiently. Initially, we also abstract from the possibility that the merger may increase appropriability. To this end, we assume that if both firms succeed, each gets a payoff of $\frac{1}{2}V$.[1] The aggregate payoff in

[1] If innovators seek patent protection, the assumption is that when innovation is duplicated each firm has a 50% probability of getting the patent and becoming a monopolist in the product market. If instead innovations are kept as secrets, in case of duplication both firms will be active in the product market. In this case, the assumption is that the firms collude

case the innovation is found is therefore always V, both before and after the merger.

These are conservative assumptions, which maximize the likelihood that mergers have anti-competitive effects. For example, Shapiro (2012, p. 386) argues that of all mergers, those most likely to diminish innovative activity are the ones

> between the only two firms pursing a specific line of research to serve a particular need [...], absent a showing that the merger will increase appropriability or generate R&D synergies that will enhance the incentive or ability of the merged firm to innovate.

Our assumptions put us precisely into the scenario envisioned by Shapiro.

To simplify the analysis, initially we assume that the R&D cost function is quadratic:

$$C(x_i) = \frac{1}{2}\beta x_i^2, \tag{1}$$

where the parameter β captures the difficulty of achieving the innovation, or the costliness of the inputs used in research projects. The quadratic specification is analytically convenient, yielding simple closed-form solutions. Furthermore, it implies an elasticity of supply of inventions of $\frac{1}{2}$,[2] which is in line with the findings of a large empirical literature.[3] In section 5, we shall discuss alternative specifications of the R&D cost function.

3 The pre-merger equilibrium

Before the merger, each firm $i = 1, 2$ chooses its own R&D effort x_i so as to maximize its expected profit

$$\begin{aligned} \pi_i &= x_i \left[(1 - x_j)V + x_j \tfrac{1}{2} V\right] - \frac{1}{2}\beta x_i^2 \\ &= x_i(1 - \tfrac{1}{2}x_j)V - \frac{1}{2}\beta x_i^2. \end{aligned} \tag{2}$$

The profit function is concave in x_i, so the firm's best response function is given by the first-order condition. It is

$$x_i = \frac{V}{\beta} - \frac{V}{2\beta}x_j \tag{3}$$

perfectly.

[2] The elasticity of supply of inventions is the elasticity of the "innovation production function" $x_i = F(R_i)$, where the function F is the inverse of C. In other words, the elasticity is the percentage increase in the number of innovations (assuming a large number of potential innovations) associated with a one percent increase in R&D expenditure. When the R&D cost function C is quadratic, the innovation production function F is the square root function, and as such has an elasticity of $\frac{1}{2}$.

[3] For a review of this literature, see Scotchmer (2004, ch. 9) and Denicolò (2007).

as long as this expression is lower than 1; otherwise, we have a corner solution $x_i = 1$.

An inspection of (3) reveals that in this model R&D efforts are strategic substitutes. The equilibrium, which is the fixed point of the best response functions, is unique and symmetric. It is given by

$$x^* = \min\left[\frac{V}{\beta + \frac{1}{2}V}, 1\right]. \tag{4}$$

4 The post-merger equilibrium

When the two firms merge into a monopoly, the merged firm's profit function becomes

$$\begin{aligned} \pi_M &= [1-(1-x_1)(1-x_2)]\,V - \frac{1}{2}\beta x_1^2 - \frac{1}{2}\beta x_2^2 \\ &= (x_1 + x_2 - x_1 x_2)V - \frac{1}{2}\beta\left(x_1^2 + x_2^2\right). \end{aligned} \tag{5}$$

The first-order conditions for a maximum are

$$(1 - x_j)V - \beta x_i = 0. \tag{6}$$

If the value of the innovation is small, i.e. $V < \beta$, the second-order conditions are satisfied,[4] and thus the merged firm chooses symmetric R&D efforts

$$x^M = \frac{V}{\beta + V} < 1. \tag{7}$$

Clearly, $x^{**} < x^*$: the merger decreases R&D investments and hence the probability of discovery. This is the result found by FLV.

However, when the value of the innovation is large, i.e. $V > \beta$, the second-order conditions fail. The point $x_1 = x_2 = \frac{V}{\beta+V}$ becomes a saddle point, and the optimum is given by a corner solution:[5]

$$x_1^M = 1; \qquad x_2^M = 0. \tag{8}$$

In this case, if the value of the innovation is not too large (to be precise, the condition is $V < 2\beta$, which implies $x^* < 1$), the merger increases the probability of invention. When the value of the innovation is very large, i.e. $V > 2\beta$, the innovation is achieved with probability one both before and after the merger. However, the merger is still socially beneficial as it prevents wasteful duplication of efforts.

[4] The critical part of the second-order conditions is that the determinant of the Hessian matrix, $|H| = \beta^2 - V^2$, be positive.

[5] By symmetry, indexes are irrelevant: $x_1^{**} = 0$ and $x_2^{**} = 1$ yields the same payoff. When $\beta = V$, the interior solution and the corner solution are equally profitable for the merged firm. However, the corner solution is socially preferable as it maximizes the probability that the innovation is found.

[insert Figure 1 here]

This result is depicted in Figure 1, which represents the probability of successful innovation $[1-(1-x_1)(1-x_2)]$ before and after the merger. In this model, monopoly always prevails in the product market, so the effect of mergers on consumers' surplus has the same sign as the effect on innovation. Therefore, when the value of innovation is large, mergers increase not only innovation but also social welfare.

The intuition behind this result is simple. The merged entity's profit function tends to be convex because the probability of success is not simply the sum of the individual probabilities, but is $x_1 + x_2 - x_1x_2$. The last term in this expression captures the fact that the same innovation may be replicated twice, which, from the merged entity's viewpoint, is valueless. As a result, with linear R&D cost functions it would always be optimal to shut down one research unit and concentrate all R&D efforts on the other.

When the returns to R&D are decreasing, there emerges a countervailing effect. Shutting down one research unit is no longer optimal if the risk of duplication, x_1x_2, is sufficiently small. This is indeed the case when the value of the innovation is small, as in equilibrium the individual probabilities of success x_i increase with V. Therefore, for small innovations the merged entity continues to operate both research units at the same level of activity. In this case, mergers reduce the innovation rate, as shown by FLV.

However, for large innovations the risk of duplication becomes significant. Independent firms that compete with each other would simply face the risk (which is a form of negative externality). The merged entity, in contrast, internalizes the externality, trying to reduce the risk of duplication. This, however, does not necessarily require decreasing the R&D investment in both research units: it suffices to do so in one unit only. For example, if one research unit is shut down, the risk of duplication is completely eliminated. Having eliminated the risk of duplication, the merged entity has now an incentive to increase the R&D investment in the research unit that remains active. The overall effect is to increase the probability of invention.

5 Robustness

In the simple model considered so far, the only factor that determines whether mergers spur or impede innovation is the value of the innovation. In this section, we relax several assumptions of the baseline model so as to identify other factors that may also be relevant in our framework.

5.1 Appropriability

We first extend the analysis to account for the possibility that mergers may increase aggregate expected profits, as FLV (2017) also do. To this end, we assume that in case of duplication each firm obtains an individual payoff of δV, with $\delta < \frac{1}{2}$. If innovators are protected by patents, this case may arise if the patent interference leads with positive probability to no patent being granted. If instead innovations are kept as secrets, the case $\delta < \frac{1}{2}$ may arise if the two firms fail to collude perfectly.[6]

Irrespective of the exact reason why $\delta < \frac{1}{2}$, the consequence of this is that mergers now increase the aggregate payoff when both firms innovate from $2\delta V$ to V, and thus increase appropriability.

The analysis proceeds as in the case $\delta = \frac{1}{2}$, with a few minor changes. As for the pre-merger equilibrium, we must now distinguish among three cases. For small innovations ($V \leq \frac{\beta}{1-\delta}$), the equilibrium is given by

$$x^* = \frac{V}{\beta + (1-\delta)V}. \tag{9}$$

For innovations of intermediate size ($\frac{\beta}{\delta} > V > \frac{\beta}{1-\delta}$), there is one symmetric equilibrium which is still given by (9), and two asymmetric equilibria in which one firm innovates with probability one and the other with probability $\frac{\delta V}{\beta} < 1$. Finally, if innovations are large ($V \geq \frac{\beta}{\delta}$), there is again only one symmetric equilibrium with $x^* = 1$.

The post-merger equilibrium does not change. The comparison with the pre-merger equilibrium largely confirms the results obtained in the case $\delta = \frac{1}{2}$. Mergers reduce the probability of success when innovations are small ($V < \beta$), but increase the probability of success when innovations are large (i.e., when $\frac{\beta}{1-\delta} > V > \beta$ and possibly also when $\frac{\beta}{\delta} > V > \frac{\beta}{1-\delta}$, depending on which equilibrium prevails before the merger). Even when the innovation is very large (i.e., $V > \frac{\beta}{\delta}$), so that the probability of invention is one both before and after the merger, mergers improve economic efficiency by saving R&D costs.

Therefore, the fact that mergers increase appropriability does not affect the sign of the impact of mergers on R&D in this model. However, it affects its size. If mergers reduce R&D efforts, they do so to a lesser extent, and if they increase R&D efforts, they do so to a greater extent than in the case in which appropriability is constant.

The downside is that when $\delta < \frac{1}{2}$, mergers increase price distortions and thus exacerbate static inefficiencies. This is a well-known effect of horizontal mergers, and the present model does not offer any new insight in this respect.

5.2 Convexity of R&D costs

As noted above, the likelihood that the merged entity's profit function may fail to be concave depends on the degree of convexity of the R&D cost function. Since costs enter the profit function with a negative sign, the more strongly

[6] In the former case, greater appropriability is the result of stronger intellectual property protection; in the latter, of better price coordination. In this simple model, the two are analytically equivalent, at least as far as the R&D equilibrium is concerned. The expected consumers surplus, though, may differ in the two cases.

convex is the R&D cost function, the more unlikely it is that non-concavities may arise.

Indeed, if the R&D cost function is sufficiently strongly convex, the merged entity's profit may always be concave. In this case, the merged entity will always operate both research units at the same level of intensity and thus the analysis of FLV would apply. An example is the function $C(x_i) = \beta [\log(1 - x_i)]^2$, which FLV (2017a) use in their numerical calculations.

For weakly convex cost functions, in contrast, the merged firm's profit function will almost always exhibit non-concavities. It is important to note that this does not necessarily entail corner solutions, but will entail asymmetric optima. For example, the R&D cost function could be highly convex for very small and very large values of x_i, but almost linear for intermediate values. In this case, the merged entity could operate one research unit on a small scale, and the other on a large scale.

The important question is, therefore, how strongly convex are R&D costs in practice. As mentioned above, the empirical literature suggests that a quadratic specification captures well the speed with which returns to R&D actually decrease in the relevant range. In fact, Griliches (1990) suggests that returns may be diminishing mainly at the industry level.[7] At the firm level,

> in the major range of the data [...] there is little evidence for diminishing returns, at least in terms of patents per R&D dollar. That is not surprising, after all. If there were such diminishing returns, firms could split themselves into divisions or separate enterprises and escape them. (p. 1167)

If this is so, then our square-root specification of the firms' innovation production functions may overestimate the extent to which returns to R&D are actually diminishing, and hence may underestimate the likelihood that mergers are good for innovation.

5.3 Correlation among R&D projects

The baseline model follows FLV (2017) in assuming that success and failure are statistically independent across R&D projects. This may be true when the research strategies pursued by different research departments are totally different. More often, however, the R&D projects of different firms overlap,

[7] Returns to R&D may be constant at the firm level and decreasing at the industry level, precisely because of the risk of duplication that is at the centre of our analysis. Suppose, for instance, that the firm-level innovation production functions are $x_i = \beta R_i$, and that investments in R&D are symmetric. Then, the relationship between the aggregate probability of success $z = x_1 + x_2 - x_1 x_2$ and aggregate R&D expenditure $\bar{R} = R_1 + R_2$ is concave:

$$z = \frac{4\beta\bar{R} - \bar{R}^2}{4\beta^2}$$

Thus, the industry-level innovation production function exhibits decreasing returns even if the firm-level production functions do not.

at least to some extent, in which case success and failure may be positively correlated across projects.

Formal models of asymmetric binomial distributions with positive correlation are complicated. Intuitively, however, positive correlation increases the risk of duplication. If this is so, then with correlated projects mergers should be more likely to spur innovation and increase social welfare than in our baseline model.

5.4 Other factors

So far we have focused on the case of two firms that merge into a monopoly. With $n > 2$, the merger may involve only a subset of the active firms. The analysis developed above is still useful to identify the unilateral effects of the merger (the "initial impetus"). However, the presence of outsiders which innovate with positive probability attenuates the convexity of the merged firm's profit function, as it lowers the coefficient that multiplies the negative term x_1x_2. Therefore, the profit function may be concave for less strongly convex R&D cost functions than in the $n = 2$ case.

The convexities in the merged firm's profit function are also reduced if the innovations achieved by the two merging firms are substitutes but not identical. This is another factor that may help meet the second-order condition, increasing the likelihood that the merged firm will activate both research units on the same scale.

Finally, our results readily extend to the case of heterogeneous firms. With $\beta_1 \neq \beta_2$, the second-order condition becomes $\beta_1\beta_2 - V^2 > 0$ and thus it will still be violated if V is large enough. In this case, the merged entity will shut down the less efficient research unit, concentrating all of its R&D effort in the more efficient one.

6 Conclusion

When research conducted by competing firms is, to some extent, duplicative, horizontal mergers may be good for innovation even if they do not increase appropriability, involve the only two firms pursuing a specific line of research, and do not entail synergies. Previous analyses overlooked this possibility as they implicitly assumed that the merged entity would spread its R&D expenditure evenly across all its research units. However, we have shown that the optimal strategy may involve operating equally efficient units at different levels of intensity. This possibility arises because of the convexities created by the duplicative nature of the research.

Our analysis has several implications for the antitrust assessment of mergers in innovative industries. First, mergers may spur innovative activity even in the most pessimistic scenarios. Second, the analysis suggests which factors should be considered in the assessment: mergers are more likely to spur innovation in more highly innovative industries, when the returns to R&D at the firm level are diminishing less rapidly, and arguably also when R&D projects are more strongly correlated. Finally, shutting down the R&D department of one of the merging firms is not necessarily bad for innovation, as this boosts the incentive to invest in other departments.

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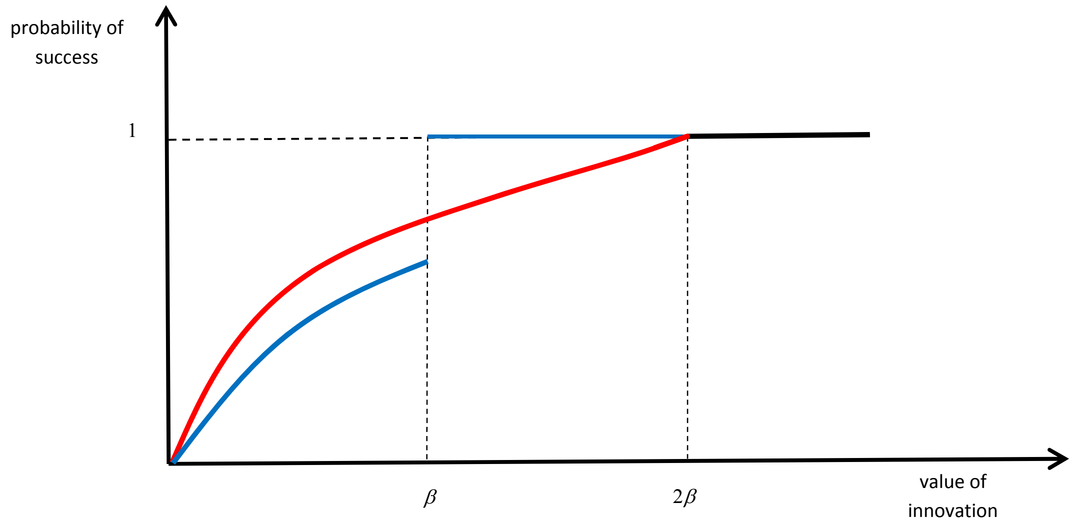

Figure 1

The merger reduces the rate of innovation (as measured by the probability that the innovation is successfully achieved) when $V < \beta$, increases the rate of innovation when $2\beta > V > \beta$, and avoids wasteful duplication of efforts when $V > 2\beta$.