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# THE INNOVATION THEORY OF HARM: AN APPRAISAL

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# The innovation theory of harm: An appraisal

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**Abstract.** In its recent decision on the Dow-DuPont case, the European Commission has adopted an innovation theory of harm (IToH), which holds that even horizontal mergers whose static effects are benign may be regarded as anticompetitive in a dynamic perspective, as mergers generally stifle innovation. This paper critically assesses the IToH, arguing that its theoretical foundations are too fragile to be the basis for radical policy changes. Antitrust authorities and the courts should continue to consider the impact of horizontal mergers on innovation, bearing in mind that the effect can go either way.

Keywords: Mergers, Innovation
JEL : L13, L40, K21, O31

## 1. Introduction

There is a wide consensus that horizontal mergers increase market power but may also bring about cost savings. In all jurisdictions, agencies and the courts seek to maximize allocative efficiency in the short-run balancing these opposing effects. The details of the balancing may vary, but overall the short-run aspects of merger control seem largely settled.

Static allocative efficiency is however only part of the story. Antitrust authorities are also concerned that horizontal mergers may affect innovation and hence dynamic efficiency.[2] When it comes to consideration of dynamics, the regulation of mergers is on much less solid ground. The relationship between competition and innovation has been explored by a huge literature, both theoretical and empirical, but general results remain elusive. Gilbert (2006) concludes his survey of the literature noting that (p. 206) "we remain far from a general theory of innovation

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[2] For example, Gilbert and Greene (2014) report that since 2004 US agencies mentioned innovation effects in over one third of the mergers challenged.

competition." According to Gilbert, the literature has shown that competition may be either good or bad for innovation, depending on the circumstances.[3]

In the light of this, antitrust authorities have generally refrained from taking extreme stances and have followed a cautious approach. Intervention has been limited mainly to cases in which the merging firms' innovative products are close to the commercialization stage. In these cases, innovation outcomes have been regarded as sufficiently predictable as to be amenable to the standard, static analysis.

But policy seems to be changing, especially in Europe. In a series of decisions that culminated in *Dow-DuPont*, the European Commission has gradually shifted the focus of its dynamic merger analysis from product pipelines to "innovation markets," or "innovation spaces." [4] According to the Commission, the impact of mergers on such innovation spaces is generally negative. In the *Dow-DuPont* decision, for instance, the Commission writes (Annex 4, §145):

> The merger between (two firms) will result in internalization by each merging party of the adverse effect of the R&D projects on […] the other merging party; hence, […] it will reduce investment in the competing R&D projects. The innovation competition effect [of a merger] follows the basic logic of unilateral effects, which is equally applicable to product market competition and to innovation competition.

Having articulated the view that mergers generally stifle innovation, the Commission concludes that even mergers whose static effects are benign could then be regarded as anticompetitive in a dynamic perspective.

In the policy debate, this approach has come to be known as the *innovation theory of harm* (IToH). The aim of this paper is to provide an assessment of the IToH from an economic perspective. In particular, we critically discuss two sets of recent papers, by Federico, Langus and Valletti (2017, 2018) and Motta and Tarantino (2017), which are often regarded as providing the theoretical underpinnings of the IToH. Both Federico et al. and Motta and Tarantino highlight conditions under which horizontal mergers impact innovation negatively.[5] They both justify the apparent contradiction with the mixed findings of the competition innovation literature by noting that those findings do not necessarily apply to the case of horizontal mergers, as competition is multifaceted, and mergers reduce competition in a specific way. In their opinion, it is the specificity of horizontal mergers that explains why the

[3] This may sound like a pessimistic conclusion. However, significant progress has been made in identifying what the relevant circumstances are.

[4] Petit (2017) documents this shift in emphasis through a detailed analysis of recent European merger cases. He describes the decision on the *Dow-DuPont* case as a "small but significant change in merger policy." Petit also points out that a similar shift was considered by US agencies in the past but seems to have been abandoned.

[5] For example, Federico et al. (2017) summarize their results as follows (p. 139): "We find that a merger reduces the incentives to innovate for the merging parties, absent efficiencies or spillover effects that would reduce appropriability ex post." Similarly, Motta and Tarantino (2017) write in the abstract of their paper: "It has been suggested that mergers, by increasing concentration, raise incentives to invest and hence are pro-competitive. […] We find no support for that claim: absent efficiency gains, the merger lowers total investments and consumer surplus."

impact on innovation is more negative than for other measures of competition considered in the literature.

Even though these articles are nice analytical contributions, they make restrictive assumptions and overlook important economic effects. In this paper, we highlight the restrictive assumptions and discuss some of the effects that may countervail those identified by Federico et al. and Motta and Tarantino. From this analysis, we conclude that the economic foundations of the Commission's IToH are in fact too fragile to be the basis for radical policy changes. Merger control should continue to consider the impact of horizontal mergers on innovation, bearing in mind that the effect can go either way.

We now briefly summarize our main arguments. In spite of the similarity of the results, the mechanisms analyzed by Federico et al. and Motta and Tarantino are in fact quite different. Federico et al. stress the specific externalities that arise when firms compete in research. These externalities may be similar to but are distinct from those arising when firms compete in the product market. Motta and Tarantino, in contrast, focus precisely on the latter externalities and analyze the implications of the internalization of such externalities for firms' investments in R&D.

This difference has one noteworthy implication: contrary to what is often claimed, Motta and Tarantino's analysis does not actually bring any support to the IToH. In their framework, output and R&D investments go hand in hand, so it is only when the static effects of the merger are anticompetitive that the merger reduces innovation. For mergers that would expand output (for a given level of the technology), the impact on the incentive to innovate is, in their model, positive. Therefore, Motta and Tarantino's analysis does not imply that a merger whose static effects would be benign can be blocked because of its negative impact on innovation. Rather, it implies that a traditional, static assessment that uses consumer surplus as a welfare criterion suffices to determine also the impact of the merger on dynamic efficiency.

Federico et al.'s model, in contrast, can in principle bring support to the IToH. They consider a model where firms that invest in research may duplicate the same innovation, or innovations that are close substitutes. This creates specific negative externalities that the merging firms internalize. According to Federico et al., they do so by always contracting their R&D efforts.

However, in our companion paper (Denicolò and Polo, 2018) we have shown that Federico et al.'s analysis rests on a restrictive assumption that they overlook. The assumption is that the returns to R&D not only decrease (which is what Federico et al. do assume) but decrease sufficiently fast. The stronger condition is needed because in addition to internalizing the externality, the merged firm can also better coordinate the R&D activity of its research units.[6] Denicolò and Polo (2018) show that when the returns to R&D do not decrease too fast, such better coordination may increase total R&D investment and the rate of innovation. In section 2, we elaborate on this result, discussing the conditions that make such a benign outcome more likely. We argue that the conditions are often realistic.

Going back to Motta and Tarantino (2017), in section 3 we point out that their analysis, too, relies on a restrictive assumption (at least in the baseline model, from which the sharpest results are derived). The assumption is that the innovations achieved by one firm can be applied only to that firm's production plants or products, both before and after the merger. In many

[6] The more recent paper, Federico et al. (2018), does recognize the need for a stronger condition.

cases, this assumption seems unrealistic. Very often, new technologies developed by a firm can in principle be used also by others.

When innovation is not firm-specific, mergers may spur innovation by facilitating the sharing of innovative technological knowledge among the merging firms.[7] This expands the scope of application of the new technologies, increasing their value and hence the merged entity's incentive to innovate. We argue that this effect may be so strong that a merger may increase total output and reduce prices, thereby benefiting consumers, even in the absence of static production synergies. This is true both in models of one-stage innovation (section 3) and also in richer models of two-stage, sequential innovation (section 4).

From this discussion, we conclude in section 5 that economic analysis does not support the claim that horizontal mergers always reduce innovation, or that they increase innovation only in exceptional circumstances. There do exist channels through which mergers may impact innovation negatively. However, there are also important and robust mechanisms, such as the coordination of R&D projects and the sharing of innovations, whereby mergers increase the incentives to innovate. When assessing the impact of mergers on dynamic efficiency, agencies and the courts should therefore consider from the outset both negative and positive effects and balance these effects in the light of the facts of each specific case.

## 2. Duplicative research and the coordination of R&D projects

In this section, we discuss the effects of mergers on innovation when research is duplicative. This means that different firms or research units may discover the same innovation, or innovations that are close substitutes for each other.

It should be apparent that in this case the merged entity can reduce wasteful duplications of R&D efforts by better coordinating the research projects of the merging firms. What is perhaps less evident is that this may increase both the productivity of R&D expenditure and the incentives to invest, and hence the overall rate of innovation. This section discusses why this is possible, and under what conditions these positive effects are more likely to materialize.

The mechanism we analyze operates precisely in models such as those considered by Federico et al. (2017). They study a setting where innovation is uncertain, and a firm's probability of discovery depends on its R&D investment. Various independent firms compete to obtain a radical innovation, the value of which is fixed and denoted by $V$. The problem is how a merger among some of the firms impacts the probability of achieving the innovation. Federico et al. claim that the impact is always negative, but in fact their model may deliver also the opposite result.

To demonstrate in the most convincing possible way that the impact on innovation may also be positive, we make assumptions that maximize the likelihood that mergers have anticompetitive

[7] Innovation sharing may take place even among independent firms, *via* voluntary disclosure or by means of contractual licensing agreements. However, various factors impede the sharing of innovations among competitors, as we shall discuss in greater details later. Mergers eliminate the economic barriers to the sharing of innovations among the merging firms.

effects. Shapiro (2012) argues that of all mergers, those most likely to diminish innovative activity are the ones (p. 386)

> 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.

We therefore consider the worst-case scenario envisioned by Shapiro.[8] Thus, we focus on the case of two firms that merge into a monopoly; we assume that there are no research synergies (all the merged entity can do is to reallocate aggregate R&D expenditure across the merging firms' research units efficiently);[9] and we assume that the merger does not increase "appropriability." This means that if both firms succeed, each gets a payoff of $\frac{1}{2}V$, so the total payoff is always $V$.[10]

In this framework, for any given level of innovation (i.e., for any given probability that the innovation is achieved) the merger does not affect output, prices and consumer welfare. In other words, the merger is neutral from a static viewpoint. Any pro or anticompetitive effect of the merger can therefore be attributed entirely to its impact on innovation. This provides an ideal setting in which the IToH can be assessed.

The mechanism whereby mergers allegedly reduce innovation is the following. When the R&D projects are statistically independent, there is a positive probability that both firms achieve the

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[8] Even Katz and Shelanski (2007), who conclude that in general there should be a presumption that a merger's effects on innovation are neutral, advocate an exception "in the case of merger to monopoly, where there would be a rebuttable presumption of harm".

[9] According to Farrell and Shapiro (1990), production synergies exist when the production cost of the merged entity is sub-additive. Likewise, research synergies correspond to the sub-additivity of the merged entity's R&D cost function. Analogously to production synergies, sub-additivity may be due to specific complementarities among the merging firms' assets used in research. For example, the scientists employed by the merging firms may be more productive when they work in a team. See Marshall and Parra (2016) for a model that emphasizes such complementarities. Their existence, however, may be a matter of speculation, so it is important to stress that research complementarities are not necessary for the arguments made in this paper.

[10] This assumption corresponds to the case in which, when the innovation is duplicated, each innovator has a 50% probability of getting the patent and becoming a monopolist in the product market. Another possibility is that innovations are kept as secrets, so that both innovators are active in the product market, but they collude perfectly and split the market evenly. In this reduced-form model, the merger would increase appropriability if, in case both firms duplicate the innovation, the individual payoffs were less than $\frac{1}{2}V$. This extension is considered in both Federico et al. (2017) and Denicolò and Polo (2018) and does not affect the results obtained in this section. A better understanding of the impact of the merger on appropriability however requires an explicit model of product market competition. This analysis is developed in Federico et al. (2018). They consider various cases in which even accounting for the appropriability effect the merger reduces innovation. Bourreau and Jullien (2017), however, analyze a framework where mergers may spur innovation precisely because they increase appropriability. Jullien and Lefouili (2018) provide a more general analysis of the issue and identify conditions under which the appropriability effect may overturn the effects considered by Federico et al.

same innovation.[11] This implies that each independent firm exerts a negative externality on the other, as in case of duplication a firm's payoff falls from $V$ to $\frac{1}{2}V$. Internalizing this externality, the merged entity decreases its R&D investment.[12]

But why should the internalization of the externality always lead to lower R&D efforts? Federico et al. presume that the merged firm makes the same R&D investment in both research units. In this case, the only way to internalize the externality is indeed to reduce the R&D efforts. But, in fact, it may be optimal for the merged entity to choose asymmetric levels of R&D investments, as we have shown in Denicolò and Polo (2018). As soon as one recognizes this possibility, it becomes apparent that the merged entity may decrease the R&D expenditure in one research unit to internalize the externality, reducing the risk of duplication, and increase the expenditure in the other to take advantage of the reduced risk. In this case, a merger may well increase the probability of success.

Federico et al. justify the presumption of post-merger symmetric R&D investments by the hypothesis that the research units are symmetric and that the returns to R&D are decreasing. But this does not suffice to guarantee that a symmetric investment strategy is always optimal.[13] This can be easily seen by considering the limiting case of constant returns to R&D. In this case, a symmetric investment strategy is always strictly sub-optimal: raising the R&D investment in one research unit and decreasing it by the same amount in the other always increases the probability of success.[14] In fact, with constant returns it is always optimal to shut down one research unit altogether and concentrate all the R&D effort in the other. Diminishing returns to R&D counter this powerful tendency towards asymmetric investment strategies, to some extent, but to overcome it fully, the returns to R&D must diminish sufficiently fast. If they do not, the analysis of Federico et al. (2017) is no longer valid.

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[11] For example, if each firm innovates with a probability of 50%, this does not mean that the innovation is obtained for sure: there is a probability of 25% that the same innovation is achieved by both firms, and a probability of 25% that it is achieved by none.

[12] Federico et al. are not the first (nor do they claim to be) to note these externalities. The negative externalities exerted on each other by firms racing to achieve the same innovation were pointed out long ago by Loury (1979) and Lee and Wilde (1980) in models where innovative activity takes places in continuous time and the timing rather than the occurrence of the innovation is stochastic. (Kamien and Schwartz (1975) provided even earlier relevant references.) Both Loury and Lee and Wilde find that the externality gets worse as the number of racing firms increases. Delbono and Denicolò (1991) however note that this result may be reversed if one takes into account that firms compete both in research and in the product market. Delbono and Lambertini (2017) have recently reconsidered the issue, showing that the relationship between the number of firms and the rate of innovation may be increasing, decreasing, or inverted-U shaped, depending on the rate of arrival of innovations.

[13] Technically speaking, a necessary and sufficient condition for a symmetric investment strategy to be optimal is that the probability of failure is a log-convex function of R&D expenditure at the symmetric investment allocation. This property may easily fail even if there are decreasing returns to R&D: see Denicolò and Polo (2018) for details.

[14] This follows from the fact that the probability of success for the merged firm is $x_A + x_B - x_A * x_B$, where $x_A$ and $x_B$ are the individual probabilities of success of the merging firms, and $x_A * x_B$ is the risk of duplication. Starting from $x_A = x_B$, increasing $x_A$ and decreasing $x_B$ by the same amount leaves the sum $x_A + x_B$ unaffected but reduces the product $x_A * x_B$.

As this intuitive discussion suggests, whether a symmetric or asymmetric investment strategy is optimal for the merged entity depends on the relative strength of two opposing effects: the size of the risk of duplication on the one hand, and the rate at which the returns to R&D diminish on the other hand. We start by considering a simple setting where research is not subject to decreasing returns. In this case, the optimal solution is always asymmetric, as we have just seen, and mergers never decrease innovation. We then introduce decreasing returns to research into the picture and analyze how the two effects interact.

## 2.1 Constant returns to R&D

Consider the following simple example. There are two firms that compete for achieving a single innovation. The inventor obtains a total discounted profit of $V = 100$ euros. In case both firms succeed, each obtains an expected payoff of 50 euros; for example, each firm has a 50% probability of obtaining a patent.

Remember that in Federico et al.'s model innovation is uncertain, and the probability of success depends on R&D investment. In the present simple example, the returns to R&D are taken to be constant at the firm level. This means that if a firm's R&D expenditure doubles, so does its probability of success (of course, since the probability cannot exceed 100%, this holds as long as the upper bound is not hit).

To be specific, suppose that by investing 1 euro a firm can increase its probability of success by 1.25%. With constant returns to R&D, the cost of achieving the innovation for sure is therefore 80 euros. In the absence of competition in research, each firm could obtain a net profit of 100 − 80 = 20 euros, meaning that investment in research is potentially profitable.

Now let us introduce competition into the picture, assuming that two symmetric firms, say A and B, can obtain the same innovation. Clearly, in equilibrium it cannot be the case that both invest 80 euros and achieve the innovation with a probability of 100%. The reason for this is that if they did, each firm would be granted the patent with a probability of 50% only. But then the expected payoff would be 50% × 100 − 80 = − 30 euros: both A and B would make a loss.

The equilibrium must therefore be different. In fact, there exists a unique symmetric equilibrium,[15] where each firm invests 32 euros and innovates with a probability of 40%.[16]

[15] Along with the symmetric equilibrium, there are also asymmetric equilibria in firm A, say, invests 80 euros and firm B does not invest at all. There are in fact two equilibria like this, with the roles of the two firms inverted. To confirm that we have a Nash equilibrium here, note that if B does not invest, A is sure of getting the entire prize of 100 euros if it innovates. This means that it is profitable to increase the R&D investment up to the point where the innovation is achieved with certainty. On the other hand, if B knows that A will innovate with a probability of 100%, the expected payoff of investing one extra euro is 1.25% × 50% × 100 = 0.625 euros. This is less than the cost, so for firm B it is optimal not to invest at all. Thus, the strategies of the two firms are each a best response to the other. However, these equilibria are somewhat puzzling as they are asymmetric even though the two firms are *ex ante* symmetric. Besides, in these equilibria one of the two firms is not active at all and thus there is no room for mergers.

[16] To confirm that this is an equilibrium, suppose that each firm knows that its rival succeeds with a probability of 40% and fails with the complementary probability of 60%. For each firm, the investment of 1 euro increases the probability of success by 1.25%. The expected additional payoff from investing 1 extra euro can then be calculated as follows: with an additional probability of 1.25% × 60%, the firm will be the only innovator since the rival fails and thus the patent is obtained for sure; with the

Since there is a probability of 40% × 40% = 16% that both firms achieve the innovation, the probability that the innovation is achieved by at least one firm is just 40% + 40% −16% = 64%.

Now suppose that A and B merge. Clearly, the optimal strategy for the merged firm is to shut down one research unit and invest 80 euros in the other, obtaining the innovation for sure.[17] Therefore, the merger has a positive effect on innovation, as the probability of invention increases from 64% to 100%.

This overall effect can be split into two parts, both positive. The first one is due to the fact that the merged entity is more efficient in translating R&D expenditure into innovation, as it avoids wasteful duplication. For example, if the merged firm invested the same aggregate R&D expenditure as in the pre-merger symmetric equilibrium, i.e. 64 euros, the probability of success would be 80% rather than 64%. Precisely because a better coordinated R&D expenditure is more "productive," the merged entity has a greater incentive to expand total R&D expenditure. This is the second component of the overall effect. In our example, total R&D expenditure raises from 64 to 80 euros, and this further increases the probability of success from 80% to 100%.

## 2.2 Diminishing returns to R&D

While the example with constant returns neatly illustrates how reducing duplication increases both the productivity of R&D expenditure and the incentive to invest in R&D, in reality the returns to R&D are generally decreasing. The extent to which they are may be measured by the elasticity of supply of inventions. This is the percentage increase in the probability of obtaining an innovation associated with a one percent increase in R&D expenditure.[18]

A large literature has tried to empirically estimate this elasticity. Although results vary considerably from study to study, literature reviews suggest that a value of $\frac{1}{2}$ may be taken as a reasonable estimate.[19] That is to say, a 10% increase in R&D expenditure may generate 5%, not

complementary probability of 1.25% × 40% the rival will innovate as well, and the patent will be assigned to the firm with a probability of 50% only. So, in this second case the additional probability of getting the patent is just 1.25% × 20%. Overall, the probability of getting the patent increases by 1.25% (60% + 20%) = 1%, which is worth exactly 1 euro. Therefore, the expected benefit is exactly equal to the cost. This means that the firm cannot increase its profit neither by increasing nor by decreasing its R&D investment: an investment of 32 euros is therefore a best response to its rival's strategy.

[17] Note that this is exactly the same outcome as in the asymmetric pre-merger equilibrium discussed in footnote 15 above. If such an equilibrium prevails before the merger, the merger does not affect market outcomes and thus does not raise any competitive concern. The case relevant for policy is when the pre-merger equilibrium is symmetric.

[18] The elasticity of supply of inventions is the elasticity of the "innovation production function" $x = F(R)$ that represents how the probability of success $x$ increases as the R&D expenditure $R$ increases. The greater the elasticity, the less rapidly diminishing are the returns to R&D. Note that the function $F$ is the inverse of the R&D cost function $R = C(x)$.

[19] See Scotchmer (2004) and Denicolò (2007) for surveys of the empirical literature. In the empirical estimates, the probability of success is replaced by the number of innovations, usually proxied by the number of patents. Most estimates of the elasticity tend to cluster in the interval 0.5.-0.7.

10% more innovations. If this is so, then the probability of invention is roughly proportional to the square root of the R&D expenditure. Equivalently, the R&D cost is roughly proportional to the square of the probability of success.

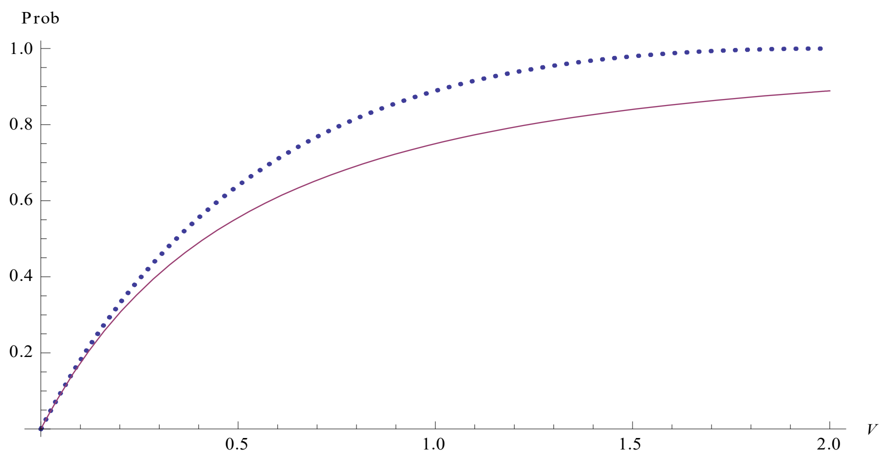


Figure 1

The curves represent the probability that at least one firm finds the innovation (vertical axis) as a function of the value of the innovation (horizontal axis), *under the assumption that the merged entity must operate both research units at the same level*. The dotted curve is the probability of success before the merger, the continuous curve after the merger. Under the symmetry assumption, the merger reduces the rate of innovation for all possible values of $V$.

Luckily, this quadratic R&D cost function has the advantage of being not only realistic but also analytically convenient: the resulting equilibrium can be calculated explicitly.[20] Under Federico et al.'s implicit assumption that the merged entity is constrained to operate both research units at the same level of activity, the comparison between the pre and post-merger equilibrium is represented in Figure 1. In this case, the merger always decreases R&D efforts, as Federico et al. (2017) claim in their Proposition 1.

However, we have already noted that the merged entity may choose to operate the two research units at different levels of intensity. Whether a symmetric or asymmetric solution is optimal depends on the relative importance of two effects. On the one hand, decreasing returns to research call for the aggregate investment to be spread evenly across the two labs. On the other hand, concentrating the research effort in one lab reduces the risk of wasteful duplication.

If the value of innovation $V$ is small, the incentives to innovate and hence the resulting probabilities of discovery in research units A and B, denoted $x_A$ and $x_B$, will be small. But then the risk of duplication, which with independent projects is $x_A * x_B$, will be still smaller. For

[20] See Denicolò and Polo (2018) for details.

example, when $x_A = x_B = 10\%$ the risk of duplication is a mere 1%. In this case, duplication is not a big concern and the driving force is diminishing returns to research. Therefore, a symmetric solution is optimal. As we have seen above, this implies that mergers reduce investment and the probability of innovation as in Valletti et al.

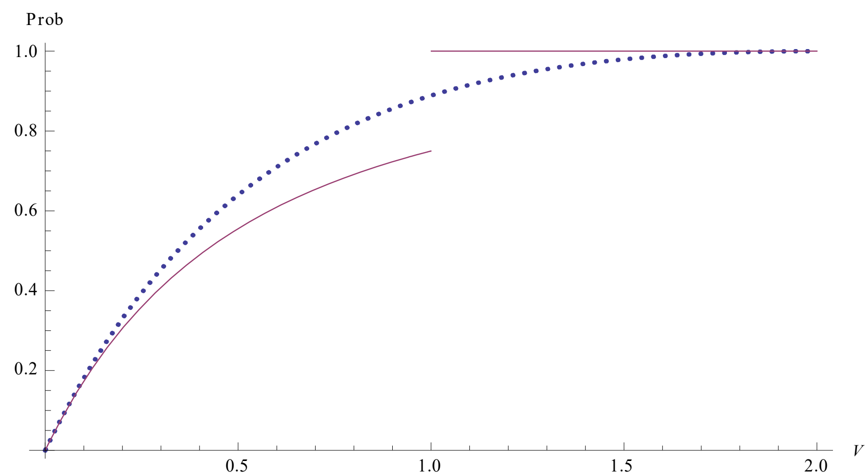


Figure 2

When $V$ is sufficiently large, the optimal investment strategy for the merged entity involves shutting down one research unit and expanding the R&D investment in the other. In this case, the merger increases the overall probability that the innovation is achieved.

However, if the value of innovation is large, the probabilities of discovery and hence the risk of duplication will be bigger. For example, when $x_A = x_B = 50\%$ the risk of duplication is a non-negligible 25%. In this case, the risk of duplication may become the dominant concern and an asymmetric allocation of efforts across research units may prevail.

The above discussion suggests that for any given rate at which the returns to R&D diminish, a symmetric solution tends to be optimal when the value of the innovation is small, an asymmetric solution when the value is large. This conjecture may be confirmed analytically. In the case of a quadratic R&D cost function, for instance, when the value of the innovation is large it is best to shut down one research unit and concentrate the R&D effort on the other. In the research unit that is expanded, the R&D investment increases by so much that the innovation is obtained for sure. This is illustrated in Figure 2. For large values of $V$, mergers increase R&D investment and the probability of success.

The case where one research unit is completely shut down is, of course, just one example. With other specifications of the R&D cost function, the optimal degree of asymmetry is less extreme: one research unit is streamlined, and the other expanded, in a smoother way. [21] To repeat, the

[21] For example, Denicolò and Polo (2018) show that this is the equilibrium pattern when the elasticity of the supply of invention is $\frac{2}{3}$, another case for which a closed-form solution is available.

R&D investment shrinks in one unit to internalize the externality and increases in the other to take advantage of the lower risk of duplication. As a result, the overall probability of success may increase.

Thus, Federico et al.'s results may be overturned if the truly optimal strategy is considered. Their model supports the innovation theory of harm when innovations are small but an "innovation theory of benefit" when innovations are large. [22] Technically speaking, the driving force behind this result is the convexity that arises because of the possibility that the innovation is duplicated. This naturally creates a sort of "economies of scope" in research, which can be exploited thanks to the coordination of different R&D projects.

## 2.3 Additional factors

The above analysis focuses on one factor which determines whether mergers increase or decrease the rate of innovation, namely, the value of the innovation $V$. But other factors may also play a role.

Firstly, we have already noted that the optimal investment strategy may depend on the extent to which the returns to R&D are diminishing. Intuitively, mergers are more likely to spur innovation when the returns to R&D diminish less rapidly. In this respect, it is important to observe that empirical estimates of the elasticity of supply of inventions capture the extent to which returns to R&D are decreasing at the industry level. However, what matters for the impact of mergers on innovation are the returns at the firm level. Griliches (1990) suggests that at the firm level (p. 1167)

> 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.

If this is so, then a quadratic specification of the R&D cost function may overestimate the extent to which returns to R&D are diminishing at the firm level, and hence may underestimate the likelihood that mergers are good for innovation.

Secondly, mergers may affect appropriability. For example, one might imagine that in case of duplication each firm obtains, before the merger, an individual payoff of $\delta V$ rather than $\frac{1}{2}V$, with $\delta < \frac{1}{2}$. After the merger, in contrast, the merged firm always obtains $V$. If innovators are protected by patents, the case $\delta < \frac{1}{2}$ may arise if the patent interference leads with positive probability to no patent being granted. If instead innovations are kept as secrets, it may arise if the two firms fail to collude perfectly. In the former case, greater appropriability is the result of stronger intellectual property protection; in the latter, of better price coordination. [23]

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[22] As we have already noted, in this simple model in which mergers do not affect appropriability, a greater probability of success directly translates into higher consumer welfare.

[23] In this simple model, the two assumptions 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.

In any case, it can be shown that in this simple model the fact that mergers increase appropriability does not affect the sign of the impact of mergers on R&D. 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, their positive impact is larger than in the case in which appropriability is constant: see Denicolò and Polo (2018) for details.

Thirdly, mergers are more likely to spur innovation when the R&D projects of different research units are positively correlated. Intuitively, positive correlation increases the risk of duplication, and hence the benefits from better coordination of the R&D investment. Negative correlation, in contrast, would imply that the symmetric investment strategy considered by Federico et al. is more likely to be optimal.

Which case is most likely? The assumption of statistical independence among R&D projects may fit the case in which different research units pursue totally different research strategies and all strategies can be successful simultaneously. Negative correlation may arise, in contrast, if only one of the different strategies may eventually lead to success. Finally, positive correlation arises when different firms pursue the same R&D project, or projects that are similar to each other. To the extent that all firms have an incentive to focus on the most promising research avenues, the case of positive correlation may be more relevant.[24] If this is so, then Figure 2, which has been drawn under the assumption of independence, may again underestimate the likelihood that mergers increase innovation.

Finally, mergers are less likely to increase innovative activity if the innovations achieved by the two merging firms are not identical. When innovations are imperfect substitutes, the duplication-of-effort effect is weaker, and hence there is less scope for gaining by better coordinating the R&D activities of the merging firms.

## 3. Mergers and innovation sharing

In the previous section, we have shown that mergers may increase R&D investment when innovation is duplicative as mergers allow a better coordination of R&D projects. In this section, we focus on another mechanism whereby mergers may stimulate innovation, namely, the sharing of innovative technological knowledge.

The setting in which this mechanism is best demonstrated is one where innovations are incremental.[25] In other words, the innovation does not create a new market but improves the technology in a market that is already active. Such incremental innovations may take the form of cost reductions, quality improvements, or a combination of the two.[26]

[24] The result that the market equilibrium exhibits too much correlation among research projects was first derived by Dasgupta and Maskin (1987). Bhattacharya and Mookherjee (1986) however find conditions under which the market chooses the right level of specialization.

[25] Federico et al. (2017), in contrast, focus on the case of radical innovations.

[26] To fix ideas, in the rest of this section we shall often refer to innovations as cost-reducing, but the same arguments apply to quality-improving innovations as well.

To a first approximation, the value of incremental innovations is proportional to the output level which they are applied to.[27] The impact of mergers on innovative activity therefore depends, in this framework, on their impact on output levels.

We shall argue that since the merged firm gets bigger, it can apply the innovations it achieves to a greater volume of output. This increases the value of the innovations for the merged firm, and hence its incentives to innovate. This simple mechanism rests on three premises. Firstly, the merged firm must indeed get bigger than any of the merging firms. Secondly, the same innovation must be applicable across various production plants, or products, of the merging firms. In the economics jargon, innovations must be non-rival. Thirdly, the merger must facilitate the sharing of innovative technological knowledge.

Before discussing these assumptions and analyzing the mechanism in greater detail, however, it may be useful to consider the benchmark case in which innovations are entirely firm-specific, preventing the possibility of any information sharing. This case corresponds to the set-up initially analyzed in Motta and Tarantino (2017), that we refer to as the baseline model. In this setting a firm's investment reduces the marginal cost for producing a given variety. Post-merger each investment continues to affect the marginal cost of a specific variety with no effects on the marginal cost of the others. Motta and Tarantino then consider the case when the merging parties benefit from RD synergies that reduce the cost of the research investment. We discuss the relationship between innovation sharing, RD synergies and spill-overs in more detail in Section 3.3. We start our discussion from the baseline model since it highlights more neatly the interaction between output contractions due to the enhanced market power of the merging parties and the reduction in innovative investment.

### 3.1 The output effect of mergers on innovative investment

In their baseline model, Motta and Tarantino assume that innovations are firm specific: the innovation achieved by firm A can be applied only to firm A's output, that achieved by firm B only to firm B's output. This remains true when firm A and B merge, becoming divisions of the new merged entity. In other words, any cost reduction achieved by a division of the merged entity can be applied only to the output of that division.

Even within the merged entity, therefore, the incentive to innovate of each division is proportional to the division's output. In the absence of static production synergies, the unilateral effect of the merger is to decrease the output of each division.[28] It follows that the

[27] This abstracts from the strategic value of incremental innovations, which may arise when a lower cost or a higher quality may induce competitors to behave more, or less, aggressively. This strategic effect will be discussed in subsection 3.4 below.

[28] This follows from the fact that the merged firm internalizes the externality caused by the fact that an increase in a firm's individual output decreases the price at which all other firms sell their outputs. This market-power (or price-coordination) effect of mergers is very robust. Together with the concern that mergers may facilitate collusion among the fewer remaining firms, it is the main reason why mergers are regulated.

unilateral effect of the merger is to reduce the incentives to innovate, and hence the R&D investments, of the merging firms. [29]

Much of the analysis in Motta and Tarantino (2017) is devoted to finding conditions under which the reaction of outsiders cannot overturn such unilateral effect. This is not obvious and thus identifying conditions that guarantee the result is a fine analytical contribution. However, it is often argued that in any case merger control should consider only the unilateral effect of the merger. In the baseline model, the unilateral effect is clear and does not require additional assumptions.

A perhaps subtler question is whether this analysis brings any support to the IToH. Remember that the IToH claims that mergers that should be permitted on the basis of their static effects might be regarded as anticompetitive because of their negative impact on innovation. If the welfare criterion is consumer surplus, all mergers in Motta and Tarantino's baseline model with no production synergies fail the static test, as they all decrease output and increase prices for any given state of the technology. Taking innovation into account increases the social losses from the merger but does not change the outcome of the static assessment.

However, to validate the IToH one must show that mergers that are benign from a static viewpoint may become harmful when the effects on innovation are considered. With a consumer surplus criterion, the merger is statically procompetitive if it increases output and reduces prices for a given level of the technology — for example, because of production synergies.[30] But, in the present setting, a firm's incentive to innovate is proportional to the firm's output. It follows that if the merged entity's output increases, its incentive to innovate increases as well. Thus, mergers that are procompetitive according to the static analysis increase innovation, and mergers that are statically anticompetitive decrease innovation. Bringing innovation into the picture does not turn any procompetitive (or neutral) merger into an anticompetitive one, as supposed in the IToH proposition. In this respect the baseline model

[29] See Motta and Tarantino (2017) Proposition 1 and 5. Unilateral effects may be defined as the effects of a change in the merging firms' strategic decisions, taking other firms' behavior as constant. It has become customary in policy assessment of mergers to focus mainly on such unilateral effects, presuming that equilibrium adjustments may change the magnitude but not the sign of the unilateral effects. See Ivaldi et al. (2003) and Farrell and Shapiro (2010).

[30] At least since Williamson (1968), economists have recognized that mergers may entail production synergies. Production synergies may be defined as any decrease in marginal costs in excess of that entailed by the simple reallocation of output among the merging firms. In the presence of synergies, mergers still increase the market power of the insiders, but if synergies are sufficiently high output may increase, prices may decrease, and consumers may gain. Recognizing this possibility, the static assessment of mergers therefore balances market power and production synergies. Since production synergies are typically difficult to measure, their assessment is often framed by a system of presumptions. In all jurisdictions, mergers that do not significantly increase market concentration are systematically cleared, whereas mergers that increase concentration substantially are regarded as potentially anticompetitive. Since all mergers increase market power to some extent, the clearance of mergers that affect concentration only slightly must be justified by a presumption that some production synergies come along with the merger. When instead concentration increases significantly after the merger, the net impact on output can be positive only if production synergies are substantial, a possibility that is presumed to be less likely. The burden of proof then is reversed: it is now the merging firms which must prove that synergies are high enough to overturn the market power effect. In other words, current policy seems to be based on a presumption that production synergies exist but are limited in size, or that high synergies are less likely.

discussed here is a useful reference since, as Motta and Tarantino show and we further discuss below adding RD synergies to the benchmark set-up would introduce further effects that boost innovative investment and therefore move in the opposite direction with respect to the IToH proposition.

The policy implication of Motta and Tarantino's analysis is therefore clear. Antitrust authorities and the courts should not worry about the effects of mergers on innovation, as the traditional static tests based on the consumer surplus criterion suffice also to determine whether the merger's dynamic effects are positive or negative. This is certainly an important policy conclusion but is one that does not bring any support to the IToH.[31]

Moving beyond Motta and Tarantino's baseline model, in the rest of this section we discuss two factors – innovation sharing and strategic effects – that may imply that the impact of mergers on innovation is less negative than in the baseline model. Since the policy conclusion of the baseline model is "neutral" for the IToH, whenever the impact on innovation is less negative (or positive) the analysis would actually bring support to an innovation theory of benefit.

### 3.2 Innovation sharing

The assumption that innovations are entirely firm-specific, which rules out the possibility of any innovation sharing, is overly restrictive. Very often, new technologies developed by a firm can, in principle at least, be used also by others.

There is huge direct and indirect evidence that innovations are generally not firm-specific. The fact that a firm's innovation can be used by others is indeed the reason why innovations are copied, imitated, or licensed. It is also the only reason why firms need to protect their innovative technological knowledge. The protection is usually achieved by keeping innovations a secret or relying on some form of intellectual property rights. This would not be necessary if innovations could not, by their very nature, be used by others.

In spite of the efforts firms make to protect their innovations, the protection mechanisms may not be effective enough to prevent imitation or inadvertent leakage of innovative technological knowledge. This creates R&D spillovers, the subject of a large and still increasing economics literature. Such spillovers could not exist if innovations were entirely firm-specific. But in fact R&D spillovers are so prevalent, that according to the "absorptive capacity" hypothesis one of the reasons why firms invest in R&D is to facilitate the absorption of these spillovers.[32] In sum,

[31] This argument assumes that the welfare criterion used in the policy assessment of mergers is consumer surplus. Including in the social welfare calculation also the profits of the firms would generally lead to a more lenient policy. There could be cases in which total welfare increases even if output falls after a merger. In this case, Motta and Tarantino's analysis could imply that consideration of dynamic efficiencies might block mergers that would pass a static welfare test. But in any case, mergers that are statically procompetitive according to the consumer surplus criterion would remain procompetitive even taking innovation into account.

[32] The absorptive capacity hypothesis has been formulated by Cohen and Levinthal (1989,1990).

the notion that innovation is to a large extent non-rival, i.e. usable at the same time by many different firms, is so obvious that it hardly needs elaboration.[33]

When innovation is non-rival, mergers may spur innovation by facilitating the sharing of innovative technological knowledge among the merging firms. Different authors refer to this effect as "learning," "information sharing," or "innovation sharing." In what follows we shall use these terms interchangeably.

It is important to note that a transfer of technological knowledge may occur even among independent firms, either through voluntary disclosure or by means of contractual licensing agreements. However, when firms are independent such technology transfers are limited for a variety of reasons, as we shall discuss in greater detail below. When firms merge, these barriers are lifted and thus the sharing of technological knowledge becomes easier and more complete.[34]

Innovation sharing is therefore another mechanism through which mergers may impact economic variables – a mechanism which in many cases is as important as those discussed in the preceding section. To demonstrate the positive effects of mergers with innovation sharing, we consider once again the case of two firms that merge into a monopoly. As discussed above, this is probably the case in which a merger is most likely to have anticompetitive effects. We start from a simple example with fixed production capacity, and then we proceed to the case where mergers may affect the level of output.

### *3.2.1 A simple example with fixed capacity*

Consider two firms that compete in a market where they supply substitute products. Each firm has a fixed production capacity of 50 units. The total capacity of 100 units is assumed to be less than the monopoly output. This implies that the capacity constraint is always binding.[35] Initially, each firm has a unit cost of 30 euros. However, firms can target one of two possible innovations. The first, smaller innovation reduces the unit production cost from 30 to 28 euros and can be achieved with certainty by investing 80 euros. The second, bigger innovation

[33] The extent of non-rivalness may be limited only by the fact that certain technologies can be used only in conjunction with specific physical assets. For example, a process innovation might be implementable only in a specific production plant. In this case, the innovation can be of any use only for the owner of the plant, who therefore need not take any particular measure to protect the new technology. As another example, consider an improved design of a specific variety of a product. This can be used only by the firm that commercializes that variety. To the extent that the firm can already rely on such protection mechanisms as brand name, marketing infrastructures etc., the improved design does not need any further specific protection. Thus, complementarity between non-rival innovations and rival physical assets may sometimes limit the effective degree of non-rivalness. Several surveys have documented that the control of complementary manufacturing or sales assets is indeed regarded as an important tool for appropriating the benefits from innovations: see, for instance Cohen, Nelson and Walsh (2001).

[34] This is not to say that mergers automatically solve all agency problems. It is well known that such problems exist also within firms, especially among divisions that are not yet fully integrated, as is likely to be the case soon after a merger.

[35] It also implies that it is irrelevant whether firms compete in quantities (Cournot competition) or prices (Bertrand competition): in each case, firms would like to produce more if they could, but output is limited by capacity.

reduces the cost to 10 but requires an R&D investment of 1600 euros. Thus, the second innovation is ten times as large, but twenty times as costly, as the first one.[36] Innovation is non-rival and duplicative: each firm can potentially use the innovation achieved by the other, but if both firms achieve the same innovation neither can learn anything more from the other. [37]

For the sake of the example, we assume that with independent firms there is no innovation sharing. This assumption will be discussed in a moment. If the assumption holds, the value of the first innovation is 2 × 50 = 100 euros, that of the second 20 × 50 = 1000. It follows that each firm will target the first innovation, which gives a profit of 100 − 80 = 20 euros, but not the second one, which would entail a loss of 600 euros.

Now consider the effect of a merger. For the merged entity, which can apply the innovation to its entire production capacity of 100 units, the value of the first innovation is 200, that of the second 2000. Therefore, the second innovation is now more profitable than the first one, as the net profit is 2000 −1600 = 400 rather than 200 − 80 = 120 euros. The merged entity will therefore make a bigger R&D investment, i.e. 1600 rather than 80 × 2 = 160 euros, and achieve a greater cost reduction, i.e. 20 rather than 2 euros, than independent firms would do.

This example neatly illustrates the mechanism discussed in this section: the merger creates a bigger firm, and this increases the value of innovations that can be applied to the merged entity's aggregate output. The example is perhaps simplistic in that it assumes that the level of output is not affected either by the merger or by the cost reduction. We shall see that the main insight extends to a more flexible model, but before turning to this issue we first discuss the possibility that even independent firms may share their innovations.

### *3.2.2 Innovation sharing among competitors*

It may be argued that if innovations are not firm-specific, technological knowledge should be transferable even across independent firms. Obviously, independent firms may not have incentives to voluntarily engage in innovation sharing, as they generally do not want their rivals to become more efficient. However, a successful innovator could license the innovation to its rivals in exchange for a payment, thereby expanding the base of sales of the innovation even without a merger.

The licensing of innovations is indeed a common phenomenon, which has attracted the attention of a huge literature in economics, law, and management. In a hypothetical world where licensing contracts were complete and efficient, an innovator could perhaps extract the entire potential value of its innovation by means of licensing. In our example, the potential value of the bigger innovation is 2000, i.e. the cost reduction of 20 applied to the entire aggregate capacity of 100. In the hypothetical world, an innovator could obtain a payoff of 2000 through a combination of direct cost savings on its plant and licensing revenue from the rival. As a result, any one of the two firms would have an incentive to achieve the bigger innovation even in the

[36] Note that that the returns to R&D are decreasing in that the R&D costs increase proportionally more than the size of the innovation.

[37] Differently from the preceding section, the assumption of duplicativeness is not crucial for the results here. In fact, if the cost reductions obtained by different divisions of the merged entity could be summed, the impact of innovation sharing would be even more benign.

absence of a merger.[38] Mergers would not enhance innovation sharing, and thus the effects of mergers would be the same as in models where innovation sharing cannot take place.[39]

However, if contracts were perfectly complete and efficient, there would be no need of complex economic organizations such as firms; all economic relationships could be arm's length. A meaningful theory of mergers must presume that firms exist, and hence must explicitly or implicitly recognize that contracts are often incomplete and inefficient. This is true for all contracts in general but is especially true for contracts whose object is the transfer of new technologies.

These contracts are particularly delicate for a variety of reasons. Firstly, by its very nature innovative technological knowledge may be difficult to codify and transmit to others, unless the sending and receiving parties belong to the same organization. Secondly, reaching an agreement about technological transfer may require some preliminary disclosure of the new technology. This may create technological spillovers, especially if innovative knowledge is not, or is only partially, protected by intellectual property rights such as patents or copyrights. Thirdly, licensing may be impeded by the fact that it is generally hard, or even impossible, to specify in a contract the object and methods of the technology transfer, an issue of contract incompleteness. Finally, the licensing of innovations is generally plagued by problems of asymmetric information. For example, the licensor may possess superior knowledge about the characteristics of the new technology, but the licensees may be better informed about local production or market conditions.

Even leaving all these problems aside, the innovator may not be able to capture the value of the innovation fully because licensees may have some bargaining power, and because of potential hold up problems. Going back to our numerical example, suppose that the two firms have equal bargaining power, and that bargaining can take place only after the innovator has sunk its R&D investment. The bargaining surplus then is 1000 euros, i.e. the value of the cost reduction for the non-innovating firm. With a fifty-fifty split of the surplus, the innovator's total payoff would be 1500 – that is, 1000 of direct cost saving and 500 of licensing revenue. This is still lower than the cost of the bigger innovation, which is 1600. Anticipating the outcome of the *ex post* bargaining,[40] no independent firm will therefore target the more valuable innovation.[41]

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[38] Here we abstract from issues of coordination of the firms' research activities that arise when innovation is duplicative. These issues have already been discussed in the preceding section.

[39] The only difference is that the impact of the merger on innovation would depend on the effect of the merger on total output rather than on the output of the merged entity. Often, however, these two variables tend to move in the same direction.

[40] The hold-up problem would not arise if firms could bargain before R&D investments are sunk, i.e. with *ex ante* bargaining. In reality, however, the licensing of prospective innovations is rather rare. Most licensing contracts have as their object innovations that have already been achieved and thus may be easier to contract upon.

[41] Recognizing these difficulties, antitrust authorities have somewhat encouraged the formation of research joint ventures (RJVs). RJVs may help firms share their innovations (and also coordinate their R&D activities more broadly). However, the ample literature on RJVs has recognized that as long as firms remain independent, coordination and sharing within a RJV may be impeded by the same factors that operate outside an RJV. Furthermore, RJVs may help firms coordinate not only research but also pricing

The importance of these obstacles to technological transfer is difficult to assess directly. However, indirect evidence may give a sense of the magnitude of these effects. If the diffusion of technological best practices were quick, and innovative technologies were rapidly shared, productivity differentials across active firms should be small and transitory. But a vast literature has abundantly documented the size and persistence of productivity differentials across firms. [42] This literature provides indirect evidence of the importance of the economic barriers to technology transfers. Evidently, the obstacles mentioned above must be quite significant.

We conclude that innovation sharing among competitors is generally limited, while it is much more complete among the merging firms. In other words, mergers generally facilitate innovation sharing. As our simple example shows, this increases the merged entity's incentive to innovate. However, the example posits a constant level of output, which implies that a merger cannot affect consumers surplus. We now extend the analysis to the more interesting case in which output may vary.

### *3.2.3 A model with variable output*

The case of variable output is difficult to deal with by means of numerical examples, as the output level can be affected both by the merger and by the firms' R&D investments. To account for these effects in a coherent way, it is necessary to resort to a formal economic model. For our purposes, the simplest possible setting is perhaps the classic model of Perry and Porter (1985), augmented for innovation. The model is presented formally in Denicolò and Polo (2018a). Here, we discuss the assumptions and present the main results.

Perry and Porter consider a Cournot oligopoly with homogeneous products. Initially firms are symmetric. The marginal costs of each firm $i$ are assumed to be linearly increasing in the firm's output:[43]

$$MC_i(q_i, x_i) = constant \ + sq_i \ .$$

The slope of the marginal cost curve, denoted by $s$, measures the extent to which production is subject to decreasing returns. After a merger, the merged entity's marginal cost curve becomes the horizontal sum of the original curves of the insiders and hence becomes flatter. As stressed by Farrell and Shapiro (1990), this effect is not due to production synergies, but simply to efficient output reallocation (e.g. splitting total output evenly) across different plants.

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and output decisions. In other words, RJVs are a form of partial integration, and to the extent that they may entail the same benefits, they will also entail the same costs as full integration (merger).

[42] Syverson (2011) summarizes the findings of this literature as follows: "large and persistent differences in productivity levels across businesses are ubiquitous."

[43] A simpler model with constant marginal costs, such as Salant, Switzer and Reynolds (1983), would not fit our mechanism as the merged entity would not become any bigger than the (equally efficient) outsiders. To guarantee this outcome, marginal costs must be increasing. Our results easily generalize to a larger class of demand and cost functions, as well as to the case in which firms may be *ex ante* asymmetric, as in Farrell and Shapiro (1990).

Now augment this model by assuming that firms can reduce their marginal costs by investing in R&D. Specifically, the constant component of the marginal cost is taken to be $c - x_i$, where $c$ is an exogenous parameter and $x_i$ is the size of the cost reduction. The cost reduction may be adjusted continuously. However, reducing the cost is costly, and the required R&D investment increases with $x_i$ at an increasing rate. Specifically, we assume that the R&D expenditure is proportional to the square of the cost reduction:

$$C(x_i) = \frac{b}{2} x_i^2.$$

The coefficient of proportionality of the R&D cost, denoted by $b$, is a parameter that captures the productivity of R&D expenditure.[44]

Like in the fixed capacity example, we assume that innovation is non-rival and duplicative. Non-rivalness means that the cost reduction achieved by one firm can in principle be used also by the others. Duplicativeness means that when two firms share their innovations, both can benefit from the larger cost reduction but not from the sum of the two. If this latter assumption were relaxed, the impact of the merger on innovation and consumer surplus would be even more positive.

Once again, results are sharpest for the case of two firms $i = A, B$ that merge into a monopoly.[45] Exploiting its increased market power, the merged firm contracts output. However, for any given level of the costs, the merged entity will produce more than either A or B did in the pre-merger equilibrium as it faces less rapidly diminishing returns. As a result, the merged entity's incentive to invest in R&D increases.

Qualitatively, this effect is exactly the same as in our simple example with fixed capacity. The difference is that a lower marginal cost now induces the merged entity to expand its output. This in turns creates an additional incentive to increase R&D investment, giving rise to a cumulative process of output and investment expansions. To keep the analysis interesting, one must assume that this cumulative process does not explode.  Convergence requires that reducing the cost is sufficiently costly, or that the marginal cost increases sufficiently rapidly as output grows. This entails a restriction on the parameters of the model, $b$ and $s$. The restriction is met above the decreasing curve depicted in Figure 3.

Even with the stability condition in place, the cumulative effect of output and investment expansion may be so strong that the merged entity eventually increases not only its R&D investment, and hence the size of the cost reduction, but also its aggregate output level. In this case, the merger becomes procompetitive *even in the absence of static production synergies*.

This is illustrated in Figure 3. The merger increases output below the horizontal line. The stability condition is met above the decreasing curve. In the region between the line and the curve, the cumulative process converges, and the final level of output is greater than the pre-

[44] That is, the greater is the productivity of R&D expenditure, the lower is $b$.

[45] With more than two firms, the analysis would determine the unilateral effect of the merger. If the equilibrium is stable, the outsiders' equilibrium responses may attenuate the unilateral effect but do not change its sign.

merger equilibrium. The analysis therefore shows that in sizeable region of parameter values a merger increases output, reduces prices, and increases consumer surplus.[46]

The possibility that a merger may be procompetitive even in the absence of static production synergies is more likely, the more rapidly increasing is the marginal cost curve, and the more productive is R&D expenditure. Strong diseconomies of scale guarantee that with constant costs the merger would not decrease the merging firms' aggregate output by too much. High productivity of R&D expenditure guarantees that the cumulative process, while non-explosive, is sufficiently strong to overturn the initial contractionary impact.

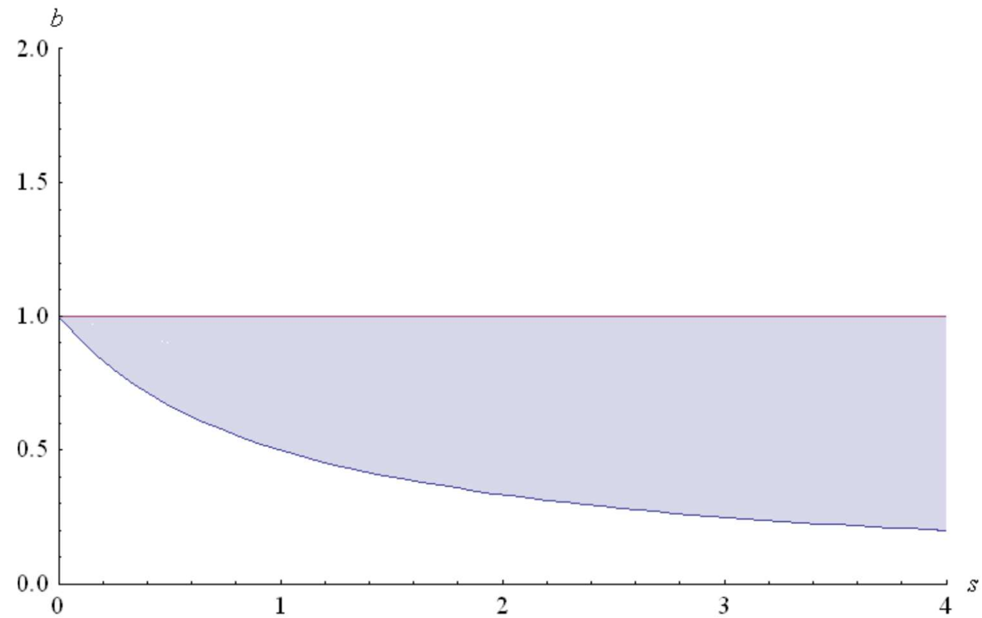


Figure 3

In the grey region the merger increases output and reduces prices, even in the absence of static production synergies.

In particular, Figure 3 shows that, in the absence of production synergies, the merger cannot be pro-competitive when the parameter *s* vanishes, i.e. when marginal costs are constant. In this case, it is still true that the merged entity's output is greater than the pre-merger individual output of any of the insiders, for any given level of the costs. However, the initial output increase

[46] Remarkably, with more than two firms a welfare-improving merger is profitable for the insiders but harms the outsiders, explaining why rivals may be concerned that the merger may create a stronger competitor.

is not large enough to make the final effect of the merger pro-competitive when the cumulative process described above converges. [47]

Another way to guarantee that the merged entity becomes sufficiently bigger that the cumulative process leads to greater output is to consider a model of differentiated products in which the merged entity's product line is the sum of the product lines of the insiders, as in Davidson and Deneckere (1985). Davidson and Ferret (2008) have been the first to analyze the consequences of innovation sharing in this setting. Consistently with our results, they have shown that mergers may expand the insiders' output and hence reduce prices, thereby benefiting consumers but harming the outsiders, even in the absence of static production synergies.[48]

### 3.3 R&D spillovers and efficiencies

Motta and Tarantino (2017) allow for innovation sharing when they discuss "efficiencies" and "R&D spillovers." These effects make the impact of mergers on innovation less negative than in the baseline model discussed in Section 3.1, or even positive. It is important to stress, once again, that since the baseline model implies that mergers whose static effects are neutral have no impact on innovation, any extension that makes the impact more favorable delivers opposite results to the IToH's.

Consider R&D spillovers first. With such spillovers, the cost reduction that a firm can enjoy is greater than what it is has achieved directly. Denoting the former by $y$ and the latter by $x$, Motta and Tarantino assume that $y_A = x_A + \sigma x_B$, with a symmetric expression holding for firm B. The parameter $\sigma < 1$ captures the size of R&D spillovers. Evidently, with R&D spillovers innovation is no longer entirely firm-specific. This extension of the model therefore recognizes that innovations may be non-rival.

Motta and Tarantino show that with R&D spillovers the merger has a less negative effect on innovation than in the absence thereof. However, their treatment of R&D spillovers is still restrictive in that it assumes that the same level of technology transfer is achieved when firms are independent as when they merge. [49] But with independent firms the technological transfer is due entirely to inadvertent leakage, whereas when the firms merge they willingly share their innovations. It is therefore quite likely that in the latter case the technology transfer may be

[47] The case of constant marginal costs has been analyzed by various papers, including for instance Kleer (2012). For the reason just explained, these papers do not find that mergers may expand output in the absence of static production synergies.

[48] Davidson and Ferret (2008) assume that the extent to which innovations are, or are not, firm-specific is variable and depends the level of product differentiation. In other words, they allow for the possibility that the less differentiated are the products, the easier it is to transfer innovations across firms. Furthermore, Davidson and Ferret consider a two-stage model where the strategic effects analyzed in the next subsection also arise.

[49] They borrow this assumption from the classic paper by d'Aspremont and Jacquemin (1988). However, Kamien, Muller and Zang (1992) noted that the assumption is restrictive. They suggest that a better assumption might be that $y_A = x_A + \sigma x_B$ when firms are separated, but $y_A = x_A + x_B$ when firms merge or form a research joint venture.

much more complete. When mergers facilitate the sharing of innovative technological knowledge, their effect on innovation is even more positive.

Motta and Tarantino allow also for “efficiency gains.” They do not elaborate on the nature of these gains, which they interpret as cost savings in R&D. The most explicit description they offer is that “by combining their assets two firms will be able to reduce the costs of their investment.” The suggested interpretation seems therefore to be that of “research synergies” that arise because of complementarities among the merging firms’ research divisions, as discussed in footnote 9 above.

However, if one recognizes that innovation sharing makes the $y'$s greater than the $x'$s and posits that the R&D cost functions have as their arguments the $y'$s rather than the $x'$s, then Motta and Tarantino’s “efficiency gains” may be an indirect way of capturing innovation sharing. And indeed Motta and Tarantino show that the impact of mergers on innovation is less negative with efficiencies (which by itself would disprove the IToH), and it may even become positive if efficiencies are large enough. Their analysis therefore is consistent with our discussion of innovation sharing.

We believe, however, that the importance of innovation sharing would justify a more explicit treatment that distinguishes between innovation sharing and research synergies due to complementarities between different research units. Even if they may be analytically analogous, these effects are different, and they may be regarded as more or less relevant in practice. In particular, the existence of complementarities in research may be a matter of speculation. If this is so, then it may be appropriate to leave the burden of proof of R&D synergies to the merging firms. Innovation sharing, in contrast, in our view is a natural and common phenomenon, that may arise when different research units benefit from each other findings and progresses on a project (RD synergies), but that materializes also when the discoveries of one research lab is at least in part applicable to the production or improvement of different varieties. Given the more general relevance of innovation sharing compared with RD synergies,we believe that merger analysis should consider this feature from the outset, rather than relegating it among the “efficiency defenses.”

### 3.4 Strategic effects

So far, we have assumed that the value of an incremental innovation is the cost saving (or the extra value of the higher quality) on the output that the innovator produces. This is usually referred to as the direct value of incremental innovations. But in certain cases, the value of incremental innovations may have a second component, the strategic value.

The strategic value may be positive or negative. It is related to the way a firm’s innovation may affect the behavior of its rivals. When the innovation is introduced, the innovator changes its market strategies. If, as a reaction to this change, rivals become more aggressive then the innovator’s gain is reduced. In this case, the strategic effect of the innovation is negative. If instead rivals become less aggressive, the strategic effect is positive.

As argued by Lopez and Vives (2016), the strategic effect of innovations rests on the observability of R&D investments on the part of the competitors.[50] Such observability cannot be taken for granted, so the strategic effect is perhaps more uncertain than the direct effect. Therefore, analyses that focus on the direct value only, such as the one developed in this section so far, may thus be interesting in their own right and not only as a first approximation. However, it may be interesting to consider also whether and how bringing the strategic effect into the picture would affect our conclusions. This is the objective of this subsection.[51]

To analyze the strategic value more formally, consider two firms that compete in the product market and invest in cost-reducing innovations. The profit of a firm, say firm A, is (with obvious notation)

$$\pi_A = [p_A(q_A, q_B) - c_A]q_A.$$

We want to analyze how the profits are affected by a reduction in the level of costs. [52]

By the envelope theorem, the increase in profit is

$$\left|\frac{d\pi_A}{dc_A}\right| = q_A + \frac{dp_A}{dq_B}\frac{dq_B}{dq_A}\left|\frac{dq_A}{dc_A}\right| q_A.$$

The first term in this expression is the direct value of the innovation; it is positive and equal to the output level. The second term is the strategic value. Since $\frac{dp_A}{dq_B}$ is negative when the firms' products are substitutes, the sign of the strategic value depends on the sign of the term $\frac{dq_B}{dq_A}$, which is the slope of the best response in the product market competition game.

With Cournot competition, output levels are strategic substitutes (that is, $\frac{dq_B}{dq_A} < 0$), meaning that when a firm increases its output the rival responds by reducing its own sales. Considering the signs of the three terms, we find that the strategic effect is then positive. In other words, if

[50] This is an instance of the general principle, first suggested by Schelling (1960), that by making an irreversible move a player can modify the way a game is played by its opponents and thus may affect equilibrium outcomes.

[51] Analytically, models in which R&D investment and output (or price) decisions are made simultaneously, such as Lopez and Vives (2016) and Motta and Tarantino (2017), capture the case in which innovations are not observable by rivals. In this case the value of innovations comprises only the direct effect. The strategic component of the value however appears if one assumes that firms choose R&D investments first, observe each other's new cost or quality levels, and then compete in the product market.

[52] The same analysis applies to the case of quality improving innovations. Such innovations increase consumers' willingness to pay for the product and hence demand. Denoting quality by $\theta$, the demand function becomes $p_A(q_A, q_B, \theta)$. The total value of an incremental quality improvement writes as

$$\frac{d\pi_A}{d\theta} = \frac{dp_A}{d\theta}q_A + \frac{dp_A}{dq_B}\frac{dq_B}{dq_A}\frac{dq_A}{d\theta}q_A.$$

The first term is the direct value, the second the strategic value. The analysis then proceeds as in the case of cost-reducing innovations.

the cost reduction is observable by rivals, firms invest more because R&D investment is a form of commitment that induces rivals to behave less aggressively. In the taxonomy of strategic investment due to Fudenberg and Tirole (1984), this case is known as the "top dog."

When firms compete in prices, this conclusion is reversed. In this case, the profit of firm A writes as

$$\pi_A = [p_A - c_A]q_A(p_A, p_B).$$

The value of an incremental cost reduction is

$$\left|\frac{d\pi_A}{dc_A}\right| = q_A - \frac{dq_A}{dp_B}\frac{dp_B}{dp_A}\frac{dp_A}{dc_A}[p_A - c_A] \quad .$$

The direct value is still $q_A$. Now however $\frac{dp_A}{dc_A}$ is positive, and $\frac{dq_A}{dp_B}$ is positive as well since the goods are substitutes. But $\frac{dp_B}{dp_A}$ is also positive as prices are strategic complements, so the strategic effect is now negative. In other words, a cost reduction that can be observed by rivals makes them more aggressive and intensifies competition by reducing the equilibrium prices, thereby harming the innovator. Hence, the firm has a strategic motive to reduce its innovative effort, an effect that Fudenberg and Tirole (1984) call "fat cat."

Having determined what is the strategic value of innovations, we can now ask how it is affected by a merger. The answer to this question is most obvious when there are only two firms that merge into a monopoly. In this case, the strategic component of the value exists before the merger but vanishes afterwards, as the merged entity does not face competitors anymore.[53] It follows immediately that for any given level of the output, and hence of the direct value of incremental innovations, mergers increase R&D investment when firms compete in prices and decrease R&D investment when firms compete in quantities.

Motta and Tarantino (2017) assume price competition. Therefore, even with firm-specific innovations and in the absence of R&D spillovers, consideration of the strategic effect would make mergers that, due to cost reductions, are statically neutral, , increase innovation. Then, extending the baseline model to strategic effects leads to policy conclusions that are directly opposite to those of the IToH. This should come as no surprise, as the baseline model in itself does not support the IToH but implies that output-neutral mergers are also innovation-neutral.

## 4. Sequential innovation

This paper highlights two mechanisms whereby mergers may spur innovation, the coordination of R&D projects and innovation sharing. So far, we have analyzed the former mechanism in a model of radical innovations, the latter in models of incremental innovations. But innovation sharing may be relevant also for radical innovations that create an entirely new product or open a new market.

Consider, for instance, the pharmaceutical industry. In this industry, new products are typically patented and hence monopolized, at least initially. With only one firm selling the new product,

[53] When there are more than two firms, it seems reasonable to conjecture that even if the strategic effect does not vanish altogether, it will generally shrink even after a merger.

it might seem that there is no scope for sharing innovations. But the merging firms could share intermediate technological knowledge that by itself has no commercial value but may open the way to the discovery of new drugs.

For example, different innovative drugs may share the same therapeutic mechanism or the same "therapeutic target," such as a protein whose activity can be modified by an external stimulus. Clearly, knowledge of the therapeutic mechanism, or of a therapeutic target, facilitates the introduction of new drugs. If different firms seek to introduce different new drugs which share the same therapeutic mechanism or target, all firms could benefit from such "intermediate" knowledge.

However, the incentives to share such knowledge among independent firms are small or non-existent. Independent firms will not voluntarily share innovative knowledge with competitors, as the new drugs they could develop would compete with their own ones. (Typically, all new drugs that share a common therapeutic mechanism belong to the same product market.) Moreover, licensing is difficult as pharmaceutical patents protect new molecules, or class of molecules that have a similar chemical structure, but not therapeutic mechanisms or targets. Such intermediate knowledge is therefore often kept as a secret and is rarely licensed. This reduces the value of basic discoveries for independent pharmaceutical companies (which, as a result, often have an incentive to focus on more applied research).

But when two companies merge, they will share these basic discoveries, which may then be applied to a broader set of applied research projects. This increases the value of basic innovations for the merged entity and hence its incentive to invest in more basic research.

In Denicolò and Polo (2018a), we develop these insights into a formal economic model. Our model extends the setting of Federico et al. (2017) by adding to the "development" stage, the output of which is a new product, a more basic, "research," stage. Successful completion of the research stage guarantees a higher productivity of the R&D expenditure done at the development stage; in other words, for any given level of second-stage R&D expenditure, the probability of inventing the final product increases. The productivity increase is not firm-specific, or product-specific: the research stage produces innovative knowledge that can be used to facilitate the invention of a range of new products.

Once again, illustrate the results focusing on the case of two firms that merge into a monopoly. When firms are independent, the market structure may be either a duopoly (if both firms successfully complete the second stage) or a single-product monopoly (if only one firm does). In this case, a firm that succeeds in the first stage has no incentive to share its intermediate innovation with its rival, as doing so will increase the probability that the rival will achieve the final innovation, reducing the firm's expected profit.

When the two firms merge, in contrast, they will share the basic innovation. This increases the R&D investment both in the research stage and in the development stage. The investment in the research stage increases as the basic innovation can be applied to the research projects of both divisions of the merged firm and hence is more valuable. The investment in the development stage increases, on average, as it is more likely that R&D expenditure is more productive thanks to the basic innovation. [54]

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[54] These results are reminiscent of Bessen and Maskin (2008), a paper that stresses the importance of sharing intermediate technological knowledge for innovation and economic efficiency. Bessen and Maskin argue that patents may impede voluntary sharing. As for patents, this conclusion requires several

As a result, the merger increases the probability that new products are eventually brought to the market. Even if the merger reduces product market competition, the positive effect on innovation may be so large that the merger may increase social welfare and consumer surplus. Once again, the claim of the IToH is reversed: a merger that would decrease output and increase prices for a given state of the technology may become procompetitive because it spurs innovation.

## 5. Conclusions

In this paper, we have discussed the claim – known in the recent policy debate as the innovation theory of harm – that mergers generally reduce innovation in the absence of specific synergies in research, We argue that this claim should be regarded with some caution as it contradicts the mixed findings of a wide literature on competition and innovation. And indeed the claim does not seem to be supported by economic analysis. There do exist mechanisms whereby mergers reduce innovation, but there are also others by which mergers spur innovation. Both types of mechanisms are sound, robust and empirically relevant, not simply theoretical curiosities.

In particular, in this paper we have focused on two mechanisms that may generate a positive impact of mergers on innovation, the coordination of R&D projects and the sharing of new technological knowledge. But other positive mechanisms also exist.[55]

The question whether mergers are more likely to stifle or spur innovation is therefore, ultimately, an empirical one. Unfortunately, the available empirical evidence does not seem to be conclusive either. When all is said and done, the question can be attacked only on a case by case basis, building on the facts of each specific case.

In fact, the innovation theory of harm does not simply claim that mergers generally reduce innovation. It makes the *stronger* claim that even mergers that would be output neutral for a given state of the technology, become generally anticompetitive when their effects on innovation are taken into account. Only such a claim can support a policy that blocks mergers that would pass the standard static tests.

The theoretical foundations of this stronger claim are even shakier. As we have seen, Motta and Tarantino (2017) do not provide any support to the claim. The analysis of Federico et al. (2017, 2018) does support the claim but focuses on a particular investment strategy. This investment strategy may however be suboptimal, in which case the opposite result may actually hold.

From all this, we conclude that the case for changing policy is weak at best. Agencies and the courts should keep in mind that the effect of mergers on innovation can be negative or positive, and that they are more likely to be positive for mergers that pass the standard static tests.

A presumption that horizontal mergers always hamper innovation risks blocking many procompetitive mergers. If any presumption is to be adopted, it must be that mergers are innovation neutral. A neutral starting point guarantees that the assessment of the impact of

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strong assumptions, and so its practical relevance is hotly debated. But it is difficult to dispute the notion that mergers facilitate the sharing of intermediate technological knowledge.

[55] See for instance Bourreau and Jullien (2017), who focus on the impact of mergers on appropriability, and Marshall and Parra (2016), who emphasize the role of complementarities in research.

mergers on innovation is not biased by arbitrary *a priori* beliefs but can be open-minded and grounded on the facts of each specific case.

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