THE INNOVATION THEORY OF HARM: AN APPRAISAL

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There is a broad consensus that horizontal mergers may increase market power but may also bring cost savings. Antitrust authorities and the courts routinely seek to maximize allocative efficiency by assessing these opposing effects. The details of this exercise may vary across jurisdictions or individual cases, but on the whole the short-run questions involved in horizontal merger control would appear to be largely settled.

Static allocative efficiency, however, is just part of the story. Antitrust authorities are also concerned that horizontal mergers may affect innovation, and hence dynamic efficiency.[1] When it comes to dynamic effects, the assessment of mergers is on much less solid ground. The relationship between competition and innovation has been explored by a vast literature, both theoretical and empirical, but results remain ambiguous. Gilbert concludes his survey of the literature by noting that "we remain far from a general theory of innovation competition."[2] In his view, the literature has shown that competition may either increase or decrease innovation, depending on the circumstances. Significant progress has been made in identifying what circumstances are relevant, but a broad consensus is still lacking.[3]

In the light of this, antitrust authorities have generally taken a cautious approach, limiting intervention mostly to cases in which the merging firms' innovative products are close to commercialization (the so-called "product pipeline"). In these cases, innovation outcomes have been regarded as predictable enough to be amenable to the standard, static analysis. The traditional tools adopted to analyze the impact of the merger on competition among existing products have then been applied also to those new products that would be marketed in the near future.

But policy now 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."[4] According to the

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[1] For example, Richard J. Gilbert & Hillary Greene, *Merging Innovation Into Antitrust Agency Enforcement of the Clayton Act*, 83 GEO. WASH. L. REV., 1919, 1921 (2015) reports that since 2004 US agencies mentioned innovation effects in over one third of the mergers challenged.

[2] Richard J. Gilbert, *Looking for Mr. Schumpeter: Where Are We in the Competition-Innovation Debate?* 6 INNOV. POL. AND THE ECON., 159, 206 (2006).

[3] *Id.* at 204.

[4] Nicolas Petit, *Innovation Competition, Unilateral Effects and Merger Control Policy* (Feb. 4, 2017), available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2911597, documents this shift in emphasis

Commission, the effect of mergers on such innovation markets is generally undesirable. In the *Dow-DuPont* decision, for instance, the Commission writes:

> 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 follows the basic logic of unilateral effects, which is equally applicable to product market competition and to innovation competition.[5]

Having articulated the view that horizontal mergers generally stifle innovation, the Commission concludes that a merger may have a negative impact on innovation, reducing R&D investment and slowing down technological progress, independently of the more traditional effects on product market competition. [6] Thus, even mergers whose static effects are benign could 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).

This paper offers an appraisal of the IToH from an economic perspective. In particular, we critically discuss recent papers by Federico, Langus and Valletti[7] and Motta and Tarantino[8] that 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 affect innovation adversely.[9] Both acknowledge the apparent contradiction between their clear-cut conclusions and the mixed findings of the literature on innovation competition.[10] They justify this difference by noting that the general findings of the innovation competition literature do not necessarily apply to horizontal mergers. What distinguishes horizontal mergers is that they do not reduce competition uniformly but rather increase the market power of a subset of

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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] European Commission, Case M.7932, 27/3/2017, Annex IV, §145.

[6] In *Dow-Dupont*, the Commission makes a clear distinction between the product markets where the two merging firms might have competed and the overlap between their research activities. European Commission Press release "European Commission clears merger between Dow and DuPont subject to release" 27 march 2017, p.1-2, *European Commission, supra, note 5*, Section 4.1 and 4.2. The assessment of these latter overlaps does not refer only to pipeline research projects, i.e. innovative products close to the marketing phase, but extends to the merging firms' research labs and long-term R&D projects.

[7] Giulio Federico, Gregor Langus & Tommaso Valletti, *A Simple Model of Mergers and Innovation*, 157 ECON. LETTERS 136 (2017) and Giulio Federico, Gregor Langus & Tommaso Valletti, *Horizontal Mergers and Product Innovation: An Economic Framework*, 61 INT. J. IND. ORG. 590 (2018).

[8] Massimo Motta, & Emanuele Tarantino, *The Effects of Horizontal Mergers When Firms Compete in Prices and Investments* (CEPR DP n. 11550, 2017).

[9] For example, Federico, et al. (2017), *supra* note 7 at 139, summarize their results as follows: "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), *supra* note 8 at the abstract, write: "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."

[10] This literature analyzes how changes in the intensity of competition, as measured for instance by variations in the number of firms or the degree of product differentiation, affects innovative activity. *See* Gilbert, *supra* note 2, for references.

the firms. This might explain why the effect of horizontal mergers on innovation may be more negative than the innovation competition literature suggests.[11]

While these articles are interesting analytical contributions, they depend on restrictive assumptions and thus do not fully account for possible innovation-enhancing effects that can exist when competing firms merge. In this paper, we highlight those assumptions and show how relaxing the assumptions can lead to conclusions at odds with the IToH. From this analysis, we conclude that the economic underpinnings of the IToH are in fact too fragile to serve as the foundation for any general presumption that horizontal mergers have harmful effects on innovation.

Let us now briefly summarize our main arguments. In spite of the similarity of their results, the mechanisms analyzed by Federico, et al. and Motta and Tarantino are in fact quite different.

Federico, et al.'s analysis can in principle offer support to the IToH. They consider a model where firms that invest in research may duplicate the same innovation or produce innovations that are close substitutes. This creates specific negative externalities that the merging firms internalize by contracting their R&D effort. This effect is to a large extent independent of the effect of the merger on product market competition and therefore may be the basis for a genuinely new theory of harm.

However, in our companion paper, we have shown that Federico, et al.'s analysis rests on a restrictive assumption that they overlook, namely that the returns to R&D not only decrease with the level of R&D expenditure (which is what the authors effectively assume) but that this decrease is sufficiently large.[12] This 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.[13] We show that when the returns to R&D decrease with R&D expenditure by a sufficiently small amount, the merged firm's better coordination may increase total R&D investment and the rate of innovation. In Section 1, we elaborate on this result and discuss the conditions that make this procompetitive outcome more likely. We argue that these conditions are in fact often realistic.

Motta and Tarantino's paper explores a different mechanism by which a merger could result in a decrease in innovation. They focus on the externalities arising in product market competition and analyze the implications of the internalization of such externalities for firms' investment in R&D. Contrary to what is often claimed, though, Motta and Tarantino do not actually bring any support to the IToH. In their analytical framework, output and R&D investments go hand in hand, so it is only when the static effects of the merger are anticompetitive, leading to an output contraction, that the merger reduces innovation. Even abstracting from R&D spillovers and dynamic efficiency gains, mergers that would expand output (for a given level of technology), have a positive impact on the incentive to innovate. Therefore, even in the worst-case scenario, Motta and Tarantino's model does not suggest

[11] Federico, et al. (2018), *supra* note 7 at 592 and Motta & Tarantino, *supra* note 8 at 4.

[12] Vincenzo Denicolò & Michele Polo, *Duplicative Research, Merger and Innovation*, 166 ECON. LETTERS 56 (2018).

[13] The more recent paper, Federico, et al. (2018), *supra* note 7, does recognize the need for a stronger condition.

that a merger with benign static effects can be blocked owing to its negative impact on innovation. Rather, it implies that a traditional, static assessment with consumer surplus as the welfare standard suffices to determine the impact on dynamic efficiency as well.

In fact, Motta and Tarantino's extended analysis allows for R&D spillovers and efficiency gains in research. With efficiency gains, even mergers whose static effect is to decrease output may spur innovation. In their paper, however, "efficiency gains" is a broad category that conflates R&D synergies and the sharing of innovative technological knowledge ("innovation sharing" for brevity). We believe that these mechanisms are better analyzed separately. R&D synergies refer to the possible complementarities between the research projects of the merging firms and as such may seem elusive and somewhat mysterious. Innovation sharing, by contrast, refers to the simple fact that new technologies developed by one firm can often be used also by others.

This innovation sharing mechanism is both easy to understand and quite common. It would be absent only if the innovations achieved by one firm could be applied only to that firm's plants or products, even after a merger. This case, however, seems quite special. Most often, innovations are transferable across the merging parties, that is, innovation is not firm- or product-specific. In this scenario, mergers may spur innovation by facilitating innovation sharing among the merging firms.[14] This expands the scope for the 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 powerful that a merger can increase total output and reduce prices, thereby benefiting consumers, even in the absence of static production synergies. This goes both for models of (one-stage) incremental innovation (Section 2) and for richer models of (two-stage) sequential radical innovation (Section 3).

The distinction between innovation sharing and R&D synergies is important for policy. In most jurisdictions, the burden of quantifying synergies is placed on the merging parties. This approach is justified not only by the obvious observation that the merging parties typically possess more information but also by a general presumption that synergies are rather elusive. But innovation sharing is a much broader and empirically relevant phenomenon than complementarities in research. In our opinion, it should therefore be considered explicitly from the outset in the agencies' assessment of mergers, rather than being relegated among the "efficiency defenses."

From this discussion, we conclude in Section 4 that economic analysis does not support the thesis that horizontal mergers always reduce innovation, or that they increase it only in exceptional circumstances. There do exist mechanisms through which mergers may negatively impact innovation. But there are also important and robust mechanisms, such as R&D coordination and innovation sharing, whereby mergers can increase the incentive to innovate. In assessing the impact of mergers on dynamic efficiency, agencies and the courts

[14] Innovation sharing may take place even among independent firms, via voluntary disclosure or through licensing. However, the sharing of innovations among competitors is impeded by various factors, as we discuss in greater detail later. Mergers eliminate economic barriers to the sharing of innovations.

should therefore consider both negative and positive effects from the outset and assess these effects in light of the facts of the specific case.

1. 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.

It should be apparent that in this case the merger can reduce wasteful duplication of R&D effort through better coordination of research projects. What is perhaps less evident is that the elimination of duplication may increase both the productivity of R&D expenditure and the incentive to invest, and hence the overall rate of innovation. This Section discusses why this outcome is possible, and under what conditions these positive effects are most likely to materialize.

The mechanism we analyze operates precisely in models such as those considered by Federico, et al. (2017), where innovation is uncertain, and a firm's probability of discovery depends on its R&D investment. In these models, various independent firms compete to obtain a radical innovation of fixed value denoted by V. The question is how a merger among some of the firms affects the probability of achieving the innovation. The authors contend that the impact is always negative. We will show, however, that their model can also deliver the opposite result.

To demonstrate in the most convincing possible way that the impact on innovation can also be positive, we make assumptions that maximize the likelihood that a merger will have anticompetitive effects. Shapiro (2012) argues that of all mergers, those most likely to diminish innovative activity are those

> 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.[15]

Here, R&D synergies refer to the possibility that combining the labs of the merging firms may increase their productivity, for instance because the scientists may become more productive when they work in a team.[16] Appropriability, instead, refers to the ability of the

[15] Carl Shapiro, *Competition and Innovation. Did Arrow Hit the Bull's Eye?*, in THE RATE AND DIRECTION OF INVENTIVE ACTIVITY REVISITED 361, 386 (Joshua Lerner & Scott Stern eds., 2012).

[16] According to Joseph Farrell & Carl Shapiro, *Horizontal Mergers: An Equilibrium Analysis*, 80 AM. ECON. REV. 107 (1990), production synergies exist when the production cost of the merged entity is a sub-additive function. Likewise, R&D synergies correspond to the sub-additivity of the merged entity's R&D cost function. As in 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* Guillermo Marshall & Alvaro Parra, *Mergers in Innovative Industries: The Role of Product Market Competition* (2016), available at https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2822319, for a model that emphasizes such

innovators to avoid competition from duplicators or imitators so as to better reap the potential profits from the innovation.

In what follows we consider Shapiro's worst-case scenario,[17] i.e., two firms that merge into a monopoly; moreover, we preclude R&D synergies (the merged entity can only efficiently reallocate aggregate R&D expenditure between the merging firms' research units); and we assume that the merger does not increase appropriability. In particular, we assume that, in the case where both firms succeed in achieving the innovation, one firm is assigned a patent (via a fair coin flip), which entitles it to capture *V*, and the other firm receives zero. This means that the appropriation is the same with or without a merger. [18] From the point of view of each firm, its expected payoff when there is duplication of the innovation is ½*V* (it has a 50% probability of winning the coin flip, receiving the patent, and capturing *V*).

In this framework, for any given probability of the innovation being achieved, the merger does not affect output, prices or consumer welfare. In other words, the merger is neutral from the static viewpoint. Any pro- or anti-competitive effect can therefore be attributed entirely to its impact on innovation. This provides an ideal setting for appraising the IToH.

The mechanism whereby a merger may reduce innovation is the following. When the different R&D projects are independent from one another, there is a positive probability that both firms will achieve the same innovation.[19] This implies that each firm exerts a negative externality on the other, since with duplication a firm's payoff falls from V to $\frac{1}{2}V$.[20] The

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complementarities. Their existence, however, may be a matter of speculation, so it is important to stress that the arguments set forth here do not require them.

[17] Even Michael Katz & Howard Shelanski, *Mergers and Innovations*, 74 ANTITRUST L. J. 1, 537 (2007), who conclude that in general the presumption should be that a merger's effects on innovation are neutral, allow an exception "in the case of merger to monopoly, where there would be a rebuttable presumption of harm."

[18] Another possibility under which appropriability is the same with or without the merger is that innovations are kept secret, so that both innovators are active in the product market but collude perfectly and split the market evenly. In this reduced-form model, the merger would instead increase appropriability if, where the two firms duplicate the innovation, each firm's expected payoff (i.e., before the patent coin flip assignment was performed) were less than $\frac{1}{2}V$. This extension is considered in both Federico, et al. (2018), *supra* note 7, and in Vincenzo Denicolò & Michele Polo, *Duplicative Research, Merger and Innovation* (CEPR Discussion Paper No. 12511, Dec. 15, 2017), available at https://cepr.org/active/publications/discussion_papers/dp.php?dpno=12511, and does not affect the results obtained in this section.

[19] 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 25% probability of the same innovation being achieved by both firms, and also a 25% probability of its not being achieved by either.

[20] Federico, et al. (2017), *supra* note 7, do not claim to be the first to have noted these externalities. The reciprocal negative externalities exerted by firms racing to achieve the same innovation were pointed out long ago by Glen C. Loury, *Market Structure and Innovation*, 93 Q. J. ECON. 395 (1979) and Tom Lee & Luis L. Wilde, *Market Structure and Innovation: A Reformulation*, 94 Q. J. ECON. 429 (1980) in models where innovative activity takes places in continuous time and the timing rather than the occurrence of the innovation is stochastic. Morton I. Kamien & Nancy L. Schwartz, *Market Structure and Innovation: A Survey*, 13 J. ECON. LIT. 1 (1975) provide even earlier relevant references. Both Loury and Lee & Wilde find that the externality gets worse as the number of firms in the race increases. Flavio Delbono & Vincenzo Denicolò, *Incentives to Innovate in a Cournot Oligopoly*, 106 Q. J. ECON. 951 (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. Flavio Delbono & Luca Lambertini, *Innovation and Product Market Concentration: Schumpeter, Arrow and the Inverted-U Shape*

merging party, then, takes into account this negative externality reducing the R&D investment. The mechanism is analogous to the contraction in output that internalizes the negative externalities arising in product market competition. As the Commission says in the *Dow-Dupont* decision, “the innovation competition effect follows the basic logic of unilateral effects, which is equally applicable to product market competition and to innovation competition”. [21]

But why should the internalization of the externality always diminish the R&D effort? Federico, et al. assume 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 both R&D investments. They justify the assumption of symmetric post-merger R&D investments by the hypothesis that the research units are symmetric and that the returns to R&D are diminishing.

In fact, however, it might be optimal for the merged entity to choose asymmetric levels of R&D investment, as is shown in our companion paper.[22] If this possibility is acknowledged, it becomes apparent that the merged entity may decrease the R&D expenditure of one unit to internalize the externality, reducing the risk of duplication, and increase the expenditure of the other to take advantage of this reduced risk. In this case, a merger could well increase the overall probability of success.

The limiting case where a research unit’s returns to R&D do not diminish at all with R&D expenditure illustrates the point.[23] In that case, a symmetric R&D investment strategy for the merged firm makes no economic sense: increasing the investment in one research unit and decreasing it by the same amount in the other always increases the *overall* probability of success.[24] In fact, when a research unit’s returns to R&D do not diminish with R&D expenditure, the merged firm’s optimal action is to shut down one research unit altogether and concentrate the entire R&D effort in the other.

When a research unit’s returns to R&D diminish with R&D expenditure, this powerful tendency towards asymmetric investment strategies is attenuated to some extent, since concentrating all the research activity in one lab reduces its marginal returns. Whether symmetric or asymmetric investment is optimal then depends on the relative strength of two opposing effects: the risk of duplication and the rate at which the returns to R&D diminish. The risk of duplication increases with the value of the innovation, as more valuable

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Curve (University of Bologna, 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.

[21]European Commission, case M.7932, 27/3/2017, Annex IV, §145.

[22] Denicolò & Polo (2018), *supra* note 12, at 57.

[23] 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 fail even if there are decreasing returns to R&D: see Denicolò and Polo (2018), *supra* note **Errore. Il segnalibro non è definito.**, at 58.

[24] This follows from the fact that the probability of success for the merged firm is $x_A + x_B - x_A \times x_B$, where x_A and x_B are the individual probabilities of success of the merging firms, and $x_A \times x_B$ 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 $x_A \times x_B$.

innovations will attract more R&D investment. Even with diminishing returns to R&D, asymmetric investments may therefore be optimal if the value of the innovation is large. In this case the conclusions of Federico, et al. (2017) no longer necessarily hold. Unless the returns to R&D diminish sufficiently fast, mergers may well increase innovation.

In what follows we shall start from a simple setting in which returns to R&D do not diminish—constant returns to R&D. Subsequently we introduce diminishing returns to R&D and analyze how the two effects, diminishing returns to R&D and the risk of duplication, interact.

1.1 CONSTANT RETURNS TO R&D

Consider the following simple example. Two firms compete to achieve a single innovation. The inventor obtains a total discounted profit of $V = \$100$. If both firms succeed, each has an expected payoff of $50 since each firm is the first developer, gets the patent and realizes the $100 profits with a 50% probability.

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 assumed constant at 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%, there is an upper bound on the expenditure).

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

Now let us introduce competition, assuming that two symmetric firms, A and B, can obtain the same innovation. Clearly, it cannot be an equilibrium for both firms to invest $80 and achieve the innovation with a probability of 100%, since if they did, each would be granted the patent with a probability of 50% only. The expected payoff for each would then be 50% × 100 − 80 = − $30: both A and B would sustain a loss.

The equilibrium must therefore involve different choices by the two firms. In fact, there exists an equilibrium,[25] in which each firm invests $32 and innovates with a probability of

[25] This equilibrium is the unique symmetric equilibrium, i.e., is the only equilibrium in which both firms make the same (symmetric) choice of R&D investment. Along with this symmetric equilibrium, there are also asymmetric equilibria where firm A, say, invests $80 and firm B does not invest at all. There are in fact two such equilibria, with the roles of the two firms reversed. To confirm that one firm investing $80 and the other investing $0 is in fact an equilibrium, note that if B does not invest, A is sure of getting the entire prize of $100 if it innovates successfully. 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 dollar is 1.25% × 50% × 100 = $0.625. This is less than the cost, so for firm B it is optimal not to invest at all. Thus, the strategy of each firm is 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, so mergers would be immaterial.

40%.[26] Since there is a probability of 40% × 40% = 16% of both firms' achieving the innovation, the probability of its being 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 in the other, obtaining the innovation for sure.[27] Therefore, the merger has a positive effect on innovation, as the overall probability of success increases from 64% to 100%.

This overall effect can be split into two parts, both positive. The first part is due to the fact that the merged entity avoids duplication and is thus more efficient in translating R&D expenditure into innovation. For example, if it invested the same aggregate amount in R&D as in the pre-merger symmetric equilibrium, i.e., $64, its probability of success would increase from 64% to 80%. This leads us to the second part: precisely because better-coordinated R&D expenditure is more "productive," the new entity has a greater incentive to expand total R&D expenditure. In our example, total R&D expenditure rises from $64 to $80, further raising the probability of success, from 80% to 100%.

With constant returns to R&D we have therefore a clear-cut result: the merged firm will concentrate all of the R&D expenditure in a single research unit. This strategy increases the probability of discovering the innovation by avoiding duplication of R&D efforts. The resulting higher returns to R&D in turn increase the incentives to invest, which further increases the probability of discovery. In this setting, mergers therefore promote innovation, contrary to the IToH.

1.2 DIMINISHING RETURNS TO R&D

While the example with constant returns to R&D illustrates how reducing duplication increases the productivity of R&D expenditure and the incentive to invest, in the real world R&D is generally characterized by diminishing returns. The rate of diminution may be measured by the elasticity of the supply of inventions with respect to R&D expenditure, i.e., the percentage increase in the probability of obtaining an innovation associated with a 1-

[26] To confirm that this is an equilibrium, suppose that each firm knows that its rival will succeed with a probability of 40% and fail with the complementary probability of 60%. For each the investment of $1 increases the probability of success by 1.25%, giving an expected additional payoff that can then be calculated as follows: with an additional probability of 1.25% × 60%, the firm will be the only innovator, as the rival fails, so the patent is obtained with certainty; with the complementary probability of 1.25% × 40% the rival also innovates, and the patent will be assigned to the firm with a probability of only 50%. 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. Therefore, the expected benefit is exactly equal to the cost, meaning that the firm cannot increase its profit either by increasing or by decreasing its R&D investment: an investment of $32 is therefore a best response to its rival's strategy.

[27] Note that this is exactly the same outcome as in the asymmetric pre-merger equilibrium discussed in footnote 20 above. If such an equilibrium prevails before the merger, then the merger does not affect market outcomes and so raises no competitive concern. The relevant case for policy is the symmetric pre-merger equilibrium.

percent increase in R&D expenditure.[28] The lower is the elasticity, the more rapidly the returns to R&D decrease with R&D expenditure.

There is a substantial literature on the empirical estimation of this elasticity. Although the results vary considerably from study to study, reviews of the entire literature suggest that a value of 0.5 may be taken as a reasonable estimate.[29] That is to say, a 10% increase in R&D expenditure may generate 10%×0.5 = 5% more innovations, rather than 10% as would be the case with constant returns to R&D.

The case of a 0.5 supply elasticity of inventions not only has some empirical support but is also analytically convenient as the resulting equilibrium can be calculated explicitly.[30] 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 merger always decreases R&D effort, in accordance with their Proposition 1.[31]

However, as we have seen in the discussion of constant returns to R&D, the merged entity may also elect to operate the two research units at different levels of intensity. Whether a symmetric or asymmetric treatment of the two research centers is optimal in the case of diminishing returns to R&D depends on the relative magnitude of two effects: diminishing returns call for the aggregate investment to be spread evenly across the two research units, but concentrating the effort in one research unit reduces the risk of duplication.

Which of the two effects prevails? Intuitively, this depends on the importance of the risk of duplication. The risk of duplication is high if, in the absence of a merger, each firm would choose to invest in R&D so as to have a high probability of success. But, investing so as to have a high probability of success makes economic sense only if the value of the innovation *V* is large. In fact, all else equal, in the absence of a merger, each firm's probability of success is an increasing function of the value of the innovation *V*, as more valuable innovations attract more R&D investment. It follows that the risk of duplication tends to be the dominant factor for high value innovations (high *V*), whereas it becomes negligible for low value inventions. In the former case, the merged firm will choose an asymmetric treatment of the two research units, while in the latter case, the merged firm will choose the symmetric treatment.

For example, suppose that if the value of the innovation V is low, the probabilities of success in research units A and B in the absence of a merger are $x_A = x_B = 10\%$. Since the risk of duplication with independent R&D projects is $x_A \times x_B$, in this case it will be a mere 1%. Duplication then is not a significant concern, and the driving force behind the merged firm's choice of R&D investment decisions is diminishing returns. Therefore, a symmetric treatment of the two research units is likely to be optimal. As we have seen above, this implies

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

[29] See Suzanne Scotchmer, INNOVATION AND INCENTIVES (2004) and Vincenzo Denicolò, *Do Patents Overcompensate Innovators*?, 22 ECON. POL. 680 (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.

[30] See Denicolò and Polo (2018), *supra* note**Errore. Il segnalibro non è definito.**, for details.

[31] Federico, et al. (2017), *supra* note 7, at 137.

that mergers reduce R&D investment and the probability of innovation, as in Federico, et al. However, if the value of the innovation is high, the incentive to innovate is high and hence in the absence of a merger each firm's probability of success will be high. This means that the risk of duplication will be higher. For example, when $x_A = x_B = 50\%$ the risk of duplication is 50%×50%, that is a non-negligible 25%. In this case, duplication risk may become the dominant concern for the merged firm, leading it to choose an asymmetric allocation of R&D expenditure between the research units.

Generalizing these examples, it can be shown that for any rate of diminution of the returns to R&D, symmetric solutions tend to be optimal for low-value innovations and asymmetric solutions for high-value ones. [32]

For the quadratic case, for instance, when the value of the innovation is high it is best to shut down one unit and concentrate the R&D effort on the other. In the research unit that is expanded, investment increases by so much that the innovation is obtained with certainty. In this class of models, for high values of V, a merger increases R&D investment and the probability of success.

The outright shutdown of one R&D unit is, of course, just one example. With other specifications of the R&D cost function, associated with less strongly decreasing returns, the optimal degree of asymmetry is less extreme: one unit is streamlined and the other expanded in a smoother way.[33] As the R&D investment shrinks in one unit (to internalize the externality) and increases in the other (to take advantage of the decreased duplication risk) the overall probability of success may well increase.

Thus, the conclusions of Federico, et al. may not hold when the merged firm pursues its optimal strategy. Their model supports the IToH for low value innovations but an "innovation theory of benefit" for high value ones.[34]

1.3 DISCUSSION

To what extent can the above insights be applied in real merger analysis? As we have seen, the major factors that determine whether mergers increase or decrease the rate of innovation in this class of models are the risk of duplication and the rate at which the returns to R&D diminish. In principle, both variables can be assessed quantitatively.

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[32] The risk of duplication *conditional on the innovation being achieved* tends to zero when V approaches zero and tends to 100% when V is so high that the innovation is achieved with near certainty. More formally, the conditional risk of duplication with symmetric R&D investments, and hence symmetric probabilities of success x, is given by the formula $\frac{x^2}{2x-x^2}$. The conditional risk of duplication therefore converges to 0 when $x \to 0$ and to 1 when $x \to 1$.

[33] For example, Denicolò and Polo (2018), *supra* note **Errore. Il segnalibro non è definito.**, show that this is the equilibrium pattern when the elasticity of the supply of inventions is $\frac{2}{3}$, another realistic case for which a closed-form solution is available.

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

The rate at which the returns to R&D diminish can be measured by the elasticity of supply of inventions. As discussed above, this elasticity has in fact been estimated in many empirical studies.[35] Most of these studies use samples of firms that are meant to be representative of the whole economy. In merger analysis, however, one would prefer to have sector-specific estimates. Furthermore, existing estimates of the elasticity capture the intensity of diminishing returns to R&D at the industry level, whereas for the purpose of merger control the variable of interest is the elasticity at the firm level.

However, these difficulties may not be insurmountable. The only obstacle to obtaining sector-specific estimates seems to be the availability of the data. Measuring the returns to R&D at the firm level is more challenging but Griliches (1990) suggests that industry-level estimates provide a lower bound for firm-level elasticities.[36]

As for the risk of duplication, the main determinant is the probability of success by each separate firm. This correlates with the value of innovation, which is in principle observable. But this conclusion holds in the models discussed above, which make the assumption that all firms target the same innovation. In reality, the innovations targeted by different firms may not be identical. If the merging firms are seeking innovations that are imperfect substitutes for one another, the duplication effect is weaker, and hence there is less scope for gaining from better coordination. (On the other hand, the negative externality would also be smaller.)

In the analysis of specific mergers, it is often possible to get a sense of the extent to which the merging parties are targeting similar innovations and thus face a high risk of duplication. The risk of duplication may be particularly high when the outcomes of projects of the merging firms' R&D units are positively correlated, meaning that both tend to succeed or to fail simultaneously. Negative correlation,[37] in contrast, reduces the risk of duplication.

Which case is more likely? Statistical independence among R&D projects may correspond to the case in which the different units pursue totally different research strategies, which can all be successful simultaneously. Negative correlation may arise where only one of the strategies may eventually lead to success. And positive correlation, lastly, arises when the firms pursue the same or similar R&D projects. To the extent that all firms have the incentive to concentrate on the most promising research avenues, positive correlation may be the more relevant case.[38]

Other factors may also play a role in determining whether, in practice, a merger would result in an increase or decrease in innovation. For example, mergers may affect appropriability, i.e., the ability to reap the returns of the innovation. This effect may be captured in our analysis by imagining that, absent a merger, in case of duplication each firm

[35] See *supra* note 28.

[36] According to Griliches, 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." Zvi Griliches, *Patent Statistics as Economic Indicators: A Survey*, 28 J. ECON. LIT. 1661, 1167 (1990).

[37] With negative correlation, one project is more likely to succeed if the other fails, and vice versa.

[38] The result that the market equilibrium exhibits excessive correlation among research projects was first derived by Partha Dasgupta & Eric Maskin, *The Simple Economics of Research Portfolios*, 97 ECON. J. 581 (1987). However, Sudipto Bhattacharya & Dilip Mookherjee, *Portfolio Choice in Research and Development,* 17 RAND J. ECON. 594 (1986) find conditions under which the market chooses the right level of specialization.

obtains a payoff less than $\frac{1}{2}V$, whereas the post-merger firm always obtains V.[39] Our simple model implies that increased appropriability does not affect the sign of the impact that a merger has on R&D spending, but does affect the magnitude of the impact. Where a merger reduces the R&D effort, it does so by a smaller amount, and where the merger increases R&D effort, it does so more by more than in the case of where appropriability is not affected by the merger.[40]

A better understanding of the impact of mergers on appropriability, however, requires an explicit model of product market competition. This analysis is developed in Federico, et al. (2018).[41] They consider various cases in which, accounting for the appropriability effect, the merger reduces innovation. Bourreau and Jullien (2017), [42] in contrast, analyze a framework where mergers may spur innovation precisely because they increase appropriability. Jullien and Lefouili (2018)[43] provide a more general analysis of the issue and identify conditions under which the appropriability effect may reverse the effects considered by Federico, et al. (2018). In short, the theoretical modeling shows that a merger may result in increased innovation regardless of the effect the merger has on appropriability.

2. MERGERS AND INNOVATION SHARING

In Section 1, we showed that a merger may increase R&D investment when innovation is duplicative, by allowing better coordination of projects. We now focus on another mechanism whereby a merger may stimulate innovation, namely, innovation sharing. The analysis provides additional reasons why the IToH may overstate the harmful effect of mergers on innovation.

Innovation sharing is most clearly demonstrated in a setting of an incremental innovation,[44] i.e., an innovation that does not create a new market but instead improves technology in an existing market. An incremental innovation may take the form of a cost reduction, a quality improvement, or a combination of the two. We will assume a marginal cost-reducing innovation, although the results hold for a quality-improving innovation as well.

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[39] Following the discussion in note 18 supra, when innovators have patent protection, the case where each firm has payoff less than $\frac{1}{2}V$ may arise if the patent interference procedure leads, with positive probability, to no patent being granted. If instead innovations are kept secret, greater appropriability with a merger may arise if the two firms fail to collude perfectly absent the merger. In the former case, greater appropriability is the result of stronger intellectual property protection; in the latter, of better price coordination. In a simple model, the two assumptions are analytically equivalent, at least as far as the R&D equilibrium is concerned. The expected consumer surplus, though, may differ in the two cases.

[40] See Denicolò and Polo (2018), *supra* note**Errore. Il segnalibro non è definito.**, for details.

[41] *See supra* note 7.

[42] Marc Bourreau & Bruno Jullien, *Mergers, Investments and Demand Expansion* (Toulouse School of Economics Discussion Paper No. 17-880, 2017).

[43] Bruno Jullien & Yassine Lefouili, *Horizontal Mergers and Innovation* (CEPR Discussion Paper No. 12773, 2018).

[44] Federico, et al. (2017), *supra* note 7, by contrast, focuses on radical innovations. The case of breakthrough innovations will be analyzed in Section 3. This case is different from that of incremental innovations in that the sharing of innovative knowledge takes place at the research stage rather than the production stage.

In this framework, the innovation sharing mechanism is very simple. Since the merged firm can apply its cost-reducing innovation to a greater volume of output, the value of the innovation is higher for the merged firm, and the incentive to innovate is strengthened. This effect rests on three premises. First, the merged firm's output is larger than that of either of the merging firms. Second, the same innovation is applicable to the entire output of the merging firms. Third, the merger facilitates the sharing of innovative technological knowledge.

2.1 THE OUTPUT EFFECT ON INNOVATIVE INVESTMENT

Before discussing the premises described above and the mechanism by which merger may increase innovation, we consider a baseline version of Motta and Tarantino's model. Each merging firm sells a product that it manufactures in its own plant. In the baseline case, innovations are firm-specific, rather than being applicable across the firms' plants: an innovation achieved by firm A can be applied only to reduce the marginal cost for firm A's product, while an innovation achieved by firm B can be applied only to reduce the cost for firm B's product.[45] This remains true when A and B merge to become divisions of a new corporation. In other words, any marginal cost reduction achieved by a division of the new entity can be applied only to that division's product.

In this case, a division's incentive to innovate is proportional to its output (the value of the marginal cost-reducing innovation is approximately equal to the decrease in marginal cost multiplied by units of output). In the absence of static production synergies, and assuming at least some competition between the merging firms' products, the unilateral effect of the merger is to decrease the output of each division.[46] With lower post-merger output levels, the unilateral effect of the merger on innovation is to reduce the incentive to innovate, and hence the R&D investments, of the merging firms.[47]

This scenario clearly highlights the interaction between output contractions due to the merged entity's enhanced market power and the reduction in innovative investment. But, in any case, this analysis does not support the IToH. Recall that the thesis of the IToH is that some mergers that would be permitted when focusing on their static effects alone might be considered anticompetitive because they have a negative effect on innovation. In the baseline model with no production synergies and (sufficiently) competing products, by assumption the merger fails the static test with consumer surplus as the welfare standard, as it decreases output and increases prices for any given state of the technology. Taking innovation into

[45] Motta & Tarantino in fact go beyond the baseline model and consider R&D efficiencies and spillovers. See Motta & Tarantino, *supra* note 8, at 23. We discuss the relationship among innovation sharing, R&D synergies, and R&D spillovers in more detail in Section 2.3.

[46] This is because the merged firm internalizes the negative externality whereby an increase in one firm's output lowers the price at which competing products sell. This type of unilateral effect of a merger is very robust to various plausible modeling assumptions. Together with the concern that mergers may facilitate collusion among the fewer remaining firms, the potential for unilateral effects forms the primary reason why mergers are regulated.

[47] See Motta & Tarantino, *supra* note 8, Propositions 1 and 5.

account increases the social loss from the merger but does not change the outcome of the static assessment.

To provide support for the IToH, however, one must show that a merger that is pro-competitive or neutral from a static viewpoint is, in fact, anticompetitive when the impact on innovation is factored in. But, because a firm's incentive to innovate is proportional to its output, its incentive to innovate is strengthened if the merged entity's output increases and weakened if the merged entity's output decreases. Thus, mergers that are pro-competitive according to static analysis should increase innovation, whereas those that are statically anti-competitive should decrease innovation. Considering effects on innovation does not turn any pro-competitive (or neutral) mergers into anticompetitive ones, as is posited by the IToH thesis.

The policy implication of the baseline case of Motta and Tarantino, then, is clear. In the absence of innovation-sharing, antitrust authorities and the courts should not be concerned with mergers' effect on innovation, because the traditional static tests based on consumer surplus suffice also to determine whether the dynamic effects will be positive or negative. This is certainly an important policy conclusion, but one that evidently offers no support for the IToH.[48]

In the following sections we discuss the addition of two factors to the baseline model– innovation sharing and strategic effects – that could stimulate innovative investment. If either factor is present, the negative impact of a merger on innovation postulated by the baseline model is reduced. Moreover, if these effects are sufficiently strong, a merger could even have a positive impact on innovation. The impact of a merger on innovation would thus move in the opposite direction from that hypothesized by the IToH. Our analysis therefore would actually suggest an "innovation theory of benefit," rather than an innovation theory of harm.

2.2 INNOVATION SHARING

Plainly, the assumption that innovations are entirely firm-specific, precluding all innovation sharing, is excessively restrictive. Very often, technologies developed by one firm can also be used by others.

There is substantial direct and indirect evidence that innovations are generally not firm-specific, but instead have broader applicability. Indeed, the possibility that an innovation can be used by other firms is the reason why innovations are copied, imitated, or licensed. It is also a reason why firms need to protect their innovative technological knowledge. Protection is usually achieved through secrecy or through some form of intellectual property. If innovations could not, by their very nature, be used by others, this would not be necessary.

[48] This argument postulates consumer surplus as the welfare standard for policy assessment. Factoring in firms' profits as well would generally lead to a more lenient policy. There could be cases in which total welfare increases even if output falls. In this case, the analysis of Motta and Tarantino could imply that consideration of dynamic efficiencies might result in blocking mergers that would pass the static welfare test. But in any case, mergers that are statically pro-competitive according to the consumer surplus criterion would remain pro-competitive even taking innovation into account.

In spite of firms' efforts to protect their innovations, the mechanisms may not effectively entirely prevent imitation or inadvertent knowledge leaks. Thus, there may be R&D spillovers from one firm to another. If innovations were entirely firm-specific, such spillovers could not exist. But in reality spillovers are so prevalent that, according to the "absorptive capacity" hypothesis, one reason why firms invest in R&D is precisely to facilitate absorption of spillovers.[49] In sum, the notion that innovations are often usable by many different firms, is so obvious that it hardly needs elaboration.[50]

When innovations are not firm-specific, mergers may spur innovation by facilitating knowledge sharing between the merging firms. Different authors call this, variously, "learning," "information sharing," or "innovation sharing." For the sake of consistency, here we use the term "innovation sharing."

Although technological knowledge transfers may occur between independent firms, either by voluntary disclosure or by licensing, such transfers are limited for a variety of reasons. When firms merge, these barriers are lifted, so innovation sharing becomes easier and more complete.[51]

To demonstrate the benefits of mergers with innovation sharing, we consider once again two firms merging to form a monopoly, the case in which anticompetitive effects a priori seem most likely. We start first with a simple example with fixed production capacity and then proceed to the case where mergers may also affect the level of output.

[49] The absorptive capacity hypothesis is based on the notion that innovative technological knowledge is often complex and hard to assimilate for those who are not actively engaged in research in the relevant field. The hypothesis was formulated by Wesley M. Cohen & David. A. Levinthal, *Innovation and Learning: The Two Faces of R&D*, 99 ECON. J. 569 (1989) and Wesley M. Cohen & David. A. Levinthal, *Absorptive Capacity: A New Perspective on Learning and Innovation*, 35 ADM. SC. Q. 128 (1990).

[50] Applicability 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 applicable only in a given plant and thus useful only to the proprietor firm, which therefore does not need to take any particular protective measures. Alternatively, consider an improved design for a specific product variety. This can be used only by the firm that commercializes that variety. Insofar as the firm already has such protection mechanisms as brand name, marketing infrastructures, etc., the improved design does not need any further specific protection. Thus, complementarity between innovations and firm-specific physical assets may sometimes limit the effective degree of applicability of the innovation to other firms. Several surveys have documented that the control of complementary manufacturing or marketing assets is indeed regarded as an important tool for appropriating the benefits of innovations. *See, e.g.*, Wesley M. Cohen, Richard R. Nelson & John P. Walsh, *Protecting Their Intellectual Assets: Appropriability Conditions and Why US Manufacturing Firms Patent (Or Not)* (National Bureau of Economic Research Discussion Paper No. w7552, 2000).

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

2.2.1 A SIMPLE EXAMPLE WITH FIXED CAPACITY

To abstract from the output effect of the merger, we initially assume that the merging firms' production capacity is fixed and that the capacity constraint is binding. This simple example highlights the innovation sharing effect in a setting with no confounding factors.

Consider two firms competing in a market where they supply substitute products. Each has a fixed production capacity of 50 units. The total capacity of 100 units is assumed to be small compared to the level of demand so as to ensure that the capacity constraint is always binding.[52] Initially, the firms have a unit cost of $30. The two firms can target one of two possible innovations. A small innovation reduces the unit cost to $28 and can be achieved with certainty by investing $80. The second, larger innovation cuts the cost to $10 but requires an R&D investment of $1600. That is, the major innovation is ten times as large, but twenty times as costly, as the small one.[53] Innovation is both not firm-specific and duplicative: each firm, potentially, could apply the other's innovation, but if both achieve the same innovation neither can learn anything more from the other.[54]

For the sake of example, we posit that with independent firms there is no innovation sharing (an assumption to be discussed shortly). If this assumption holds, the value of the first innovation is 2 × 50 = $100, that of the second 20 × 50 = $1000, where the value corresponds to the cost savings times the output. It follows that each firm will target the first innovation, which gives a profit of 100 − 80 = $20. Neither will target the second innovation, which would entail a loss of $600.

Now let us consider the effect of a merger. For the merged entity, which can apply the innovation to its entire capacity of 100 units, the value of the first innovation is $200, that of the second $2000. Therefore, the large innovation is now more profitable than the smaller one, as it nets $2000 −$1600 = $400 as compared to $200 − $80 = $120. The merged entity will therefore make a larger R&D investment, i.e., $1600 rather than $80 × 2 = $160, achieving a greater cost reduction, i.e. $20 rather than $2, than the two firms would in the absence of the merger.

This example illustrates in a simple way the mechanism discussed in this section. The merged firm produces more than each of the two firms did before the merger, and this increases the value of the innovations that can now be applied to the aggregate output of the merged firm. The example may be somewhat simplistic in assuming that the level of output is not affected either by the merger or by the cost reduction. Yet as we shall see, the main insight extends to a more flexible model.

[52] Technically, the assumption is that total capacity is less than the monopoly output. This also implies that it is irrelevant whether firms compete in quantities (Cournot competition) or prices (Bertrand competition): either way, firms would like to produce more if they could, but output is limited by capacity.

[53] Note that that the returns to R&D are diminishing, in that the R&D investment increases proportionally more than the magnitude of the innovation.

[54] Unlike those of the preceding section, the results here do not depend on the assumption of duplication. 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 procompetitive.

2.2.2 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 R&D outcomes, which in turn depend on the firms' R&D investments. To account for these effects in a coherent way, we need a formal economic model. Here we present the one developed in Denicolò and Polo (2018a).[55]

The model shows that, with innovation sharing, a merger may increase not only R&D investment, and hence the size of the cost reduction, but also aggregate output. This is possible even if the merger would have an output reducing effect in the absence of any innovation. The intuition is that a lower post-merger marginal cost from the innovation induces an expansion of output, creating an additional incentive to increase R&D investment in a cumulative process of output and investment growth. If this cumulative process is sufficiently strong, it may more than offset the initial contractionary effect that would exist in the absence of any innovation. The merger may thus become pro-competitive *even in the absence of static production synergies*, precisely because it spurs innovation rather than stifling it. In this case, the IToH is turned upside down.

In the rest of this subsection, we discuss the assumptions and present the main analytical results of Denicolò and Polo (2018a). The reader is referred to the original paper for the derivation of the results.[56]

We build on Perry and Porter's classic analysis,[57] augmenting their model to include innovation. Perry and Porter consider a Cournot oligopoly with homogeneous products. Initially firms are symmetric. The marginal costs of each firm i are linearly increasing in output at a rate s:[58]

$$MC_i(q_i, x_i) = c + s \cdot q_i.$$

The slope s of the marginal cost curve measures the extent to which production is subject to diminishing returns. After a merger, the marginal cost curve is the horizontal sum of the original curves of the merging firms and hence becomes flatter, meaning that the marginal cost of the merged firm at a given output level is lower than for either of the merging firms at the same output level. As Farrell and Shapiro (1990) stress, this effect is not due to production synergies but simply to efficient output reallocation (e.g., splitting total output evenly) across different plants.

[55] Vincenzo Denicolò & Michele Polo, *Mergers and Innovation Sharing* (University of Bologna, 2018).

[56] *Id.* at 3.

[57] Martin K. Perry & Robert H. Porter, *Oligopoly and the Incentive for Horizontal Merger*, 75 AM. ECON. REV. 219 (1985).

[58] A simpler model with constant marginal costs, like that of Stephen W. Salant, Sheldon Switzer & Robert J. Reynolds, *Losses From Horizontal Merger: The Effects of an Exogenous Change in Industry Structure on Cournot-Nash Equilibrium*, 98 Q. J. ECON. 185 (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 are easily generalized to a larger set of demand and cost functions, as well as to the case in which firms may be *ex ante* asymmetric, as in Joseph Farrell & Carl Shapiro, *Horizontal Mergers: An Equilibrium Analysis*, 80 AM. ECON. REV. 107 (1990).

Now let us 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 the marginal cost for the first unit of output if there were zero cost reduction, and x_i is the size of the cost reduction. The cost-reducing innovation is achieved through an R&D investment that increases with x_i at an increasing rate. Specifically, we assume that the R&D expenditure required to achieve a cost reduction of size x_i is proportional to the square of x_i:

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

The coefficient of proportionality of the R&D cost, denoted by b, is a parameter that captures the productivity of R&D expenditure. The greater the productivity of R&D expenditure, the lower is b.

As in the example positing fixed capacity, we assume that innovation is not firm-specific and duplicative. Lack of firm-specificity means that the cost reduction achieved by one firm can in principle also be used by the other. Duplication means that when two firms share their innovations, both benefit from the larger cost reduction but not from the sum of the two. If this latter assumption were relaxed, the positive impact of a merger on innovation and consumer surplus would be even greater.

Once again, the results are sharpest for the case of two firms, A and B, that merge to form a monopoly.[59] There are two offsetting effects. First, exploiting its augmented market power, the merged firm reduces output. However, because the merged firm has less rapidly rising marginal cost due to its ability to reallocate production across the two firms' plants, it will produce more than either A or B did in the pre-merger equilibrium. As a result, the merged entity's incentive to invest in R&D increases.

Qualitatively, this effect is exactly the same as in the example with fixed capacity. The difference is that a lower marginal cost now induces an expansion of output, creating an additional incentive to increase R&D investment. To keep the analysis relevant, one must assume that the resulting cumulative process of output and investment growth does not explode, i.e., result in output and investment growing unboundedly. This "stability condition" requires that reducing the marginal cost be sufficiently costly, or that the marginal costs rise sufficiently rapidly as output grows. This constrains the parameters of the model, b and s, to be above the decreasing curve depicted in Figure 3.

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

[59] 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 cannot change its sign.

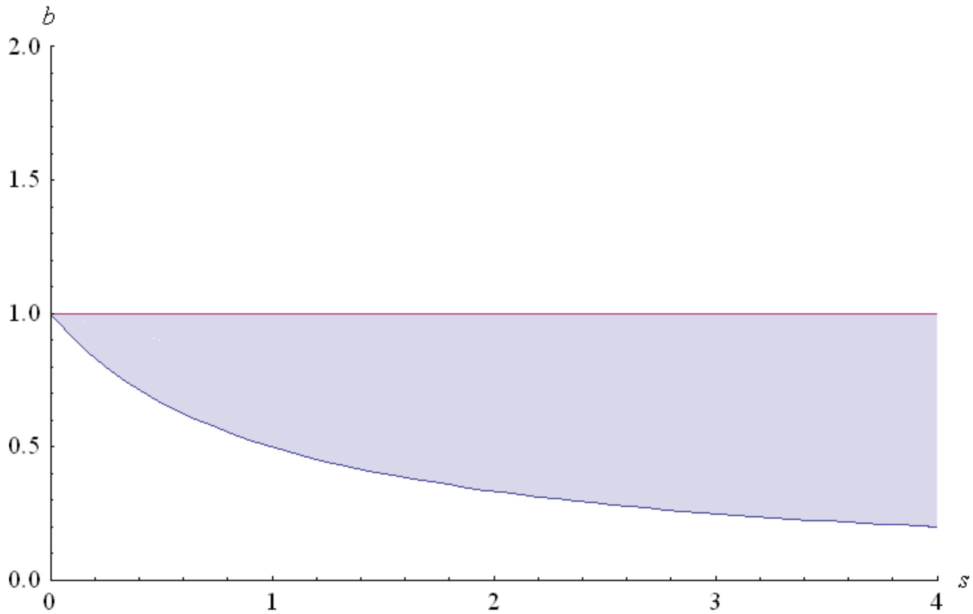

Figure 1

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

This is illustrated in Figure 1. For values of *b* and *s* that fall in the region below the horizontal line, a merger increases output. For values of *b* and *s* that fall into the region above the decreasing curve, the stability condition holds. For values of *b* and *s* that fall in the intersection between these two regions, i.e., the shaded region between the horizontal line and the decreasing curve, the level of output is higher than in the pre-merger equilibrium. The analysis therefore shows that in a sizeable region of parameter values a merger between firms with substitute products will increase output, reduce prices, and increase consumer surplus even in the absence of static marginal cost efficiencies.[60]

The shaded region representing procompetitive mergers can be roughly characterized as combinations of "large" values of *s* and "small" values of *b*. The intuition for this is that, with such combinations of *b* and *s*, the output-expanding effects of the merger are more able to offset the output-contracting effects. A "large" *s* means that marginal cost increases sharply with output. When marginal cost increases sharply with output, a merger does not cause a large static output reduction (putting aside the R&D considerations). The reason is that as the merged firm cuts back on output, its marginal cost decreases sharply, which in turn sharply increases the profit margin that the merged firm would lose from a further output reduction. This limits the output reduction the merged firm undertakes. A "small" *b* means that R&D expenditure is highly productive, i.e., a small R&D expenditure produces a large

[60] 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.

marginal cost reduction. The large marginal cost reduction induces the merged firm to expand its output by a greater amount (putting aside the static effects). Thus, the "large" s (implying a small static output contraction) and the "small" b (implying a large output expansion due to the cost reduction) combine to yield a procompetitive merger.

Note that Figure 1 shows that the shaded area ends at the vertical axis where $s = 0$. In other words, in this model the merger cannot be pro-competitive (in the absence of production synergies) when parameter s is zero, i.e., when marginal costs are constant regardless of the level of output. In this case, the static output contraction is sufficiently large that it cannot be offset by the output expansion due to the cost-reducing innovation.[61]

Another type of model in which a merger may be procompetitive without static production efficiencies is one in which products are differentiated, as in Davidson and Deneckere.[62] The first to analyze the consequences of innovation sharing in this setting were Davidson and Ferrett (2008).[63] Consistent with our results, they demonstrated that mergers may expand the output of the merged entity (relative to the combined output of the pre-merger firms) and so reduce prices, thereby benefiting consumers but harming non-merging firms, even in the absence of static production synergies.[64]

2.2.3 INNOVATION SHARING AMONG COMPETITORS

It may be argued that, if innovations are not firm-specific, there should be a means other than a merger to transfer technological knowledge across independent firms. Obviously, independent firms may not have an incentive for voluntary sharing, as they generally do not want their rivals to become more efficient. Nevertheless, a successful innovator could license the innovation to its rivals in exchange for a payment, thereby expanding the base of sales for the innovation even without a merger.

Licensing is indeed a common practice, the subject of a vast legal, economics, and management literature. In a hypothetical world of complete and efficient licensing contracts, an innovator might extract the entire potential value of the innovation by licensing. In our simple example with fixed production capacity, for instance, the potential value of the bigger innovation is $2000, i.e., the cost reduction of $20 applied to the entire aggregate capacity of 100 units. In the hypothetical world, an innovator could obtain a payoff of $2000 through a combination of direct cost savings on its own plant and licensing revenue from the rival. As a result, either of the two firms would have an incentive to achieve the bigger innovation

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[61] The case of constant marginal costs has been analyzed by various papers, including Robin Kleer, *The Effects of Mergers on the Incentives to Invest in Cost Reducing Innovations*, 21 ECON. INNOV. NEW TECH. 287 (2012). For the reason just set forth, these papers do not find that mergers may expand output in the absence of static production synergies.

[62] Carl Davidson & Raymond Deneckere, *Incentives to Form Coalitions with Bertrand Competition*, 16 RAND J. ECON. 473 (1985).

[63] Carl Davidson & Ben Ferrett, *Mergers in Multidimensional Competition*, 74 ECONOMICA 695 (2008).

[64] *Id*. The authors assume that the extent to which innovations are firm-specific is variable and depends on the degree of product differentiation. In other words, they allow for the possibility that where products are less differentiated, innovation transfer between firms is easier. They consider a two-stage model where the strategic effects analyzed in the next subsection also arise.

even in the absence of a merger.[65] A merger would not enhance innovation sharing, and thus innovation sharing would not provide a procompetitive justification for a merger.

However, if contracts were all perfectly complete and efficient there would be no need for complex economic organizations such as firms; all economic relationships could be carried out at arm's-length. Any meaningful theory of mergers must posit the existence of firms, and hence must recognize, explicitly or implicitly, that contracts can be incomplete and inefficient. This goes for contracts in general and for contracts for the transfer of a new technology in particular.

Contracts involving technology transfer are especially delicate, for a variety of reasons. First, by its very nature innovative technological knowledge may be hard to codify and transmit, unless the sending and receiving parties are both part of the same organization. Second, agreement on technology transfer may require some preliminary disclosure of the new technology, which can generate technological spill-overs, especially if innovative knowledge is not fully protected by patents, copyrights, and the like. Third, licensing may be impeded by the difficulty of specifying 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 abstracting from all these problems, the innovator may be unable to capture the full value of the innovation, because the licensees too may have some bargaining power, and because of potential hold-up problems. Going back to our numerical example with fixed capacity, 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, 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: $1000 in direct cost saving and $500 in licensing revenue. This is still less than the cost of the bigger innovation, which is $1600. Anticipating the *ex post* bargaining outcome postulated here,[66] no independent firm will target the more valuable innovation.[67]

The importance of these obstacles to technology transfer is difficult to assess directly, but indirect evidence may give a sense of their magnitude. If the diffusion of best practices were quick and innovative technologies were rapidly shared, productivity differentials across active firms would be expected to be small and transitory. But a vast literature has abundantly

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[65] Here we abstract from the problems of coordination of the firms' research activities that arise when the innovation is duplicative, which have already been discussed in the preceding section.

[66] The hold-up problem would not arise if firms could bargain before the R&D investment is sunk, i.e. with *ex ante* bargaining. In reality, however, the licensing of prospective innovations is rare. Most licensing contracts have as their object innovations already achieved and so easier to contract on.

[67] Recognizing these difficulties, antitrust authorities have provided some encouragement for research joint ventures (RJVs). RJVs may help firms to share innovations (and coordinate their R&D activities more broadly), but an ample literature has shown that as long as firms remain independent, even within an RJV coordination and sharing may be impeded by the same factors that operate outside them. Furthermore, RJVs may help firms coordinate not only research but also pricing and output decisions. In short, research joint ventures are a form of partial integration, and insofar as they may give rise to the same benefits, they may also entail the same costs as full integration (merger).

documented substantial, persistent productivity differentials.[68] This literature offers indirect evidence of the importance of the economic barriers to technology transfer. Evidently, the obstacles mentioned must be quite significant.

We conclude that innovation sharing among competitors tends to be limited, while it is much more extensive between merging firms. In other words, mergers generally facilitate innovation sharing. As our analysis has shown, this increases the merged entity's incentive to innovate.

In our view, the importance of innovation sharing warrants an explicit treatment in merger analysis, distinguishing innovation sharing from research synergies (complementarities between different labs). Though they may be analytically analogous, these effects are different, and their importance in practice can vary. In particular, the existence of research synergies is sometimes regarded as rather speculative as it may be difficult to specify the detailed mechanism through which complementarities may materialize. If this is so, then it may be appropriate to place the burden of proving R&D synergies on the merging firms. Innovation sharing, by contrast, is much more natural and easy to understand. For this reason, we believe that merger analysis should consider this feature explicitly from the outset, rather than relegating it to the class of "efficiency defenses."

2.3 STRATEGIC EFFECTS

In the previous discussion, we have assumed that the value to an innovator of an incremental innovation is a marginal cost saving (or the extra value due to higher quality), which is usually referred to as the "direct value" of an incremental innovation. In certain cases, however, an incremental innovation may also have a strategic value.

The strategic value can be positive or negative. It relates to the way an innovation affects the behavior of the innovator's rivals. With the innovation, the innovator alters its market strategies. If in response rivals become more aggressive, the innovator's gain is curtailed. In this case, the strategic value of the innovation is negative. If instead rivals become less aggressive, the strategic value of the innovation is positive.

Lopez and Vives argue that the strategic effect of an innovation appears only if a firm's innovative activity can be observed by its competitors. If innovation is not observable, competitors obviously cannot react.[69] Since observability cannot be taken for granted, the strategic effect may be more uncertain than the direct effect. Thus, an analysis limited to direct value, like that made here so far, may be interesting in its own right, and not only as a

[68] Chad Syverson, *What Determines Productivity?*, 94 J. ECON. LIT. 326, 326 (2011) summarizes the findings of this literature as follows: "large and persistent differences in productivity levels across businesses are ubiquitous."

[69] Angel Lopez & Xavier Vives, *Cross-ownership, R&D Spillovers and Antitrust Policy* (CESifo Working Paper Series No. 5935, 2016). The strategic value is an instance of the general principle, first suggested by Thomas Schelling, THE STRATEGY OF CONFLICT (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.

first approximation. Yet, it is also interesting to discuss how consideration of strategic effects affects our conclusions.[70]

The strategic value of an innovation is formally analyzed in the technical Annex, which shows that it is negative when firms compete in prices and positive when they compete in output levels. With this insight, we can inquire how the strategic value is affected by a merger. The answer is most straightforward when there are only two firms and they merge into monopoly. In this case, strategic value exists before the merger but ceases to exist afterwards, as the merged entity has no competitors. It follows immediately that, considering the strategic effect, mergers increase R&D investment when firms compete in prices (the negative strategic effect that reduced R&D investment pre-merger no long exists) and decrease it when they compete in quantities (the positive strategic effect that increased R&D investment pre-merger no longer exists). This holds true for any given level of output, and irrespective of the direct value of incremental innovations.

Motta and Tarantino assume price competition. In this case, the strategic effect would result in increased innovation in the case of a merger that is statically neutral. This holds true even with firm-specific innovations and in the absence of R&D spillovers. Thus, simply extending the Motta and Tarantino baseline model to strategic effects leads to policy conclusions that are diametrically opposed to those of the IToH. This should come as no surprise, however, because the baseline model does not support the IToH but implies that output-neutral mergers are also innovation-neutral.

3. SEQUENTIAL INNOVATIONS

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

This may sound surprising at first. Consider, for instance, the pharmaceutical industry, where new products are typically patented. With only one firm selling the new product, there might appear to be no scope for innovation sharing.

But the merging firms could share intermediate technological knowledge that has no commercial value by itself but that could open the way to the discovery of new drugs. For example, different new drugs may share a therapeutic mechanism or "therapeutic target" – say, a protein whose action can be modified by an external stimulus. Clearly, knowledge of the mechanism or target facilitates the introduction of new drugs. If different firms are

[70] Analytically, models in which R&D investment and output (or price) decisions are made simultaneously, such as Lopez & Vives (2016), *supra* note 69, and Motta & Tarantino (2017), *supra* note 8, capture the case in which innovations are not observable by rivals. In this case their value consists in the direct effect alone. But the strategic component 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.

attempting to develop different new drugs that share the same therapeutic mechanism or target, all could benefit from such "intermediate" knowledge.

However, in this scenario the incentive to share such knowledge among independent firms will be weak or non-existent. That is, independent firms will not voluntarily share intermediate innovative knowledge with competitors. The reason for this is obvious. Typically, new drugs with a common therapeutic mechanism are all in the same product market, so the new drugs a competitor could develop as a result of innovation sharing would compete with the drugs of the initial innovator. Even licensing would be difficult in this scenario, insofar as pharmaceutical patents protect new molecules or classes of molecules of similar chemical structure, but not therapeutic mechanisms or targets. Consequently, such intermediate knowledge is often kept secret and very rarely licensed. This reduces the value of such discoveries for independent pharmaceutical companies (which accordingly often have the incentive to engage in more applied research).

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

In Denicolò and Polo (2018a),[71] we develop these insights into a formal economic model, which extends the setting of Federico, et al. (2017)[72] by supplementing the "development" stage, whose output is a new product, with a "research" stage that occurs before the development stage. Successful completion of the research stage guarantees greater productivity of development-stage R&D expenditure; in other words, for any given level of R&D expenditure, there is a higher probability of inventing the final product. The productivity increase is not firm-specific or product-specific: the research stage produces intermediate innovative knowledge that can be used to facilitate the invention of a range of products.

Once again, we illustrate the results for the case of two firms merging into a monopoly. When firms are independent, the market structure may be either a duopoly (if both firms successfully complete the second stage, i.e., invent a new product) or a single-product monopoly (if only one does). In this case, a firm that succeeds in the first stage has no incentive to share the intermediate innovation, which would give the rival a better chance of achieving the final innovation, reducing the originator's expected profit.

When the two firms merge prior to the research stage, the intermediate innovation is shared between their two research units. This increases R&D investment in both the research stage and the development stage: in the research stage because the intermediate innovation can be applied to the research projects of both research units of the merged firm and hence is more valuable; and in the development stage because, on average, R&D expenditure is more likely to be productive thanks to the intermediate innovation.[73]

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[71] Denicolo & Polo, *supra* note 55.

[72] *See supra* note 7.

[73] These results are reminiscent of James Bessen & Eric Maskin, *Sequential Innovation, Patents and Imitation*, 40 RAND J. ECON. 11 (2009), a paper that stresses the importance of sharing intermediate technological knowledge for innovation and economic efficiency.

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

4. CONCLUSIONS

We have discussed the thesis known as "the innovation theory of harm" – namely, that in the absence of specific research synergies mergers generally reduce innovation. In fact, the innovation theory of harm does not merely claim that mergers generally reduce innovation. It makes the stronger claim that even mergers that would be output-neutral for a given state of technology become generally anti-competitive when their effects on innovation are taken into account. This stronger claim could justify blocking mergers that would pass the standard static tests.

This thesis needs to be examined with great care, as it contradicts the findings of a wide literature on competition and innovation that shows much more mixed results. Indeed, the thesis is not supported by economic analysis. We have demonstrated that the theoretical foundations of the IToH's stronger claim are shaky. As we have shown, Motta and Tarantino provide no support whatever for the stronger IToH claim. The analysis of Federico, et al. (2017, 2018) does support an IToH claim, but makes strong, and unjustified, assumptions about the R&D strategy the merged firm would employ. We have shown that this strategy could be suboptimal for the merged firm, and that the opposite result is possible if the merged firm follow a different, more profitable, strategy.

Although there are mechanisms whereby mergers reduce innovation, we have demonstrated that there are also mechanisms whereby mergers increase innovation. Both types of mechanism are sound, robust and empirically relevant, not simply theoretical curiosities.

In particular, we have focused on two mechanisms that show that a merger can have a positive impact on innovation, namely the coordination of R&D projects and the sharing of new technological knowledge. But other positive mechanisms also exist.[74]

General negative presumptions about the effects of mergers on innovation are not appropriate. When all is said and done, the question whether a particular merger likely will harm or stimulate innovation can be approached only on a case-by-case basis, examining the specific facts.

On the basis of these considerations, our conclusion is that the case for changing merger control policy is weak at best. A presumption that horizontal mergers always hamper innovation is not justified and risks leading regulators to block pro-competitive mergers.

[74] See for instance Bourreau & Jullien, *supra* note 42, who focus on mergers' effect on appropriability, and Marshall & Parra, *supra* note 16, who emphasize the role of complementarities in research.

Regulators and the courts should instead recognize that the effect of a merger on innovation may be negative or positive, and that it is more likely to be positive for a merger that passes the standard static tests. Such neutral *a priori* belief guarantees that the assessment of a prospective merger's impact on innovation will not be biased but will be open-minded and grounded in the facts of the specific case.

ANNEX

Consider two firms that compete in the product market and invest in cost-reducing innovations. The profit of firm A (with obvious notation) is

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

We want to analyze how the profits are affected by a cost reduction. [75] 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 in this case the strategic effect is positive. In other words, if the cost reduction can be observed by rivals, the firm will invest more, because R&D investment is a form of commitment that induces the rivals to be less aggressive. In Fudenberg and Tirole's taxonomy of strategic investment,[76] this is known as the "top dog" effect.

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

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

The value of an incremental cost reduction is

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

[75] The same analysis applies to the case of quality-enhancing innovations, which increase consumers' willingness to pay for the product, and hence demand. Denoting quality by θ, the demand function becomes $p_A(q_A, q_B, \theta)$. The total value of an incremental quality improvement can be written 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 and the second the strategic value. The analysis then proceeds as in the case of cost-reducing innovations.

[76] Drew Fudenberg & Jean Tirole., *The Fat Cat Effect, the Puppy Dog Ploy and the Lean and Hungry Look*, 74 AM. ECON. REV. 361 (1984).

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 $\frac{dp_B}{dp_A}$ too is 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, lowering equilibrium prices and harming the innovator. Hence, the firm has a strategic motive to reduce its innovative effort, what Fudenberg and Tirole call the “fat cat” effect.