Horizontal Mergers and Product Innovation*

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Abstract

We set up a stylized oligopoly model of uncertain product innovation to analyze the effects of a merger on innovation incentives and on consumer surplus. The model incorporates two competitive channels for merger effects: the "price coordination" channel and the internalization of the "innovation externality". We solve the model numerically and find that price coordination between the two products of the merged firm tends to stimulate innovation, while internalization of the innovation externality depresses it. The latter effect is stronger in our simulations and, as a result, the merger leads to lower innovation incentives for the merged entity, absent cost efficiencies and knowledge spillovers. In our numerical analysis both overall innovation and consumer welfare fall after a merger.

JEL Classification: D43, G34, L13, L40, O30, O31.

1 Introduction

The relationship between mergers and innovation is an important question in competition policy, as it is well-established that innovation is one of the main determinants of long-term growth and consumer welfare. Competition authorities typically maintain that horizontal mergers risk reducing innovation incentives. For example, the U.S. Horizontal Merger Guidelines state that "competition often spurs firms to innovate". Similarly, the E.C. Horizontal Merger Guidelines maintain that effective competition benefits consumers by promoting innovation, and that a merger may deprive consumers of this benefit. The U.K. Merger Assessment Guidelines posit that rivalry between firms creates incentives to introduce new and better products.

The position that mergers risk reducing innovation incentive is not universally shared. Some commentators argue that horizontal mergers may rather raise innovation incentives even in the absence of cost efficiencies or knowledge spillovers, by increasing the market power of the merging firms and thus raising the reward from innovation.[1]

In this paper we investigate how a horizontal merger may affect product innovation via its effects on market power.[2] We set out a stylized model which allows us to isolate and study two separate channels for the

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[1] Shapiro (2012) summarizes this debate.

[2] We focus on product innovation, defined as innovation that increases the quality of existing products. We do not consider the case of cost-reducing innovation (i.e. process innovation).

effects of a merger on innovation. We denote these two channels as the *price coordination* and the *innovation externality* channels. We employ the model to analyze numerically the interaction of these two channels and, ultimately, to assess the overall merger effect on innovation and consumer welfare.

The first channel we study—price coordination—relates to the elimination of price competition between the merging firms. The merger internalizes the negative pricing externality that the merging firms exert on each other in the absence of the merger. The reduction of price competition affects the profits of each merging firm both when it successfully innovates and when it does not. Therefore, the reduction of price competition affects the incremental profit of innovating and, with that, the incentive to innovate. While merger-induced price coordination harms consumers via higher prices for current and future products, its effect on innovation incentives is ambiguous. If the merger increases pre-innovation profits in the product market by more than it increases post-innovation profits, price coordination introduces a downward pressure on the merging firms' incentive to innovate. If the converse is true, it exerts an upward pressure. Which of the two directions prevails depends on the specific assumptions made on the nature of competition. In our model, the reduction in the intensity of price competition following a merger tends to favor innovation.

A merger will also affect innovation through a second channel – the innovation externality. The innovation externality reflects the reduction of expected profits that innovation by one of the merging firms causes on its merging partner (and vice-versa). Innovation by one of the merging firms reduces the profits of its partner both if the latter has innovated and if it has not. In the first case, innovation by one of the merging firms diverts profitable post-innovation sales of the other merging firm. In the second case, innovation by one of the merging firms cannibalizes the pre-innovation sales of the merging partner. The merged firm internalizes the negative externality from innovation effort. In our model, a merger therefore exerts a downward pressure on innovation incentive of the merging firms via the innovation externality channel.

Similar to the standard unilateral price effect, the internalization of the innovation externality and the associated loss of innovation competition are more likely to be significant when (1) the merger brings together two out of a limited number of significant innovators and (2) the merging firms, absent the merger, would have been likely to divert to a significant extent future sales from each other when introducing innovative products.

We employ our model to study the interaction of the price coordination and innovation externality channels in a merger. While it is not possible to fully solve the model analytically, except in its simplest form, we use numerical simulations to obtain our insights. In our simulations the innovation externality channel overcomes the countervailing effect of the price coordination channel. The innovation effort of the merging parties therefore decreases with the merger. The negative effect on innovation incentives tends to be stronger when the merging parties are close competitors. The non-merging firms increase their innovation effort following a merger, but this increase does not compensate for the reduction of innovation effort by the merging firms. This implies that total innovation falls after the merger.

We find that the merger is welfare reducing for consumers. This is not a surprising result in light of the fact that overall innovation falls and prices increase as a result of the merger.

We also consider innovation-related efficiencies that a merger may release, including reductions in R&D costs and merger-specific enhancements in the effectiveness of innovation. We do not, however, model involuntary knowledge spillovers. Both the results on innovation incentives and on consumer welfare can be overturned if there are sufficiently large R&D efficiencies.

Literature review. Our paper is related to the economic literature on competition and innovation. Whilst extensive, much of this literature does not explicitly model horizontal mergers between rival innovators. A notable recent exception, and the closest paper to ours, is Motta and Tarantino (2017), who study the impact of a horizontal merger on the incentives to engage in continuous and deterministic innovation. They find that a horizontal merger tends to reduce innovation incentives in the absence of efficiencies. Our modelling approach differs in that we focus on stochastic product innovation in a sequential game. We assume in particular that innovation investment affects the probability of successful innovation but not the value of the innovation. The assumption simplifies our analysis as we only need to consider a finite number of discrete outcomes of innovation.[3] Notwithstanding the different modelling assumptions, our results on the impact of a merger on innovation are qualitatively similar to those of Motta and Tarantino (2017).

More generally, the literature on competition and innovation provides relevant insights on the price coordination and innovation externality channels that we analyse. It often does not, however, consider horizontal mergers between innovators, making it difficult to draw implications for merger control from this strand of the literature. In contrast to these papers, our framework explicitly considers the effect of eliminating both product market and innovation competition between rival firms following a merger that brings together rival products and R&D assets under common ownership.

Several papers consider the impact of product market competition on the innovation incentives of a monopoly innovator, hence abstracting from the effects of a merger on competition between rival innovators. Arrow (1962), Greenstein and Ramey (1998) and Chen and Schwartz (2013) reflect (at least implicitly) the two channels modelled in our paper.[4] The results of Arrow (1962), and Greenstein and Ramey (1998) suggest that a secure product-market monopolist has less incentive to innovate than a firm facing product market rivalry. However there are circumstances where a reduction in product market competition can stimulate innovation due to the effect of price coordination, e.g. this is the case in the horizontal differentiation model of Chen and Schwartz (2013).

A related strand of the literature models the impact of the intensity of product market competition on innovation incentives, in leader-follower models of innovation (see Aghion *et al.* (2001) and Aghion *et al.* (2005)). These models take as given the number of competing innovators, whilst varying parameters that proxy for the intensity of product market competition. They find that the relationship between innovation and product market competition is non-monotonic (e.g. as shown in Aghion *et al.* (2005)).

The interplay between the price coordination and the innovation externality effects is also captured in models of R&D cooperation, including recent models of partial ownership.[5] D'Aspremont and Jacquemin (1988), for example, show that R&D cooperation between Cournot duopolists leads to less R&D effort if spillovers are sufficiently low. R&D efforts decrease because of the internalization of the innovation externality.[6] Lopez and Vives (2017) extend the model of d'Aspremont and Jacquemin (1988) and consider a more general setting with n firms, partial cooperation due to overlapping ownership stakes, and alternative functional forms for demand. They confirm that, absent sufficient spillovers, partial R&D and output cooperation between firms leads to lower R&D efforts and lower consumer surplus. This is similar to our results, given that the innovation externality in Lopez and Vives' model prevails over the possible countervailing effects of cooperation in the product market (absent spillovers). In related work, Shelegia and Spiegel (2015) consider partial cross-ownership in a duopoly model.[7] Our paper differs from the work on R&D cooperation in that we consider the impact of a

[3] A simpler reduced-form version of our model that allows us to derive some analytical results, is set out in Federico *et al.* (2017). There competition is assumed to be either imperfect with only 2 firms, or leading to Betrand outcomes with at least 3 firms. In the present paper we spell out both consumer preferences and product market competition in more general terms.

[4] For example, Chen and Schwartz (2013) refer to a "diversion effect" and a "coordination effect" of changes in market structure, which are closely related to the channels that we analyse here. Similarly, the "replacement" effect associated with Arrow (1962) is related to the "innovation externality" channel.

[5] Partial ownership is akin to a partial merger, with similar effects to those we describe, except that with partial ownership firms internalize these effects only partially and firms are still independent decision makers rather than one single entity as in the case of a full merger.

[6] D'Aspremont and Jacquemin (1988) also compare the cases of R&D cooperation with and without output cooperation. They show that R&D efforts are higher with output cooperation than without, but that R&D efforts still fall relative to the no-cooperation case if spillovers are sufficiently low. This result implies that the price coordination effect partially offsets the innovation externality effect, but it is not sufficient to overturn it (absent spillovers), in line with the results shown in this paper.

[7] This paper finds that starting from a position of no partial ownership, a small and symmetric increase in cross-ownership stakes may increase innovation incentives. The paper identifies two effects driving innovation incentives (a "price effect" and a

merger between two out of a number of rival innovators, as opposed to full or partial cooperation across all firms in a market.

Finally, some papers analyze the impact on innovation of changes in market structure by modelling the effect of an exogenous change in the number of competing products as opposed to a merger. This is the case of Vives (2008), and more recently Marshall and Parra (2018).

Our simulations support the conclusions set out in a number of policy surveys (e.g. Gilbert (2006), Baker (2007), Shapiro (2012) and Gilbert and Greene (2015)). These papers posit that a merger between two out of a few rival innovators is likely to reduce product innovation incentives if (1) pre-merger appropriability is high (resulting from the fact that innovators obtain an effective exclusive right to their innovation, with limited knowledge spillovers) and (2) there are no merger-related efficiencies.

We proceed as follows. In Section 2 we set out the model and characterize, separately, the price coordination and innovation externality channels in a partial analysis of the effect of the merger on the innovation incentives of the merging firms. In Section 3, we use numerical simulations to study the price coordination and innovation externality channels, and to analyze the merger's equilibrium effect on innovation and consumer welfare. In Section 4 we conduct robustness checks and consider extensions, while Section 5 concludes.

2 A model of stochastic product innovation

In this section we set out the model. Firms own product lines and compete in a sequential two-stage game. Before the merger, each product owner j from a set of owners N is selling a single product i of some baseline quality, which it can improve by innovating.[8] The increment in quality after a successful innovation is an exogenously fixed discrete amount. The probability of a successful innovation for product i is an increasing concave function $x(\cdot)$ of innovation effort w_i. For simplicity, probabilities of a successful innovation are independent across products. The cost of effort is a linear function $e(w) = aw$. Thus, it becomes increasingly costly to boost the likelihood of success of an innovation. We assume that, once a product improvement has been discovered, there are no additional costs before the improvement can be brought to the market (i.e. there are no "development" costs). We also assume that the improved product entirely replaces the old one − it is not profitable for a firm to simultaneously sell both a low and a high quality version of its product. In our model, innovation can be thought of as the introduction of a new product that renders the old product obsolete, i.e., a drastic innovation.

In stage one of the game, product owners simultaneously choose the investment level for their products. In stage two, product owners observe the quality of all products (that is, they observe a particular product quality profile k from the set S of all possible profiles) and independently set prices to maximize their profits. With n products there are 2^n different possible quality profiles. The $i-$th entry in k, denoted by k_i, takes the value of zero if innovation effort in product i is not successful and one when it is successful (and thus gives the stage-two quality level of product i). k_{-i} denotes vector k with its i-th entry deleted and analogously for vector w_{-i}.

The merger brings the ownership of two products—denoted as products 1 and 2 throughout—in the hands of a single owner who decides, for both products, on the innovation effort in the first stage and on prices in the second stage. Formally, before the merger, the set of products owned by firm j is given by a singleton $\wp_j = \{j\}$. Following the merger between product owners 1 and 2, the two firms cease to exist and a new firm is

"cannibalisation effect") which closely correspond to the "price coordination" and "innovation externality" effects emphasised in our paper.

[8] With this notation, we distinguish between the product owners and products to allow for the fact that, after the merger, a single product owner owns two products.

created which owns the two products. The set of products owned by the merged firm is given by $\wp_m = \{1, 2\}$ and $\wp_j = \{j\}, \forall j \in N \setminus \{1, 2\}$.

We now briefly characterize the equilibrium in stage two of the model (price setting), and then give the first-order conditions for stage one (R&D investment).

2.1 Stage two - price setting

Assume that there exists a unique equilibrium in prices in stage two for any possible product quality profile given by k— denoted by a vector $p^*(k)$ — where all products i face non-negative demand. The equilibrium profits in state k for product owner j with products in $\wp_j$ are defined as

$$\Pi_j(k) :\equiv \sum_{i \in \wp_j} \pi_i(p^*(k)), \tag{1}$$

where $\pi_i(p^*(k))$ denotes the gross profits (i.e. second stage revenues net of production costs) from product i in state k. Notice that profits in stage two depend only on realized states, and not on innovation effort exerted in stage one (which instead affects the probability of occurrence of a state).[9]

2.2 Stage one - R&D investment

In stage one, firms observe the vector of baseline qualities of all products and then simultaneously set innovation effort w_i for each of the products that they own to maximize their expected profits. The expectations are taken over all the possible quality profiles $k \in S$. $P[k|w]$ is the probability that profile k is realized, conditional on the vector of efforts w.

By $P[k_{-i}|w_{-i}, k_i = 1]$ we denote the probability of observing outcome profile k_{-i}, conditional on firm i successfully innovating and given effort w_{-i}. Correspondingly, $P[k_{-i}|w_{-i}, k_i = 0]$ denotes the probability of observing k_{-i} when firm i is not successful. The assumption of independence of innovation outcomes across products and firms implies that $P[k_{-i}|w_{-i}, k_i = 1] = P[k_{-i}|w_{-i}, k_i = 0] \equiv P[k_{-i}|w_{-i}]$.

Firm j solves the following problem in the first stage, for each product that it owns $i \in \wp_j$:

$$\max_{w_i \in \wp_j} \sum_{k \in S} P[k|w_i, w_{-i}]\Pi_j(k) - \sum_{i \in \wp_j} e(w_i). \tag{2}$$

The system of first-order conditions for product i and firm j

$$\sum_{k \in S} \frac{\partial P[k|w]}{\partial w_i} \Pi_j(k) - e'(w_i) = 0, \quad j \in N, i \in \wp_j \tag{3}$$

implicitly defines the best response $w_i(w_{-i})$ for all firms and products.

Observing that innovation in product i fails with probability $1 - x(w_i)$ and that, by the independence of innovation outcomes, $x(w_i)P[k_{-i}|w_{-i}] = P[k|w]$, we can write the previous expression as

$$\frac{\partial x}{\partial w_i} \sum_{k_{-i} \in S_{-i}} P[k_{-i}|w_{-i}] \; (\; \Pi_j(k_{-i}|k_i = 1) - \Pi_j(k_{-i}|k_i = 0) \;) - e'(w_i) = 0 \;\; \forall j, i \in \wp_j, \tag{4}$$

where S_{-i} is the set of all possible realizations of k_{-i}.

[9]This assumption eliminates the issues related to strategic commitment in stage one of the model.

For our chosen demand and cost functions, the second-order conditions are satisfied (profit functions are strictly concave in firms' own R&D efforts) in the range of parameters that we consider in our numerical simulations. We restrict the parameters of our simulations to values that generate interior equilibria (pre- and post-merger).

Under our assumptions, the existence of an equilibrium in the first stage is ensured by the strict concavity of payoffs in own innovation effort and by the compactness of the feasibility set (recalling that profits in stage two depend on the realization of a state and not on efforts that affect only the probability of occurrence of a state - see (1)).

Pre-merger. Before the merger each firm owns one product only, so $\wp_i = \{i\}$, and the condition above can be written as

$$\frac{\partial x}{\partial w_i} \sum_{k_{-i} \in S_{-i}} P[k_{-i}|w_{-i}] \; (\; \pi_i(p^*(k_{-i}, k_i = 1)) - \pi_i(p^*(k_{-i}, k_i = 0)) \;) - e'(w_i) = 0 \;\; \forall i. \tag{5}$$

Post-merger. After the merger between firms 1 and 2, the merged firm's first-order condition for product 1 (we denote the post-merger equilibrium price vector by $\widetilde{p}^*(k)$) is

$$\frac{\partial x}{\partial w_1} \sum_{k_{-1} \in S_{-1}} P[k_{-1}|w_{-1}](\pi_1(\widetilde{p}^*(k_{-1}|k_1 = 1)) - \pi_1(\widetilde{p}^*(k_{-1}|k_1 = 0)) \\ + \pi_2(\widetilde{p}^*(k_{-1}|k_1 = 1)) - \pi_2(\widetilde{p}^*(k_{-1}|k_1 = 0))) - e'(w_1) = 0, \tag{6}$$

and analogously for product 2.

The first-order conditions for the non-merging firms after the merger are analogous to the pre-merger ones, except for the change in equilibrium prices (and gross profits) in each state k in the second stage of the model.

2.3 The effect of a merger on the innovation incentives of the merging firms

To characterise the impact of a merger on the innovation incentives of the merging firms, and to provide intuition for the equilibrium simulations results reported in the next section, it is useful to analyse the sign of the difference between the post- and pre-merger first-order conditions of stage one of our model, for each of the two products owned by the merged firm. This difference can be evaluated at the pre-merger innovation effort levels, thus measuring the initial impetus faced by the merging firms to change their innovation efforts, taking as given both the innovation levels of their rivals, and the impact of the merger on equilibrium prices in stage two. We denote this measure as the "Downwards Innovation Pressure" (*DIP*) from the merger, given that in our simulations the difference in the stage one first-order conditions, evaluated at pre-merger innovation levels, is always negative. The *DIP* is similar in spirit to the "Upwards Pricing Pressure" (UPP) metric put forward by Farrell and Shapiro (2010), who look at the effect of a merger on pricing incentives. As for the case of UPP, the *DIP* is not an equilibrium effect and so does not capture the reaction of non-merging rivals, and feedback effects on the merging firms. Nonetheless, the *DIP* is useful for our characterization of the impact of a merger on the merged firm's innovation incentive.

We define the *DIP* for product 1 (and analogously for product 2) as the difference between the equations describing the post- and pre-merger first order conditions (6) and (5), at pre-merger optimal innovation effort levels. The sign of the *DIP* for product 1 determines the partial equilibrium effect of the merger on innovation incentives (e.g. a negative sign implies a weaker incentive to innovate).

The sign of the *DIP* for product 1 is given by the sign of the following expression:

$$\sum_{k_{-1}\in S_{-1}} P\left[k_{-1}|w_{-1}\right]\left[\tilde{\gamma}_1(k_{-1})-\gamma_1(k_{-1})+\tilde{\rho}_2(k_{-1})\right], \tag{7}$$

where the terms in square brackets are defined as:

$$\gamma_1(k_{-1}) :\equiv \pi_1(p^*(k_{-1},k_1=1))-\pi_1(p^*(k_{-1},k_1=0)), \tag{8}$$

$$\tilde{\gamma}_1(k_{-1}) :\equiv \pi_1(\widetilde{p}^*(k_{-1}|k_1=1))-\pi_1(\widetilde{p}^*(k_{-1}|k_1=0)), \tag{9}$$

$$\tilde{\rho}_2(k_{-1}) :\equiv \pi_2(\widetilde{p}^*(k_{-1}|k_1=1)-\pi_2(\widetilde{p}^*(k_{-1}|k_1=0). \tag{10}$$

The two terms $\gamma_1(k_{-1})$ and $\tilde{\gamma}_1(k_{-1})$ capture the gross incremental profit from innovation in product 1, respectively pre- and post-merger, in a given state k_{-1}. The gross incremental profit is given by the difference between gross profits from sales of product 1 when innovation in product 1 was successful and the gross profits when innovation was not successful, given the outcome k_{-1} of innovation for all other products. For brevity, we refer to this measure as the "profit gain" for product 1. As shown by the expression for the sign of the *DIP* (7), merger-induced innovation incentives increase with the difference between the post- and pre-merger profit gain, $\tilde{\gamma}_1(k_{-1})-\gamma_1(k_{-1})$. We refer to this effect on the innovation incentives of the merging firms as the "price coordination" channel.

The third term ($\tilde{\rho}_2(k_{-1})$) captures the externality that a quality improvement in product 1 has on the profits that the merged entity realizes in the sales of good 2 for a realization of innovation outcomes k_{-1} (and analogously for the effect of innovation on product 2 on the profits made on product 1). This term is always negative. We refer to it as the "innovation externality". The innovation externality only enters the first-order condition post-merger, and is evaluated at post-merger equilibrium prices. As the expression for the sign of the *DIP* illustrates, the expected externality on product 2 of innovation in product 1 becomes an additional (opportunity) cost of innovation effort on product 1, thus reducing innovation incentives of the merged firm.

Note that if the absolute value of the innovation externality $\tilde{\rho}_2(k_{-1})$ exceeds the difference in profit gains $\tilde{\gamma}_1(k_{-1})-\gamma_1(k_{-1})$ for each possible realisation of k_{-1} the *DIP* is always negative (without the need to consider the first term in (7)). If this is the case, the merger necessarily leads to a reduction in the innovation incentives of the merging firms, evaluated at pre-merger innovation efforts.

3 Baseline simulations with linear demand

In our baseline set of simulations, we consider a linear demand system, generated by the following utility of a representative consumer[10]

$$U=\sum_i(q_i-\frac{q_i^2}{\delta_i^{2\gamma}})-\sigma\sum_i\sum_{j<i}\frac{q_i}{\delta_i^\gamma}\frac{q_j}{\delta_j^\gamma}+Y-\sum_i p_iq_i,$$

where δ_i is good i's quality level. The parameter $\gamma>0$ measures the consumer's responsiveness to quality and $Y-\sum_i p_iq_i$ is the amount money spent on outside goods. The parameter $\sigma\in[0,2]$ is a measure of the degree of horizontal product differentiation (for $\sigma=0$, the products are independent). The consumer's demand function for good i is then

$$q_i(p)=\delta_i^\gamma\frac{[2+\sigma(N-2)]\delta_i^\gamma(1-p_i)-\sigma\sum_{j\neq i}\delta_j^\gamma(1-p_j)}{(2-\sigma)[2+\sigma(N-1)]}. \tag{11}$$

[10] This demand system was proposed by Sutton (1998), and generalized by Symeonidis (2000).

This demand function has desirable properties. Both the (absolute value of the) own-price elasticity and the cross-price elasticity increase with the degree of substitution σ among products. The demand elasticity with respect to quality is constant in the quality level and it increases with σ as well as with the parameter γ of quality responsiveness.[11]

This demand system also preserves, in stage two, the strategic complementarity featured by pricing games. To see this, denote with c the marginal cost of sales. Then, for firm i, $\pi_i = (p_i - c)q_i(p)$ and $\frac{\partial^2 \pi_i}{\partial p_i \partial p_j} = \frac{\delta_i^\gamma \delta_j^\gamma \sigma}{(2-\sigma)[2+\sigma(N-1)]} > 0$, for all $j \neq i$.

For the simulations reported below we consider a range of values of σ that ensures that each firm has a positive output level in each relevant state. For our baseline simulations of this demand system, we set $\sigma = \frac{1}{2}$ and $\gamma = \frac{1}{2}$. In the baseline case we consider a merger from 4 to 3 independent and symmetrically differentiated firms.

3.1 Downward Innovation Pressure (DIP)

We start by discussing simulation results for the *DIP*. In order to study the sign of the *DIP*, we compute the values of the pre- and post-merger profit gains (8) and (9), and of the innovation externality (10), on product 1, for each of the relevant realisations of innovation in the other products. For four firms, there are $2^4 = 16$ possible states k in the second stage of the game. This means that there are 8 possible states k_{-1} to consider for the evaluation of the profit gains and innovation externality for product 1.[12] Observation 1 summarises simulations on the *DIP* (the corresponding figures are included in the Appendix).

Observation 1: The price coordination channel strengthens the innovation incentives of the merging firms in each relevant state, but it is outweighed in each state by the innovation externality channel (which instead weakens the innovation incentives). As a result, there is a downward innovation pressure – the *DIP* is negative. This result holds for the relevant range of values of σ considered in our simulations.

Our simulations suggest that under our chosen demand specification the price coordination effect, when considered in isolation, increases innovation incentives for product 1 in line with the results of Chen and Schwartz (2013).[13] However, this countervailing force is not enough to compensate for the larger effect arising from the negative innovation externality.

In Appendix A.2 we plot the pre- and post-merger profit gains, and of the innovation externality, for each relevant state, as a function of the closeness parameter σ. We note that the largest contribution to the reduction in innovation incentives in product 1 comes from the state where the product of the other merging firm (product 2) has innovated, and rivals have not.[14]

[11] With symmetric prices and quality, respectively, $|\varepsilon_{p_i}| \equiv -\frac{\partial q_i}{\partial p_i}\frac{p_i}{q_i} = \frac{p}{1-p}\frac{2+\sigma(N-2)}{2-\sigma}$, $\varepsilon_{p_j} \equiv \frac{\partial q_i}{\partial p_j}\frac{p_j}{q_i} = \frac{p}{1-p}\frac{\sigma}{2-\sigma}$, $\varepsilon_{\delta_i} \equiv \frac{\partial q_i}{\partial \delta_i}\frac{\delta_i}{q_i} = \gamma\frac{4+\sigma(N-3)}{2-\sigma}$.

[12] These 8 states can be categorised in four groups pre-merger: the state where none of the other products innovate; states where only one rival product innovates; states where two rival products innovate; and the state where all three rival products innovate. Similarly, these 8 states can be categorised in 6 states post-merger, depending on the innovation outcome of the other merging product (product 2), and of the two non-merging products.

[13] Chen and Schwartz (2013) highlight the fact that optimal multi-product pricing associated with a merger boost innovation incentives. This effect is also present in our setting. For example, when product 2 does *not* innovate, post-merger the price of product 2 is set to drive demand towards product 1 if product 1 has innovated. This boosts innovation incentives in product 1. In the alternative cases where product 2 has innovated, the profits on product 1 will be relatively low post-merger if it does not innovate (as its price will be set by the merged firm so as to transfer sales and profits to product 2). This effect is not present if product 1 also innovates, thus again boosting the post-merger profit gain for product 1.

[14] This is Case 5 in Figure 7 in the Appendix.

3.2 Equilibrium impact of a merger on innovation efforts

We now examine the full equilibrium effects of a merger on innovation. In all our reported simulations we assume that innovation effort translates into a probability of innovation according to the following function $x(w_i) = 1 - e^{-\sqrt{w_i}}$. This function is sufficiently concave so that it ensures an interior equilibrium over a range of different values of parameters. It also ensures a symmetric equilibrium both pre-merger (for all firms), and post-merger (for the two products of the merged firm and the non-merging firms, respectively). We do not consider alternative specifications of $x(\cdot)$ that may induce corner solutions or asymmetric outcomes pre or post-merger.[15]

We assume that $\delta_i = 1$ if the innovation in product i is not successful and $\delta_i = 2$ if the innovation is successful. The cost of effort w_i is equal across firms and is defined as $e(w_i) = \frac{w_i}{100}$. Firms have unit costs of sales of products that we set at $c = 0.1$.

We restrict our analysis to the range of parameters for which we obtain an interior equilibrium both before and after the merger. We find the equilibrium by an iterative Newton search method.[16] We also check that, in equilibrium, the merger is profitable.[17]

3.3 Simulation results

Figure 1 illustrates the equilibrium impact of a 4-to-3 merger on the innovation probabilities of each of the two products of the merged firm ("insider") and each of the two non-merging parties ("outsider"). In the left panel of Figure 1 we show the simple difference between pre and post-merger probabilities of a successful innovation (Δ prob) for the linear demand specification at different values of σ, for $\gamma = \frac{1}{2}$. In the right panel of the same figure, we show the results for the same demand specification at different values of γ, for $\sigma = \frac{1}{2}$. In the absence of analytical proofs, we limit ourselves to a number of observations arising from our simulations.

Observation 2: In line with the preceding *DIP* analysis, the merger reduces R&D investment in each of the merged firms' products also in equilibrium. Non-merging rivals respond with an increase in R&D investment. The increase by non-merging firms is a result of an increase in the expected profit gain for the outsiders and the absence of a countervailing effect via the innovation externality channel.[18]

As can be seen from Figure 1, the increase in innovation probabilities for the outsiders is not sufficient to compensate for the corresponding decrease for the insiders, implying that the merger leads to an overall reduction in innovation.

Observation 3: The strength of the negative effect of the merger on the innovation incentives of the merged firm increases with the degree of substitutability (σ) between the products of the merging firms before and

[15] Recently, Denicolò and Polo (2017) analyze a duopoly model along the lines of the reduced-form model of Federico *et al.* (2017). They show that, if the cost function is not sufficiently convex, a merger to a monopoly can increase investment when, after the merger, one R&D lab is shut down while the other lab innovates with probability 1. They do not conduct a welfare analysis of the merger. We note that the relevance of asymmetric outcomes on R&D effort is discussed in the literature on R&D joint ventures. For example, Leahy and Neary (2005) show that the second-order conditions for a symmetric cooperative optimum take a simple form, and compare those conditions to the ones required for stability of a non-cooperative equilibrium. They also find that in the linear quadratic model of R&D joint ventures introduced by d'Aspremont and Jacquemin (1988) the comparison between a symmetric non-cooperative equilibrium and an asymmetric cooperative outcome is only relevant for a narrow range of parameters.

[16] We have ran the search algorithm with different starting values to check that it always converges to the same equilibrium effort vector. We are therefore reasonably confident that there is a unique equilibrium for each set of parameters that we consider. We have also checked that the Rosen's (1965) condition for stability is satisfied in equilibrium. From that we cannot conclude that the equilibrium is globally stable. It is, however, at least locally stable.

[17] Appendix A.5 includes plots for the profits of the merged firm in our baseline case.

[18] We give the conditions for strategic substitutability of R&D efforts in Appendix A.1.

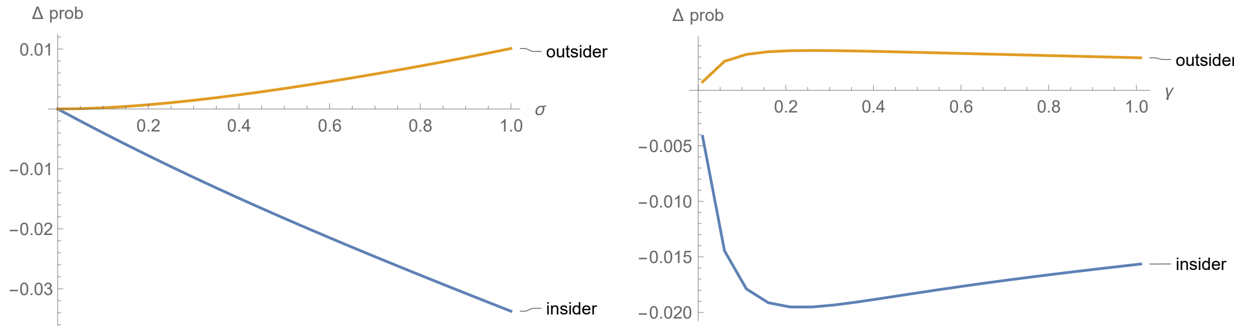

Figure 1: The effects of merger on innovation – Linear demand

after innovation.[19] These results confirm the standard intuition for unilateral effects in mergers.

To further characterize the overall effect of opposing responses in innovation effort by the merger insiders and the merger outsiders, we rely on the concept of stochastic dominance. A probability distribution over possible outcomes first-order stochastically dominates another such distribution if for each number of successful innovations–say t–the former has at least as high probability of at least as many innovations. Formally, define two random variables for the number of innovations before and after the merger, b and a, respectively. We say that if $P[b \leq t] \leq P[a \leq t] \;\; \forall t$ (with a strict inequality for at least one t), the distribution over possible outcomes before the merger (b) first-order stochastically dominates the one after the merger (a). This means that before the merger the probability that at least t innovations will successfully arrive to the market is higher than after the merger.

Observation 4: For the 4-firm case the pre-merger distribution stochastically dominates the post-merger situation, for our baseline parameters. This shows that in our baseline simulations the non-merging firms' response is not sufficient to compensate for the decrease in investment by the merging firms.[20]

We also compute the overall impact of the merger on consumer surplus (Δ CS), via its effect on prices and innovation effort.

Observation 5: The merger results in a decrease of consumer welfare, as illustrated in Figure 2 where we plot the simple difference between post- and pre-merger consumer surplus. The decrease in overall innovation contributes to the negative effect of the merger, in addition to the effect due to the reduction of price competition on both pre- and post-innovation products. The merger also affects the allocation of innovation effort between the merged and non-merging firms given that the non-merging firms innovate more after the merger. Because the non-merging firms increase their prices by less than the merged firm does, this reallocation of effort mitigates the negative impact on consumer welfare of the overall decrease in innovation.[21]

[19] Note that the innovation externality effect increases at a faster rate than the countervailing effect of the price coordination channel as σ increases - see Appendix A.2. The result that negative effect on the innovation incentives of the merged firm increases with σ holds also in relative terms, given that in our simulations pre-merger innovation effort falls with σ.

[20] In Appendix A.4 we report the distribution of successful innovations pre- and post-merger. We have also run additional numerical simulations when the numbers of firms varies between 3 and 8 before the merger, for our baseline parameters, and again confirm the result on stochastic dominance.

[21] We note that in the baseline simulations the loss of consumer welfare caused by the reduction of price competition on pre-innovation products under-estimates the total loss of consumer welfare due to the merger. This is illustrated by comparing the consumer welfare loss for $\gamma = 0$ (where no innovation takes place and thus the consumer welfare computation only captures the adverse price effect on pre-innovation products), with the consumer welfare loss for $\gamma > 0$ (see right panel of Figure 2).

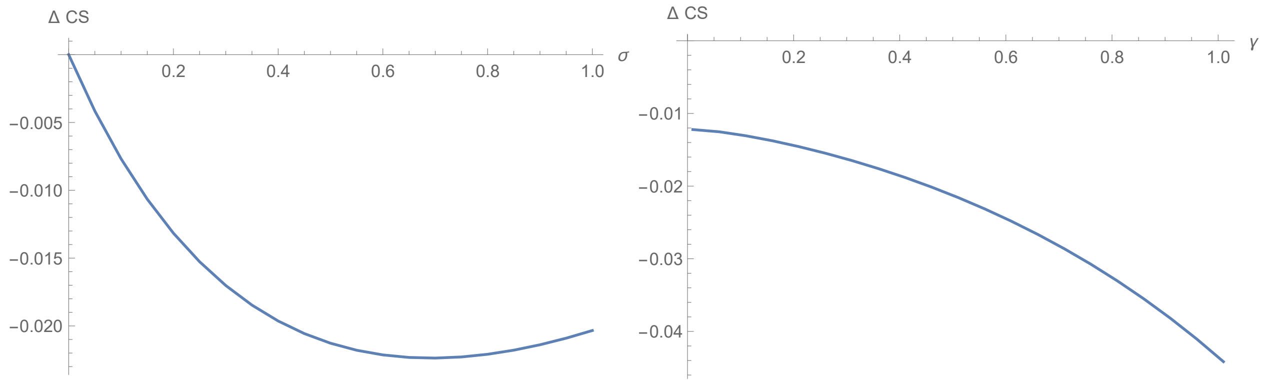

Figure 2: The effects of merger on consumer welfare – Linear demand

4 Sensitivity analysis

4.1 Alternative parameter values

To check the sensitivity of our results to the choice of parameters, we have performed several additional simulations. Notably, starting from the baseline case, we considered: (i) changes in the effectiveness of innovation; (ii) changes in the cost of innovation effort; and (iii) changes in marginal cost of production. Our qualitative results on innovation effort and consumer surplus remain unchanged in these simulations as detailed in Appendix A.3.

4.2 Alternative demand functions

In addition to the linear demand system given by (11), we also present simulations using two alternative demand functions. First, we consider the nested logit demand system with two nests

$$q_i(p) = \frac{\exp[\frac{\delta_i - bp_i}{\lambda}](\sum\limits_{j \in V_i} \exp[\frac{\delta_j - bp_j}{\lambda}])^{\lambda - 1}}{1 + (\sum\limits_{j \in V_i} \exp[\frac{\delta_j - bp_j}{\lambda}])^{\lambda} + (\sum\limits_{l \in V_{-i}} \exp[\frac{\delta_l - bp_l}{\lambda}])^{\lambda}},$$

where $q_i(p)$ is the market share of good i at prices p and, again, δ_i is good i's quality level. V_i is the set of products in the same nest that contains product i and V_{-i} is the set of products in the nest that does not contain product i. We impose two nests; one includes the two products of the merged firm and the other includes all other products. We compute equilibria for various values of parameter λ, which is an indication of the degree of correlation in unobserved utility within each nest (symmetric for the two nests). $\lambda = 1$ thus gives the standard flat logit. We also set the (elasticity) parameter $b = 1$.

Second, we present simulations for the CES demand system defined as

$$q_i(p) = \frac{(\frac{p_i}{\delta_i})^{r-1}}{\sum_{j \in V} p_j (\frac{p_j}{\delta_j})^r} I,$$

where $r = \frac{\rho}{\rho - 1}$, I is income that we normalize to 1 and we take $\rho \in (0, 1)$. As before, δ_i is the quality level. The elasticity of substitution, for a given δ, increases in ρ.

In Figure 3, we show the effects of the merger on innovation for the nested logit demand (left panel) and for the CES demand systems (right panel). This figure confirms Observation 2. Also in line with Observation 3,

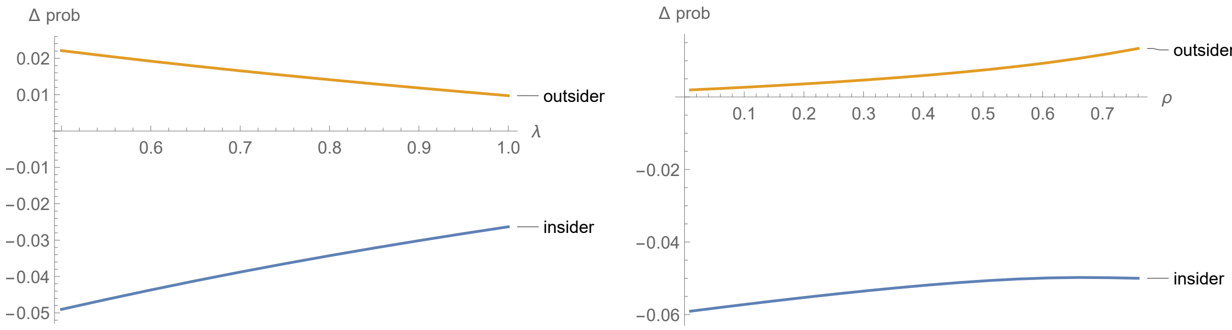

Figure 3: The effect of merger on innovation – Nested Logit and CES

for nested logit, the effect of the merger on R&D effort of the merged firms and outsiders is highest for low levels of λ, that is when the correlation in preferences for the merged firms' products is high. This is intuitive as low values of λ involve a merger of closer rivals.

4.3 R&D efficiencies and spillovers

A merger may result in R&D efficiencies. We model two possible mechanisms for merger-specific R&D efficiencies: improvements in the effectiveness of innovation and reduction in R&D costs.

We first consider the case where the synergy arises through an improvement in the effectiveness of innovation effort, for example by bringing together complementary R&D assets and/or by enabling voluntary knowledge spillovers. As in the baseline case, we assume that if they are successful in innovation, the outsiders to the merger improve their quality from 1 to $1 + 1 = 2$. The insiders, instead, improve it from 1 to $1 + y$, with $y \geq 1$. y can be seen as a measure of the efficiency gains that the merger releases. Results of the corresponding simulations, for the impact of a merger on the probability of a successful innovation and on consumer surplus for different values of y, are shown in the two panels of Figure 4.[22] The negative impact on the incentives to invest of the merged firm can be reversed for sufficiently large R&D efficiencies. At the levels where this occurs, the impact on consumer surplus is still negative, due to higher prices induced by the merger, both for existing products (i.e. absent innovation) and for improved products (those resulting from successful innovation). To overturn the overall negative impact on consumer surplus, efficiency gains have to be higher as can be seen by comparing the left and right panels in Figure 4.

We also consider the case where R&D efficiencies reduce the cost of innovation effort for the merged firm, but not for the merger outsiders. Starting with a pre-merger cost of effort of aw, where $a = 1/100$ as in our baseline simulations, post-merger the cost for the merged firm becomes $(1 - \epsilon)aw$. Figure 5 shows the results of this simulation. As with efficiencies on the effectiveness of innovation, in this case too the merger result in an increase in the innovation effort of the merging parties for sufficiently large efficiencies (ϵ), and eventually also in an increase in consumer surplus.[23]

We have omitted involuntary knowledge spillovers from our analysis. If a firm benefits from R&D conducted by its rivals, independent firms will tend—all else given—to underinvest. A merger would partially internalize this positive externality, thus resulting in additional incentives to invest in R&D (for recent work looking at the impact of spillovers see Lopez and Vives (2017) and Motta and Tarantino (2017)).[24]

[22] For these simulations we set $\sigma = 1/2$ and $\gamma = 1/2$.

[23] For these simulations we again set $\sigma = 1/2$ and $\gamma = 1/2$.

[24] For a qualitative discussion of appropriability and spillovers see Shapiro (2012) and the U.S. Horizontal Merger Guidelines (Section 10). For an empirical study of spillovers, see Bloom *et al.* (2013).

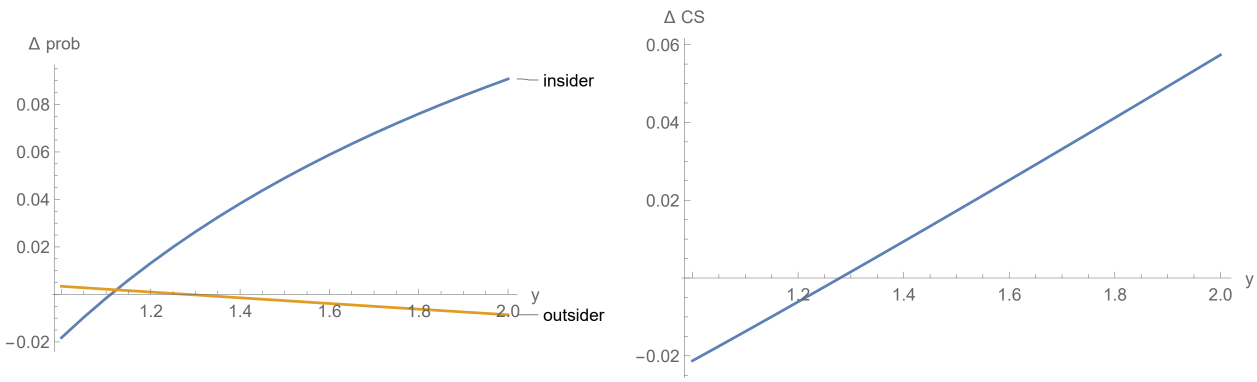

Figure 4: Merger efficiencies – increase in the effectiveness in innovation

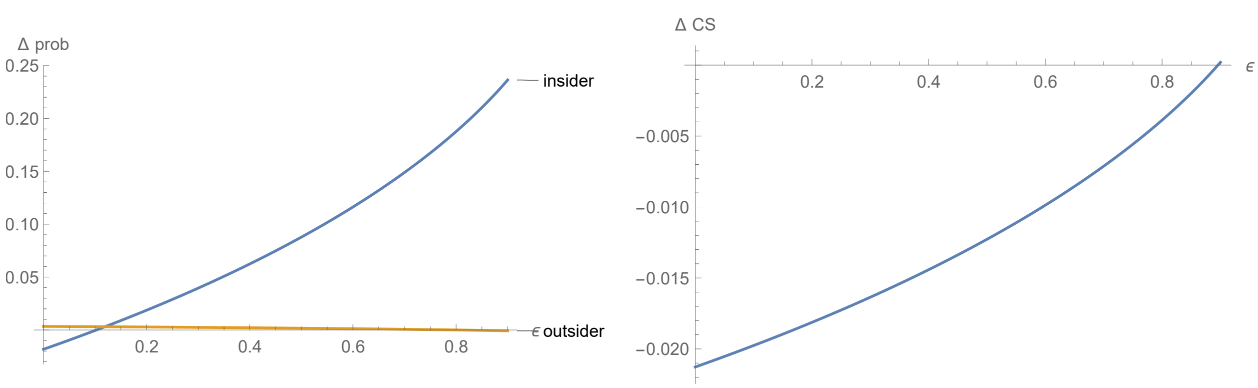

Figure 5: Merger efficiencies - lower cost of R&D effort

5 Conclusion

We set out a stylized two-stage model of uncertain product innovation and price competition. We then employed the model to study how two of the competitive channels associated with a merger—the price coordination and innovation externality channels—interact to affect the incentives to introduce product innovations. We also considered the overall impact of a merger on consumer welfare.

The first channel relates to the impact on innovation resulting from the fact that a merger leads to price coordination between the two merging firms in the product market. Whilst this channel harms consumers by suppressing price competition between the merging firms, in principle it has an ambiguous effect on innovation incentives (as it increases profits both with and without innovation). In our set-up this channel tends to increase the incentive to innovate by the merged entity.

The second channel relates to the externality that innovation by one of the merging firms has on the profits of its merging partner. The merger leads to the internalization of this externality, and hence tends to reduce the incentives to innovate through this channel.

In our model, despite employing demand and parameter specifications where the price coordination channel acts to increase the incentive to innovate, the opposing innovation externality channel dominates. This implies that the merger leads to a reduction in the incentives to innovate of the merging parties. This effect is stronger if the merging firms are close competitors, which is similar to the standard unilateral effects in price.

We undertook numerical simulations of the equilibrium effects of a merger on innovation incentives of both merging and non-merging firms. The simulations indicate that under some assumptions that are not highly restrictive (including different functional forms for demand, and variations in the number of competing firms), a merger leads to lower innovation by the merging parties, and higher innovation by non-merging parties. The negative effect on the innovation by the merging parties tends to dominate, implying that the merger leads to lower overall innovation in a concentrated market, in the absence of efficiencies. In our simulations the merger also reduces consumer welfare.

While our analyses indicate that the net impact of the price coordination and innovation externality channels associated with a merger reduces overall innovation, a merger may also lead to a number of countervailing innovation-related effects. For example, a merger may increase appropriability, by internalizing positive knowledge spillovers between the merging parties, thus enhancing their incentives to innovate. Alternatively, a merger may bring together complementary R&D assets or lead to higher productivity in R&D by enabling cost efficiencies. Sufficient innovation efficiencies overturn the reduction in innovation due to market power, and ultimately also offset the negative impact of a merger on consumer welfare.

The results set out in this paper are intuitive. A merger suppresses innovation competition between rivals, and hence leads to weaker innovation incentives. Our simulations thus support the antitrust concern that a merger between two out of a limited number of innovators may lead to a reduction of innovation in a market characterized by limited knowledge spillovers and in the absence of possible countervailing R&D efficiencies.

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A Appendix

A.1 Condition for strategic substitutability of R&D efforts

We derive the condition for the strategic substitutability of R&D efforts in our model.

Applying the implicit function theorem to the pre-merger first-order condition (5), and noting that $e''(w) = 0$, we find that:

$$\frac{dw_j}{dw_i} = -\frac{\frac{\partial x}{\partial w_j} \sum_{k_{-j} \in S_{-j}} \frac{\partial P[k_{-j}|w_{-j}]}{\partial w_i}(\pi_j(p^*(k_{-j}|k_j = 1)) - \pi_j(p^*(k_{-j}|k_j = 0)))}{\frac{\partial^2 x}{\partial w_j^2} \sum_{k_{-j} \in S_{-j}} P[k_{-j} \mid w_{-j}](\pi_j(p^*(k_{-j}|k_j = 1)) - \pi_j(p^*(k_{-j}|k_j = 0)))}. \quad (12)$$

We have that

$$P[k_{-j} \mid w_{-j}] = x(w_i)^{k_i}(1 - x(w_i))^{1-k_i} \prod_{l \in N \setminus \{i,j\}} x(w_l)^{k_l}(1 - x(w_l))^{1-k_l},$$

so that

$$\frac{\partial P[k_{-j} \mid w_{-j}]}{\partial w_i} = (-1)^{1-k_i} \frac{\partial x(w_i)}{\partial w_i} \prod_{l \in N \setminus \{i,j\}} x(w_l)^{k_l}(1 - x(w_l))^{1-k_l}.$$

Because $x(\cdot)$ is concave, the denominator of (12) is negative and it follows, since we know that $\frac{\partial x(w_i)}{\partial w_i} > 0$, that efforts of firms i and j are strategic substitutes if the following sufficient condition holds for $\forall k_{-\{j,i\}} \in S_{-\{j,i\}}$

$$[\pi_j(p^*(k_{-\{j,i\}}|k_j = 1, k_i = 1)) - \pi_j(p^*(k_{-\{j,i\}}|k_j = 0, k_i = 1))] - \\ - [\pi_j(p^*(k_{-\{j,i\}}|k_j = 1, k_i = 0)) - \pi_j(p^*(k_{-\{j,i\}}|k_j = 0, k_i = 0))] < 0.$$

The above condition simply states that the efforts are strategic substitutes when the incentives to catch up with a successful rival innovator are weaker than the incentives to increase a quality advantage over a rival. For example, this condition is satisfied in the 4-firm case illustrated in Section 3 of the paper.

A.2 Downward Innovation Pressure (DIP)

In Section 3 we consider a merger from 4 to 3 independent firms, using a linear demand system. In Figure 6 we plot, for all the relevant states k_{-1}, separately the difference in the pre- and post-merger profit gains, and the innovation externality for product 1, as defined in the main text (see (8) - (10)). There are 6 relevant states to consider, depending on the innovation outcomes for products 2, 3 and 4. These states are denoted as different cases in Figure 6; note that cases 2 and 3 and 6 and 7, respectively, are the same for the purpose of our analysis. In state $k_{-1} = (0, 1, 1)$, for instance, innovation was successful for products 3 and 4, but not for product 2. As expected, the merger has no impact on innovation incentives when products are independent ($\sigma = 0$), while the effect on the difference in profit gains and on the innovation externalities increases in all cases as products become closer substitutes.

Figure 7 reports the overall impact of the two channels in each relevant state. That is, it shows the difference between profit gains and the innovation externality in each state (as depicted in Figure 6). It therefore

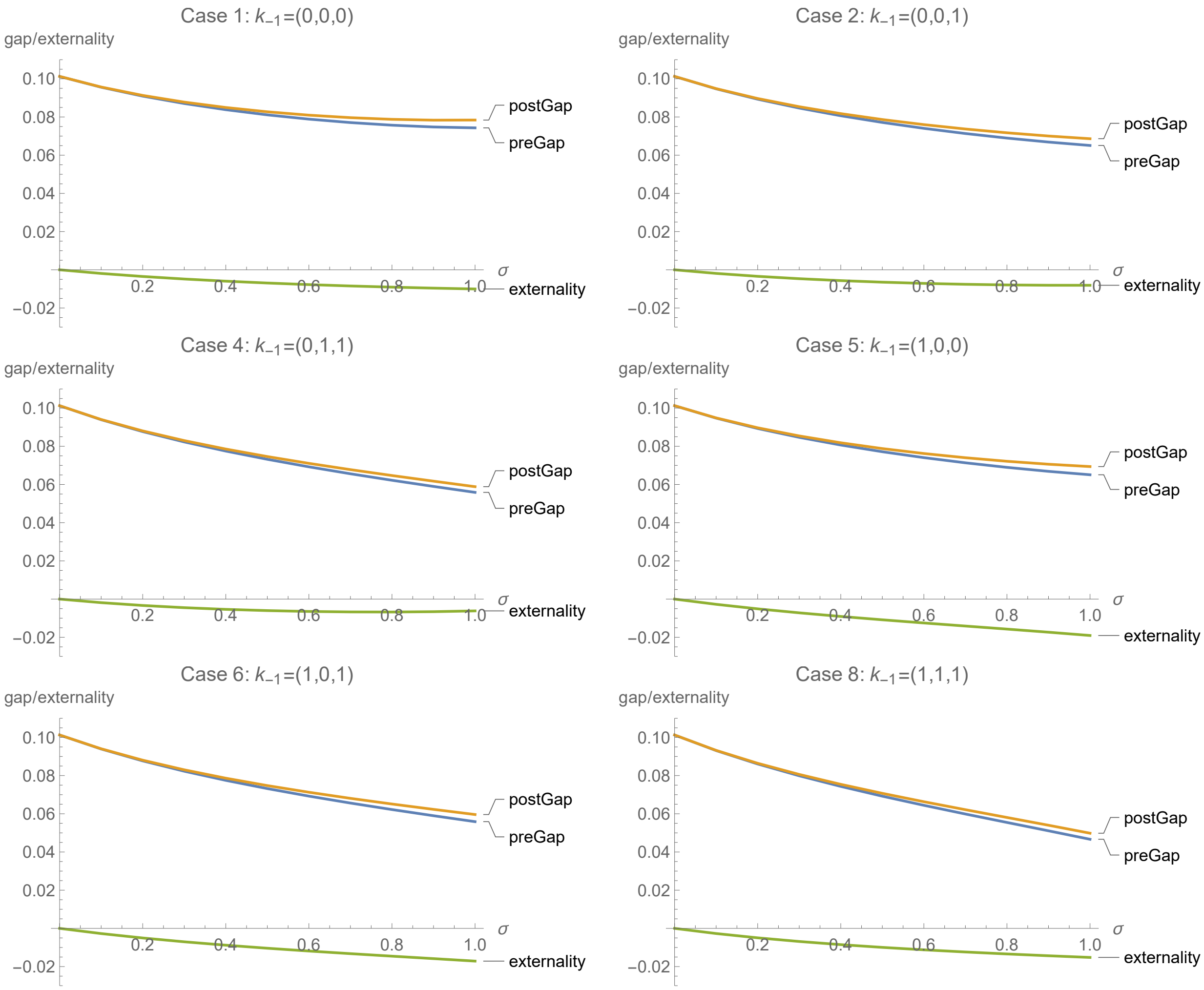

Figure 6: Profit gaps and externalities in each relevant state

illustrates the sign of the change in the incentive to innovate for product 1 (at pre-merger innovation levels), in each state. Note that, in each state, the positive difference in profit gains is outweighed by the negative innovation externality. The figure also ranks the states in terms of their contribution, before weighting with probability, to the overall effect of the merger on innovation incentive, for each level of σ. This analysis leads to Observation 1 in the main text (Section 3.1).

A.3 Additional simulations

We check first that our results are robust to different values in innovation effectiveness of each firm (as captured by the improvement in quality that can be achieved by innovating). Specifically, while in the baseline case the quality increment after a successful innovation is 1, we now calculate the merger effects for different values of the increment (denoted by y) in quality between 0.5 and 2. Results are presented in Figure 8 (where y is plotted on the horizontal axis). The impact on the probability of innovation is almost unchanged across different increment values. As the higher quality increment gives additional incentives to invest, and consumer surplus increases with quality, we also find that increases in the quality increment amplify the negative effects of the merger on consumer surplus.

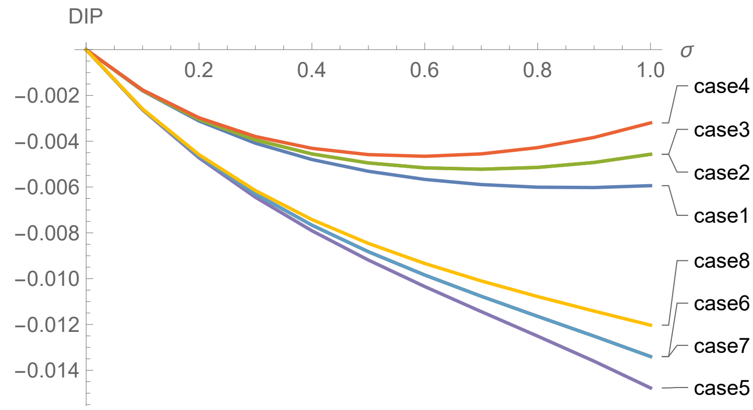

Figure 7: Downward innovation pressure

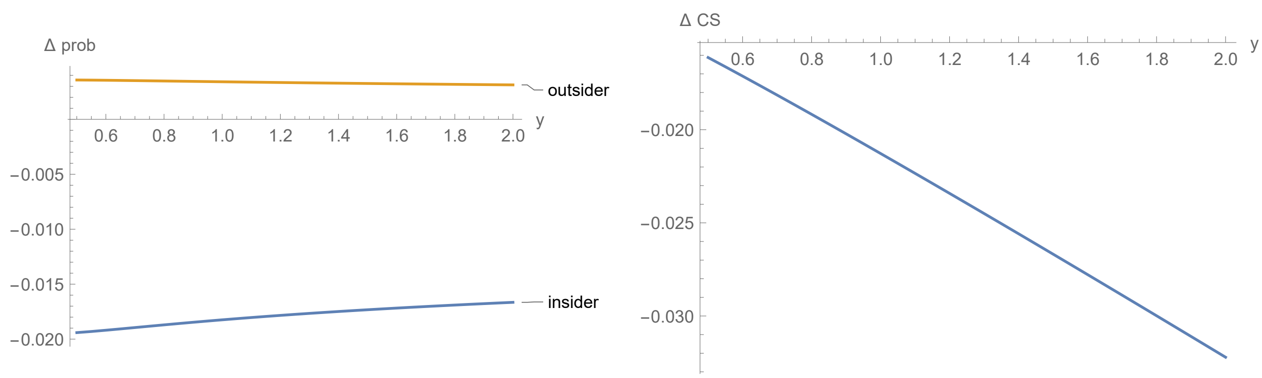

Figure 8: Robustness with respect to quality increment

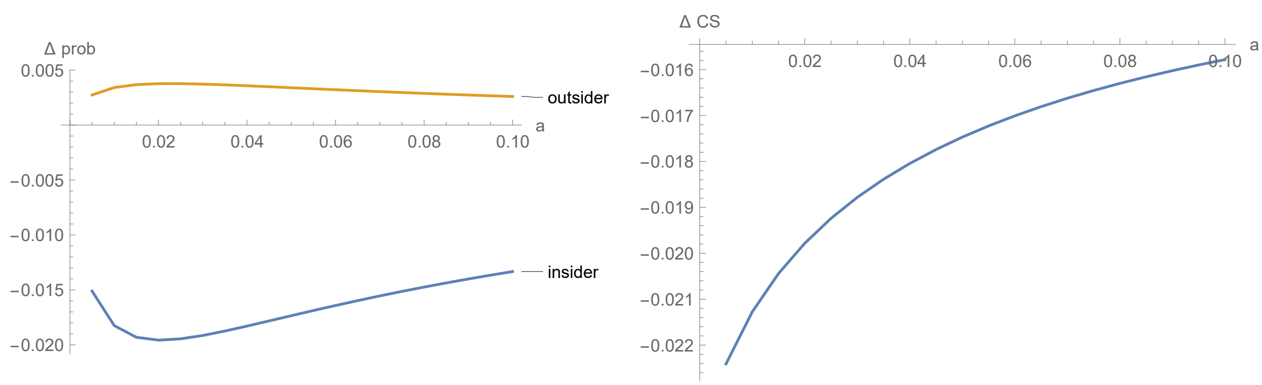

Figure 9: Robustness with respect to cost of effort

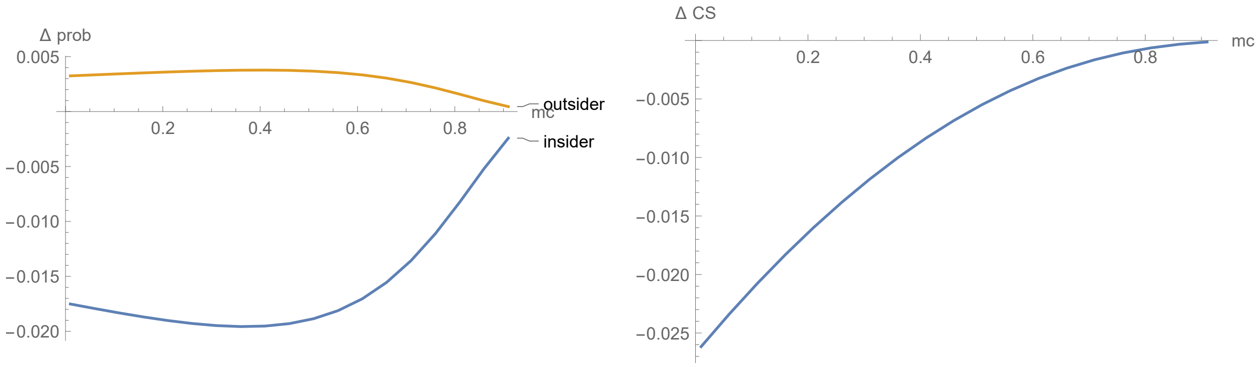

Figure 10: Robustness with respect to marginal costs

Table 1: Stochastic dominance P[number of successes $\leq t$]

		t								
n	Scenario	0	1	2	3	4	5	6	7	8
3	Pre	0.026743	0.214798	0.655594	1					
	Post	0.029886	0.229334	0.672382	1					
4	Pre	0.009954	0.096189	0.376365	0.780931	1				
	Post	0.010897	0.102295	0.389526	0.790384	1				
5	Pre	0.00402	0.044504	0.207579	0.536021	0.866771	1			
	Post	0.004337	0.047056	0.215278	0.546344	0.87196	1			
6	Pre	0.001739	0.021396	0.113962	0.346441	0.674866	0.922316	1		
	Post	0.001856	0.022494	0.118097	0.354231	0.682203	0.92508	1		
7	Pre	0.000798	0.010684	0.063203	0.218205	0.492685	0.784314	0.956453	1	
	Post	0.000844	0.011173	0.065373	0.223333	0.499501	0.789146	0.957881	1	
8	Pre	0.000384	0.005526	0.035623	0.1363	0.346781	0.628409	0.863926	0.976471	1
	Post	0.000404	0.005752	0.036762	0.13948	0.352107	0.633761	0.866913	0.977185	1

As a second roubstness check, we consider the cost of effort, $e(w) = aw$. While in the baseline case we have $a = 1/100$, we now allow it to vary between $1/1000$ and $1/10$. Again, we confirm the main results on the changes in innovation efforts, as well as on the impact on consumer surplus - see Figure 9.

The last robustness check is on the marginal cost of production in the second stage of game, which we vary between 0 and 1.[25] Results are presented in Figure 10.

A.4 Stochastic dominance

We consider the random distribution of successful innovations. In particular, with n products, we look at the probability that there are at least t innovations, with $0 \leq t \leq n$. For instance, with $n = 4$ and $t = 2$, we look at the probability that there are $0, 1, 2$ innovations. Table 1 reports the cumulative distribution for the baseline case, extended to mergers up to 8 firms. The Table shows that the cumulative distribution before the merger is always higher that the cumulative distribution after the merger (first-order stochastic dominance).[26] These results lead us to Observation 4 in the main text (Section 3.3).

[25] In a situation with symmetric prices and quality, (11) simplifies to $q_i(p) = \delta^\gamma \frac{1-p}{2+\sigma(N-1)}$. Thus marginal costs above 1 do not make economic sense.

[26] Clearly, both CDFs are equal to 1 when $t = n$.

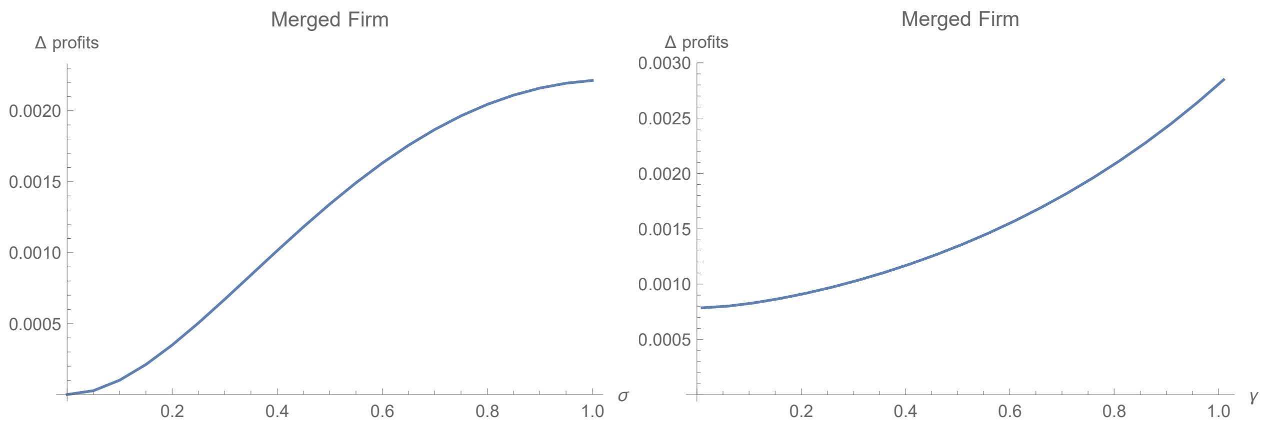

Figure 11: The effects of merger on profits – Linear demand

A.5 Profits

We plot the effect of the merger on expected profits (defined as the difference between expected post- and pre-merger profits) of the merged firm (net profits from the sales of one of its products) in Figure 11. The figure confirms that the merger is always profitable for the merging parties.