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JEL Codes
L1, L4

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by Federico Etro[1]

Ca' Foscari University, University of Florence and C.R.A.

July 2018

Abstract

I study a merger between producers of complement inputs facing entry of superior inputs, with investment by the incumbents in deterministic cost reduction and by the entrants in probabilistic innovation, and competition in prices. The merger is profitable by solving Cournot complementarity problems in investment and pricing, and has positive (negative) effects on R&D by the incumbents (entrants). With inelastic demand the merger harms consumers if the incumbents are efficient enough even without bundling, and always when a commitment to bundling is adopted. Instead, with a demand elastic enough, the merger increases consumer surplus even when a commitment to pure bundling is feasible.

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1 Introduction

Innovation and mergers are key determinants of market structures and their evolution. The theory of industrial organization has recently investigated the impact of mergers on innovation in a systematic way with a focus on antitrust implications (see Shapiro, 2012, and Gilbert and Greene, 2015). At a theoretical level, Motta and Tarantino (2017) and Federico *et al.* (2017a,b) have examined horizontal mergers respectively in aggregative games of price competition between firms producing substitute goods and investing in cost reduction, and in symmetric patent races with probabilistic innovation.[2] In both these contexts mergers tend to exert a negative effect on consumer welfare driven by both higher prices and lower R&D of the merged firms internalizing business stealing effects.[3] Here I explore the alternative case of a conglomerate merger between firms producing complement goods and investing in R&D, a scenario that is traditionally associated with positive effects on consumer welfare driven by lower prices and strengthened by higher R&D, except for the case where the merged entity adopts some form of bundling to divert demand from rival producers (see Economides and Salop, 1992, and especially Choi, 2008). In contrast to this common view, my main result is to show that a merger of complements can harm consumers even without bundling and even if it allows for the internalization of Cournot complementarities, and this happens through its indirect negative effects on R&D of the entrants. Instead, when downstream demand is elastic enough, I show that that the merger tends to benefit consumers even when pure bundling can be adopted and even if this deters entry, due to positive effects on R&D and pricing of the incumbents.

Conglomerate mergers between producers of complement goods have been the focus of a variety of antitrust cases, as those involving GE and Honeywell, Tetrapak and Laval Sidel, Intel and McAfee and few more ongoing cases in highly innovative industries. Bundling issues have been often at the core of the discussion for their anti-competitive implications. Recently, the merger between Qualcomm and NXP has been cleared by the European antitrust authorities under conditions aimed at avoiding risks of foreclosure for actual and potential rivals. In this case, the merging firms produce complement components for smartphones, respectively baseband chipsets by Qualcomm and near-field com-

[2] As well known, horizontal mergers with a fixed number of firms are hardly profitable with quantity competition (Salant, Switzer and Reynolds, 1983) but not under price competition (Deneckere and Davidson, 1985), which is the reason why Motta and Tarantino (2017) focus on the second case.

[3] As well understood, Schumpeterian theories featuring an inverse-U relation between competition and innovation (Aghion and Griffith, 2005) can be hardly applied to merger analysis, but they confirm that mergers in highly concentrated sectors tend to reduce innovation. The negative impact of mergers on R&D can be overturned in the presence of gains from coordination of R&D investments with correlated outcomes, scale economies in R&D and other synergies, an endogenous number of research projects for each firm (see Sah and Stiglitz, 1987) or endogenous entry of firms (the neutrality of mergers in aggregative games with free entry was noticed in Davidson and Mukherjee, 2007, and Etro, 2007, Prop. 2.10), but the cited works suggest that there is a strong presumption for anti-competitive effects of horizontal mergers in concentrated innovative industries.

munication (NFC) and secure element (SE) chips for contacless payments by NXP, which owns and licenses IP on the Mifare technology, an essential technology for high-end devices used as mobile wallets (for instance to pay for public transport or make other secure payments). The merger has been approved conditionally on a) insuring interoperability of Qualcomm's basebands with NFC and SE products by competitors (namely excluding pure bundling of the two components) and b) continuing to license the Mifare technology to other producers for an eight-year period. These are appropriate remedies to avoid the negative effects of a conglomerate merger on the incentives of competitors to invest in product development and exert competitive pressure on the merged entity. At a more general level, conglomerate mergers in high-tech industries often involve "must-have" inputs generating a rigid demand for a composite good (for instance because there are not substitute producers of essential components protected by IP), while other mergers relate to composite goods with a more elastic demand (for instance because there are rivals producing imperfect substitutes for either the composite goods or their components). My analysis suggests that mergers can raise anti-competitive concerns in the former case and not in the latter.

My focus is on the impact of a merger between two suppliers of complement inputs in the production of a final good. They face entry of two rivals, that can produce a new cheaper or superior version of an input. When a new component is made available there is always demand for its use in the final good. The incumbent producers can invest in cost reductions in a deterministic way, while the entrants are engaged in risky investment to create the new components: this captures the fact that large incumbents tend to invest more in process innovation while entrants tend to focus on product innovation (for empirical evidence on this distinction see Cohen, 2010).[4] Once innovations have been established, firms compete in prices. It is well known that independent producers of complement goods adopt inefficient decisions due to Cournot complementarity problems: in our framework both the investment in cost reduction and the pricing decision are inefficient and a merger allows the incumbents to coordinate them with potentially positive effects on consumers. Whether these benefits materialize for consumers depends on the elasticity of demand and on whether the merged entity adopts a bundling strategy.

I start by considering the case of a fixed willingness to pay for the composite good, for instance due to the lack of other producers of the components. This is a benchmark case where a merger would be neutral in the absence of an impact on R&D. Indeed, with endogenous R&D, the merger does not lead to direct price reductions by the merging firms but allows them to solve the Cournot complementarity problem in R&D, increasing their investment in cost reduction and their profitability compared to the pre-merger situation. This is potentially good for consumers in spite of the inelastic demand because the entrants are forced to reduce their prices in case of joint innovation to match the costs of the

[4] However, notice that analogous results could be obtained assuming that also the incumbents are engaged in probabilistic R&D.

incumbents. However, it also reduces the incentives of the entrants to invest in R&D, so that the expected price for the consumers can increase post-merger if the incumbents are already efficient enough in the pre-merger situation: in such a case, the merger reduces consumer surplus even without any commitment to a bundling strategy. Instead, when the merged entity can credibly commit to pure bundling, bundling is adopted to deter entry when a single entrant can appropriate a large fraction of the value of its innovation pre-merger (as in Choi and Stefanadis, 2001) or the incumbents are efficient enough: in such a case the merger reduces further the investment of the entrants and increases further the cost reduction activity of the merging parties, always with a loss in consumer surplus.

While I use a consumer welfare standard in the analysis, I show that similar results apply also under a total welfare standard. Moreover, the results are robust to a variety of extensions, namely with rather general R&D technologies (though bundling may not lead to entry deterrence), bargaining on prices instead of competition on posted prices (where the merged entity gains negotiation power), pre-commitments on R&D by the incumbents (implying substitutability between bundling and R&D as tools to limit entry) and the possibility of a counter-merger of the entrants (which makes bundling more profitable and therefore makes consumer harm more likely).

The scenario can change when the demand for the composite good is more elastic, as when there are substitute producers for the composite good or its components. To verify this, I extend the model to a downward sloping demand function assuming a quasilinear specification that nests the cases of a fixed willingness to pay, a linear demand and a perfectly elastic demand for the composite good, as well as any intermediate level of demand elasticity (analogous results emerge modeling downstream competition with a producer of a rival bundle). A crucial consequence is that there is no more the multiplicity of equilibria emerging in the model with fixed demand. In the absence of bundling, the merger generates a similar impact on the innovation activity as in the baseline model, internalizing R&D complementarities, but it also induces an additional incentive to directly reduce the prices of the merged entity, internalizing pricing complementarities: the final effect on consumer welfare tends to be positive and is always so in our linear specification. When a commitment to pure bundling is feasible, it is always optimal to adopt it (as a consequence of equilibrium uniqueness in price competition), but the merger can still be beneficial for consumers, because the benefits of the reduction in prices by the incumbents dominate any losses due to the reduced investment by the entrants: this is indeed always the case under our linear specification and, more generally, whenever the demand elasticity is high enough and the difficulty of innovation low enough.

Few recent works have emphasized the possibility that conglomerate mergers can generate anti-competitive concerns, including Denicolò (2000), Choi (2008), Alvisi *et al.* (2011) and Masson *et al.* (2014), but none of them focuses on the innovation channel, which is crucial here. The work is also strictly related to recent theories of merger analysis with endogenous innovation (Lopez and Vives, 2016; Motta and Tarantino, 2017; Federico *et al.*, 2017a,b; Denicolò and

Polo, 2017; Marshall and Parra, 2017, 2018), but all of them focus on horizontal mergers between producers of substitutes, while this work is focused on mergers between complements. Finally, part of this work is related to theories of anti-competitive tying, some of which have analyzed when a merger with bundling of complementary goods can soften or tighten competition (see Matutes and Regibeau, 1992, for a classic analysis in a different framework).[5] Choi and Stefanadis (2001) have studied the role of a commitment to pure bundling by an incumbent producing two complement goods to deter entry of rivals that invest in alternative components. Their work, unlike the present one, does not consider a merger between two incumbents with potentially different marginal costs that can be reduced with deterministic R&D activity, and is limited to the case of a fixed willingness to pay. Instead Choi (2008) focuses on product differentiation between four composite goods and mixed bundling by the merged firm, with high prices for the standalone components and low price for the bundle. While I abstract from product differentiation and mixed bundling, his linear-demand model implies that the merger benefits consumers when the demand of a bundle is very sensitive to its own price and very rigid in the prices of the rivals (so that gains from Cournot effects are large), and the merger harms consumers when the demand is rigid in its own price but highly elastic in the price of others (so that bundling diverts demand from the rivals), a case that can also lead to the adoption of pure bundling. Choi's extension to deterministic R&D activity by all the four firms adds ambiguous implications on welfare impact of the merger. This work can be seen as complementary to those of Choi and Stefanadis (2001) and Choi (2008).

The paper is organized as follows. Section 2 presents the baseline model with a perfectly rigid demand. Section 3 extends the baseline model in a variety of directions. Section 4 discusses the more general case of a downward sloping demand curve determining conditions for pro-competitie effects of the merger. Section 5 concludes.

2 Anti-competitive conglomerate mergers

The baseline model is as simple as possible, leaving generalizations to further sections. A final good includes two components A and B that are perfect complements. Consumers have a fixed willingness to pay for the composite good which is normalized to one: this is the typical case of firms producing one or two components that are considered as "must have" in the market (for instance because they are protected by IPRs that are essential to produce a composite good with an inelastic demand). This benchmark with a fixed demand is useful because the merger would be neutral in the absence of endogenous R&D choices (later I extend the model to a downward sloping demand). The two incumbent firms produce the components at marginal costs respectively c_A and c_B. Two

[5] For a more recent analysis of anti-competitive bundling of perfect complements in two-sided markets see Choi and Jeon (2016) and Etro and Caffarra (2017), though these works abstract from a merger.

entrants can innovate and produce substitute components at a lower marginal costs if they are successful (for instance by patenting a new technology alternative to one of an incumbent). Notice that the model can be easily reintepreted in terms of innovation in quality improvements rather than cost reductions.

The game has two stages. In the first stage, both the incumbents and the entrants invest simultaneously in R&D. The investment of the incumbents is deterministic and finalized at reducing their marginal cost of production, therefore it can be interpreted as an investment in *process innovation*: in particular, each incumbent has a maximum cost $\bar{c} \in (0, 1/2)$ if it does not invest, but can spend $I(\bar{c} - c)$ to reduce the marginal cost to $c < \bar{c}$, with $I'(\cdot) > 0$, $I''(\cdot) > 0$, and $I(0) \geq 0$ with $I'(0) = 0$. I allow for a positive fixed cost, therefore the optimal investment of the incumbents can indeed be zero (by leaving their marginal cost at $\bar{c}$), but most of the analysis will focus on positive investments. To obtain closed form solutions I will assume a quadratic investment cost $I(\bar{c}-c) = \beta(\bar{c}-c)^2$ with $\beta > 0$ parametrizing the difficulty of process innovation. The investment of the entrants is probabilistic and finalized at inventing a new component produced at a lower cost normalized to zero, therefore it can be interpreted as an investment in *product innovation*.[6] In particular, each entrant for component $i = A, B$ innovates with probability $z_i \in [0, 1]$ at the cost $F(z_i) = \frac{z_i^2}{2}$, assumed quadratic for simplicity. Once the outcome of innovation is realized, firms compete in prices in the second stage.[7] The game is solved by backward induction.

Before analyzing the game, it is useful to establish the first best outcome for this market. Welfare can be expressed as the surplus generated by the goods net of the expected cost of production and the R&D costs, and the social planner problem is its maximization:

$$\max_{c_A, c_B, z_A, z_B} 1 - \sum\nolimits_{j=A,B} \left[c_j(1 - z_j) + \frac{z_j^2}{2} + I(\bar{c} - c_j) \right]$$

When there is an interior solution, it is symmetric and requires $c_A = c_B = z_A = z_B = c^{FB}$ satisfying the optimality condition:

$$1 - c^{FB} = I'(\bar{c} - c^{FB})$$

which equates the marginal cost of each investment to its marginal benefit. Adopting the quadratic investment cost $I(\bar{c} - c) = \beta(\bar{c} - c)^2$ with $\bar{c} = 1/2$ I can

[6] While it is natural to think that the entrants invest in new products under uncertainty and the incumbents can improve their existing technology with lower uncertainty (captured by a deterministic technology here), the main results of the model are robust to alternative assumptions. However, probabilistic innovation by four firms complicates the analysis in a considerable way (see Choi, 2008).

[7] In the interpretation of the model in terms of quality innovations, the incumbents invest to increase the willingness to pay for their components, and the entrants invest to create new components for which users have a higher willingness to pay relative to the components of the incumbents. In particular $1 - c_A - c_B$ should be re-interpreted as the willingness to pay for the composite good provided by the incumbents and c_i as the increase in the willingness to pay when the new component of entrant i is used.

compute explicitly:

$$c^{FB} = \left[\frac{\beta - 1}{2\beta - 1}, 0\right]^+ \in \left[0, \frac{1}{2}\right]$$

where $[z]^+ \equiv \max(z, 0)$. The optimal marginal cost of the incumbents and the optimal investment of the entrants are increasing in β, since this represents the relative efficiency of the entrants in improving the technology compared to the incumbents. Ordinarily, the market cannot reach efficiency because firms that bear the costs of innovation do not appropriate the entire surplus of it.

2.1 Pre-merger situation

In this section I study the pre-merger situation starting from the pricing stage.

The incentives to invest depend on the expected profits in this stage as in Choi and Stefanadis (2001). If there is no successful innovation by either entrant, the incumbents set prices to share the surplus $1 - c_A - c_B$: there is indeed a continuum of equilibria where each incumbent gets a different fraction of the surplus, but I will focus on the symmetric equilibrium in which each incumbent obtains half of it; anyway consumers have no surplus in this case. If both entrants innovate, they outbid the incumbents selling at prices just below their marginal costs, obtaining respectively c_A and c_B; this leaves surplus $1 - c_A - c_B$ to consumers. Finally, if only one entrant innovates, say in component $i = A, B$, there is again a continuum of Bertrand equilibria, where the successfull entrant obtains a fraction of the surplus created by its innovation, and the remaining incumbent obtains the rest of the total surplus: I index these equilibria by $\lambda \in (0, 1]$ as the fraction of rents created by the innovation that is appropriated by the entrant: the successful entrant and the monopolistic incumbent share the surplus c_i, with rents λc_i for the former and $1 - \lambda c_i - c_j$ for the latter (including the rent from its own component); consumers retain zero surplus also in this case.[8]

According to this analysis of the pricing stage, expected consumer surplus is:

$$\mathbb{E}(CS) = z_A z_B (1 - c_A - c_B)$$

which corresponds to the probability of joint innovation multiplied by the surplus of consumers in that state of the world. Moreover, I can express the expected profits of the incumbents producing component $i, j = A, B$ as:

$$\mathbb{E}(\pi_i) = (1 - z_i)(1 - z_j)\frac{1 - c_i - c_j}{2} + (1 - z_i) z_j (1 - \lambda c_j - c_i) - I(\bar{c} - c_i) \quad (1)$$

and the expected profits of the entrants in component $i, j = A, B$ as:

$$\mathbb{E}(\pi_i^e) = z_i z_j c_i + z_i (1 - z_j) \lambda c_i - \frac{z_i^2}{2} \quad (2)$$

[8] As we will see later on, the case $\lambda = 1$ has a very attractive property: it is associated with the unique Bertrand equilibrium obtained when the demand is elastic and its elasticity approaches zero.

I now consider the first stage where the four firms decide simultaneously on their R&D investments. The FOCs of the incumbents are:

$$\frac{(1-z_i)(1-z_j)}{2}+(1-z_i)z_j=I'(\bar{c}-c_i)\quad \text{for } i,j=A,B$$

where the marginal benefit of investment by i is decreased by the probability of innovation of the direct rival z_i, but it is increased by the probability of innovation of the non-competing entrant z_j, since each incumbent makes more profits when there is an innovation by the non-competing entrant. The FOCs of the entrants deliver the following best response functions for the probability of innovation of each entrant:

$$z_i=z_jc_i+(1-z_j)\lambda c_i\quad \text{for } i,j=A,B$$

which shows strategic complementarity with the other entrant and strategic substitutability with the competing incumbent. Under symmetry, the unique equilibrium investment of each entrant is:

$$z(\lambda,c)=\frac{\lambda c}{1-c(1-\lambda)}\in[0,c] \tag{3}$$

which is increasing in λ and in c, since entrants find it more profitable to invest when they can appropriate more rents and when they can set higher prices due to the inefficiency of the incumbents. Under symmetry, the marginal cost of the incumbents satisfies $1-z^2=2I'(\bar{c}-c)$, where the marginal benefit of investment is decreasing overall in the investment of the entrants. Replacing $z=z(\lambda,c)$ I obtain an implicit expression for the investment of the incumbents:

$$\frac{(1-c^*)[1-c^*(1-2\lambda)]}{2[1-c^*(1-\lambda)]^2}=I'(\bar{c}-c^*) \tag{4}$$

associated with the equilibrium probability of innovation $z(\lambda,c^*)$. The marginal benefit of investment for the incumbents ranges between $1/2$ under full price squeeze ($\lambda\to 0$) and $(1-c^{*2})/2$ when the entrant can extract the entire surplus of its innovation ($\lambda=1$). In either case, it is easy to verify that the equilibrium entails too little investment by the two incumbents compared to the first best, while the investment of the entrants is too much when λ is large (high appropriability) and too little when λ is small.

Since each incumbent neglects the positive impact of its investment on the profits of the other incumbent, there is underinvestment also from the point of view of the two firms. This underinvestment in cost reduction implies that, in case of entry, the innovators can set high prices, which is of course detrimental to consumers. Therefore, we are in front of a form of Cournot complementarity problem, where both incumbents and consumers could benefit from further investment in cost reduction. The joint profits of the incumbents can be computed as:

$$\mathbb{E}(\pi_{Joint}(c^*))=\left(1-z(\lambda,c^*)^2\right)(1-2c^*)+2(1-z(\lambda,c^*))z(\lambda,c^*)c^*(1-\lambda)-2I(\bar{c}-c^*) \tag{5}$$

which is a continuous and non-monotonic function maximized for an intermediate value of λ that optimizes the trade-off between appropriating the expected surplus created by the innovations of the entrants and incentivizing the same innovations (for instance, when $c = \bar{c}$, the joint profits are maximized by $\lambda = 1/3$). Adopting the quadratic investment cost $I(\bar{c} - c) = \beta(\bar{c} - c)^2$ with $\bar{c} = 1/2$, for $\lambda = 1$ I can compute explicitly:

$$c^* = \left(2\beta - \sqrt{4\beta^2 - 2\beta + 1}\right)^+ \in \left[0, \frac{1}{2}\right] \tag{6}$$

which is increasing in β (with the corner solution $c^* = 0$ for $\beta \leqslant 0.5$).[9]

The consumer surplus in equilibrium is given by the following function of the equilibrium marginal cost:

$$\mathbb{E}\left(CS(c^*)\right) = \frac{\lambda^2 c^{*2}(1 - 2c^*)}{\left[1 - c^*(1 - \lambda)\right]^2} \tag{7}$$

Notice that $\mathbb{E}\left(CS(c)\right)$ is an inverse-U curve of c, with zero value for $c = 0$ and $c = 1/2$ and maximum consumer surplus obtained when the marginal cost is given by:

$$\hat{c}(\lambda) = \frac{3 - \sqrt{9 - 4(1 - \lambda)}}{2(1 - \lambda)}$$

with $\hat{c}(1) = 1/3$ and $\hat{c}(0) \to 0.38$. Only by accident the equilibrium marginal cost of the incumbents c^* would match such a "golden rule". When it is above this level, both the incumbents and the consumers would gain from an additional investment in cost reduction, because this would increase the expected profits of the incumbents and reduce the price in case of entry as well as the expected price. Instead, when the equilibrium marginal cost is below this cut-off, an additional investment would benefit the incumbents, but would harm consumers through a reduction in the probability of entry, which increases the expected price.

2.2 Merger analysis

Let us now consider the *merger* between the two incumbents. While price competition takes place as before, the investment in each component for the merged firm is now selected to maximize the joint profits:

$$\begin{aligned}\mathbb{E}\left(\pi_M\right) \quad &= \quad (1 - z_A)(1 - z_B)\left(1 - c_A - c_B\right) + (1 - z_A)z_B\left(1 - \lambda c_B - c_A\right) \\ &\quad\; +(1 - z_B)z_A\left(1 - \lambda c_A - c_B\right) - I(\bar{c} - c_A) - I(\bar{c} - c_B)\end{aligned} \tag{8}$$

with FOCs:

$$(1 - z_i)(1 - z_j) + (1 - z_i)z_j + \lambda(1 - z_j)z_i = I'(\bar{c} - c_i) \quad \text{for } i, j = A, B$$

The new terms on the left hand side show that the merger fixes the Cournot complementarity problem, increasing the investment of the incumbents. Indeed,

[9] The joint profits $\mathbb{E}(\pi_{Joint}) = \frac{3}{2}\beta[1 - 4\beta + 2\sqrt{4\beta^2 - 2\beta + 1}]^2$ are decreasing in β.

in a symmetric equilibrium I have $(1-z)(1+\lambda z) = I'(\bar{c}-c)$, whose left hand side is higher than before for any $\lambda < 1$ and always decreasing in the investment of the entrants. Since the FOCs of the entrants are the same as before, I can solve for the same investment rule of the entrants, with $z^M = z(\lambda, c^M)$ where c^M satisfies:

$$\frac{(1-c^M)[1-c^M(1-\lambda-\lambda^2)]}{[1-c^M(1-\lambda)]^2} = I'(\bar{c}-c^M) \tag{9}$$

The marginal benefit of R&D ranges between 1 under full price squeeze ($\lambda \to 0$) and $1-(c^M)^2$ when the entrant can extract the entire surplus of its innovation ($\lambda = 1$). Under full price squeeze $z^M = 0$, and when the entrant can extract the entire surplus $z^M = c^M$. Compared to the first best, now the merged incumbents invest too much and the entrants invest always too little.

The expected profits for the merged firms are $\mathbb{E}(\pi_M) = \mathbb{E}(\pi_{Joint}(c^M))$, and they must increase compared to the pre-merger situation because the merger delivers coordination of R&D. The expected profits are again a continuous and non-monotonic function of λ because a low λ allows the merged firm to appropriate most of the surplus created by each single entrant but disincentivizes its innovation, and a high λ increases the probability of innovations but leaves most of the rents to the entrants, while an intermediate λ generates higher expected profits. In any case, since $z(\lambda, c^M) < z(\lambda, c)$, the merger reduces always the investment of the entrants and therefore the probability of a price reduction. Expected consumer surplus becomes:

$$\mathbb{E}\left(CS(c^M)\right) = \frac{\lambda^2 \left(c^M\right)^2 (1-2c^M)}{\left[1-c^M(1-\lambda)\right]^2}$$

Remembering that $\mathbb{E}(CS(c))$ is an inverse-U curve, the merger reduces consumer surplus $\mathbb{E}\left(CS(c^M)\right)$ whenever the incumbents are efficient enough before the merger: this happens always for $\bar{c} < \hat{c}(\lambda)$, but a weaker condition is that the marginal cost pre-merger is below the "golden rule" level $\hat{c}(\lambda)$. Assuming the quadratic investment cost as before with $\lambda = 1$ I have:

$$c^M = \left(\beta - \sqrt{\beta^2 - \beta + 1}\right)^+ \tag{10}$$

which is always below the pre-merger value and increases with the difficulty of innovation β.[10] Since the "golden rule" marginal cost $\hat{c}(1) = 1/3$ is reached when $\beta = 4/3$ before the merger (as can be verified from (6)), the merger harms consumers at least for any $\beta \leq 4/3$. I can summarize the impact of a merger between producers of complements as follows:

Proposition 1. *Assuming competition in posted prices, simultaneous investments in R&D and a quadratic cost of product innovation, when a commitment to pure bundling is not feasible, the merger is profitable, reduces the investment*

[10] The profits $\mathbb{E}(\pi_M) = \frac{\beta}{2}[1-2\beta+2\sqrt{\beta^2-\beta+1}]^2$ are above the pre-merger level.

of the entrants and increases the investment of the merging parties, with a reduction of consumer surplus if the merging firms are efficient enough in the pre-merger situation.

Until now I have focused the analysis on consumer surplus, which is the relevant standard for most antitrust authorities. However, one may want to verify if the results are robust under a total welfare standard. In this environment one can compute total expected welfare as the sum of consumer surplus and expected profits of the four firms as in function of the marginal cost:

$$\mathbb{E}\left(W(c)\right) = \frac{(1-c)^2[1-2c(1-\lambda)]}{\left[1-c(1-\lambda)\right]^2} - 2I(\bar{c}-c) \tag{11}$$

which has also an inverted-U shape due to the negative impact of c on the sum of industry profits and consumers surplus (the first term) and on R&D costs (the second term). Clearly total welfare is $\mathbb{E}\left(W(c^*)\right)$ pre-merger and $\mathbb{E}\left(W(c^M)\right)$ post-merger. The implication is that the merger delivers also a reduction of total if the merging firms are efficient enough in the pre-merger situation. However, the welfare impact depends on the R&D technology of the incumbents, which is irrelevant for consumer surplus, therefore a reduction in the latter may be associated with either a reduction or an increase of welfare.[11]

2.3 Bundling

Until now, the only purpose of the merger was to coordinate the R&D activity, therefore the incumbents could have reached the same result with an R&D joint venture. I now introduce a new purpose of the merger, which is related to the pricing stage. Let us consider the possibility of a commitment to *pure bundling*, in the sense that the merged firm offers the bundle at a single price and commits not to sell any of its components as standalone products even if one of the entrants innovates. In such a case, unless both entrants innovate, the merged entity sets a unitary price of the bundle and obtains $1-c_A-c_B$, while consumers have no surplus. Only when both the entrants innovate, they can outbid the incumbents obtaining c_A and c_B, which leaves consumer surplus $1-c_A-c_B$. The expected profits of the merged entity are:

$$\mathbb{E}(\pi_M^B) = (1-z_A z_B)(1-c_A-c_B) - I(\bar{c}-c_A) - I(\bar{c}-c_B)$$

and the expected profits of the entrant producing component $i, j = A, B$ are:

$$\pi_i^e = z_i z_j c_i - \frac{z_i^2}{2}$$

Under simultaneous investments, the FOCs of the incumbents are $1 - z_i z_j = I'(\bar{c}-c_i)$ for $i, j = A, B$, and the FOCs of the entrants are $z_i = z_j c_i$ for

[11] For instance, assuming $\lambda = 1$ and the quadratic cost function, total welfare $\mathbb{E}\left(W(c)\right) = (1-c)^2 - \beta(\frac{1}{2}-c)^2$ is maximized at the first best level c^{FB}, which is above or below the one maximizing consumer surplus for β above or below 2.

$i, j = A, B$. The only Nash equilibrium satisfies:

$$1 = I'(\bar{c} - c^B) \quad \text{and } z^B = 0 \tag{12}$$

which implies too much investment by the incumbents and too little by the entrants relative to the first best. With a quadratic investment cost $I(\bar{c} - c) = \beta(\bar{c} - c)^2$ and $\bar{c} = 1/2$ the equilibrium under bundling has:[12]

$$c^B = \frac{1}{2}\left(1 - \frac{1}{\beta}\right)^+ \tag{13}$$

while for $\beta < 1$ the incumbents reduce the marginal cost to zero.

Bundling reduces the incentives to invest of the entrants as in Choi and Stefanadis (2001), and the impact is magnified by a form of moral hazard due to the fact that each firm does not internalize the beneficial impact of its investment on the other. Here, this increases further the investment of the incumbents because of a scale effect: the certain rent has a larger expected size compared to the merger without bundling, and this incentivizes further investment of the merging firms. However, none of the benefits of this additional investment reaches consumers since the incumbents appropriate all of it.

The profits of the merged entity are $\pi_M^B = 1 - 2c^B - 2I(\bar{c} - c^B)$, which is independent from the degree of price squeeze. It is immediate to verify that pure bundling weakly increases joint profits compared to the pre-merger situation for $\lambda = 0$ and increases them for $\lambda = 1$, but it does not necessarily increase profits for intermediate values of λ when the incumbents are relatively inefficient before the merger: this is indeed the case where the merger without bundling optimizes the trade-off between appropriating the rents of a single innovator between the entrants and leaving enough incentives to the same entrants to invest.[13]

The comparison of the profits with and without pure bundling is now straightforward. With a full price squeeze ($\lambda \to 0$) I obtain $c^M = c^B$ and zero investment by the entrants in both regimes, therefore $\mathbb{E}(\pi_M) = \pi_M^B$. When the entrant can extract the entire surplus of its innovation ($\lambda = 1$), I have $z^M = c^M > c^B$ and:

$$\mathbb{E}(\pi_M) = (1 - (c^M)^2)(1 - 2c^M) - 2I(\bar{c} - c^M) < 1 - 2c^M - 2I(\bar{c} - c^M) < \pi_M^B$$

since c^B maximizes $1 - 2c - 2I(\bar{c} - c)$. Nevertheless, for low levels of λ and high levels of c^M, a merger without pure bundling must be superior because it allows the merged firm to extract some of the surplus created by the entrants, which is useful when the incumbents are not very efficient. Therefore, by continuity, a commitment to pure bundling for the merged entity is profitable at least when λ

[12] The profits $\pi_M^B = 1/2\beta$ are above the profits without bundling.

[13] When $c = \bar{c}$ (there is no investment by the incumbents), it is easy to verify that the merger with pure bundling is profitable if and only if $\lambda > 2/3$ and $\bar{c} < \frac{3\lambda - 2}{2(2\lambda - 1)}$. This requires that the merging firms are efficient enough. Indeed, pure bundling allows them to reduce the probability of joint entry at the cost of giving up to the appropriation of some rents in case of innovation by one entrant only. When the merging firms are already quite efficient, this cost is small because the rents to be appropriated in case of a single innovation are small, so the merger with pure bundling is profitable.

is high enough. This allows me to draw the following conclusions on the impact of a merger between producers of complements:

Proposition 2. *Assuming competition in posted prices, simultaneous investments in R&D and a quadratic cost of product innovation, when a commitment to pure bundling is feasible:*

a) *the merged entity adopts pure bundling when a single innovator appropriates a large enough fraction of the value of its innovation, and in such a case the merger reduces further the investment of the entrants and increases further the investment of the merging firms, always with a reduction in consumer surplus;*

b) *otherwise the merger occurs without bundling and delivers a reduction of consumer surplus if the merging firms are efficient enough in the pre-merger situation.*

Last, I note that total welfare after a merger with bundling is just given by the profits of the merged firm. It is then easy to verify that the adoption of bundling is compatible with an increase in welfare even if it always harms consumers.

3 Extensions

In this section I consider few realistic extensions of the baseline model to verify if the possibility of anti-competitive effects of the merger generalizes in important dimensions, namely with more general cost functions for the entrants, bargaining on prices, pre-commitments on R&D by the incumbents and the possibility of a counter-merger of the entrants. I retain for the rest of this section the assumption of a rigid demand structure, which is relaxed in the next section.

3.1 General technology for product innovations

First, I consider a general cost function for the investment of the entrants, $F(z)$ with $F'(z) > 0$, $F''(z) > 0$, $F(0) = F'(0) = 0$ and $F'(1) \geq \bar{c}$. Following the same steps as above, in the pre-merger situation one can obtain a symmetric equilibrium where the strategies of the incumbents and the entrants satisfy the following relations:

$$\frac{1 - z^2}{2} = I'(\bar{c} - c) \quad \text{and} \quad F'(z) = zc + (1 - z)\lambda c \tag{14}$$

The first condition provides a continuous function expressing the marginal cost of the incumbents in function of the probability of innovation of the entrants:

$$c(z) = \bar{c} - I'^{-1}\left(\frac{1 - z^2}{2}\right) \quad \text{with } c'(z) = \frac{z}{I''(\bar{c} - c(z))} > 0$$

where $c(0) \geqslant 0$ and $c(1) = \bar{c}$ (convexity holds if $I''' \geq 0$). The second condition defines another continuous function $z(\lambda, c)$ if the technology is convex enough, namely if the elasticity of the marginal cost $\sigma(z) \equiv F''(z)z/F'(z)$ is larger than $[1+\lambda/(1-\lambda)z]^{-1}$ for any λ, as I will assume. Inverting it, allows me to define a second relation in the space (z, c) as:

$$C(z) = \frac{F'(z)}{z(1-\lambda)+\lambda} \quad \text{with } C'(z) = \frac{C(z)}{F'(z)}[F''(z) - (1-\lambda)C(z)] > 0$$

where $C(0) = 0$ and $C(1) > \bar{c}$, and the sign of the derivative relies on the assumption of convexity (which was always satisfied in the quadratic example where $\sigma(z) = 1$). These conditions are sufficient to insure that the two functions cross at an equilibrium $c(z) = C(z) \in [0, \bar{c}]$, which is assumed to be unique for any λ.[14] Since the probability of innovation derived from the optimality conditions of the entrants, $z(\lambda, c)$, is still increasing in c under our assumptons, consumer surplus $\mathbb{E}(CS(c)) = z(\lambda, c)^2(1-2c)$ remains an inverted-U curve of the marginal cost for $c \in [0, \frac{1}{2}]$.

In the post-merger situation the equilibrium strategies of the incumbents and the entrants satisfy the following relations:

$$(1-z)(1+\lambda z) = I'(\bar{c}-c) \quad \text{and} \quad F'(z) = zc + (1-z)\lambda c \tag{15}$$

and the only difference compared to the case above is that the post-merger function $c(z) = \bar{c} - I'^{-1}[(1-z)(1+\lambda z)]$ is strictly below the pre-merger function for any z. This confirms the increase in investment for the incumbents after the merger and the reduction of investment for the entrants. As before, the merger must be profitable and reduces consumer surplus if the merging firms are already efficient enough before the merger (because, in such a case, it acts on the upward sloping side of the $\mathbb{E}(CS(c))$ function).

In case of pure bundling the equilibrium strategies satisfy the new symmetric optimality conditions:

$$1 - z^2 = I'(\bar{c}-c) \quad \text{and} \quad F'(z) = zc$$

The first one delivers a function $c(z) = \bar{c} - I'^{-1}\left(1-z^2\right)$ which is weakly below the corresponding one for the merger without bundling for any z. The second condition confirms the existence of an equilibrium with $z^B = 0$ and $c^B = c(0)$ with the same implications as in the baseline model. However, when $C(z) = F'(z)/z$ is increasing, which requires a cost function convex enough that $\sigma(z) > 1$, I obtain another equilibrium with positive investment by the entrants satisfying:

$$1 - z^{B2} = I'\left[\bar{c} - \frac{F'(z^B)}{z^B}\right] \tag{16}$$

Remarkably, also such an equilibrium implies less investment by the entrants and more by the incumbents compared to the pre-merger situation. Therefore

[14] Unicity requires additional conditions on the shape of the technology, insuring $c'(z) < C'(z)$ in equilibrium for any λ. With our quadratic specifications, $c(z) = 1/2 - (1-z^2)/4\beta$ is convex, $C(z) = z/[z(1-\lambda)+\lambda]$ is convex if and only if $z < \lambda/(1-\lambda)$, and the interior equilibrium is unique for any $\beta > 1/2$.

a commitment to bundling can still be profitable and reduce consumers surplus. For instance, consider the cost function $F(z) = \frac{z^{1+\sigma}}{1+\sigma}$ where $\sigma > 0$ is the constant elasticity of the marginal cost, and assume $\lambda = 1$. The pre-merger relation for the entrants delivers $z = c^{\frac{1}{\sigma}}$ while pure bundling implies an equilibrium with $z^B = 0$ and, when $\sigma > 1$, another equilibrium with $z^B = c^{B\frac{1}{\sigma-1}} < c^{\frac{1}{\sigma}}$ (since $c < 1$).[15] I conclude with the following:

Proposition 3. *Assuming an increasing and convex cost of innovation the merger is profitable, reduces the investment of the entrants and increases the investment of the merging parties, but pure bundling does not necessarily deter entry.*

3.2 Bargaining on prices

It is sometimes the case that pricing of complement inputs by dominant producers is the fruit of bargaining rather than competition in posted prices.[16] It has been argued (for instance see Nalebuff, 2002) that in case of perfect information on the willingness to pay on the demand side and bargaining on prices, a merger between producers of complements is unlikely to exert anti-competitive effects because the One Monopoly Profit Theorem holds. In spite of this, I show that an extension of our model to bargaining on prices between producers (not on investment, which is assumed not contractable, in the spirit of Grossman and Hart, 1986) does not alter the earlier results.

Let us reconsider the basic model where the pricing stage is characterized by bargaining. In particular, let us assume Nash bargaining with equal bargaining power when there are two effective suppliers of each component, namely the two incumbents (if there is no successful innovation by the entrants) or the two entrants (when they jointly innovate). Otherwise, let us assume competition between two rival suppliers of a component to partner with the monopolistic supplier of the other component.

In the pre-merger situation, if there is no successful innovation by either entrant, the incumbents bargain to share the surplus $1-c_A-c_B$: Nash bargaining leads to equal rents. If both entrants innovate, they bargain to share equally the surplus $c_A + c_B$. Finally, if only one entrant innovates, say in component $i = A, B$, it is willing to reduce its rent to c_i to convince the other incumbent to partner with it (the competing incumbent cannot profitably offer anything better than this), leaving to the incumbent the residual rent $1 - c_A - c_B$.[17]

[15] With the quadratic cost of investment for the incumbents and $\sigma = 3$ one can solve the example for $c^B = \frac{\beta-1}{2\beta-1}$ and $z^B = \sqrt{c^B}$ for $\beta > 1$.

[16] This is the case for the mentioned merger between Qualcomm and NXP, where bargaining takes place for each new device by OEMs. Other factors of this case, related to bargaining with the same OEMs, such as buyer power, are not discussed here.

[17] Of course this is the state of the world where there are three players and economic theory does not offer a definitive solution to the problem of multilateral bargaining. Our solution seems relevant for the practical situation under investigation.

Accordingly, I can express the expected profits of the incumbents producing component $i, j = A, B$ as:

$$\mathbb{E}(\pi_i) = (1-z_i)(1-z_j)\left(\frac{1-c_i-c_j}{2}\right) + (1-z_i)z_j(1-c_j-c_i) - I(\bar{c}-c_i) \quad (17)$$

and the expected profits of the entrant in component $i, j = A, B$ as:

$$\mathbb{E}(\pi_i^e) = z_i z_j\left(\frac{c_i+c_j}{2}\right) + z_i(1-z_j)c_i - \frac{z_i^2}{2} \quad (18)$$

Under simultaneous investments, the equilibrium satisfies $\frac{1-c^2}{2} = I'(\bar{c}-c)$ and $z = c$, which is identical to the equilibrium under posted prices for $\lambda = 1$.

Consider the merger without bundling. If there is no successful innovation by either entrant, the merger entity obtains $1 - c_A - c_B$. If both entrants innovate, they bargain to share equally the surplus $c_A + c_B$. Finally, if only one entrant innovates, say in component $i = A, B$, this has to bargain with the merged entity, whose outside option is now the surplus from the internal solution. In such a case Nash bargaining delivers the rent for the innovator:

$$e_i = \arg\max\{\log[1-c_j-e_i-(1-c_A-c_B)] + \log e_i\} = \frac{c_i}{2}$$

leaving the rent $1 - c_j - c_i/2$ to the merged firm. Notice that the rent of the single innovator is reduced post-merger because the merged entity is now internalizing the impact of bargaining on both incumbents and has *de facto* a higher negotiation power compared to the single incumbents in the pre-merger situation. The expected profits of the merged firm become:

$$\begin{aligned}\mathbb{E}(\pi_M) &= (1-z_A)(1-z_B)(1-c_A-c_B) + (1-z_A)z_B\left(1-\frac{c_B}{2}-c_A\right) \\ &\quad +(1-z_B)z_A\left(1-\frac{c_A}{2}-c_B\right) - I(\bar{c}-c_A) - I(\bar{c}-c_B)\end{aligned}$$

and the expected profits of the entrant in component $i, j = A, B$ are:

$$\mathbb{E}(\pi_i^e) = z_i z_j c_i + z_i(1-z_j)\frac{c_i}{2} - \frac{z_i^2}{2}$$

Following the usual analysis, the innovation stage delivers a symmetric equilibrium with:

$$\frac{(1-c^M)(4-c^M)}{(2-c^M)^2} = I'(\bar{c}-c^M) \quad \text{and} \quad z^M = \frac{c^M}{2-c^M} \quad (19)$$

which implies a further increase in the investment of the merging firms and a further reduction of the probability of innovation of the entrants. The case of pure bundling, instead, confirms exactly the equilibrium under price competition as in (12), with the same implications as in the baseline model. Again, the merger increases investment and profits of the incumbents (even more under bundling) and can decrease consumer surplus (always under bundling):[18]

Proposition 4. *Assuming Nash bargaining between two effective suppliers of each component and competition between two rival suppliers of a component to partner with the monopolistic supplier of the other component, the pre-merger equilibrium is equivalent to the one with price competition and full appropriability of innovations, the merger without bundling is more profitable reducing further the investment of the entrants and increasing further the one of the merging parties, and the impact of the merger with bundling is unchanged.*

3.3 Innovation by leaders

Incumbents with the leading-edge technologies are often first movers in R&D decisions compared to entrants engaged in probabilistic innovation, and they can also extract a strategic advantage from this by pre-committing to a higher investment (see Czarnitzki *et al.*, 2014, for some theory and evidence). In this perspective it is not obvious what is the additional impact of a merger on the incentives to invest of incumbents and entrants. I explore this issue here.

The baseline model is extended to three stages: in the first stage the incumbents invest simultaneously in cost reductions, in the second stage the entrants invest to develop alternative products knowing the marginal cost of the incumbents, and in the third stage price competition takes place. The last stage is the same as in the benchmark model, with competition in posted prices. What is important, therefore, is to understand what is going on in the first stage on the basis of expectations on the second stage.

The incumbents understand that the investment of the entrants satisfy $z_i = z_j c_i + (1 - z_j)\lambda c_i$ for $i, j = A, B$, which gives reaction functions $z_i(c_i, c_j) = \frac{\lambda c_i[1+(1-\lambda)c_j]}{1-c_i c_j(1-\lambda)^2}$ increasing in each marginal cost. To focus on the crucial aspects of this extension, in what follows I consider the simpler case where $\lambda = 1$, so that $z_i(c_i, c_j) = c_i$.

Let us start from the pre-merger situation. In the first stage each incumbent $i = A, B$ has expected profits:

$$\mathbb{E}(\pi_i) = (1 - c_i)(1 - c_j)\frac{1 - c_i - c_j}{2} + (1 - c_i)c_j(1 - c_j - c_i) - I(\bar{c} - c_i) \quad (20)$$

Computing the FOCs for the incumbents, the symmetric equilibrium implies:

$$\frac{(1 + c)(2 - 3c)}{2} = I'(\bar{c} - c) \quad \text{and} \quad z = c \quad (21)$$

[18] This can be verified with the quadratic specification used above, where the adoption of bundling is also optimal. In case of $\beta = 1$ we have simple solutions for the marginal cost, which is $c = 0.27$ before the merger and $c^M = c^B = 0$ after the merger: the joint profits are 0.32 before the merger and 0.5 after, while consumer surplus drops from 0.033 to 0. For $\beta = 2$ the marginals cost pre-merger and post merger without and with bundling are respectively $c = 0.39$, $c^M = 0.27$ and $c^B = 0.25$ with joint profits 0.13, 0.25 and 0.27 and consumer surplus 0.032, 0.013 and 0.

which can be compared to the earlier equilibrium. With $\lambda = 1$ the marginal benefit of investment for the incumbents in the simultaneous moves game was $(1 - c^2)/2$, always below the corresponding level here. Accordingly, the incumbents exploit the precommitment to invest more in R&D because this induces the entrants to invest less: this is a classic Stackelberg effect in the presence of strategic substitutability between incumbents and entrants.

Consider the merger now. Maximizing the joint profits of the merged firms with respect to c_A and c_B, the symmetric equilibrium requires:

$$1 + c^M(1 - 3c^M) = I'(\bar{c} - c^M) \quad \text{and} \quad z = c^M \tag{22}$$

Comparing (21) and (22), one can verify that the investment of the incumbents is increased because the merged firm internalizes the Cournot complementarities in cost reduction (compared to the pre-merger situation) and uses R&D strategically to reduce the investment of the entrants (compared to the simultaneous moves game). The consequence is of course that the probability of innovation of the entrants is now decreased. As usual, this has an anti-competitive impact on consumers as long as the incumbents are efficient enough before the merger.

Finally, let me consider the bundling option. As without a pre-commitment of the incumbents, the entrants do not invest, therefore the equilibrium remains as in (12). The investment of the entrants drops as usual under bundling, but something new emerges for the investment of the incumbents. It is indeed immediate to show that $c^B \lesseqgtr c^M$ if and only if $c^M \gtreqless \frac{1}{3}$. When the incumbents are relatively inefficient ($c^M > 1/3$), they increase investment under bundling for the usual reason that deterring entry makes their cost reduction more profitable. However, when the incumbents are relatively efficient ($c^M < 1/3$), they reduce their investment when they can adopt bundling. In this case, bundling and investment in cost reductions are substitute tools in reducing the probability of entry: once a commitment to bundling can be credibly adopted, the merged entity can reduce its investment in R&D without increasing the likelihood of entry by the rivals. I take stock of this in the following result:

Proposition 5. *Allowing for a pre-commitment by the incumbents on their R&D, the merger reduces the investment of the entrants and increases the investment of the merging parties, but the adoption of bundling can reduce the investment of the merged firm in cost reduction.*

3.4 Counter-merger

At last, I briefly consider the possibility of a counter-merger of the entrants taking place before innovation choices.[19] This could also be interpreted as an R&D joint venture since its purpose is just to coordinate investments. The interesting case is the one where the merged incumbents are not engaged in

[19] Notice that the entrants have an incentive to merge even without a merger by the incumbents.

bundling. The entrants maximize the joint profits:

$$\mathbb{E}\left(\pi^e_{CM}\right) = z_A z_B (c_A + c_B) + z_A(1-z_B)\lambda c_A + z_B(1-z_A)\lambda c_B - \frac{z_A^2}{2} - \frac{z_B^2}{2} \quad (23)$$

with optimality conditions $z_i = z_j(c_i + c_j) + (1-z_j)\lambda c_i - z_j \lambda c_j$ that determine the symmetric equilibrium investment:[20]

$$z_{CM}(\lambda, c) = \frac{\lambda c}{1 - 2c(1-\lambda)} \quad (24)$$

while the marginal cost of the merged firm solves $(1-z)(1+\lambda z) = I'(\bar{c} - c)$. Since $z_{CM}(\lambda, c) > z(\lambda, c)$ for any $\lambda \in (0,1)$, the counter-merger reduces the investment of the incumbents and increases the one of the entrants. This makes the entrants better off and increases also consumer surplus for a given c. However, it is now possible for the initial merger to become unprofitable for intermediate values of λ when the gains from coordination between incumbents are more than compensated by the losses due to the coordination of the entrants. If the merger takes place, as before, it is detrimental to consumers when the incumbents are already efficient enough.

Instead, when the merger with pure bundling is profitable in the absence of a counter-merger, it remains profitable because a counter-merger cannot generate R&D by the entrants in front of a credible bundling strategy. Once again, bundling reduces consumer surplus. Most important, the possibility of a counter-merger enlarges the set of parameters for which a commitment to bundling is optimal (it takes a lower λ for this to hold), and therefore it makes consumer harm more likely. I summarize these insights as follows:

Proposition 6. *The entrants find it profitable to merge to increase R&D investment after a merger of the incumbents without commitment to bundling, but not after a merger with a commitment to bundling.*

4 Downward sloping demand and pro-competitive effects

In this section I generalize the model to take into account a downward sloping demand for the composite good. This applies whenever the demand for the final good is not rigid or, in any case, when in the downstream market there is a supply of imperfect substitutes for the goods of the incumbents, therefore the merging firms face an elastic demand for their composite good. It is immediate to extend the analysis introducing downstream competition with a rival producer of a substitute composite good, but this enhances the pro-competitive effects of the merger since it strengthens price competition, therefore I will only

[20] Contrary to what happens in case of R&D investments that are substitute and duplicative (see Denicolò and Polo, 2017), here the second order conditions for the optimal symmetric investment are always satisfied.

consider this possibility at the end of the section.[21] Facing a downward sloping demand, the merged entity has always incentives to reduce prices with additional indirect effects on R&D: such new pro-competitive effects can more than compensate the anti-competitive effects emphasized until now, but of course it is the shape of the demand function that determines whether this is the case.

To microfound an elastic demand function I assume that final consumers have a quasilinear indirect utility $V = v(P) + E$, where E is income and $v(P)$ is decreasing and convex in the total price $P = p_A + p_B$, where p_i is the price of component $i = A, B$, with $v(1) = 0$ to preserve the unitary choke price. The demand function is $Q = |v'(P)|$ by Roy's identity. It is particularly useful to adopt an isoelastic specification $v(P) = \frac{(1-P)^{\gamma+1}}{\gamma+1}$ with $\gamma \geq 0$, that provides the demand function:[22]

$$Q = (1 - p_A - p_B)^{\gamma} \tag{25}$$

This has the advantage of nesting the case of a fixed willingness to pay when $\gamma \to 0$ and the familiar case of a linear demand when $\gamma = 1$, as well as other cases where $\gamma \in (0, \infty)$ parametrizes the demand elasticity $\left|\frac{d \ln Q}{d \ln P}\right| = \frac{\gamma P}{1-P}$. I also assume that the innovation of the entrants is not drastic, in the sense that the unconstrained Bertrand equilibrium prices they would set upon entry are always above the marginal cost of the competing incumbent, therefore the entrants must be engaged in limit pricing. The *ansatz* for this, which must hold in equilibrium, is $c < 1/(\gamma + 3)$, requiring a low marginal cost in equilibrium or a demand that is not too convex.[23]

Let me revisit price competition depending on which goods are developed. If there is no successful innovation by either entrant the profits of the incumbents are $\pi_i = (1 - p_A - p_B)^{\gamma}(p_i - c_i)$. In case of independent incumbents, this implies a Bertrand equilibrium with prices $p_i = \frac{1+(1+\gamma)c_i - c_j}{\gamma+2}$,[24] which generates profits:

$$\pi_i = \frac{\gamma^{\gamma}(1 - c_A - c_B)^{\gamma+1}}{(2+\gamma)^{\gamma+1}}$$

In case of a merged entity, the two prices are chosen to maximize joint profits,

[21] Alternatively, one can think of the merged firm as a leader in the downstream market setting prices on the reaction function of a follower or a fringe of competitors.

[22] The corresponding direct utility is:

$$U = Q - \frac{\gamma Q^{\frac{1+\gamma}{\gamma}}}{1+\gamma} + Q_0$$

where Q_0 is the consumption of the *numeraire*. Extensions to multiple goods exploiting indirect additivity are gaining rapid adoption in the analysis of monopolistic and imperfect competition (see Bertoletti and Etro, 2016, 2017, and Nocke and Schutz, 2018).

[23] It is not difficult to extend the analysis to the case where the innovation is drastic with similar results. We should remark that in such a case a counter-merger by the entrants could induce further gains for consumers by fixing also the Cournot complementarity problem in pricing of the entrants.

[24] Notice that $\lim_{\gamma \to 0} p_i = \frac{1+c_i-c_j}{2}$ as in the baseline model with $\lambda = 1$, $\lim_{\gamma=1} p_i = \frac{1+2c_i-c_j}{3}$ as expected under a linear demand, and $\lim_{\gamma \to \infty} p_i = c_i$.

which delivers $P = \frac{1+\gamma(c_A+c_B)}{\gamma+1}$,[25] which is below the earlier total price (since the merger fixes the Cournot complementarity in pricing). In such a case the joint profits increase to:

$$\pi_M = \frac{\gamma^\gamma(1-c_A-c_B)^{\gamma+1}}{(1+\gamma)^{\gamma+1}}$$

If both entrants innovate, they outbid the incumbents selling at $p_i = c_i$ for $i = A, B$, and obtain the following profits:

$$\pi_i^e = (1-c_A-c_B)^\gamma c_i$$

Finally if only one entrant innovates, say in component $i = A, B$, it adopts limit pricing $p_i = c_i$ leaving the other incumbent $j = B, A$ to maximize its profits $\pi_j = (1-p_j-c_i)^\gamma(p_j-c_j)$, which leads to the price $p_j = \frac{1+\gamma c_j - c_i}{\gamma+1}$ under our assumptions.[26] This avoids the multiplicity of sub-game equilibria of the Choi and Stefanadis (2001) model and delivers the profits of the entrant and the incumbent given respectively by:

$$\pi_i^e = \gamma^\gamma \left(\frac{1-c_A-c_B}{\gamma+1}\right)^\gamma c_i \quad \text{and} \quad \pi_j = \gamma^\gamma \left(\frac{1-c_A-c_B}{\gamma+1}\right)^{\gamma+1}$$

I can now examine the innovation stage starting from two extreme cases.

4.1 The limit case with $\gamma \to 0$

This case delivers the limit of a perfectly rigid demand with a unitary willingness to buy, but with the key difference that the equilibrium corresponds to the one of the benchmark model with $\lambda = 1$ since equilibrium multiplicity disappears. It is useful to amend the ambiguous results of the baseline model as follows:

Proposition 7. *In the limit case of a perfectly rigid demand, when a commitment to pure bundling is feasible, the merged entity adopts it and the merger increases the investment of the incumbents, and reduces the investment of the entrants and consumer surplus.*

A by-product of this allows me to revisit results of the Choi and Stefanadis (2001) model: bundling by a producer of complements is always profitable in front of an almost perfectly rigid demand.

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[25] In this case $\lim_{\gamma\to 0} P = 1$ confirms full extraction of the consumer rents with a fixed willingness to pay, $\lim_{\gamma=1} P = \frac{1+c_A+c_B}{2}$ and $\lim_{\gamma\to\infty} P = c_A + c_B$.

[26] The unconstrained Bertrand equilibrium between the entrant and the incumbent would deliver a price $p_i = \frac{1-c_j}{\gamma+2}$ for the entrant, which allows one to confirm the *ansatz* above, namely $\frac{1-c}{\gamma+2} > c$, for $c < 1/(\gamma+3)$.

4.2 The case of a linear demand

Replacing $\gamma = 1$ in our earlier derivations for pre-merger outcomes, the expected profits of the incumbents producing component $i, j = A, B$ become:

$$\mathbb{E}(\pi_i) = (1-z_i)(1-z_j)\frac{(1-c_i-c_j)^2}{9} + (1-z_i)z_j\frac{(1-c_i-c_j)^2}{4} - I(\bar{c}-c_i) \quad (26)$$

and the expected profits of the entrants in component $i, j = A, B$ are:

$$\mathbb{E}(\pi_i^e) = z_i z_j (1-c_i-c_j)c_i + z_i(1-z_j)\frac{(1-c_i-c_j)c_i}{2} - \frac{z_i^2}{2} \quad (27)$$

Under simultaneous investments, the FOCs of incumbents and entrants are respectively:

$$(1-z_i)(1-z_j)\frac{2(1-c_i-c_j)}{9} + (1-z_i)z_j\frac{(1-c_i-c_j)}{2} = I'(\bar{c}-c_i)$$

and

$$z_i = z_j(1-c_i-c_j)c_i + (1-z_j)\frac{(1-c_i-c_j)c_i}{2}$$

where I now obtain strategic complementarity not only between the entrants, but also between the incumbents: a higher investment by an incumbent (an entrant) induces the other incumbent (entrant) to invest more as well. Imposing symmetry, the probability of innovation of the entrants becomes now:

$$z(c) = \frac{c(1-2c)}{2-c(1-2c)} \quad (28)$$

which is an increasing function of the marginal cost of the incumbents in the relevant range ($z'(c) > 0$) due to the assumption that the innovations of the entrants are not drastic (notice that this requires $c < 1/4$): the entrants invest more when the marginal cost of the incumbents increases as in the baseline model.

The FOCs of the incumbents in a symmetric equilibrium become:

$$\frac{(1-2c)(1-z)(4+5z)}{18} = I'(\bar{c}-c) \quad (29)$$

The left hand side is increasing in the investment of the entrants in the relevant range ($c'(z) < 0$): this result differs from the baseline model and it is due to the substantial increase in profits for the incumbents when the non-competing entrant innovates. Clearly, one can use both conditions to obtain a unique equation for the pre-merger value of the marginal cost of the incumbents and derive therefore the equilibrium probability of innovation,[27] but this is not necessary

[27] In particular, the equilibrium marginal cost of the incumbents must now satisfy:

$$\frac{(1-2c)[1-c(1-2c)][8+c(1-2c)]}{9[2-c(1-2c)]^2} = I'(\bar{c}-c)$$

for our subsequent comparisons. In the pre-merger situation the joint profits of the incumbents can be computed as $\mathbb{E}(\pi_{Joint}) = \frac{[4+z(c)-5z(c)^2](1-2c)^2}{18} - 2I(\bar{c}-c)$. The expected consumer surplus is a weighted average of consumer surplus in the four states of the world, and can be simplified as:

$$\mathbb{E}(CS(c)) = \frac{[2+5z(c)+11z(c)^2](1-2c)^2}{36} \tag{30}$$

which is a strictly positive and non-monotonic function of c (to be evaluated at the equilibrium marginal cost characterized above).

I now move to consider the merger without bundling. The optimality conditions of the entrants are the same as before, while the equilibrium condition for the investment of the merged firm becomes:[28]

$$\frac{(1-2c^M)(1-z^2)}{2} = I'(\bar{c}-c^M) \tag{31}$$

whose left hand side, representing the marginal benefit of investment, is always larger than the corresponding expression pre-merger. This clearly implies that the merger induces the incumbents to invest more and set lower prices, and it also means that the merger is always profitable with expected profits $\mathbb{E}(\pi_M) = \frac{[1-z(c^M)^2](1-2c^M)^2}{4} - 2I(\bar{c}-c^M)$. Under our assumptions it also implies that the investment of the entrants must decrease post-merger. The expected consumer surplus can be computed as:

$$\mathbb{E}\left(CS_M(c^M)\right) = \frac{[1+3z(c^M)^2](1-2c^M)^2}{8} \tag{32}$$

which is again an inverse-U function of the marginal cost c^M with $\mathbb{E}(CS_M(c)) > \mathbb{E}(CS(c))$ for any possible c. The first implication is that without investment by the incumbents, i.e. $c = c^M = \bar{c}$, the merger increases always consumer surplus. If there is endogenous investment by the incumbents, the merger tends to benefit consumers when the incumbents are inefficient, because the interest of incumbents and consumers in reducing costs are aligned: the gains from reducing high prices in all states of the world are large and the losses from reducing the probability of joint entry (with prices below those of other states of the world) are small. The merger could harm consumers only if the incumbents are initially efficient enough. However, this is now a necessary condition, but not a sufficient one, because the merger must also induce a large enough reduction in the probability of innovation (a large enough $c^M - c$) for consumer surplus to decrease in expected terms. While the extent of this cost reduction depends on the R&D technology of the incumbents, such an anti-competitive outcome cannot occur under our linear demand model.[29]

[28] The equilibrium investment must satisfy:

$$\frac{2(1-2c^M)\left[1-c^M(1-2c^M)\right]}{\left[2-c^M(1-2c^M)\right]^2} = I'(\bar{c}-c^M)$$

[29] Indeed:

Finally, let us consider the possibility of a credible commitment to adopt pure bundling after the merger. This delivers the following expected profits for the merged firm:

$$\mathbb{E}\left(\pi_M^B\right) = (1 - z_i z_j)\frac{(1 - c_i - c_j)^2}{4} - I(\bar{c} - c_i) - I(\bar{c} - c_j)$$

while the profits of the entrants become:

$$\mathbb{E}\left(\pi_i^e\right) = z_i z_j (1 - c_i - c_j) c_i - \frac{z_i^2}{2}$$

It is immediate to derive the unique Nash equilibrium with:[30]

$$\frac{1}{2} - c^B = I'(\bar{c} - c^B) \quad \text{and} \quad z^B = 0 \tag{33}$$

Once again bundling induces entry deterrence and increases the investment of the incumbents beyond the case of a baseline merger. Notice that the profits of the merged firm are $\pi_M^B = \frac{(1-2c^B)^2}{4} - 2I(\bar{c} - c^B)$, which is necessarily above the profits from the merger without bundling. Therefore, when a commitment to bundling is feasible, it is always optimal to adopt it (notice again the contrast with Choi and Stefanadis, 2001). Expected consumer surplus is simply:

$$CS_M^B(c^B) = \frac{(1 - 2c^B)^2}{8} \tag{34}$$

It is now immediate to verify that $\mathbb{E}\left(\pi_{Joint}\right) < \mathbb{E}\left(\pi_M\right) < \pi_M^B$ and $\mathbb{E}\left(CS_M(c)\right) > CS_M^B(c^B) > \mathbb{E}\left(CS(c)\right)$. This confirms that pure bundling is always adopted for entry deterrence purposes when possible. It also follows that a merger with bundling reduces consumer surplus compared to a merger without bundling. However, the merger with bundling cannot make consumers worse off compared to the pre-merger situation, because it leads to a large enough price reduction. This allows us to revise the baseline result as follows:

Proposition 8. *Under a linear demand for the composite good, the merger is profitable, increases the investment of the incumbents, reduces the investment of the entrants and increases consumer surplus. When a commitment to pure bundling is feasible, the merged entity adopts bundling.*

Of course, when the commitment to bundling is not credible, the merger takes place without it and consumers are again better off.

I conclude this section mentioning a relevant extension to downstream competition with a producer of an alternative bundle. The first order impact of

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$$\mathbb{E}\left(CS(c)\right) < \frac{[2 + 5z(1/4) + 11z(1/4)^2](1 - 2c)^2}{36} < \frac{(1 - 2c)^2}{8} < CS_M(c^M)$$

[30] As in the baseline model, a more convex cost function for the entrants can generate positive investment in equilibrium, though always below the pre-merger level.

this extension is to increase the consumer benefits from the merger because the reduction in the price of the merging firms strengthens competition with the downstream rival reducing also its price. The simplest case of Hotelling competition delivers a linear demand $Q=\frac{1}{2}-\frac{P-R}{2}$ where R is the price of the bundle of the downstream rival. One can easily verify that this environment replicates the same qualitative results on the impact of the merger as the earlier model with linear demand.[31]

4.3 The general case

I can finally sketch the analysis of the merger when $\gamma>0$. In the pre-merger situation, the probability of innovation generalizes to:

$$z(c)=\frac{\left(\frac{\gamma}{\gamma+1}\right)^{\gamma}c(1-2c)^{\gamma}}{1-c(1-2c)^{\gamma}\left[1-\left(\frac{\gamma}{\gamma+1}\right)^{\gamma}\right]} \tag{35}$$

which corresponds to $z(c)$ in (28) when $\gamma=1$. The marginal cost pre–merger satisfies:

$$\Psi(c)(1-z(c))\left\{1+z(c)\left[\left(\frac{\gamma+1}{\gamma+2}\right)^{\gamma+1}-1\right]\right\}=I'(\bar{c}-c)$$

where $\Psi(c)\equiv\left(\frac{\gamma(1-2c)}{\gamma+1}\right)^{\gamma}$. The expected consumer surplus can be computed as:

$$\mathbb{E}\left(CS(c)\right)=\left[\frac{(1-z(c))^2\gamma^{\gamma+1}}{(\gamma+1)(\gamma+2)^{\gamma+1}}+\frac{z(c)^2}{\gamma+1}+\frac{2z(c)\left(1-z(c)\right)\gamma^{\gamma+1}}{(\gamma+1)^{\gamma+2}}\right](1-2c)^{\gamma+1} \tag{36}$$

After a merger without bundling the innovation rule for the entrants (35) is unchanged but the investment of the incumbents satisfies:

$$\Psi(c^M)(1-z(c^M)^2)=I'(\bar{c}-c^M)$$

implying lower marginal costs and higher profits, with expected consumer surplus:

$$\mathbb{E}\left(CS_M(c)\right)=\frac{\gamma^{\gamma+1}(1-2c)^{\gamma+1}}{(\gamma+1)^{\gamma+2}}\left[1+z(c)^2\left[\left(\frac{\gamma+1}{\gamma}\right)^{\gamma+1}-1\right]\right] \tag{37}$$

[31] If this rival produces at no cost and all firms choose prices simultaneously, the profits of the independent incumbents without innovations are $\pi_i=\frac{(3-c_A-c_B)^2}{32}$, the profits of the entrants when they both innovate are $\pi_i^e=\frac{c_i(3-c_A-c_B)}{4}$ and the profits when only one entrant innovates are $\pi_i^e=\frac{c_i(3-c_A-c_B)}{6}$ for the innovative entrant and $\pi_i=\frac{(3-c_A-c_B)^2}{18}$ for the other incumbent. The merger reduces the prices of the incumbents as well as of the downstream rivals, generating profits $\pi_M=\frac{(3-c_A-c_B)^2}{18}$ for the merged entity. The equilibrium investment of the entrants follows the rule $z(c)=\frac{c(3-2c)}{12-c(3-2c)}$ unless the merged entity adopts bundling to deter entry. The marginal cost pre-merger satisfies $(3-2c)(9-2z(c)-7z(c)^2)=144I'(\bar{c}-c)$. The marginal cost post-merger satisfies $(3-2c^M)(1-z(c^M)^2)=9I'(\bar{c}-c^M)$ without bundling and $(3-2c^B)=9I'(\bar{c}-c^B)$ with bundling, implying $c^B<c^M<c$.

In case of bundling the equilibrium implies $z^B = 0$ and $\Psi(c^B) = I'(\bar{c} - c^B)$, with lower marginal costs, higher profits and lower consumer surplus compared to the merger without bundling:

$$CS_M^B(c) = \frac{\gamma^{\gamma+1}(1-2c)^{\gamma+1}}{(\gamma+1)^{\gamma+2}} \tag{38}$$

To verify the impact of the merger on consumers, let us consider the simpler case where the incumbents do not invest ($c = \bar{c}$) but can commit to bundling. The identity $\mathbb{E}(CS(\bar{c})) = CS_M^B(\bar{c})$ defines implicitly an increasing function $\gamma(\bar{c})$ such that the merger harms consumers for any $\gamma \in [0, \gamma(\bar{c}))$ and benefits them for $\gamma > \gamma(\bar{c})$. For instance, it can be computed $\gamma(0.1) \approx 0.02$, $\gamma(0.2) \approx 0.08$ and $\gamma(0.3) \approx 0.17$. It should be now clear what is the role of the parameter γ which determines the demand elasticity. Reducing γ toward zero makes it more likely that the merger becomes anti-competitive because a lower portion of the gains created by the merger and by the entrants is translated to consumers and a higher portion is appropriated by the incumbents. Instead, increasing γ makes it more likely that the merger increases consumer surplus by reducing expected prices due to both the Cournot complementarity effect and the innovation effect.

Allowing for a positive investment by the incumbents preserves the optimality of the merger and of bundling. Of course, the set of parameter values under which the merger is pro- or anti-competitive changes with the cost reduction technology. For instance, adopting the earlier quadratic cost function $I(\bar{c} - c) = \beta(\bar{c} - c)^2$ where $\beta > 0$ parametrizes the difficulty of process innovation,[32] the space (β, γ) can be divided in a low-γ and high-β region where the merger is anti-competitive, because it generates low gains from the internalization of price and R&D complementarities between incumbents and large losses from entry foreclosure, and a complementary region with high-γ and low-β where the merger is pro-competitive because consumers can appropriate large benefits from cost and price reductions.

5 Conclusion

The model presented here applies to the frequent cases of conglomerate mergers between firms producing complement products in industries where R&D is important. When the demand for the composite good is rigid, for instance because it is a "must have" for the production of a final good, mergers can raise anti-competitive concerns because the direct positive effects for consumers from the strategies of the merging firms (lower prices and higher R&D) are more than

[32] Notice that, assuming $\bar{c} = 1/2$, the marginal cost after the merger with bundling can be computed in closed form solution as:

$$c^B = \frac{1}{2}\left[1 - \left(\frac{\gamma^\gamma}{(\gamma+1)^\gamma \beta}\right)^{\frac{1}{1-\gamma}}\right] \quad \text{for } \beta > \left(\frac{\gamma}{\gamma+1}\right)^\gamma$$

which generalizes (13).

compensated by the indirect negative effects from the R&D investment of the non-merging firms. Such an outcome is overturned when the demand for the composite good is elastic enough (for instance due to substitutability with alternative products): in such a case the merger increases consumer surplus because a big enough portion of the benefits of innovation are translated into lower prices, and this happens also when the merging firms adopt pure bundling strategies to limit entry.

The analysis could be extended in other directions, including probabilistic innovation by the incumbents, endogenous size of the innovations of the entrants, research spillovers between the merging firms, imperfect complementarity between different components or imperfect substitutability between rival components, and multiple entrants or endogenous entry in the contest for product innovation. Finally, our one-shot game could be used to study repeated chain store games where pure bundling of multiple components can be adopted even if it is not optimal in the one-shot game. In such a case bundling may serve as a predatory strategy in the long run (see Choi and Stefanadis, 2006), possibly in the presence of asymmetric information *à la* Kreps and Wilson (1982) or Milgrom and Roberts (1982). Mergers between producers of complement goods have been occasionally finalized at strategies of pure bundling aimed at deterring entry of future innovators in single components.

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