Product innovation and pro-competitive horizontal merger with network externalities

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Abstract: Considering horizontally differentiated products with network externalities, we show that horizontal merger may increase investment in product innovation, consumer surplus, and welfare. We show that these results can hold with or without merger-specific efficiency. We provide examples to demonstrate the implications of product differentiation and network effects on investment in product innovation, consumer surplus, and welfare. Hence, the antitrust authorities need not be overly concerned about the effects of horizontal mergers in network industries.

Key Words: Consumer surplus; Product innovation; Merger; Network externality; Product differentiation

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1. Introduction

There is a wide perception that horizontal mergers have perverse effects on innovation. The DOJ/FTC annual reports points to concerns about the adverse effects of mergers on innovation (Gilbert, 2006). In addition to this, the Hutchison 3G/Orange merger case in Austria, COMP/M.6497, December 2012, the *Dow-DuPont* merger case, and more recently, the Microsoft and Blizzard merger case stand testimony to the above concern.

In recent times, a lot of debate is also going on for the adverse social effects of the strategic merger and acquisitions by the tech firms in the network industry. See, e.g., the recent antitrust case against Meta (https://www.bbc.co.uk/news/articles/cedy2ygy50do). FTC/DOJ in US, and the antitrust authorities worldwide, are aiming to reduce the adverse social effects of horizontal mergers by bringing several antitrust lawsuits against them.

In this context, the purpose of this paper is to examine how a horizontal merger in a horizontally differentiated network industry can affect product innovation and consumer surplus. More specifically, in contrast to the usual belief of the "innovation theory of harm" (Federico et al., 2017), suggesting that mergers make the consumers and the society worse off by reducing innovation, we examine whether a merger in a horizontally differentiated network industry can increase product innovation and make the consumers better off.

The innovation theory of harm, articulated in Federico et al. (2017), shows that mergers affect innovation in two ways compared to non-cooperation. First, innovation by a firm creates a negative externality on the rival firm under non-cooperation. Merger tends to reduce the R&D investments compared to non-cooperation by internalising this negative externality. Second, merger tends to increase the R&D investments compared to non-cooperation by increasing the profits ex-post R&D. In their analysis, the first effect dominates the second effect and merger reduces R&D investments.

We consider a duopoly version of the product innovation model of Federico et al. (2017) but with horizontally differentiated network products. More specifically, there are two firms competing in R&D and production. We assume that neither firm has any product to start with and each firm invests in R&D to invent a new product. Success in R&D is uncertain and the probability of success in R&D increases with higher R&D investment. Conditional on the R&D outcome, the firms take their product market decisions. If the firms merge, the merged firm operates two research labs and procures the products conditional on the R&D outcomes. In this framework, we examine whether horizontal merger between the firms can increase R&D investments and consumer surplus, which is often used as the guiding principle for competition policy.[1]

We do our analysis with and without merger-specific efficiency. As Shapiro (2012) explained, merger-specific efficiency occurs when certain activities can be done only in the merged firm but not without merger. As explained below, merger-specific efficiency can occur in our analysis through innovation sharing within the merged firm. Even if only one research lab of the merged firm is successful in R&D, the merged firm can use this technology to produce both products if product differentiation is not created by the technologies.

R&D synergy (or complementarities between different research labs) and merger-specific efficiency are two important issues for policy. R&D synergy is sometimes regarded as speculative since it may be difficult to find information about the detailed mechanism creating the benefit from complementarities. In many

[1] For example, the consumer surplus standard is a guiding principle of competition policy in the U.S., EU, and UK (OECD, 2012, p. 26-27).

jurisdictions, the burden of quantifying R&D synergy falls on the merging firms (may be because they hold more information about the complementarities). On the other hand, merger-specific efficiency is more empirically relevant and much easier to understand. Shapiro (2012) and Denicolò and Polo (2019) explain the differences between these two aspects clearly. Since the merger-specific efficiency is more natural and easier to observe, some researchers argue that the authorities should consider this aspect explicitly from the outset, rather than relegate it to the efficiency defences (Denicolò and Polo, 2019). However, some researchers, although recognise that the merger-specific efficiency is practically relevant, do not consider this aspect as the benchmark for the innovation theory of harm (Valletti, 2025). Hence, we consider the cases of *no merger-specific efficiency* and *merger-specific efficiency* separately.

We show in this framework that a merger may increase investment in product innovation, and the expected consumer surplus. Since merger will increase the expected profit of the firms compared to non-cooperation, it is then immediate that merger will also increase the expected welfare. We show that these results hold *with and without merger-specific efficiency*. Therefore, mergers in the network industries may not be detrimental to society as it can increase both the total profits of the firms and consumer surplus, thereby increasing overall welfare. Hence, the antitrust authorities may need to take more informed decisions by considering the economic effects of mergers more carefully.

Federico et al. (2017) is a special case of our analysis with no network externality and no merger-specific efficiency. As we show below, even if there is no merger-specific efficiency, merger may increase the R&D investments and consumer surplus with network externality but not without network externality, which was the case in Federico et al. (2017). Thus, our paper shows the importance of the network effects when evaluating the effects mergers on innovation and consumer surplus.

Considering a duopoly market structure for our analysis is not overly restrictive since, as Shapiro (2012) argues that a merger is most likely to diminish innovative activity when only two firms pursue a specific line of research to serve a particular need in the absence of appropriability or R&D synergy in the merger. Federico et al. (2017) also show that a merger decreases total investments in the industry if the number of firms is small. Gama et al. (2020) suggest that "… the most relevant market structure in the real world is duopoly (and perhaps triopoly) for the classical examples of industries with network effects ...". Hence, like many other papers in the extant literature (which we review in the next section), we consider a duopoly market structure to examine the effects of a merger.

The remainder of the paper is organized as follows. Section 2 reviews the relevant literature. Section 3 describes the basic model. Section 4 determines the equilibrium R&D investments under non-cooperation. Section 5 determines the equilibrium R&D investments under merger with no merger-specific efficiency, and shows that the merger may increase the R&D investments and consumer surplus. Section 6 determines the equilibrium R&D investments under merger with merger-specific efficiency, and shows that the merger may increase the R&D investments and consumer surplus. Section 7 concludes.

2. Literature review

Using a model with stochastic product innovation, Federico et al. (2017) articulated the innovation theory of harm.[2] This paper has initiated a literature examining the

[2] Federico et al. (2018) generalize Federico et al. (2017) with respect to consumer preferences and competition in the product market but with similar conclusions.

robustness of the innovation theory of harm. There are two strands of the literature examining the robustness of the innovation theory of harm. One strand is focusing on product innovation and the other one is focusing on process innovation.

2.1. Papers on product innovation

Denicolò and Polo (2018) use the framework of Federico et al. (2017) to show that their results may not hold true if the probability of failure in innovation is log-concave in R&D investments.

Mukherjee (2023) also uses the framework of Federico et al. (2017) to show that merger may increase the R&D investments and consumer surplus in the presence of cross ownership and cooperative R&D. He shows the results with no merger-specific efficiency.

Das et al. (2025) consider a dynamic model of product innovation with no merger-specific efficiency to show that merger can be beneficial by making the arrival of the product quicker.

2.2. Papers on process innovation

Mukherjee (2022) uses stochastic process innovation with product differentiation to show that merger may increase the R&D investments and consumer surplus when there is merger-specific efficiency. Valletti (2025) shows that merger-specific efficiency is necessary for the result of Mukherjee (2022).

There are other papers on process innovation considering deterministic R&D instead of stochastic R&D. Bourreau and Jullien (2018) show that a merger can increase investments to cover a larger territory but reduce the coverage of multi product zone.

They show with an example that the merger can increase consumer surplus and welfare if the products are not very differentiated.

Denicolò and Polo (2021) show that merger can be pro-competitive if the total cost of production is significantly convex. Mukherjee and Ray (2024) show that merger can be pro-competitive if firms cannot observe the R&D investments of the rival firms.

Although many merger proposals are in the industries characterized by network externalities, such as in the telecommunications, gaming, and social media,[3] the theoretical literature did not pay much attention to this aspect when examining the effects of horizontal mergers on innovation and welfare. To the best of our knowledge, Banerjee et al. (2025) is the only paper that show the effects of merger in a network industry in the presence of deterministic process innovation where R&D investments reduce the marginal costs of production. They show that merger may increase consumer surplus for moderate product differentiation.[4]

The current paper differs from Banerjee et al. (2025) in some important ways. First, the current paper considers a stochastic model of product innovation, while Banerjee et al. (2025) consider deterministic process innovation. Hence, unlike Banerjee et al. (2025), the marginal benefit from R&D investment is not proportional to output in our paper. Second, unlike Banerjee et al. (2025), we show the implications of the merger-specific efficiency and the divisionalisation strategy of the merged firm.

In general, our paper is related to the broad literature on network effects and cooperation between the firms. With homogeneous goods, industry-wide network compatibility, and *no innovation*, Amir and Lazzati (2011) show that a fewer number

[3] See, e.g., Allen (1988), Sobolewski1 and Czajkowski (2018) for network externalities in the mobile network industry and Liu et al. (2015) for network externalities in the gaming industry.
[4] These papers generally show the results with no merger-specific efficiency, except Denicolò and Polo (2021).

of firms can increase consumer surplus if there is a strong network externality.[5] Amir et al. (2021) consider markets with homogeneous goods, firm-specific network compatibility, and *no innovation*, to compare their results with that of in Amir and Lazzati (2011). With homogeneous products, firm-specific network compatibility, and no innovation, Gama et al. (2020) show that a merger can increase consumer surplus and welfare if the network externality is very strong.

In contrast to these papers, we consider stochastic product innovation in a horizontally differentiated network industry and show the effects of merger on innovation and consumer surplus. In this respect we show the implications of the merger-specific efficiency and the divisionalisation strategy of the merged firm. Our examples show the implications of product differentiation and network effects.

3. The basic model

Like many other papers, such as Bourreau and Jullien (2018), Denicolò and Polo (2018), Mukherjee (2022, 2023, 2024), Mukherjee and Ray (2024), and Banerjee et al. (2025), we consider a duopoly market structure to examine the effects of a merger.

We consider the duopoly version of Federico et al. (2017) with the exception that there are network externalities. There is neither knowledge spillover nor R&D synergy in merger. Consider two symmetric risk-neutral firms, firm 1 and firm 2, which invest in R&D to invent a new product. The R&D process is uncertain. If firm i invests z_i^2 in R&D, it succeeds in R&D with probability z_i, $i = 1,2$.

We assume that firms 1 and 2 produce horizontally differentiated products with network externalities. Product differentiation may occur for different reasons, such as,

[5] The seminal paper by Katz and Shapiro (1985) extends Rohlfs (1974) to imperfect competition with homogeneous products, no cost reducing investments, and different network compatibilities, such as, firm-specific network compatibility and industry-wide network compatibility.

technology, colour, design, and so on. Although the reduced form profit functions considered below will not focus on any particular demand and network compatibility, our examples with linear demand functions will consider particular network compatibility.

We will consider two situations:

Non-cooperation: Each firm maximises its total expected profit by choosing its R&D investment and the product market strategy.

Merger: The firms merge and the merged firm chooses R&D investment and the product market strategy to maximise the expected profit of the merged firm.

4. Non-cooperation

We consider the following game. At stage 1, both firms invest in R&D simultaneously and the R&D outcome is observed. At stage 2, the firms determine their outputs depending on the R&D outcomes, and the profits are determined. We solve the game through backward induction.

Consider the following profits ex-post R&D under non-cooperation. If both firms succeed in R&D, each firm gets π^D. If only one firm succeeds in R&D, the successful firm gets π^M, and the unsuccessful firm gets *0*. If neither firm succeeds in R&D, both firms get *0*.

The i^{th} firm determines its R&D investment to maximise the following expression:

$$\pi_i^{NC} = z_i z_j \pi^D + z_i(1 - z_j)\pi^M - {z_i}^2, \tag{1}$$

The symmetric equilibrium R&D investment (and therefore, the equilibrium probability of success) is:

$$z_1^{NC*} = z_2^{NC*} = z^{NC*} = \frac{\pi^M}{2 + \pi^M - \pi^D}. \tag{2}$$

We get $z^{NC*} \in (0,1)$ if $\pi^D < 2$, i.e., the decreasing returns to innovation are sufficiently high compared to the duopoly profit, which is assumed to hold. $\pi^D < 2$ also ensures the stability condition that requires $2 + \pi^M - \pi^D > 0$.

5. Merger with no merger-specific efficiency

Under merger, both firms merge and the merged firm uses both research labs and produces like a monopolist.

If both research labs are successful in R&D, we consider that both products will be produced by the monopolist, which is likely to hold when the products are significantly differentiated with significant network externality. There can be situations depending on the network externality and product differentiation where the merged firm will produce only one product. However, we will skip this case, since the other case, where the merged firm produces both products will be enough to convey our points in the simplest way. Further, if the merged firm produces only one product even if both labs are successful in R&D, this case can be considered as "killer merger". Since the concern about killer merger is not part of the innovation theory of harm (Valletti, 2025), it may be reasonable to skip this case in this paper, which is focusing on the innovation theory of harm.

Even if the merged firm produces both products, it is not immediate whether (1) the merged firm will choose the product market variables (outputs or prices) to maximise the joint profits from the both products or (2) the merged firm will create two competing separate divisions producing different products where each division chooses the product market variables to maximise the profit of its division. We will consider these cases separately.

If the merged firm produces both products to maximise the joint profit of the merged firm, the total profit of the merged firm is $\widehat{\pi^M}$. We will call this strategy as "joint profit maximisation".

If the merged firm creates two divisions, which compete non-cooperatively, this case is like the divisionalisation strategy of, say, Schwartz and Thompson (1986), Corchón (1991), and Veendorp (1991). In this situation, the total profit of the merged firm is $2\pi^D$. We will call this strategy as "divisionalisation".[6]

There are also two possibilities when only one research lab is successful. We will first consider a situation where the technology of the successful research lab can be used to produce one product only. This may happen if product differentiation is created by the technologies of the firms and not through, say, by brand names, colour, or designs. The reason for considering this situation is to eliminate the effect of merger-specific efficiency by making the same profits under non-cooperation and merger when there is unilateral success in R&D. We will call this situation as *no merger-specific efficiency*. Hence, with no merger-specific efficiency if only one research lab is successful, only one product is produced and the total profit of the merged firm will be π^M, where $\pi^M < \widehat{\pi^M}$.

We will then consider a situation with merger-specific efficiency, where, even if one research lab is successful in R&D, the merged firm produces both products. This may happen if product differentiation is created not through technologies but through other factors, such as colour, design, brand name, and so on.[7] Hence, the same technology will be used to produce both products, since different appearances of the

[6] Banerjee et al. (2025) consider a horizontally differentiated network industry to show the conditions under which a merged firm prefers divisionalisation or joint profit maximisation or killer merger.
[7] This situation may occur when some consumers prefer WhatsApp messenger and some consumers prefer Facebook messenger due to their layout and not due to the technologies behind these products.

products help the merged firm to get the benefit of product differentiation even if these products are produced with the same technology and this is possible only when there is merger specific efficiency. Thus merger-specific efficiency creates higher profits under merger compared to non-cooperation when there is unilateral success in R&D. We will call this situation as '*with merger-specific efficiency'*.

With merger-specific efficiency, we will consider that the total profit of the merged firm is either $\widehat{\pi^M}$ (if the merged firm produces both products to maximise the total profit of the merged firm) or $2\pi^D$ (if the merged firm takes the divisionalisation strategy).[8]

5.1. No merger-specific efficiency

5.1.1. Divisionalisation by the merged firm

If there is no merger-specific efficiency and the merged firm takes the divisionalisation strategy, i.e., $\widehat{\pi^M} < 2\pi^D$, the i^{th} lab determines z_i, $i, j = 1,2, i \neq j$, under merger to maximise

$$\Pi^{ME,DI} = z_i z_j 2\pi^D + z_i(1 - z_j)\pi^M + (1 - z_i)z_j\pi^M - ({z_i}^2 + {z_j}^2). \tag{3}$$

Remember that with no merger specific efficiency, only one product is produced when only one research lab is successful and therefore the payoff is π^M. The symmetric equilibrium R&D investment (and therefore, the equilibrium probability of success in R&D) for each lab is

$$z_1^{ME,DI*} = z_2^{ME,DI*} = z^{ME,DI*} = \frac{\pi^M}{2(1+\pi^M-\pi^D)}. \tag{4}$$

[8] We are considering two extreme cases where product differentiation is created either by the technologies or by the other factors, such as appearances, design, colour and so on. There could be situations where both the technological factors and the non-technological factors can create product diferentiation. We ignore this complication to show our point in the simplest way. However, our qualitative results will hold even for this case, since it will be a mixture of the two extreme cases considered in the paper.

The second order condition for maximisation requires $1 > (\pi^D - \pi^M)^2$, which is assumed to hold. Hence, in equilibrium, it is optimal for the merged firm to use both research labs. Thus, we eliminate the reason for the innovation raising merger in Denicolò and Polo (2018).

We get $z^{ME,DI*} \in (0,1)$ for $2 + \pi^M - 2\pi^D > 0$, which is assumed to hold. This condition also implies that $2(1 + \pi^M - \pi^D) = 2 + \pi^M - 2\pi^D + \pi^M > 0$. Therefore we can state our first proposition:

Proposition 1: *If there is no merger-specific efficiency and the merged firm takes the divisionalisation strategy, which happens for $\widehat{\pi^M} < 2\pi^D$ and $\pi^M < 2\pi^D$, the R&D investment is higher under merger compared to non-cooperation if $\pi^M < \pi^D$.*

Proof: Comparison of (2) and (4) proves the result. ■

Two opposing marginal effects on the i^{th} lab's R&D incentive are the reasons for Proposition 1. On the one hand, the monopolization effect helps to increase R&D investment under merger. Merger increases the i^{th} firm's marginal expected profit from a one unit increase in z_i under bilateral success in R&D compared to non-cooperation by $(z_j 2\pi^D - z_j\pi^D) = z_j\pi^D$. On the other hand, there is a negative effect. Under unilateral success, under merger, the i^{th} lab can get π^M even if it fails but the j^{th} lab succeeds. This leads to a reduced incentive for the i^{th} firm (or lab) to invest in costly R&D. Put differently, merger (compared to non-cooperation) internalises the effects of the j^{th} lab's R&D investment on the i^{th} lab's expected gain from R&D investment under unilateral success. This effect reduces the expected marginal profit from an additional unit of R&D investment by the i^{th} lab under merger compared to non-cooperation by $(1 - z_j)\pi^M - [(1 - z_j)\pi^M - z_j\pi^M] = z_j\pi^M$. Therefore, overall, merger will increase R&D investment compared to non-cooperation if $z_j\pi^M < z_j\pi^D$ or $\pi^M < \pi^D$ holds.

Proposition 1 is different from Federico et al. (2017). It shows that even if there is no merger-specific efficiency, merger can increase R&D investment compared to non-cooperation. If there is no network externality, as in Federico et al. (2017), the conditions in Proposition 1, which are $\widehat{\pi^M} < 2\pi^D$ and $\pi^M < \pi^D$, does not hold. Hence, even if there is no merger-specific efficiency, merger can increase R&D investments and can increase consumer surplus (as shown below) in a network industry while that may not occur without network externality.

An example with a linear demand: Consider the following inverse demand function:[9]

$$P_i = 1 - q_i - \gamma q_j + n\left(y_i + \theta y_j\right), i, j = 1,2, i \neq j, \tag{5}$$

where P_i is the price of the firm's product, $q_i(q_j)$ is the output of the i^{th} (j^{th}) firm, $\gamma \in [0,1]$ is the degree of product differentiation, $\theta \in [0,1]$ is the degree of network compatibility, $n \in [0,1)$ shows the strength of network externality, and $y_i(y_j)$ is the consumer's expectation about the i^{th} (j^{th}) firm's total sales. The products are perfect substitutes (isolated) if $\gamma = 1(\gamma = 0)$. There is firm-specific (industry-wide) network compatibility if $\theta = 0$ ($\theta = 1$). As n increases, the strength of network externality increases. There is no network externality for $n = 0$. Network effect is given by $n\theta$.

[9] See Basak and Petrakis (2021) for this type of demand function.

Considering zero marginal cost and Bertrand competition, we consider three examples – the cases of $\theta = 1$,[10] $\theta = \gamma$,[11] and $\theta = 0$[12] respectively.

If $\theta = 1$, we get $P_i^D = \frac{1-\gamma^2}{(2-\gamma)(1+\gamma)-2n} > 0$, $P_i^M = \frac{1}{2-n} > 0$, $\widehat{P_i^M} = \frac{1+\gamma}{2-2n+2\gamma} > 0$, $q_i^D = \frac{1}{2(1-n)+\gamma(1-\gamma)} > 0$, $q_i^M = \frac{1}{2-n} > 0$, $\widehat{q_i^M} = \frac{1}{2-2n+2\gamma} > 0$, $\pi^D = \frac{1-\gamma^2}{((2-\gamma)(1+\gamma)-2n)^2} > 0$, $\pi^M = \frac{1}{(2-n)^2} > 0$, and $\widehat{\pi^M} = \frac{1+\gamma}{2(1-n+\gamma)^2} > 0$. Using these equilibrium expressions, we plot $(\pi^M - \pi^D)$ in Figure 1 for $\gamma \in [0,1]$, $n \in [0,1]$ and the constraints of $n < \gamma$,[13] $\widehat{\pi^M} < 2\pi^D$, $\pi^M < 2\pi^D$, $z^{NC*} \in (0,1)$, $1 > (\pi^D - \pi^M)^2$, and $z^{ME,DI*} \in (0,1)$.

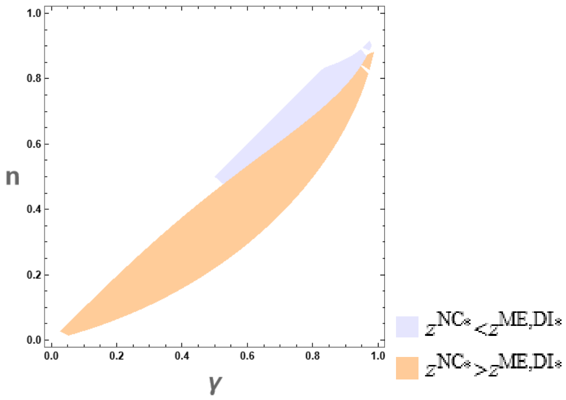

Figure 1: $(\pi^M - \pi^D)$ for $\theta = 1$

If $\theta = \gamma$, we get $P_i^D = \frac{1-\gamma}{2-n-\gamma} > 0$, $P_i^M = \frac{1}{2-n} > 0$, $\widehat{P_i^M} = \frac{1}{2-n} > 0$, $q_i^D = \frac{1}{(1+\gamma)(2-n-\gamma)} > 0$, $q_i^M = \frac{1}{2-n} > 0$, $\widehat{q_i^M} = \frac{1}{(2-n)(1+\gamma)} > 0$, $\pi^D = \frac{1-\gamma}{(1+\gamma)(2-n-\gamma)^2} > 0$,

[10] In a different context, Amir and Lazzati (2011) consider the case of $\theta = 1$, i.e., industry-wide network compatibility.
[11] See, e.g., Hoernig (2012), Pal (2014, 2015), and Song and Wang (2017) where network compatibility is equal to product differentiation.
[12] In different contexts, Gama et al. (2020) and Amir et al. (2021) consider the case of $\theta = 0$, i.e., firm-specific network compatibility.
[13] Following the assumptions of many papers in the literature, we have assumed $n\theta < \gamma$, i.e., product differentiation is not lower than the network effect. With $\theta = 1$, this condition reduces to $n < \gamma$, implying that the relevant range for consideration is to the right of the diagonal from the lower left hand corner to the upper right hand corner. If we don't restrict the range in this way and allow $n > \gamma$, the range for the favourable effects of the merger increases.

$\pi^M = \frac{1}{(2-n)^2} > 0$, and $\widehat{\pi^M} = \frac{2}{(2-n)^2(1+\gamma)} > 0$. Using these equilibrium expressions, we plot $(\pi^M - \pi^D)$ in Figure 2 for $\gamma \in [0,1]$, $n \in [0,1]$ and the constraints of $\widehat{\pi^M} < 2\pi^D$, $\pi^M < 2\pi^D$, $z^{NC*} \in (0,1)$, $1 > (\pi^D - \pi^M)^2$, and $z^{ME,DI*} \in (0,1)$.[14]

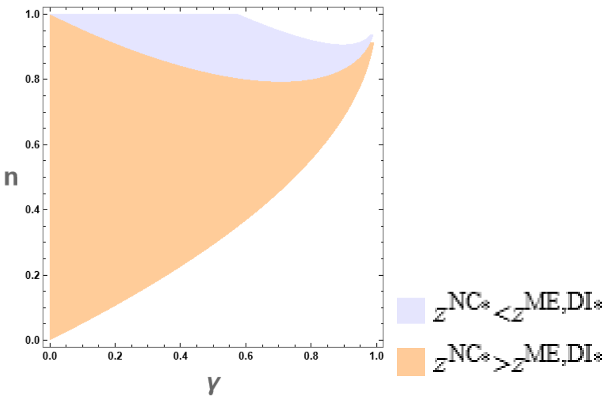

Figure 2: $(\pi^M - \pi^D)$ for $\theta = \gamma$

The blue areas in Figures 1 and 2 show $(\pi^M - \pi^D) < 0$, suggesting that merger increases the R&D investments in these areas compared to non-cooperation. On the other hand, the orange areas in Figures 1 and 2 show $(\pi^M - \pi^D) > 0$, suggesting that merger decreases the R&D investments in these areas compared to non-cooperation.

If $\theta = 0$, we get $P_i^D = \frac{1-\gamma^2}{(2-\gamma)(1+\gamma)-n} > 0$, $P_i^M = \frac{1}{2-n} > 0$, $\widehat{P_i^M} = \frac{1+\gamma}{2-n+2\gamma} > 0$, $q_i^D = \frac{1}{2-n+\gamma-\gamma^2} > 0$, $q_i^M = \frac{1}{2-n} > 0$, $\widehat{q_i^M} = \frac{1}{2-n+2\gamma} > 0$, $\pi^D = \frac{1-\gamma^2}{((2-\gamma)(1+\gamma)-n)^2} > 0$, $\pi^M = \frac{1}{(2-n)^2} > 0$, and $\widehat{\pi^M} = \frac{2(1+\gamma)}{(2(1+\gamma)-n)^2} > 0$. It is immediate from these expressions that $\pi^M = \frac{1}{(2-n)^2} > \frac{1-\gamma^2}{(2-n+\gamma(1-\gamma))^2} = \pi^D$, suggesting that merger decreases the R&D investments.

[14] $n\theta < \gamma$ always holds for $\theta = \gamma$.

It is easy to see that the equilibrium expected total profits of firms 1 and 2 are higher under merger compared to non-cooperation, i.e., merger is profitable. The equilibrium total expected profits of firms 1 and 2 are $\frac{2(\pi^M)^2}{(2+\pi^M-\pi^D)^2}$ under non-cooperation and $\frac{(\pi^M)^2}{2(1+\pi^M-\pi^D)^2}$ under merger. We get $\frac{2(\pi^M)^2}{(2+\pi^M-\pi^D)^2} - \frac{(\pi^M)^2}{2(1+\pi^M-\pi^D)^2} = -\frac{(\pi^M)^2(\pi^M-\pi^D)^2}{2(1+\pi^M-\pi^D)(2+\pi^M-\pi^D)^2} < 0$, since $1+\pi^M-\pi^D > 0$.

Proposition 2: *If there is no merger-specific efficiency, the merged firm takes the divisionalisation strategy, and merger increases the R&D investment compared to non-cooperation. The equilibrum expected consumer surplus is higher under merger compared to non-cooperation.*

Proof: The equilibrium expected consumer surplus under non-cooperation is $ECS^{NC*} = (z^{NC*})^2 CS^D + 2z^{NC*}(1-z^{NC*})CS^M$. We get $\frac{\partial ECS^{NC*}}{\partial z^{NC*}} = 2[z^{NC*}CS^D + (1-2z^{NC*})CS^M] = 2[z^{NC*}(CS^D - CS^M) + (1-z^{NC*})CS^M] > 0$, since $CS^D > CS^M$ (due to increased competition and more products) and $1-z^{NC*} > 0$. If merger increases the equilibrium R&D investment compared to non-cooperation, $\frac{\partial ECS^{NC*}}{\partial z^{NC*}} > 0$ implies that the equilibrium expected consumer surplus is higher under merger compared to non-cooperation. ■

If there is no merger-specific efficiency and the merged firm takes the divisionalisation strategy, the product market structure ex-post R&D is the same under non-cooperation and merger, implying that the consumer surplus ex-post R&D is the same under merger and non-cooperation. Higher R&D investment under merger compared to non-cooperation then increases the probability of success in R&D to create higher equilibrium expected consumer surplus under merger compared to non-cooperation.

5.1.2. Joint profit maximisation by the merged firm

If there is no merger-specific efficiency and the merged firm takes the product market decision to maximise its total profit, which occurs for $\widehat{\pi^M} > 2\pi^D$, the i^{th} lab determines z_i, $i, j = 1,2, i \neq j$, under merger to maximise

$$\Pi^{ME,M} = z_i z_j \widehat{\pi^M} + z_i(1 - z_j)\pi^M + (1 - z_i)z_j\pi^M - (z_i{}^2 + z_j{}^2). \tag{6}$$

The symmetric equilibrium R&D investment (and therefore, the equilibrium probability of success in R&D) for each lab is

$$z_1^{ME,M*} = z_2^{ME,M*} = z^{ME,M*} = \frac{\pi^M}{2+2\pi^M-\widehat{\pi^M}}. \tag{7}$$

We get $z^{ME,M*} \in (0,1)$ for $2 + \pi^M - \widehat{\pi^M} > 0$, which is assumed to hold. This condition also satisfied the second order condition for maximisation, which requires $2 + 2\pi^M - \widehat{\pi^M} > 0$. Hence, in equilibrium, it is optimal for the merged firm to use both research labs. Thus, we eliminate the reason for the innovation raising merger in Denicolò and Polo (2018).

Proposition 3: *If there is no merger-specific efficiency and the merged firm takes the joint profit maximising strategy, which happens for $\widehat{\pi^M} > 2\pi^D$ and $\widehat{\pi^M} > \pi^M$, the R&D investment is higher under merger compared to non-cooperation if $(\pi^D + \pi^M) < \widehat{\pi^M}$.*

Proof: The comparison of (2) and (7) proves the result. ■

The reason for Proposition 2 is similar to that of for Proposition 1. On the one hand, the monopolization effect increases the R&D investment under merger. Merger increases the i^{th} firm's profit under bilateral success in R&D compared to non-cooperation by $z_j\widehat{\pi^M} - z_j\pi^D = z_j(\widehat{\pi^M} - \pi^D)$. On the other hand, merger (compared to non-cooperation) internalises the effects of the j^{th} lab's R&D investment on the i^{th} lab's expected gain from R&D investment under unilateral success. This effect reduces the R&D investment under merger compared to non-cooperation by $(1 - z_j)\pi^M - [(1 - z_j)\pi^M - z_j\pi^M] = z_j\pi^M$. Hence, merger increases R&D investment compared to non-cooperation if $z_j\pi^M < z_j(\widehat{\pi^M} - \pi^D)$ or $(\pi^D + \pi^M) < \widehat{\pi^M}$.

Proposition 3 is also different from Federico et al. (2017). They have considered homogeneous products and no network externality, and therefore, $\pi^M = \widehat{\pi^M}$, suggesting that $(\pi^D + \pi^M) < \widehat{\pi^M}$ cannot occur there. Significant product differentiation and network externality in our paper may make $\pi^M < \widehat{\pi^M}$, and creates the possibility of $(\pi^D + \pi^M) < \widehat{\pi^M}$. However, we used the linear demand function $P_i = 1 - q_i - \gamma q_j + n(y_i + \theta y_j)$, $i, j = 1,2, i \neq j$, and found under Bertrand competition that $(\pi^D + \pi^M) < \widehat{\pi^M}$ does not occur for $\theta \in [0,1]$. We checked that $(\pi^D + \pi^M) < \widehat{\pi^M}$ does not occur also under Cournot competition for $\theta \in [0,1]$. Hence, a different demand function is necessary for Proposition 3 to hold.

If merger increases the R&D investments compared to non-cooperation it may increase the equilibrium expected consumer surplus compared to non-cooperation if the higher probability of success in R&D under merger dominates the adverse effect of higher market concentation under merger when there is bilateral success in R&D. However, this will not happen under the linear demand considered in this paper, since, as mentioned in the previous paragraph, merger does not increase the R&D investments compared to non-cooperation under this linear demand function.

6. Merger with merger-specific efficiency

6.1. Divisionalisation by the merged firm

Now we consider the case of merger-specific efficiency, where, under unilateral success in R&D, the merged firm produces both products with the same technology. This situation can be appropriate if product differentiation is created by the factors, such as appearances of the products.

We have already shown that merger can increase the R&D investments and consumer surplus if there is no merger-specific efficiency and the merged firm takes the divisionalisation strategy. Since the merger-specific efficiency would increase the R&D investment of the merged firm compared to no merger-specific efficiency, it is intuitive that merger will create higher R&D investments and consumer surplus compared to non-cooperation when there is merger-specific efficiency.[15] Hence, we skip the details here and move on to the cases where the merged firm does not take the divisionalisation strategy and produces to maximise its total profit.

6.2. Joint profit maximisation by the merged firm

Now we consider the case of merger-specific efficiency where the merged firm produces to maximise its total profit. In this situation, under merger, the ith lab determines z_i, $i, j = 1,2, i \neq j$, to maximise

$$\Pi^{ME,E,M} = z_i z_j \widehat{\pi^M} + z_i(1 - z_j)\widehat{\pi^M} + (1 - z_i)z_j\widehat{\pi^M} - ({z_i}^2 + {z_j}^2). \qquad (8)$$

[15] The objective function of the merged firm under this situation is $\Pi^{ME,E,DI} = z_i z_j 2\pi^D + z_i(1 - z_j)2\pi^D + (1 - z_i)z_j 2\pi^D - ({z_i}^2 + {z_j}^2)$. Under merger specific efficiency, the successful lab or firm can always share its technology with the other lab or firm since both divisions are under one umbrella and both firms can produce with slight product differentiation (which is non-technological). The symmetric equilibrium R&D investment for each lab is $z^{ME,E,DI*} = \frac{\pi^D}{2+\pi^D}$, with $1 > \pi^D$ due to the stability condition. We get $z^{ME,DI*} - z^{ME,E,DI*} = \frac{-(1-\pi^D)(2\pi^D-\pi^M)}{2(1+\pi^D)(1+\pi^M-\pi^D)} < 0$, because the merged firm takes the divisionalisation strategy when $2\pi^D - \pi^M$.

The symmetric equilibrium R&D investment (and therefore, the equilibrium probability of success in R&D) for each lab is

$$z_1^{ME,E,M*} = z_2^{ME,E,M*} = z^{ME,E,M*} = \frac{\widehat{\pi^M}}{2+\widehat{\pi^M}}, \tag{9}$$

where $0 < z^{ME,E,M*} < 1$. The second order condition for maximisation is satisfied for $\widehat{\pi^M} < 2$, which is assumed to hold. Hence, in equilibrium, it is optimal for the merged firm to use both research labs. Thus, we eliminate the reason for the innovation raising merger in Denicolò and Polo (2018).

Proposition 4: *If there is merger-specific efficiency and the merged firm takes the joint profit maximising strategy, the R&D investment of the merged firm is higher under merger compared to no non-cooperation if* $2\pi^M - 2\widehat{\pi^M} + \pi^D\widehat{\pi^M} < 0$.

Proof: Comparison of (2) and (9) proves it. ■

If product differentiation is created not due to technologies but due to other factors, such as appearances, design, colour and so on, it creates merger-specific efficiency and helps the merged firm to increase its profits ex-post R&D by allowing it to produce both products even if only one research lab of the merged firm is successful in R&D. This benefit increases the merged firm's marginal benefit from R&D compared to the situation with no merger-specific efficiency. As a result, we get $z^{ME,M*} - z^{ME,EM*} < 0$, implying that the possibility of higher R&D investments under merger compared to non-cooperation is more under merger-specific efficiency than under no merger-specific efficiency.

This can be shown easily from (7) and (9). The probability of success in R&D under merger with no merger-specific efficiency is lower than that of with merger-specific efficiency since $\frac{\pi^M}{2+2\pi^M-\widehat{\pi^M}} - \frac{\widehat{\pi^M}}{2+\widehat{\pi^M}} = \frac{\left(\pi^M-\widehat{\pi^M}\right)\left(2-\widehat{\pi^M}\right)}{\left(2+2\pi^M-\widehat{\pi^M}\right)\left(2+\widehat{\pi^M}\right)} < 0$, because we are considering a situation where the merged firm wants to maximise its profit by producing both products compared to producing one product, i.e., $\pi^M < \widehat{\pi^M}$. Hence, merger (compared to non-cooperation) creates the possibility of higher probabilities of success in R&D (and therefore, the R&D investments) under merger-specific efficiency than under no merger-specific efficiency.

Considering the linear demand function in (5), zero marginal cost and Bertrand competition, we consider three examples – the cases of $\theta = 1$,[16] $\theta = \gamma$,[17] and $\theta = 0$[18] respectively.

If $\theta = 1$, we have shown in subsection 5.1.1 that $\pi^D = \frac{1-\gamma^2}{\left((2-\gamma)(1+\gamma)-2n\right)^2} > 0$, $\pi^M = \frac{1}{(2-n)^2} > 0$, and $\widehat{\pi^M} = \frac{1+\gamma}{2(1-n+\gamma)^2} > 0$. Using these equilibrium expressions, we plot $2\pi^M - 2\widehat{\pi^M} + \pi^D\widehat{\pi^M}$ in Figure 3 for $\gamma \in [0,1]$, $n \in [0,1]$ and the constraints of $n < \gamma$, $\widehat{\pi^M} > 2\pi^D$, $\widehat{\pi^M} > \pi^M$, $z^{NC*} \in (0,1)$, $z^{ME,E,M*} \in (0,1)$, and $\widehat{\pi^M} < 2$.

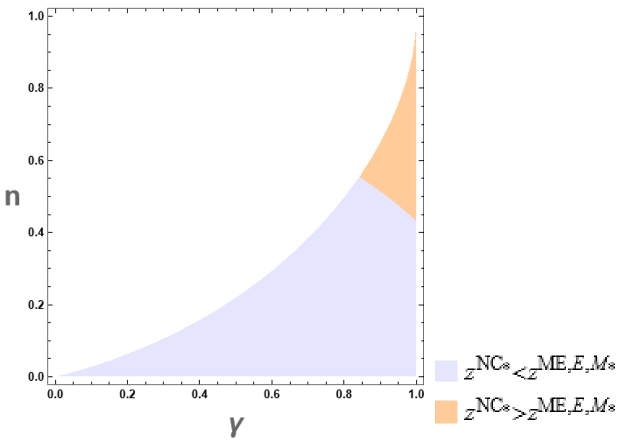

Figure 3: $2\pi^M - 2\widehat{\pi^M} + \pi^D\widehat{\pi^M}$ for $\theta = 1$

[16] In a different context, Amir and Lazzati (2011) consider the case of $\theta = 1$, i.e., industry-wide network compatibility.
[17] See, e.g., Hoernig (2012), Pal (2014, 2015), and Song and Wang (2017) where network compatibility is equal to product differentiation.
[18] In different contexts, Gama et al. (2020) and Amir et al. (2021) consider the case of $\theta = 0$, i.e., firm-specific network compatibility.

If $\theta = \gamma$, we have shown in subsection 5.1.1 that $\pi^D = \frac{1-\gamma}{(1+\gamma)(2-n-\gamma)^2} > 0$, $\pi^M = \frac{1}{(2-n)^2} > 0$, and $\widehat{\pi^M} = \frac{2}{(2-n)^2(1+\gamma)} > 0$. Using these equilibrium expressions, we plot $2\pi^M - 2\widehat{\pi^M} + \pi^D\widehat{\pi^M}$ in Figure 4 for $\gamma \in [0,1]$, $n \in [0,1]$ and the constraints of $\widehat{\pi^M} > 2\pi^D$, $\widehat{\pi^M} > \pi^M$, $z^{NC*} \in (0,1)$, $z^{ME,E,M*} \in (0,1)$, and $\widehat{\pi^M} < 2$.

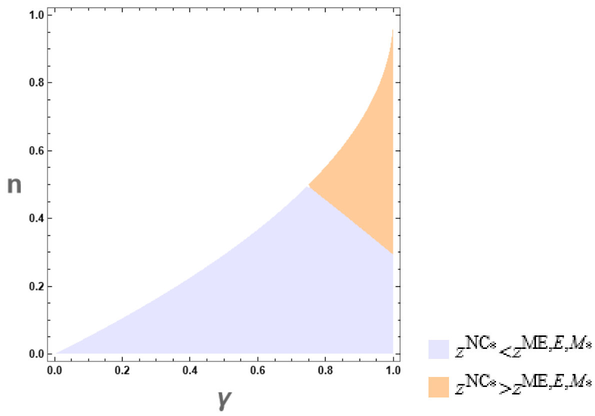

Figure 4: $2\pi^M - 2\widehat{\pi^M} + \pi^D\widehat{\pi^M}$ for $\theta = \gamma$

If $\theta = 0$, we have shown in subsection 5.1.1 that $\pi^D = \frac{1-\gamma^2}{\left((2-\gamma)(1+\gamma)-n\right)^2} > 0$, $\pi^M = \frac{1}{(2-n)^2} > 0$, and $\widehat{\pi^M} = \frac{2(1+\gamma)}{(2(1+\gamma)-n)^2} > 0$. Using these equilibrium expressions, we plot $2\pi^M - 2\widehat{\pi^M} + \pi^D\widehat{\pi^M}$ in Figure 5 for $\gamma \in [0,1]$, $n \in [0,1]$ and the constraints of $\widehat{\pi^M} > 2\pi^D$, $\widehat{\pi^M} > \pi^M$, $z^{NC*} \in (0,1)$, $z^{ME,E,M*} \in (0,1)$, and $\widehat{\pi^M} < 2$.[19]

[19] $n\theta < \gamma$ always holds for $\theta = 0$.

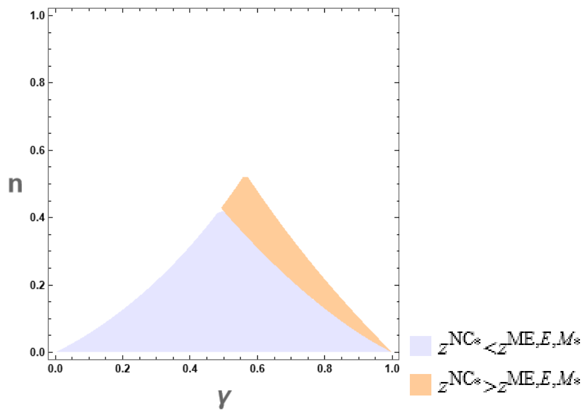

Figure 5: $2\pi^M - 2\widehat{\pi^M} + \pi^D\widehat{\pi^M}$ for $\theta = 0$

The blue areas in Figures 3, 4 and 5 show $2\pi^M - 2\widehat{\pi^M} + \pi^D\widehat{\pi^M} < 0$, suggesting that merger increases the R&D investments in these areas compared to non-cooperation. On the other hand, the orange areas in Figures 3, 4 and 5 show $2\pi^M - 2\widehat{\pi^M} + \pi^D\widehat{\pi^M} > 0$, suggesting that merger decreases the R&D investments in these areas compared to non-cooperation.

It can be shown that the equilibrium total expected profits of firms 1 and 2 under non-cooperation, i.e., $\frac{2(\pi^M)^2}{(2+\pi^M-\pi^D)^2}$, are lower than that of under merger, i.e., $\frac{(\widehat{\pi^M})^2}{2+\widehat{\pi^M}}$. Hence, merger is profitable.

Now compare the equilibrium expected consumer surplus under non-cooperation to that of under merger. The equilibrium expected consumer surplus under non-cooperation is $ECS^{NC*} = (z^{NC*})^2 CS^D + 2z^{NC*}(1 - z^{NC*})CS^M$, and that of under merger is $ECS^{ME,E,M*} = (z^{ME,E,M*})^2 \widehat{CS^M} + 2z^{ME,E,M*}(1 - z^{ME,E,M*})\widehat{CS^M}$.

Considering the linear demand function in (5), zero marginal cost, and Bertrand competition, we consider three cases of $\theta = 1$, $\theta = \gamma$, and $\theta = 0$.

If $\theta = 1$, we have shown in subsection 5.1.1 that $q_i^D = \frac{1}{2(1-n)+\gamma(1-\gamma)} > 0$, $q_i^M = \frac{1}{2-n} > 0$, $\widehat{q_i^M} = \frac{1}{2-2n+2\gamma} > 0$, $\pi^D = \frac{1-\gamma^2}{((2-\gamma)(1+\gamma)-2n)^2} > 0$, $\pi^M = \frac{1}{(2-n)^2} > 0$, and $\widehat{\pi^M} = \frac{1+\gamma}{2(1-n+\gamma)^2} > 0$. Using these equilibrium expressions, we plot $ECS^{NC*} - ECS^{ME,E,M*}$ in Figure 6 for $\gamma \in [0,1]$, $n \in [0,1]$ and the constraints of $n < \gamma$, $\widehat{\pi^M} > 2\pi^D$, $\widehat{\pi^M} > \pi^M$, $z^{NC*} \in (0,1)$, $z^{ME,E,M*} \in (0,1)$, and $\widehat{\pi^M} < 2$.[20]

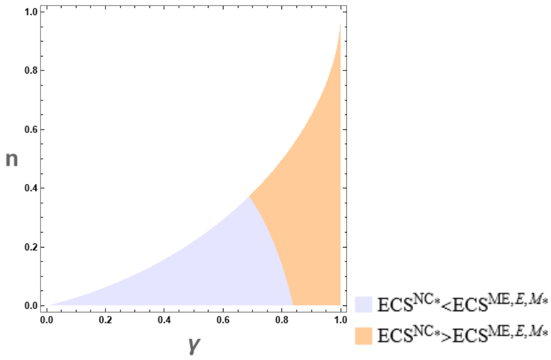

Figure 6: $ECS^{NC*} - ECS^{ME,E,M*}$ for $\theta = 1$

If $\theta = \gamma$, we have shown in subsection 5.1.1 that $q_i^D = \frac{1}{(1+\gamma)(2-n-\gamma)} > 0$, $q_i^M = \frac{1}{2-n} > 0$, $\widehat{q_i^M} = \frac{1}{(2-n)(1+\gamma)} > 0$, $\pi^D = \frac{1-\gamma}{(1+\gamma)(2-n-\gamma)^2} > 0$, $\pi^M = \frac{1}{(2-n)^2} > 0$, and $\widehat{\pi^M} = \frac{2}{(2-n)^2(1+\gamma)} > 0$. Using these equilibrium expressions, we plot $ECS^{NC*} - ECS^{ME,E,M*}$ in Figure 7 for $\gamma \in [0,1]$, $n \in [0,1]$ and the constraints of $\widehat{\pi^M} > 2\pi^D$, $\widehat{\pi^M} > \pi^M$, $z^{NC*} \in (0,1)$, $z^{ME,E,M*} \in (0,1)$, and $\widehat{\pi^M} < 2$.

[20] The linear demand function in (5) can be found from the utility function $U = q_1 + q_2 - \frac{q_1^2+q_2^2+2\gamma q_1 q_2}{2} + n\left[(y_1+\theta y_2)q_1 + (y_2+\theta y_1)q_2 - \frac{y_1^2+y_2^2+2\theta y_1 y_2}{2}\right]$. This utility function, the demand function in (5), and q_i^D, q_i^M, $\widehat{q_i^M}$ are used to find the consumer surplus ex-post R&D, i.e., CS^D, CS^M, and $\widehat{CS^M}$.

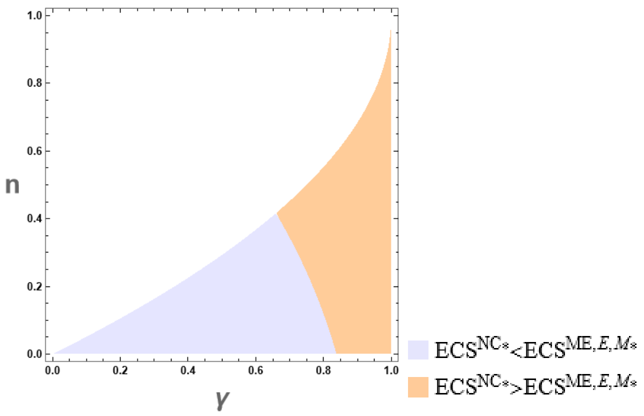

Figure 7: $ECS^{NC*} - ECS^{ME,E,M*}$ for $\theta = \gamma$

If $\theta = 0$, we have shown in subsection 5.1.1 that $q_i^D = \frac{1}{2-n+\gamma-\gamma^2} > 0$, $q_i^M = \frac{1}{2-n} > 0$, $\widehat{q_i^M} = \frac{1}{2-n+2\gamma} > 0$, $\pi^D = \frac{1-\gamma^2}{\left((2-\gamma)(1+\gamma)-n\right)^2} > 0$, $\pi^M = \frac{1}{(2-n)^2} > 0$, and $\widehat{\pi^M} = \frac{2(1+\gamma)}{(2(1+\gamma)-n)^2} > 0$. Using these equilibrium expressions, we plot $ECS^{NC*} - ECS^{ME,E,M*}$ in Figure 8 for $\gamma \in [0,1]$, $n \in [0,1]$ and the constraints of $\widehat{\pi^M} > 2\pi^D$, $\widehat{\pi^M} > \pi^M$, $z^{NC*} \in (0,1)$, $z^{ME,E,M*} \in (0,1)$, and $\widehat{\pi^M} < 2$.

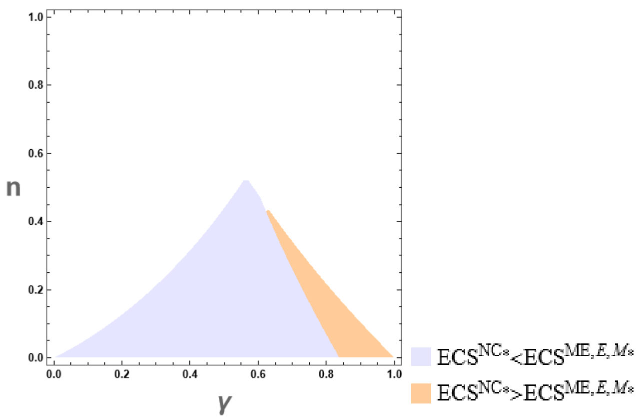

Figure 8: $ECS^{NC*} - ECS^{ME,E,M*}$ for $\theta = 0$

The blue areas in Figure 6, 7 and 8 show $ECS^{NC*} - ECS^{ME,E,M*} < 0$, suggesting that merger increases the equilibrium expected consumer surplus in these areas compared to non-cooperation. On the other hand, the orange areas in Figure 6, 7 and 8 show $ECS^{NC*} - ECS^{ME,E,M*} > 0$, suggesting that merger decreases the equilibrium expected consumer surplus in these areas compared to non-cooperation.

We can get the following proposition from Figures 6, 7 and 8.

Proposition 5: *If there is merger-specific efficiency and the merged firm takes the joint profit maximising strategy, the equilibrum expected consumer surplus can be higher under merger compared to non-cooperation for* $\theta \in [0,1]$.

7. Conclusion

Considering a stochastic product innovation model similar to Federico et al. (2017) but with horizontally differentiated network products we show that merger may increase R&D investments and consumer surplus. Hence, a merger need not be blocked in network industries. Federico et al. (2017) did not consider merger specific efficiency and showed that merger reduces R&D investments and consumer surplus. But we show that merger can increase R&D investments and expected consumer surplus in a network industry *even without merger specific efficiency*. This points to the fact that if we consider merger specific efficiency (which is more natural if we are exploring the effect of mergers) then it is more likely that merger will increase R&D investments and expected consumer surplus in a network industry. Indeed we show that with merger specific efficiency R&D investments and expected consumer surplus increases post-merger and therefore the authorities need not be overly concerned about merger in network industries.

In addition to this, we show the implications of the divisionalisation strategy of the merged firm and how that can effectively raise the R&D investments and expected consumer surplus with or without merger specific efficiency. Our examples show that product differentiation and network effects play important roles for the innovation and consumer surplus raising merger.

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