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Kesavayuth, Dusanee and Lee, Sang-Ho and Zikos, Vasileios

University of the Thai Chamber of Commerce, Chonnam National University, University of the Thai Chamber of Commerce

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Merger and Innovation Incentives in a Differentiated Industry*

Dusanee Kesavayuth** Sang-Ho Lee*** Vasileios Zikos†

Abstract

In this paper, we consider a duopoly with product differentiation and examine the interaction between merger and innovation incentives. The analysis reveals that a merger tends to discourage innovation, unless the investment cost is sufficiently low. This result holds whether or not side payments between firms are allowed. When side payments are permitted, a bilateral merger-to-monopoly is always profitable, a standard result in the literature. When side payments are not permitted, however, we show that a merger is not profitable when the efficiency of the new technology is relatively high and the investment cost is below a particular level.

Keywords: Merger, R&D, innovation, differentiated products.
JEL codes: D21, L13, L41, O31.

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** Research Institute for Policy Evaluation and Design (RIPED), and School of Economics, University of the Thai Chamber of Commerce, 126/1 Vibhavadee-Rangsit Road, Dindaeng, Bangkok, 10400, Thailand. Email: dusanee_kes@utcc.ac.th.

*** Department of Economics, Chonnam National University, 77 Yongbong-Ro, Bukgu, Gwangju, 500-757, South Korea. Email: sangho@jnu.ac.kr.

† *Corresponding author*: Research Institute for Policy Evaluation and Design (RIPED), and School of Economics, University of the Thai Chamber of Commerce, Dindaeng, Bangkok, 10400, Thailand. Email: v.zikos@riped.utcc.ac.th. Tel.+662 697 6644, Fax.+662 692 3168.

1. Introduction

There is a large literature on mergers among firms competing in a homogeneous good market. The aim of this literature is to provide a performance evaluation of the merger decision by looking at the profits of the insider and outsider firms. A key finding is that a merger would be profitable if it includes more than 2/3 of the firms in the industry, also known as the 80-percent rule (Salant et al., 1983). Nonetheless, relatively little is known about the conditions under which a merger is profitable when firms invest in R&D, as well as whether firms will be more or less willing to innovate post-merger. In this paper we examine these two issues systematically by developing a unique model of endogenous merger and innovation decisions.

The current study is motivated by real market observations. The Boeing Company is active in the industries of commercial aircrafts, defence systems and aerospace, and has experienced several mergers during the recent past. For example, at the end of 1996, it merged with the Rockwell International Corporation's aerospace and defence units. The aircraft units were renamed Boeing North American, Inc., and operated as a Boeing subsidiary. On August 1, 1997, Boeing and its North American component merged with McDonnell-Douglas. These mergers are considered as horizontal as they occurred between firms with 'overlapping' products (in principle, commercial aircrafts). Looking at the R&D expenditure of the Boeing company (as a percentage of total sales),[1] we notice that they were significantly reduced after the first merger in 1996.[2] In some other instances, however, horizontal mergers may not be proposed at all, as is the case of Unilever and Procter and Gamble (P&G).[3]

These empirical observations inspire two questions. First, if a horizontal merger is realized, will the merged firm invest in new technologies – and if so under which conditions? Second, is there an economic explanation – in addition to potential antitrust concerns – of why firms operating in substitute product markets may prefer to stay independent?

Providing an answer to these questions would contribute to three strands of literature. First, it would contribute to the literature on the effects of increased concentration on R&D spending. This literature dates back to Schumpeter's (1943) conjecture that the creation of

[1] See Figure A1 in the Appendix.
[2] It is worth mentioning that R&D expenditure would presumably increase after a conglomerate merger. (See, for instance, the merger of Boeing with Hughes Electronics in Figure A1). Analyzing this type of merger is not very interesting, though, as "merger" is generally preferred over "no merger" in complement product markets.
[3] Note that the subsidiary of P&G, which specializes in personal care products for women, decided to merge with Gillette, which specializes in personal care products for men. This type of merger is classified as conglomerate.

monopolies can be tolerated as long as monopolistic firms have a larger capacity to carry out R&D. Arrow (1962), by contrast, showed that perfect competition implies stronger innovation incentives compared to monopoly. This result stems from a replacement effect: while a firm under perfect competition is only able to cover its costs, the monopolist would 'replace' part of its existing profit with a larger one. Arrow's (1962) seminar contribution was later extended to oligopolistic markets representing an intermediate form of competition (e.g. Delbono and Denicolo, 1990; Bester and Petrakis, 1993; Yi, 1999). Building on earlier studies, Belleflamme and Vergari (2011) developed a unifying framework in order to examine how the intensity of competition affects innovation incentives. They showed that different dimensions of competition, including the number of firms, the degree of product differentiation and the nature of competition, affect firms' incentives to innovate in a variety of diverse ways. What this implies is that, under certain conditions, highest innovation incentives can be attained under any form of market structure.

Our study further contributes to the literature which looks at firms' willingness to invest in cost-reducing R&D in oligopolistic markets (e.g. d' Aspremont and Jacquemin, 1988; Kamien et al., 1992; Poyago-Theotoky, 1995, 1999; Atallah, 2005; Falvey et al., 2013; Manasakis et al., 2014).[4] Such analysis departs from Arrow's (1962) approach and that of subsequent contributions (e.g. Belleflamme and Vergari, 2011) by relaxing the assumption that there is a sole innovator who cannot be imitated by competitors. Put another way, competing innovations are possible, and given that R&D investments take place before firms make their output decisions, there are strategic effects emanating from innovation. The main focus of this literature is on a comparison between non-cooperative R&D with the case in which firms coordinate their R&D activities to maximize their joint profits (for example, through a research joint venture or an R&D cartel). Like the earlier studies, we consider the case in which firms invest independently in R&D. However, the issues examined in prior studies differ from those motivating us here. Rather than focusing on the comparison between R&D cooperation and R&D competition, we are interested in firms' innovation incentives when they integrate with each other through a merger. Our results have an Arrowian flavor in the sense that a merger-to-monopoly tends to discourage innovation, unless the investment cost is sufficiently low.

[4] Other related strands of literature investigate R&D financing of public firms (e.g. Poyago-Theotoky, 1998; Ishibashi and Matsumura, 2006; Gil Molto, et al., 2011; Kesavayuth and Zikos, 2013; Lee and Tomaru, 2017) and firms' incentives to engage in R&D collaboration through networks (e.g. Goyal and Moraga-González, 2001; Zikos, 2010; Kesavayuth et al., 2016).

There is also a growing literature on the relationship between mergers and innovation in imperfectly competitive markets (e.g. Davidson and Ferrett, 2007; Matsushima et al., 2013; Cabolis et al., 2016; Atallah, 2016; Miyagiwa and Wan, 2016).[5] For example, revisiting the merger paradox, Miyagiwa and Wan (2016) show that, in a Cournot oligopoly where firms invest in R&D, a merger can be profitable even if it does not include more than 2/3 of the firms in the industry. Matsushima et al. (2013) show that the decision to merge or not may depend on the R&D cost as well as the extent of heterogeneity between firms. Mukherjee and Chowdhury (2013) consider a duopoly in order to examine when a merger is socially desirable. They find that the social desirability of a merger is determined by two key elements of the R&D environment; the effectiveness of the patent system and the efficiency of the R&D technology.

The current study contributes to this literature by bringing some new insights into the interplay between merger and innovation incentives in a duopoly with differentiated goods. The analysis reveals that, consistent with some stylized facts from the commercial aircraft industry, a merger tends to discourage innovation, unless the investment cost is sufficiently low. This result holds whether or not side payments between firms are allowed. When side payments are permitted, a bilateral merger-to-monopoly is always profitable, a standard result in the literature. When side payments are not permitted, however, we identify conditions on the investment cost, the degree of product differentiation and the new technology efficiency under which a merger is profitable. At the same time, we are able to show that when two conditions are met – the efficiency of the new technology is relatively high and the investment cost is below a certain level – the firms would prefer to stay independent, although they would enjoy significant market power through a merger.

The paper is organized as follows. Section 2 discusses the model. Section 3 characterizes its subgame perfect Nash equilibria. Section 4 extends the analysis in various ways. Section 5 concludes the paper.

2. Model

Consider an industry consisting of two firms with the same initial technology. Each firm can alter its existing technology by adopting a new technology at a fixed cost of $F \geq 0$. F is a firm's sunk cost which can be viewed as an R&D investment for getting access to the

[5] For exceptional studies in the general field of mergers see, for example, recent work by Liu et al. (2015), Liu and Wang (2015) and Gelves and Heywood (2016).

new technology. Thus firm i's cost function can be written out as $C_i(q_i) = k_i q_i^2 + F_i$, where q_i is output and k_i is the production technology; that is, a higher level of k_i implies a lower level of productive efficiency. To model firm i's decision of whether or not to adopt the new technology, we follow Calabuig and González-Maestre (2002).[6] Specifically, if firm i decides to purchase the new technology available[7] then $k_i = e$, for $e \in (0,1)$ and $F_i = \epsilon > 0$; whereas if it decides to stay with the same (initial) technology then $k_i = 1$ and $F_i = 0$. This means that the effect of the new technology is to decrease the slope of the innovator's marginal cost curve, $mc_i(q_i) = 2k_i q_i$, for $k_i = e < 1$. The use of a quadratic cost function allows the second order conditions of all maximization problems to hold and solutions to be interior, thus permitting sensible predictions for merger.[8]

Each firm faces the linear (inverse) demand function $P(q_i, q_j) = a - q_i - \gamma q_j$, for $i \neq j$ and $i, j \in \{1,2\}$, where $\gamma \in (0,1)$ denotes the degree of product substitutability; namely the higher γ is the closer substitutes the products are. The objective of firm i is to maximize its profits $\pi_i = P(q_i, q_j)q_i - C_i(q_i)$.

We consider the following three-stage game.

Stage 1: The firms decide simultaneously whether to merge or not. This implies that the strategy set in Stage 1 is defined as $s = \{M, N\}$, where M denotes the case of a merger and N the case in which a merger does not occur. The merged firm then becomes a multi-plant monopoly (with two divisions producing differentiated products). We assume that no side payments are permitted between firms and the merged firm is constrained to make the same investment decision for both its constituent divisions.[9] This means that a merger is voluntary in the sense that it can only be realized under a unanimous and symmetric agreement.

[6] Like Calabuig and González-Maestre (2002), we consider firms' innovation incentives but instead of focusing on how centralized versus decentralized labor unions affect these incentives, we look at the interplay between merger and innovation decisions.

[7] When firms decide to adopt a new technology, there are two possible situations one may think of. The first possibility is outsourcing, that is to purchase a new technology available or to finance an external lab in order to produce it. The second possibility is to make use of an internal research lab (if there already exists one). Since in our model the new efficiency level is expected prior to the respective decision, the total cost of the new technology can be estimated and so it is considered to be a fixed amount F.

[8] It is worth noting that the quadratic cost function implies decreasing returns to scale (increasing marginal cost) for output production, as well as decreasing returns to R&D, consistent with the previous studies in this area (e.g. Atallah, 2016; Mukherjee and Chowdhury, 2013; Calabuig and González Maestre, 2002).

[9] We relax these assumptions in Section 4. It is worth noting that, although cross-subsidization is pretty widespread within multi-product firms, agreeing upon side payments may often be difficult. According to Peck and Temple (2002), one reason for this might be that firms have different preferences. For example, firms may differ in their discount rates and, if one firm happens to be more (or less) future-oriented than the other, divergence of opinion is likely. But reaching an agreement can be an even more delicate matter in industries characterized by rapid technological change. In such environments, there is uncertainty surrounding a variety of future conditions

Stage 2: The firms (or the merged firm) make their technology choices simultaneously; to purchase the new technology or stay with the old one. The strategy set in Stage 2, conditioned on the Stage 1 decisions, is then defined as $r = \{I, D|s\}$, where I stands for "invest" and D for "do not invest". Moreover, we assume that the new technology is product-specific. This means that if a merger occurs, the two divisions need to pay the technology cost F individually. We note that the decision of whether to merge or not precedes the innovation decision as the former is typically a longer-term issue.

Stage 3: The firms (or the merged firm) select their output quantities.

The game is solved by backward induction to obtain its subgame perfect Nash equilibria (SPNE). For contrast, and to allow comparison with the findings of our baseline model, we also extend the analysis to consider the role of asymmetric technology choices of the merged firm, side payments, complement goods, price competition in the product market, a reversal of the timing of the merger and innovation decisions, spillover effects, and a larger number of firms.

3. Equilibria characterization

In the last stage of the game, if the firms have merged ($s = M$) then for given innovation decisions k_i and k_j, the equilibrium output of division i is

$$q_i^{M,rr} = \frac{a(1+k_j-\gamma)}{2(1+k_i+k_j+k_ik_j-\gamma^2)} \tag{1}$$

where 'rr' stands for the technology choices of divisions i and j, respectively. If the firms have decided to stay independent ($s = N$), however, the equilibrium output is

$$q_i^{N,rr} = \frac{a(2+2k_j-\gamma)}{4(1+k_i)(1+k_j)-\gamma^2} \tag{2}$$

where 'rr' respectively identifies the technology choices of firms i and j.

In the second stage, firms make their innovation decisions strategically, aiming to alter competition at the output selection stage. Given the firms' strategies in Stage 1, there are two possible subgames: the "merger" subgame and the "independent firms" subgame.

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and therefore firms may disagree on things like production costs, demand, and product lines. In addition, rapid technological change means that the direction and pace of innovation are largely unknown at the time of negotiations between firms, making it difficult to agree upon suitable transfers (see Peck and Temple, 2002).

3.1 Merger subgame

Using Table A1's payoffs in the Appendix, the merged firm will adopt the new technology if $\Pi^{M,II} > \Pi^{M,DD}$. Define ϵ^{M_1} to be the value of the fixed technology cost ϵ such that $\Pi^{M,II} = \Pi^{M,DD}$. Straightforward calculation yields

$$\epsilon^{M_1} = \frac{a^2(1-e)}{4(2+\gamma)(1+e+\gamma)}\,. \tag{3}$$

Hence, if the innovation costs are sufficiently low, $0 < \epsilon < \epsilon^{M_1}$, it is intuitive that the merged firm will innovate; whereas if $\epsilon > \epsilon^{M_1}$, the merged firm will not innovate.

3.2 Independent firms subgame

Here each firm has two strategies available, $r = \{I, D\}$, meaning that there are four candidate equilibria; two symmetric, (N, II) and (N, DD), and two asymmetric, (N, ID) and (N, DI). Using the equilibrium outcomes in Table A2 of the Appendix, define ϵ^{N_1} to be the value of ϵ such that $\pi_i^{N,II} = \pi_i^{N,DI}$, and ϵ^{N_2} to be the value of ϵ such that $\pi_i^{N,DD} = \pi_i^{N,ID}$. This leads to

$$\epsilon^{N_1} = \frac{a^2(1-e)(32(1+e)^3-\gamma^4)}{(2+2e+\gamma)^2(8+8e-\gamma^2)^2} \tag{4}$$

$$\epsilon^{N_2} = \frac{a^2(1-e)(128(1+e)-\gamma^4)}{(4+\gamma)^2(8+8e-\gamma^2)^2}. \tag{5}$$

Comparing ϵ^{N_1} and ϵ^{N_2}, we obtain $\epsilon^{N_1} < \epsilon^{N_2}$. It follows that if $\epsilon > \epsilon^{N_2}$, then both firms will not innovate and (D, D) is the equilibrium outcome; if $\epsilon^{N_1} < \epsilon < \epsilon^{N_2}$, only one firm innovates and $(D, I), (I, D)$ are the outcomes; and if $\epsilon < \epsilon^{N_1}$, both firms innovate and (I, I) is the outcome.

Perhaps the most interesting finding arises for intermediate values of the investment cost, in which case the firms' investment decisions differ. This follows from the fact that the new technology transforms a firm into a more aggressive competitor, as it can now price at a lower rate and attract more of the rival firm's customers; a business stealing effect. Thus, if a firm anticipates its rival to innovate, it will not itself adopt the same strategy when the investment cost is intermediate – as a means of relaxing competition in the product market. It is worth noting that when the products are independent ($\gamma = 0$), the firms do not compete in the product market. This implies that the role of an asymmetric outcome regarding technology choices, which was to reduce the intensity of competition, is no longer relevant. In this case, the critical values of the fixed technology cost are equal ($\epsilon^{N_1} = \epsilon^{N_2}$), meaning that an asymmetric outcome vanishes.

3.3 Incentives for merger

Comparing the critical values of the investment cost, we obtain the following ranking.[10]

Lemma 1

$0 < \epsilon^{M_1} < \epsilon^{N_1} < \epsilon^{N_2}$.

Lemma 1 allows us to characterize the SPNE of the entire game by comparing the profit of the candidate equilibria with the aid of the following table.

Table 1: Comparison of the different subgames

Conditions	Merger subgame	Independent firms subgame
$\epsilon > \epsilon^{N_2}$	(M, DD)	(N, DD)
$\epsilon^{N_2} > \epsilon > \epsilon^{N_1}$	(M, DD)	(N, ID) and (N, DI)
$\epsilon^{N_1} > \epsilon > \epsilon^{M_1}$	(M, DD)	(N, II)
$\epsilon^{M_1} > \epsilon > 0$	(M, II)	(N, II)

We employ the following definition.

Definition 1

The investment cost is 'low' if $0 < \epsilon < \epsilon^{M_1}$, *'intermediately low' if* $\epsilon^{M_1} < \epsilon < \epsilon^{N_1}$, *'intermediately high' if* $\epsilon^{N_1} < \epsilon < \epsilon^{N_2}$, *and 'high' if* $\epsilon > \epsilon^{N_2}$.

The definition above facilitates our comparisons. Calculating the difference in profits, we find that $\frac{1}{2}\Pi^{M,II} > \pi_i^{N,II}$ if the investment cost is low ($\epsilon^{M_1} > \epsilon > 0$), as well as $\frac{1}{2}\Pi^{M,DD} > \pi_i^{N,DD}$ if the investment cost is high ($\epsilon > \epsilon^{N_2}$), indicating that a merger is always profitable given that the firms make the same innovation decisions post-merger. In other words, (M, II) and (M, DD) are the SPNE outcomes when the investment cost is *low* and *high*, respectively.

Turning to the case of *intermediately low* investment cost, straightforward calculation implies that $\frac{1}{2}\Pi^{M,DD} > \pi_i^{N,II}$. Thus, for given innovation decisions, "merger" is preferred to

[10] To show that $\epsilon^{M_1} < \epsilon^{N_1} < \epsilon^{N_2}$, it is relatively straightforward to establish that $\epsilon^{N_1} - \epsilon^{M_1} > 0$ and $\epsilon^{N_2} - \epsilon^{N_1} > 0$. The result then follows immediately.

"no merger", and (M, DD) is the SPNE. Intuitively, when the firms stay independent, they tend to overinvest in R&D as a means of improving their competitive position. However, the overinvestment problem can be easily mitigated through a merger. This in turn helps firms internalize the concomitant negative externalities on their profits (business stealing and strategic overinvestment).

When the investment cost is *intermediately high*, the firms can deviate from (M, DD) to (N, ID) or (N, DI), and vice versa. We find that $\frac{1}{2}\Pi^{M,DD} > \pi_j^{N,ID}$, indicating that firm j who does not innovate (D) always wants to merge with firm i. For firm i, however, the decision of whether to merge or not is not clear-cut and may depend on the level of R&D efficiency, e. Specifically, we find that $\frac{1}{2}\Pi^{M,DD} > \pi_i^{N,ID}$ if $e > e^*(\gamma)$. Thus, when R&D is relatively inefficient, it is more profitable for firm i to merge with firm j, and (M, DD) emerges in equilibrium.

For higher levels of R&D efficiency, there are two possibilities. When $0 < e < e^*(\gamma)$, straightforward calculation suggests that there is a critical value of ϵ, $\epsilon^{N_3} \in (\epsilon^{N_1}, \epsilon^{N_2})$ such that $\frac{1}{2}\Pi^{M,DD} < \pi_i^{N,ID}$ if $\epsilon < \epsilon^{N_3}$; and $\frac{1}{2}\Pi^{M,DD} > \pi_i^{N,ID}$ otherwise. This critical value is given by

$$\epsilon^{N_3} = \frac{a^2(64(1-e^2)-8\gamma^2-4e\gamma^2(2-\gamma)+4\gamma^3-\gamma^4)}{4(2+\gamma)(8+8e-\gamma^2)^2}. \quad (6)$$

The following proposition summarizes the analysis.

Proposition 1

(i) When the investment cost is low, (M, II) *is the SPNE outcome.*

(ii) When the investment cost is intermediately low, (M, DD) *is the SPNE outcome.*

(iii) When the investment cost is intermediately high, there exists a critical value of the R&D efficiency $e^*(\gamma) \in (0,1)$ *such that:*

- *For* $e > e^*(\gamma)$, (M, DD) *is the SPNE outcome.*
- *For* $0 < e < e^*(\gamma)$, *there is a critical value of the investment cost* $\epsilon^{N_3} \in (\epsilon^{N_1}, \epsilon^{N_2})$, *such that* (N, ID) or (N, DI) *is the SPNE outcome when* $\epsilon < \epsilon^{N_3}$; *while* (M, DD) *is the SPNE outcome when* $\epsilon > \epsilon^{N_3}$.
- *The critical value* $e^*(\gamma)$ *is decreasing in* γ, $\frac{\partial e^*(\gamma)}{\partial \gamma} < 0$.

(iv) When the investment cost is high, (M, DD) *is the SPNE outcome.*

In the most interesting case where the efficiency of the new technology is relatively high ($e < e^*(\gamma)$), the firms would prefer to stay independent provided that the investment cost is below a certain threshold ($\epsilon < \epsilon^{N_3}$). The intuition is that firm i expects to gain more by competing with firm j and, through asymmetric technology choices, succeed in improving its position in the product market. Firm j, on the other hand, has an incentive to merge with firm i, as it does not undertake any R&D investments if the firms remain independent, meaning that it suffers a lot in product-market competition. It is worth noting that, as γ rises, the goods become more homogeneous, and thus inter-firm competition intensifies. This naturally makes a merger more attractive as a means of relaxing the intensity of competition. Thus, $e^*(\gamma)$ tends to decline as γ rises, thereby expanding the set of $\{\gamma, e\}$ configurations for which a merger is profitable.

Overall, Proposition 1 suggests that when two conditions are met – the efficiency of the new technology is relatively high and the investment cost is below a certain level – the firms would prefer to stay independent. From prior studies we know that convex costs (Perry and Porter, 1985; Heywood and McGinty, 2008) as well as product differentiation (Lommerud and Sørgard, 1997; Hsu and Wang, 2010; Gelves, 2014) tend to increase firms' merger incentives. However, the current paper shows that, when the firms have the option to invest in a cost-reducing technology, a merger-to-monopoly is not a unique equilibrium outcome. Under certain conditions on the investment cost and the efficiency of the new technology, firms may prefer to stay separated, as part (iii) of Proposition 1 reports.[11]

From Proposition 1 we can also see that the merged firm has generally weak innovation incentives.

Corollary 1

A merger tends to discourage innovation, unless the investment cost is sufficiently low.

This stems from the fact that the merged firm reduces its output. Any efficiency improvements are, therefore, applicable to less units of output – a lower incentive to invest in R&D.

[11] As noted earlier, the decision of whether to merge or not precedes the innovation decision, as the former is typically a longer-term issue. Nonetheless, when the timing of the game is reversed and the firms decide first whether or not to adopt the new technology, we find that a merger is still not a unique SPNE outcome (provided that side payments are not permitted), which is consistent with Proposition 1. In particular, although (M, II) is preferred over (N, II), and (M, DD) yields higher profit than (N, DD), it can be shown that firm i who invests in R&D would prefer (N, ID) over (M, ID) when the efficiency of the new technology is not too low.

4. Extensions

4.1 Asymmetric technology choices

The analysis to this point has assumed that the merged firm is constrained to make the same investment decision for both its constituent divisions. This raises the question of whether Proposition 1 – especially the finding that a bilateral merger may not be profitable in part (iii) – continues to hold when the merged firm is no longer constrained by symmetric choices regarding its investment decisions. To shed some light on this issue, we re-conduct our analysis and obtain the following equilibrium quantities and profits of the merged firm under asymmetric technology choices

$$q_1^{M,ID} = \frac{a(2-\gamma)}{2(2+2e-\gamma^2)},\ q_2^{M,ID} = \frac{a(1+e-\gamma)}{2(2+2e-\gamma^2)},\ \pi_1^{M,ID} = \frac{a^2(2-\gamma)}{4(2+2e-\gamma^2)} - \epsilon, \text{ and } \pi_2^{M,ID} = \frac{a^2(1+e-\gamma)}{4(2+2e-\gamma^2)}. \quad (7)$$

Using the profits in (7), we perform a comparison with the profits of the merged firm obtained in the two symmetric cases. To do this, define ϵ^{M_2} to be the value of ϵ such that $\pi_i^{M,II} = \pi_i^{M,DI}$, and ϵ^{M_3} to be the value of ϵ such that $\pi_i^{M,DD} = \pi_i^{M,ID}$. This leads to

$$\epsilon^{M_2} = \frac{a^2(1-e^2)}{4(1+e+\gamma)(2+2e-\gamma^2)} \quad (8)$$

$$\epsilon^{M_3} = \frac{a^2(1-e)}{2(2+\gamma)(2+2e-\gamma^2)}. \quad (9)$$

Comparing ϵ^{M_2} and ϵ^{M_3}, we obtain $\epsilon^{M_1} < \epsilon^{M_2} < \epsilon^{M_3}$. It follows that if $\epsilon > \epsilon^{M_3}$, then both merged firms will not innovate and (D, D) is the equilibrium outcome; if $\epsilon^{M_2} < \epsilon < \epsilon^{M_3}$, only one firm innovates and $(D, I), (I, D)$ are the outcomes; and if $\epsilon < \epsilon^{M_2}$, both merged firms innovate and (I, I) is the outcome. This implies that if ϵ belongs to $(\epsilon^{M_2}, \epsilon^{M_3})$, then the merger decision in Proposition 1 might be affected by asymmetric technology choices.

Comparing the values of the investment cost between the independent firms subgame and the merger subgame, we obtain $0 < \epsilon^{N_1} < \epsilon^{N_2} \lesseqgtr \epsilon^{M_2} < \epsilon^{M_3}$. Here it is interesting to note that the value ϵ^{M_3} is always above $(\epsilon^{N_1}, \epsilon^{N_2})$ – the interval within which a merger may not be profitable under symmetric technology choices. However, depending on the level of the R&D efficiency and the degree of product differentiation, it is possible that $\epsilon^{N_2} \lesseqgtr \epsilon^{M_2}$. In particular, ϵ^{M_2} is above $(\epsilon^{N_1}, \epsilon^{N_2})$ if $e > e^{**}(\gamma)$, while ϵ^{M_2} lies within the interval $(\epsilon^{N_1}, \epsilon^{N_2})$ if $e < e^{**}(\gamma)$.

First consider $\epsilon^{M_2} > \epsilon^{N_2}$, which occurs when $e > e^{**}(\gamma)$. In this case, we can show that (i) both (M, II) and (N, ID) are possible equilibrium outcomes when ϵ belongs to the interval $(\epsilon^{N_1}, \epsilon^{N_2})$; (ii) both $(M, II)$and (N, DD) can arise in equilibrium when ϵ belongs to $(\epsilon^{N_2}, \epsilon^{M_2})$; and (iii) both (M, ID) and (N, DD) are possible outcomes when ϵ belongs to $(\epsilon^{M_2}, \epsilon^{M_3})$. What this implies is that a merger might not be profitable even if asymmetric technology choices are permitted. Similarly, when $\epsilon^{M_2} < \epsilon^{N_2}$, which arises if $e < e^{**}(\gamma)$, it can be shown that a merger is not a unique equilibrium outcome. By contrast, when ϵ lies within the interval $(0, \epsilon^{N_1})$ or when $\epsilon > \epsilon^{M_3}$, a merger is always profitable, results consistent with Proposition 1. Overall, these findings suggest that whether the merged firm is constrained or not in its ability to make asymmetric investment decisions across its constituent divisions leaves the merger decision largely unchanged.

4.2 Side payments

One of key assumptions in our study is that a merger can only be realized under a unanimous agreement between firms in which no side payments are permitted. In that sense, our analysis can be seen as a variant of a voluntary collusive agreement. If we relax this assumption by allowing side payments, it is relatively straightforward to show that a bilateral merger-to-monopoly is always profitable. This result, not new in the literature, follows from the fact that the decisions of the two independent firms can now be made by the merged firm, which maximizes total industry profits. In other words, a merger with side payments can always achieve higher profits compared to a duopoly. In addition, when side payments are allowed, we find that a merger tends to discourage innovation under symmetric technology choices but tends to encourage innovation if technology choices are asymmetric.

4.3 Complement goods

Up until now the analysis has assumed that the firms produce substitute goods. When the products are complements, we find that the ranking of the values of the investment cost is reversed; that is, $0 < \epsilon^{N_2} < \epsilon^{N_1} < \epsilon^{M_1}$. This implies that the set of parameter configurations for which the merged firm innovates becomes larger and thus, compared to Corollary 1, a merger increases innovation incentives. At the same time, a merger is now always profitable. This follows from the fact that investing in R&D reduces cost and expands the demand for a firm's own product. Given that the products are complements, an increase in the demand for firm *i*'s product has a positive spill-over effect on the demand for the product of firm *j*. This positive externality in turn can be internalized through a merger, thereby encouraging the firms not only to integrate with each other through a merger but also to invest in R&D. We may conclude that the degree of product differentiation plays an important role for our key findings; when the goods are substitutes, it affects the merger decision for intermediately high investment cost, while switching from substitute to complement goods stimulates innovation and makes a merger always profitable.

4.4 Price competition

In our baseline model the firms compete in quantities. When they compete in prices instead, we find that for most parameter configurations (except if e is sufficiently low and γ is sufficiently high), the results are qualitatively similar to our previous findings. More specifically, when the investment cost is low, a merger is always profitable and the merged firm innovates; that is, (M, II) is the SPNE outcome. When the investment cost is intermediately low, although a merger is still profitable, the merged firm does not innovate; the same is also true when the investment cost is high and therefore (M, DD) is the outcome. By contrast, when the investment cost in intermediately high, there are circumstances in which a merger may not be profitable; such circumstances depend on the degree of product differentiation and the efficiency of the new technology. Overall, these results imply that when the firms compete in prices, a merger-to-monopoly may not always be profitable, thus lending support for our previous findings.

4.5 Technological spillovers

The analysis so far has assumed that there are no spillover effects between firms. To check the sensitivity of our results to the presence of spillovers, we postulate that spillovers are involuntary in the sense that they represent leakages of information from one firm to another without any compensation. This implies that a firm's overall cost function can be written out as $C_i(q_i) = \left(k_i - \beta(1 - k_j)\right) q_i^2 + F_i$, where β is the spillover rate and $1 - k_j$ is the extent of cost reduction of firm j.[12] From the preceding analysis we know that when the efficiency of the new technology is relatively high and the investment cost is below a certain level, the firms would prefer to stay independent and thus (N, ID) emerges in equilibrium. It turns out that this outcome continues to hold provided that spillovers are sufficiently low. Intuitively, when spillovers are low, firm i – the sole innovator – can conceal most of its re-

[12] Here the effect of spillovers is to induce a (further) reduction in a firm's marginal cost.

search output. Thus firm *i* has an incentive to remain independent when spillovers are sufficiently low as doing so means that it can increase its success in the product market.

4.6 Pre-merger market structure

Finally, we checked the robustness of our results by allowing for a larger number of firms. A commonly encountered difficulty in the literature is to construct a model that overcomes the merger paradox and thus yields sensible predictions for merger: (i) insiders gain, (ii) outsiders lose, (iii) the insiders produce more than the outsiders. Within a three-firm industry, we find that when all firms innovate, a bilateral merger becomes harmful for the insiders but beneficial for the outsider, if the products are sufficiently homogeneous and the new technology is relatively efficient. Intuitively, the market power effect of the merger (higher price and lower output) is to make the insiders less aggressive competitors. Because quantities are strategic substitutes, the implication of that is to expand the output of the outsider firm and, in turn, to increase its profit. Therefore, the net effect of the merger on the insiders' profit becomes negative, provided that the goods are sufficiently homogeneous and the new technology is relatively efficient. Importantly, this finding is consistent with Proposition 1, which indicates that a merger is not a unique SPNE outcome.

5. Conclusion

Using a simple model, this paper investigates the interplay between merger and innovation incentives in an industry with product differentiation. The analysis reveals that whether or not side payments between firms are allowed, a merger tends to discourage innovation, unless the investment cost is sufficiently low. This result has an Arrowian flavor in the sense that a merger-to-monopoly mostly weakens innovation incentives. Moreover, when side payments are permitted, a bilateral merger-to-monopoly is always profitable, a standard result in the literature. However, when side payments are not allowed and two conditions are met – the efficiency of the new technology is relatively high and the investment cost is below a particular level – the firms would prefer to stay independent, although they would enjoy significant market power through a merger.

The current study, like most that preceded it in industrial organization, is not without shortcomings. A potential limitation is that our model is stylized. Although we have attempted to relax some of its key assumptions, this will always be a difficult issue to address, given that the presence of three key parameters – the investment cost, the degree of product differentiation and the new technology efficiency – do not permit the use of a more general setting.

Nonetheless, we believe that our results carry an important message, indicating that firms' innovation decisions may be of profound importance for their decision to merge. Given that there are only a handful of studies on this topic, additional research is necessary to further our understanding. Future research might consider the role of heterogeneity, looking at how long-lasting differences between firms may influence both their merger and innovation incentives.

6. Appendix

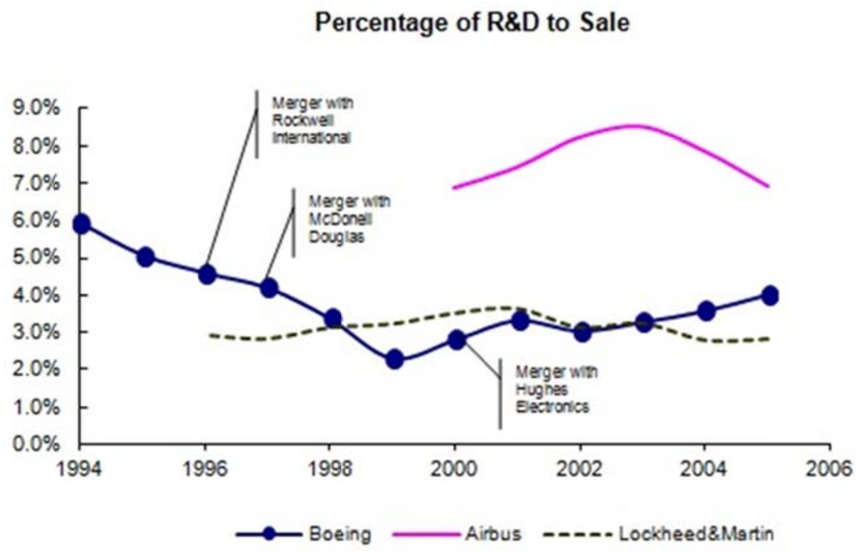

Figure A1. Note: Own calculations based on data from the companies' annual reports.

Merger subgame	**Output** $(Q^{M,rr})$	**Profit** $(\Pi^{M,rr})$
Invest	$\frac{a}{1+e+\gamma}$	$\frac{a^2}{2(1+e+\gamma)} - 2\epsilon$
Do not invest	$\frac{a}{2+\gamma}$	$\frac{a^2}{2(2+\gamma)}$

Table A1: Equilibrium output and profit of the merged firm

Independent firms subgame	**Output** $(q_i^{N,rr}, q_j^{N,rr})$	**Profit** $(\pi_i^{N,rr}, \pi_j^{N,rr})$
Both invest	$\left\{\frac{a}{2+2e+\gamma}, \frac{a}{2+2e+\gamma}\right\}$	$\left\{\frac{a^2(1+e)}{(2+2e+\gamma)^2} - \epsilon, \frac{a^2(1+e)}{(2+2e+\gamma)^2} - \epsilon\right\}$
Both do not invest	$\left\{\frac{a}{4+\gamma}, \frac{a}{4+\gamma}\right\}$	$\left\{\frac{2a^2}{(4+\gamma)^2}, \frac{2a^2}{(4+\gamma)^2}\right\}$
Only *i* invests	$\left\{\frac{a(4-\gamma)}{8+8e-\gamma^2}, \frac{a(2+2e-\gamma)}{8+8e-\gamma^2}\right\}$	$\left\{\frac{a^2(1+e)(4-\gamma)^2}{(8+8e-\gamma^2)^2} - \epsilon, \frac{2a^2(2+2e-\gamma)^2}{(8+8e-\gamma^2)^2}\right\}$

Table A2: Equilibrium output and profit of independent firm *i*

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