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Vertical Integration, Knowledge Disclosure and Decreasing Rival's Cost

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Abstract

We study vertical integration incorporating the fact that it creates the possibility of knowledge disclosure. We consider a setting where, through integrating, an upstream monopolist learns its downstream partner's innovation, and can disclose it to its downstream rival. We show that a vertically integrated firm chooses to fully disclose its knowledge to its downstream rival. Knowledge disclosure intensifies downstream competition but, at the same time, expands the downstream market size. We also show that, due to knowledge disclosure, vertical integration increases firms' innovation incentives, consumer and total welfare, and decreases, instead of raises, the rival's cost.

Keywords: vertical integration; R&D investments; market foreclosure; knowledge disclosure

JEL classification: L13; L22; L42

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1 Introduction

The pro- and anti-competitive effects of vertical integration have attracted a lot of attention in both antitrust theory and practice. The most well-known anti-competitive effect of vertical integration is that it "raises rival's cost": When an upstream firm integrates with a downstream firm, it increases the input price that it charges to its unintegrated downstream rivals, and thus, it raises their cost. By raising the rivals' cost, the vertically integrated firm forecloses its downstream rivals from the market and enjoys higher downstream profits.[1]

In this paper, we show that vertical integration decreases instead of raises the rivals' cost. We do so incorporating the fact that vertical integration can result into R&D knowledge disclosure. In particular, we take into account that when two vertically related firms integrate, information flow among them gets easier (e.g., the merged firms may integrate their IT networks). As a result, the upstream subsidiary of the integrated entity gets informed about its downstream partner's R&D activities and has the option of disclosing its knowledge to its downstream customers-rivals. We investigate whether vertical integration may result into such knowledge disclosure, as well as the incentives and implications of vertical integration.

Empirical evidence suggests that sharing of R&D knowledge is not restricted to research joint ventures or technical consortia. Firms often purposefully disclose their knowledge to their rivals (see e.g., Lhuillery, 2006, Penin, 2007), as well as to their customers/suppliers in the vertical supply chain (see e.g., Cassiman and Veugelers, 2002, Harhoff et al., 2003, Bonte and Keilbach, 2005). Interestingly, a number of real world cases indicate that vertically integrated firms also reveal their knowledge to their downstream customers-rivals. For instance, in the market for web-based applications for business clients, Google is both a producer and a direct retailer of its applications. There are several other independent resellers of Google's applications authorized by Google. Clearly, these resellers are both customers and rivals of Google. In 2009, Google developed a program through which Google offers training, support, and tools for sales and marketing to its resellers.[2] In other words, Google shares with its downstream customers-rivals knowledge that it has developed on its own as a retailer. Similarly, McAfee, the producer of security software, although it sells its

[1] A number of papers develop this point in depth (see e.g., Hart and Tirole, 1990, Ordover et al., 1990 and 1992, Rey and Tirole, 2007).

[2] For additional information see http://www.searchengineworld.com/google/3459069.htm as well as http://www.informationweek.com/news/development/mobility/231900685.

products on its own, it also offers training and marketing support to resellers of its products through its resellers partner program.[3]

We consider a framework in which an upstream monopolist sells an essential input to two competing downstream firms. Initially, we assume that only one of the downstream firms enjoys a cost-advantage due to an exogenous innovation. The upstream monopolist is considering integrating with the more efficient downstream firm. If they integrate, the integrated firm decides whether it will disclose its knowledge regarding the innovation of its downstream partner to its non-integrated downstream rival. If it discloses, the downstream rival will also enjoy the cost-advantage. After the integration decision, firms set the terms of vertical trade and compete in quantities. We also consider a richer framework in which we allow for endogenous R&D investments by both downstream firms, as well as for partial knowledge disclosure under vertical integration. Throughout, we focus on the case in which disclosure takes place for free, i.e., we abstract from licensing. This allows us to isolate the strategic effects of disclosure and to point out that it can be motivated by other incentives besides the licensing fees revenue.

Surprisingly, we demonstrate that the vertically integrated firm fully discloses its knowledge to its downstream rival. Knowledge disclosure increases the downstream rival's efficiency. From the vertically integrated firm's viewpoint, this has two opposite effects. First, it intensifies downstream competition and decreases the integrated firm's downstream market share and profits. Second, it expands the downstream demand and increases the integrated firm's upstream profits. The expansion of the downstream demand compensates the evasion in market share and full disclosure takes place.

Importantly, in contrast to the established view in the literature that vertical integration raises the rival's cost, we show that vertical integration always decreases the rival's cost. Under vertical integration, the vertically integrated firm increases the input price, causing an increase in the rival's cost. At the same time though, it discloses all its knowledge to the rival downstream firm, decreasing the latter's cost. The decrease in the rival's production cost turns out to be larger than the increase due the input price. We should note that the negative impact of vertical integration on the rival's cost depends crucially on the fact that we allow for the possibility of knowledge disclosure. If we had ignored this possibility, in line with the related literature, we would have found that vertical integration leads to a

[3]This can be seen at http://www.mcafee.com/us/partners/reseller-partners.

raise in rival's cost. Clearly then, taking into account the fact that vertical integration can give rise to the possibility of knowledge disclosure is an issue of great importance in the evaluation of the implications of vertical integration.

When innovation is endogenous, knowledge disclosure can reinforce the R&D investments of both downstream firms. For the non-integrated downstream firm, this result is quite intuitive: Since knowledge disclosure translates into free-riding on the integrated firm's R&D investments, it decreases its marginal cost. The latter effect results in an increase in its output, which reinforces the value of any cost reduction and causes an increase in its R&D investments. For the vertically integrated firm this result is counter-intuitive because the free-riding of its rival on its own R&D investments clearly weakens its investments incentives. However, knowledge disclosure increases the efficiency of the downstream rival and allows the vertically integrated firm to charge a higher wholesale price that results into higher profits from input sales. This effect reinforces the vertically integrated firm's investment incentives.

In light of the above, this paper identifies a number of pro-competitive effects of vertical integration that make it desirable from a welfare viewpoint. Vertical integration by eliminating double marginalization and by leading to knowledge disclosure, improves the efficiency of the downstream firms, increases the size of the downstream market and benefits both firms and consumers.

Our above mentioned insights carry over to trading through other types of contracts, such as two-part tariff contracts, and to downstream competition in prices instead of quantities. Moreover, they are robust when the disclosure decision is taken after firms' R&D investments, as well when R&D investments are research substitutes instead of research complements.

There is an emerging literature on knowledge disclosure in vertically related industries. Bonte and Wiethaus (2007) and Harhoff et al. (2003) consider an industry where an upstream monopolist sells an input to two downstream firms. The downstream firms have some exogenous R&D knowledge and choose the amount of knowledge that they will transfer to the upstream firm. In Bonte and Wiethaus (2007), the upstream firm, in turn, chooses how much of the knowledge that it obtained from a downstream firm it will transmit to the rival downstream firm. In Harhoff et al. (2003) instead, the disclosure to the upstream input manufacturer automatically triggers a complete spillover to the other downstream firm. None of these papers allows for vertical integration, and thus, none of them examines

how vertical integration affects the diffusion of downstream innovation.

The literature on vertical integration and market foreclosure abstracts, to a large extend, from the possibility of knowledge disclosure due to vertical integration.[4] Exceptions include the papers by Hughes and Kao (2001), Milliou (2004), and Allain et al. (2011). In particular, Hughes and Kao (2001) consider an industry with three asymmetric upstream firms and two downstream firms, one of which has private demand information. They allow for vertical integration among the more efficient upstream firm and the uniformed downstream firm and examine whether the upstream entity of the integrated firm has incentives to share with its downstream entity the demand information that it learns through its trading with the informed non-integrated downstream firm. Milliou (2004) and Allain et al. (2011) examine how the information flow from a downstream non-integrated firm to the downstream division of a vertically integrated firm regarding the former's R&D investments, via its upstream subsidiary, affects downstream R&D investments, profits and welfare. Milliou (2004) considers a market structure similar to ours and demonstrates that information flow can enhance firms' R&D investments. Allain et al. (2011) allow instead for an alternative upstream supplier at which downstream customers can turn under vertical integration in order to avoid information flow at the expense of having to pay a higher input price. All of these papers consider knowledge disclosure from the rival downstream non-integrated firm to the downstream integrated firm and tend, under certain circumstances, to provide an argument against vertical integration. Instead, we consider the reverse direction of knowledge disclosure, from the downstream integrated firm to the downstream non-integrated firm and identify a novel argument in favor of vertical integration.

Our paper relates also to the literature on licensing. Within this literature, a number of papers (see e.g., Lemarie, 2005, Arya and Mittendorf, 2006, Fauli-Oller and Sandonis, 2006) study the incentives and the implications of vertical integration when an upstream monopolist sells its innovation to downstream firms through a licensing contract. Our paper differs from this literature in many aspects. Importantly, in this literature knowledge transmission to the downstream rivals is mainly motivated by the revenues generated from the licensing fees. In our paper, we abstract from such incentives. Moreover, whereas in this literature innovation is upstream and trading is possible only if there is licensing, in our paper innovation is downstream and firms trade even in the absence of knowledge disclosure.

[4] For an in depth review of this literature see Rey and Tirole (2007) and Riordan (2008).

The rest of the paper is organized as follows. In Sections 2 and 3, we analyze the disclosure incentives, as well as the implications and incentives of vertical integration with exogenous and endogenous innovation respectively. In Section 4, we extend our analysis in various ways. We conclude in Section 5. The proofs are relegated to the Appendix.

2 Vertical Separation Vs. Vertical Integration and Knowledge Disclosure with Exogenous Innovation

To demonstrate in a more clear way the main intuition of our paper, in this Section, we analyze briefly a simple model in which one of the downstream firms is endowed with an exogenous innovation and there is full or none knowledge disclosure under vertical integration.

In particular, we consider a two-tier industry consisting, initially, by an upstream monopolist, denoted by U, and two downstream firms, each denoted by D_i, with $i = 1, 2$. The upstream firm sells an essential input to the downstream firms which transform it into a final product in a one-to-one proportion.

Each D_i faces the following (inverse) demand function:

$$p_i(q_i, q_j) = a - q_i - \gamma q_j, \quad i, j = 1, 2, \ i \neq j, \ 0 < \gamma \leq 1, \tag{1}$$

where p_i and q_i are respectively the price and the quantity of D_i's product and q_j is the quantity of D_j's product. The parameter γ measures the degree of product differentiation: The higher is γ, the closer substitutes the two products are.

U's production cost is normalized to zero. Instead, D_1's and D_2's marginal production costs are $c - \Delta + w_1$ and $c + w_2$ respectively. Parameter c denotes an exogenous constant marginal cost, Δ, with $0 < \Delta < c$, the outcome of the innovation possessed only by D_1, and w_i the wholesale price that D_i pays per unit of input to U, i.e., linear wholesale price contracts are used.

U can integrate with one of the downstream firms. Clearly, it prefers to integrate with the more efficient downstream firm, i.e., with D_1. Vertical integration brings about two important changes. First, the input is transferred at marginal cost within the vertical integrated entity, denoted by $U - D_1$. Thus, the latter's marginal cost becomes $c - \Delta$. Second, due to the information flow between the upstream and downstream units of the

integrated entity, U gains access to the outcome of the D_1's innovation. This gives U the option of disclosing what it learned to its downstream customer-rival D_2.[5] In particular, under vertical integration, D_2's marginal cost becomes $c-k\Delta+w_2$, with $k \in \{0,1\}$. Without disclosure, $k=0$, while with disclosure, $k=1$.

Firms play a three-stage game with observable actions. In stage 1, U and D_1 decide whether they will integrate. If they integrate, the vertically integrated firm decides whether it will disclose its knowledge to D_2. In stage 2, under vertical separation, U makes simultaneous take-it-or-leave-it offers to the downstream firms regarding w_1 and w_2. Under vertical integration, $U-D_1$ makes a take-it-or-leave-it offer only to D_2 regarding w_2. Lastly, in stage 3, downstream firms compete in quantities.

Under vertical separation, in the final stage, each D_i solves the following problem:

$$\max_{q_i} \ \pi_{D_i}(q_i, q_j, w_i, w_j) = p_i(q_i, q_j)q_i - C_i(q_i, w_i), \tag{2}$$

where $C_1(q_1, w_1) = (c - \Delta + w_1)q_1$ and $C_2(q_2, w_2) = (c + w_2)q_2$.

In stage 2, U faces the following problem:

$$\max_{w_1, w_2} \ \pi_U(w_1, w_2) = w_1 q_1(w_1, w_2) + w_2 q_2(w_1, w_2), \tag{3}$$

where $q_i(w_i, w_j)$ is the solution of (2). The equilibrium wholesale prices, quantities and firms' profits are reported in Appendix A1.

Under vertical integration, in stage 3, $U-D_1$ and D_2 face the following problems:

$$\max_{q_1} \pi_{VI}(q_1, q_2, w_2, k) \ = \ p_1(q_1, q_2)q_1 - (c - \Delta)q_1 + w_2 q_2; \tag{4}$$

$$\max_{q_2} \pi_{D_2}(q_1, q_2, w_2, k) \ = \ p_2(q_1, q_2)q_2 - (c - k\Delta + w_2)q_2. \tag{5}$$

Solving we obtain $q_i(w_2, k)$. In the previous stage, $U-D_1$ chooses w_2:

$$\max_{w_2} \ \pi_{VI}(w_2, k) = [q_1(w_2, k)]^2 + w_2 q_2(w_2, k) \tag{6}$$

[5] It is natural to think that once two firms start operating as an integrated entity, they get informed about the characteristics of each other - they exchange more information. Alternatively, we could have assumed that even without integration, U, in its role as a supplier of D_1 and D_2, has some knowledge regarding their innovations. Again though integration increases U's knowledge regarding its downstream partner's innovation relative to the knowledge that it has regarding its downstream rival's innovation.

The resulting equilibrium values are included in Appendix A1.[6]

We note that there is full market foreclosure, $q_2^{VI}(k) \leq 0$, when $\Delta \leq \Delta_f(k) \equiv -(a-c)(1-\gamma)/(k-\gamma)$. This implies that when there is full knowledge disclosure ($k=1$), vertical integration never drives D_2 out of the market, $\Delta_f(1) < 0$. It also implies that if there is no knowledge disclosure ($k=0$), vertical integration drives the downstream non-integrated firm out of the market when the level of exogenous innovation is too high. Part of our subsequent analysis is performed under the following assumption:

Assumption 1: $\Delta < \Delta_f(0) \equiv (a-c)(1-\gamma)/\gamma$.

Surprisingly, under Assumption 1, we find that $\pi_{VI}(1) - \pi_{VI}(0) > 0$. In other words, we find that the vertically integrated firm is better off when instead of protecting its own downstream innovation by keeping it in house, it reveals it to its downstream rival. Intuitively, disclosure makes the downstream non-integrated rival more efficient. This means that disclosure intensifies downstream competition, and thus, has a negative impact on the vertically integrated firm's downstream profits. However, it also means that disclosure augments the downstream market size and results into an increase in the integrated firm's profits from input sales - in fact, both the wholesale price and D_2's quantity are higher with disclosure. The latter positive effect compensates for the loss in downstream profits and makes disclosure attractive.

As mentioned above, when $k=1$, Assumption 1 is satisfied and vertical integration does not lead to full market foreclosure. However, the vertically integrated entity might prefer setting $k=0$ in order that Assumption 1 is not always satisfied. In that case, it will be a monopolist with profits $\pi_{VI}^f = (a-c+\Delta)^2/4$**.** Comparing $\pi_{VI}(1)$ with π_{VI}^f, we conclude that the vertically integrated entity never chooses to fully foreclose its downstream rival. If the vertically integrated firm fully forecloses its downstream rival, it will enjoy monopoly profits from the downstream market and null profits from the upstream market. The latter, as we saw above, are higher with knowledge disclosure. In fact, they are so high that the vertically integrated firm chooses not to sacrifice them through foreclosure. If we did not allow for the possibility of disclosure, we would predict that full market foreclosure could arise in equilibrium. Therefore, allowing for this possibility, we demonstrate that vertical integration never results into full market foreclosure. Importantly, we also demonstrate that vertical

[6] All the statements which are made in the rest of this Section follow from simple comparisons of the relevant expressions reported in Appendix A1.

integration decreases, instead of raising, its downstream rival's cost, i.e., $c - \Delta + w_2^{VI}(1) < c + w_2^{VS}$.

Given its implications, vertical integration is always desirable from U and D_1' viewpoint, $\pi_{VI}(1) - (\pi_U^{VS} + \pi_{D_1}^{VS}) > 0$. Integration not only solves the double marginalization problem, but it also increases the upstream profits of the integrated entity due to the induced knowledge disclosure. Vertical integration is also desirable from D_2's viewpoint as long as the cost-reducing outcome of the exogenous innovation is sufficiently low. Intuitively, as vertical integration induces knowledge disclosure, it increases the absolute efficiency of D_2, tending to increase its output and profits. However, a high cost-reducing outcome of innovation allows the integrated entity to charge a high input price, thus deteriorating D_2's relative efficiency and, in turn, decreasing its output and profits. Consumers are also better off when vertical integration materializes. This occurs because both firms face lower cost under vertical integration, and thus, they produce more, $q_i^{VI}(1) > q_i^{VS}$. In light of the above, it is not surprising that vertical integration enhances total welfare.

3 Vertical Separation Vs. Vertical Integration and Knowledge Disclosure with Endogenous Innovation

In this Section, we consider a richer framework in which we endogenize the innovation of both downstream firms and we allow for partial knowledge disclosure under vertical integration.

In particular, we consider the same market structure as in Section 2. However, we assume now that under vertical separation D_i's variable production cost is $C_i(w_i, q_i) = (c + w_i - x_i)q_i$, where x_i is the level of D_i's endogenous R&D investments.

Respectively, under vertical integration, we assume that the variable cost of $U - D_1$ is $(c - x_1)q_1$ while that of D_2's is $(c + w_2 - x_2 - \delta x_1)q_2$, where δ is the degree of knowledge that U discloses to D_2 regarding D_1's R&D investments. As mentioned above, we allow now for partial disclosure, i.e., $0 \leq \delta \leq 1$.

As standard in the literature (see e.g., d'Aspremont and Jacquemin, 1988), we assume that the cost of the R&D investments is quadratic, and more specifically, it is given by x_i^2.

In terms of timing of moves, we add a stage, just after stage 1, in which firms simultaneously and independently choose their R&D investments x_1 and x_2. The rest of the game remains the same.

3.1 Vertical Separation

When U and D_1 remain separated, in the last stage, each D_i faces the following problem:

$$\max_{q_i} \pi_{D_i}(q_i, q_j, w_i, w_j, x_i, x_j) = p_i(q_i, q_j)q_i - (c + w_i - x_i)q_i - x_i^2. \tag{7}$$

Solving we obtain $q_i(w_i, w_j, x_i, x_j)$. In stage 3, U chooses the wholesale prices in order to maximize its profits:

$$\max_{w_1, w_2} \pi_U(w_1, w_2, x_1, x_2) = w_1 q_1(w_1, w_2, x_1, x_2) + w_2 q_2(w_1, w_2, x_1, x_2). \tag{8}$$

Solving we obtain $w_i(x_i, x_j)$. Finally, maximizing, in stage 2, D_i's profits in terms of x_i, we obtain the equilibrium R&D investments, and in turn, the equilibrium wholesale prices and quantities:

$$x_i^{VS} = \frac{a - c}{15 + 2\gamma(4 - \gamma(2 + \gamma))} \tag{9}$$

$$w_i^{VS} = \frac{(a - c)(2 - \gamma)(2 + \gamma)^2}{15 + 2\gamma(4 - \gamma(2 + \gamma))};\ q_i^{VS} = \frac{(a - c)(4 - \gamma^2)}{15 + 2\gamma(4 - \gamma(2 + \gamma))} \tag{10}$$

Note that $\frac{\partial x_i^{VS}}{\partial \gamma} > 0$ if and only if $\gamma > \frac{2}{3}$.[7]

3.2 Vertical Integration and Disclosure Incentives

Under vertical integration, in the last stage, the two firms solve the following problems:

$$\max_{q_1} \pi_{VI}(q_1, q_2, w_2, x_1, x_2, \delta) = p_1(q_1, q_2)q_1 - (c - x_1)q_1 + w_2 q_2 - x_1^2; \tag{11}$$

$$\max_{q_2} \pi_{D_2}(q_1, q_2, w_2, x_1, x_2, \delta) = p_2(q_1, q_2)q_2 - (c + w_2 - x_2 - \delta x_1)q_2 - x_2^2. \tag{12}$$

The resulting equilibrium quantities are $q_i(w_2, x_1, x_2, \delta)$. In the previous stage, $U - D_1$ chooses the wholesale price that it charges to D_2:

$$\max_{w_2} \pi_{VI}(w_2, x_1, x_2, \delta) = [q_1(w_2, x_1, x_2, \delta)]^2 + w_2 q_2(w_2, x_1, x_2, \delta) - x_1^2.$$

[7] I.e., there is a U-shaped relation between the R&D investments and the intensity of downstream competition. This is in line with Sacco and Schmutzler (2011) who consider the relationship between R&D investments and product differentiation in a one-tier industry.

The solution is:

$$w_2(x_1, x_2, \delta) = \frac{(a-c)(8-(4-\gamma)\gamma^2) + 8(x_2 + \delta x_1) - \gamma^2(4x_2 + 4\delta x_1 - \gamma x_1)}{16 - 6\gamma^2}. \tag{13}$$

One can easily note that $\frac{\partial w_2}{\partial x_i} > 0$, $\frac{\partial w_2}{\partial \delta} > 0$, and $\frac{\partial^2 w_2}{\partial x_i \partial \delta} > 0$ for $i = 1, 2$. The latter implies that the positive impact of the R&D investments on the wholesale price gets stronger when knowledge disclosure increases.

Finally, maximizing the vertically integrated and non-integrated downstream firms' profits in terms of x_1 and x_2 respectively, we obtain the equilibrium R&D investments as a function of δ:

$$x_1^{VI}(\delta) = \frac{(a-c)[60 + 4\delta(1-\gamma)(8-3\gamma^2) - \gamma(32 + \gamma(16 - 3(4-\gamma)\gamma))]}{180 - 176\gamma^2 + 39\gamma^4 + 4\delta(4\gamma - \delta)(8 - 3\gamma^2)}; \tag{14}$$

$$x_2^{VI}(\delta) = \frac{4(a-c)(3 + \delta - 4\gamma)}{180 - 176\gamma^2 + 39\gamma^4 + 4\delta(4\gamma - \delta)(8 - 3\gamma^2)}. \tag{15}$$

The resulting equilibrium wholesale price and quantities are:

$$w_2^{VI}(\delta) = \frac{2(a-c)[48 + \delta(2 + \gamma - \delta\gamma)(8 - 3\gamma^2) - \gamma[4 + \gamma(50 - \gamma(8 + 3\gamma(4 - \gamma)))]]}{180 - 176\gamma^2 + 39\gamma^4 + 4\delta(4\gamma - \delta)(8 - 3\gamma^2)}; \tag{16}$$

$$q_1^{VI}(\delta) = \frac{(a-c)[(2-\gamma)[60 + \gamma(10 - 3\gamma(9 + 2\gamma))] - \delta(8 - 3\gamma^2)(2\delta - 2 - \gamma)]}{180 - 176\gamma^2 + 39\gamma^4 + 4\delta(4\gamma - \delta)(8 - 3\gamma^2)}; \tag{17}$$

$$q_2^{VI}(\delta) = \frac{2(a-c)(3 + \delta - 4\gamma)(8 - 3\gamma^2)}{180 - 176\gamma^2 + 39\gamma^4 + 4\delta(4\gamma - \delta)(8 - 3\gamma^2)}. \tag{18}$$

Note that $q_2^{VI}(\delta) \leq 0$, i.e., there is full market foreclosure, when $\gamma \geq \gamma_f(\delta) \equiv (3 + \delta)/4$. This implies that if there is no knowledge disclosure ($\delta = 0$), vertical integration drives the non-integrated downstream out of the market when downstream competition is sufficiently strong, and in particular, if and only if $\gamma \geq .75$. However, it also implies that full market foreclosure is less likely, the higher is knowledge disclosure. In fact, $\gamma_f(1) = 1$. Thus, similarly to the model with exogenous innovation, when there is full knowledge disclosure ($\delta = 1$), vertical integration never drives D_2 out of the market. We make the following assumption in part of our subsequent analysis:

Assumption 2: $\gamma < \gamma_f(\delta) \equiv (3 + \delta)/4$

Next, we examine how knowledge disclosure influences firms' equilibrium behavior.

Proposition 1 *Under Assumption 2,*

(i) the downstream non-integrated firm's R&D investments $x_2^{VI}(\delta)$ always increase in δ,

(ii) the vertically integrated firm's R&D investments $x_1^{VI}(\delta)$ increase in δ except if, for given δ, γ is sufficiently high,

(iii) the downstream non-integrated firm's effective R&D investments $x_2^{VI}(\delta) + \delta x_1^{VI}(\delta)$ always increase in δ,

(iv) the wholesale price charged to the downstream non-integrated firm $w_2^{VI}(\delta)$ always increases in δ,

(v) the downstream non-integrated firm's unit cost $c + w_2^{VI}(\delta) - x_2^{VI}(\delta) - \delta x_1^{VI}(\delta)$ always decreases in δ,

(vi) the downstream non-integrated firm's output $q_2^{VI}(\delta)$ always increases in δ,

(vii) the vertically integrated firm's output $q_1^{VI}(\delta)$ increases in δ except if, for given δ, γ is sufficiently high.

Proposition 1(i) asserts that the more knowledge is transferred to D_2, the more D_2 invests in R&D. Intuitively, D_2's marginal cost is reduced due to the free-riding on the R&D investments of $U - D_1$. The decrease in its marginal cost results into an increase in its output, which in turn reinforces the value of any cost reduction, and induces an increase in its own R&D investments. This effect is often referred to as *output effect* (see e.g., Bester and Petrakis, 1993, Milliou, 2004).

Interestingly, an increase in knowledge disclosure can reinforce the investment incentives of the integrated firm too (Proposition 1(ii)). This holds unless products are sufficiently close substitutes. The intuition is as follows. An increase in knowledge disclosure has two opposite effects. First, it translates into an increase in the free-riding of the rival downstream firm, and thus, it weakens the integrated firm's investments incentives. Second, as we saw above, it intensifies the positive impact of an increase in the integrated firm's R&D investments on the input price. Therefore, it leads to higher profits from input sales and, in turn, reinforces the integrated firm's investment incentives. When downstream competition is not too strong, the first negative effect is weak and it is outweighed by the second positive effect. We should point out that this finding is in contrast with respective findings in one-tier industries (see e.g., Milliou, 2009) and in vertically related industries in the absence of vertical integration.[8] In light of the above, it is not surprising that the *effective R&D investments* of the downstream non-integrated firm, that is, the total cost reduction that

[8] This last point is discussed in Section 4.

D_2 enjoys due to the R&D investments, $x_2^{VI}(\delta) + \delta x_1^{VI}(\delta)$, always increase with knowledge disclosure (Proposition 1(iii)).

Proposition 1(iv) informs us that the input price increases with knowledge disclosure. This is a straightforward implication of the fact that disclosure increases D_2's effective R&D investments. The latter increase the gross profits of D_2. $U - D_1$ extracts D_2' higher gross profits by charging a higher input price.

Up to now, we have seen that the knowledge disclosure impact on D_2's cost, on the one hand, is positive due to the increase in the input price, and on the other hand, it is negative due to the increase in D_2's effective R&D investments. Naturally, the following question arises: What is the overall impact of knowledge disclosure on the rival's cost? As Proposition 1(v) states, the negative impact of knowledge disclosure dominates and the more knowledge is disclosed, the lower is the rival's cost.

Further, the implications of knowledge disclosure on firms' output are similar to the respective ones on R&D investments. In other words, D_2's output increases with δ, since its cost decreases with δ. Respectively, D_1's output increases with δ when products are sufficiently differentiated since then δ reinforces D_1's R&D investments, and thus, decreases its cost.

We turn now to the analysis of the vertically integrated firm's choice of the optimal degree of knowledge disclosure.

Proposition 2 *Under Assumption 2, the vertically integrated firm optimally sets* $\delta^* = 1$.

Similarly to the case with exogenous innovation, we find that the vertically integrated firm chooses to disclose its knowledge. Actually, it chooses to disclose all of its knowledge. The more knowledge is disclosed, the higher is the input price and the output of the rival downstream firm (Proposition 1(iv) and (vi)). As a consequence, the more knowledge is disclosed, the higher are the vertically integrated entity's profits from the input sales. The latter effect is so strong that it dominates the negative impact of disclosure on the integrated firm's downstream profits.

Taking into account the fact that under vertical integration there is full knowledge disclosure, a number of observations are in order. First, it is easy to check that the vertically integrated firm's R&D investments are higher than those of the downstream non-integrated firm, $x_1^{VI} > x_2^{VI}$.[9] This is a straightforward implication of the fact that the input is

[9] For notational convenience, from now on we define $x_i^{VI} \equiv x_i^{VI}(1)$. Similarly, for the rest of the variables.

transferred at marginal cost within the vertically integrated firm, while the downstream non-integrated firm suffers from double marginalization. Second, that the vertically integrated firm's variable cost is lower than that of the downstream non-integrated firm's, $c - x_1^{VI} < c + w_2^{VI} - x_2^{VI} - x_1^{VI}$. This is so, because the burden of double marginalization is too heavy that the cost of the downstream non-integrated firm turns out to be higher than that of the vertically integrated firm, even though only the former firm free-rides on R&D investments. Finally, that the vertically integrated firm's output is higher than the downstream non-integrated firm's output, $q_1^{VI} > q_2^{VI}$. Since the vertically integrated firm faces lower cost, and thus enjoys a competitive advantage relative to its downstream rival, it follows that it also has a larger market share.

3.3 Merger Implications and Incentives

A fundamental question we need to address is whether vertical integration leads to the complete market foreclosure of the rival downstream firm. According to Proposition 2, under Assumption 2, vertical integration leads to full knowledge transfer ($\delta^* = 1$). When $\delta = 1$, Assumption 2 is always satisfied. However, when $\gamma \geq .75$ the vertically integrated entity might prefer instead to set δ such that Assumption 2 is not satisfied. Thus, it might prefer to fully foreclose D_2. In the latter case, there is a bilateral monopoly in the market and $U - D_1$'s equilibrium profits are $\pi_{VI}^f = \frac{(a-c)^3}{3}$. Comparing $U - D_1$'s profits with and without market foreclosure, we conclude that the vertically integrated entity is better off when its downstream rival is present in the market.[10]

Proposition 3 *In equilibrium, the vertically integrated firm never fully forecloses the downstream non-integrated firm.*

The intuition behind Proposition 3 is similar to the one mentioned in the case with exogenous innovation. We should stress again though that if we did not allow for knowledge disclosure, we would find that vertical integration leads to full market foreclosure when downstream competition is sufficiently strong.

The following Proposition summarizes the main implications of vertical integration with full knowledge disclosure.

[10] To be more precise, this statement is true for all $\gamma < 1$. When goods are homogenous ($\gamma = 1$), the vertically integrated firm essentially forecloses its downstream rival even when it fully discloses knowledge. In fact, when $\gamma = 1$, $q_2^{VI} = x_2^{VI} = 0$.

Proposition 4 *In equilibrium, vertical integration leads to an increase in*

(i) the R&D investments of the vertically integrated firm, $x_1^{VI} > x_1^{VS}$,

(ii) the R&D investments of the non-integrated downstream firm, $x_2^{VI} > x_2^{VS}$, *if and only if* γ *is sufficiently low,*

(iii) the effective R&D investments of the non-integrated downstream firm, $x_2^{VI} + x_1^{VI} > x_2^{VS}$,

(iv) the wholesale price, $w_2^{VI} > w_2^{VS}$,

(v) the output of the vertically integrated firm, $q_1^{VI} > q_1^{VS}$,

(vi) the output of the non-integrated downstream firm, $q_2^{VI} > q_2^{VS}$, *if and only if* γ *is sufficiently low.*

Vertical integration reinforces both the R&D investments and the output of the integrated firm. Intuitively, under vertical separation, both downstream firms face the problem of double marginalization and share equally the downstream market. Under vertical integration though, D_1 enjoys a competitive advantage and has a larger market share relative to its non-integrated downstream rival. It follows from this that D_1's output is larger when it is vertically integrated. The subsequent *output effect* reinforces D_1's R&D investments in the presence of integration. And in fact, it outweighs the negative impact of free-riding on D_1's investments and leads to higher investments under integration.

Further, vertical integration increases both the R&D investments and the output of the downstream non-integrated firm when downstream competition is not too strong. The intuition is as follows. When downstream competition is strong, the competitive advantage of the vertically integrated entity is more pronounced, and as a result, vertical integration shrinks D_2's market share, and its subsequent incentives to invest in R&D. Thus, we observe *partial foreclosure* of the rival downstream firm but only if the competitive pressure is rather strong in the market. When instead downstream competition is relatively weak, since the downstream non-integrated firm free-rides on the integrated firm's R&D investments and the latter are higher under vertical integration, strategic complementarity reinforces D_2's investment incentives and results into both higher R&D investments and output under integration.

As we mentioned in the discussion of Proposition 1(iv), when the rival downstream firm becomes more efficient, its upstream supplier has incentives to increase the input price. Proposition 4(iii) informs us that vertical integration increases the efficiency of the

downstream rival. Thus, it increases the input price (Proposition 4(iv)). As the following Proposition states, similarly to the case with exogenous innovation, the net effect of vertical integration on the rival's cost is in the rival's favor.

Proposition 5 *In equilibrium, vertical integration leads to a decrease in the non-integrated downstream firm's variable cost,* $c + w_2^{VI} - x_2^{VI} - x_1^{VI} < c + w_2^{VS} - x_2^{VS}$.

We should note that the decrease in the rival's cost due to vertical integration holds more generally. In fact, it holds as long as $\delta > \delta_{cr}(\gamma)$, with $\frac{\partial \delta_{cr}}{\partial \gamma} > 0$ and $\delta_{cr}(1) = .14$. If by assumption knowledge transfer is impossible, i.e., $\delta = 0$, vertical integration raises the rival's cost. Therefore, the negative impact of vertical integration on the rival's cost depends crucially on the fact that we allow for the possibility of knowledge disclosure. If we had ignored this possibility, in line with the related literature, we would have found that vertical integration leads to a raise in rival's cost. Clearly then, taking into account the fact that vertical integration can give rise to the possibility of knowledge disclosure is an issue of great importance in the evaluation of the implications of vertical integration.

Proposition 6 *(i) Vertical integration always arises in equilibrium.*

(ii) Vertical integration increases the profits of the non-integrated downstream firm if and only if γ *is sufficiently low.*

(iii) Vertical integration always increases both consumers surplus and total welfare.

Proposition 6 informs us that merger incentives always exist. It also informs us that when downstream competition is not too strong, vertical integration increases the profits of the downstream rival. This occurs because vertical integration increases the efficiency of the non-integrated downstream firm and, in turn, this effect causes the expansion in its output and profits unless downstream competition is too fierce. Vertical integration, thus, instead of driving the downstream rival out of the market, it enhances, under certain circumstances, the rival's profits. Moreover, as Proposition 6(iii) states, vertical integration also enhances both consumers surplus and total welfare. This is so because both the total quantity produced and the total industry profits are always higher under vertical integration than under vertical separation.

4 Extensions and Discussion

In what follows, we examine the robustness of our findings by considering various extensions of our model with endogenous innovation.

4.1 Knowledge Disclosure Incentives Under Vertical Separation

In our analysis so far, we assumed that only vertical integration creates the possibility of knowledge disclosure. Naturally, one might wonder whether disclosure could occur in the absence of vertical integration too. In order to examine this, we consider a modification of our model in which, under vertical separation, D_1 decides in stage one, how much knowledge it will disclose to D_2 regarding its own R&D investments, i.e., D_1 chooses the level of δ.

We find that an increase in knowledge leads to an increase in D_2's R&D investments. However, in contrast to what happens under vertical integration, under vertical separation, an increase in knowledge disclosure weakens D_1's investment incentives. This occurs because the more knowledge is disclosed, the more D_2 free-rides on D_1's investments. Since under vertical separation D_2 is only a rival of D_1 and not a customer too, D_1 only loses from D_2's free-riding. In equilibrium, D_1 does not disclose any of its R&D knowledge to D_2.[11,12] Therefore, we can conclude that the existence of vertical integration is crucial for knowledge disclosure to occur.

4.2 Two-Part Tariff Contracts

We extend now our analysis to the case in which vertical trading is conducted through two-part tariff contracts, i.e., through contracts which consist of both a wholesale price w_i per unit of input and a fixed fee-tranfer F_i. For the analysis to be non-trivial, we consider bargaining over two-part tariffs.[13] In particular, we invoke the Nash bargaining solution

[11] Clearly, D_1's knowledge disclosure incentives might have been different if it could sell its knowledge to D_2, e.g., through a licensing contract. As we mentioned in the Introduction, our working assumption here, as well as throughout our analysis, is that knowledge cannot be sold.

[12] Note that we consider the case of only one-way knowledge disclosure from D_1 to D_2 so that the setting is similar to the one under vertical integration. If we allowed for two-way knowledge disclosure (i.e., allow also for the possibility of disclosure from D_2 to D_1), firms might have incentives to disclose due to the presence of a "reciprocity effect". Milliou (2009) demonstrates this in a one-tier industry.

[13] Clearly, under two-part tariff contracts, when the upstream monopolist makes its take-it-or-leave-it contract offer(s) in stage 3, it will obtain through the fixed fees all the downstream gross profits. Given this, the downstream firms make negative profits if they undertake R&D investments in stage 2. Thus, they choose not to invest in R&D. Therefore, a necessary condition for downstream firms to invest in R&D is to possess some bargaining power during their negotiations with the upstream monopolist.

and assume that the bargaining power of the upstream firm is given by β, with $0 \leq \beta \leq 1$, while that of the downstream firms is given by $1-\beta$. Under vertical integration, $U-D_1$ bargains with D_2 over (w_2, F_2). Under vertical separation, U, D_1 and D_2, conduct public negotiations over both (w_1, F_1) and (w_2, F_2). This specification guarantees that the outcome of the negotiations becomes publicly known and is non-renegotiable ex-post so that U does not suffer from the well-known "commitment problem".[14]

Under vertical separation, the solution of the last stage of the game results into the same $q_i(w_i, w_j)$ as in the respective case in Section 3. In stage 3, firms bargain over the terms of the two-part tariff contracts. Assuming that the downstream bargaining power $1-\beta$ is equally split between D_1 and D_2, the negotiation outcome is the solution to the following three player Nash bargaining problem:

$$\max_{w_1,F_1,w_2,F_2} [\pi_U(w_1,w_2,x_1,x_2)+F_1+F_2]^{\beta}[\pi^g_{D_1}(w_1,w_2,x_1,x_2)-F_1]^{(1-\beta)/2} \times [\pi^g_{D_2}(w_1,w_2,x_1,x_2)-F_2]^{(1-\beta)/2}. \quad (19)$$

where $\pi^g_{D_i}(.)$ are D_i's gross (from the R&D costs) profits. Note that all players have zero outside options. Maximizing (19) first with respect to F_1 and F_2, it is easy to see that the problem reduces to the maximization of the industry's total gross profits, $\pi_U(.)+\pi^g_{D_1}(.)+\pi^g_{D_2}(.)$, with respect to w_1 and w_2. It is also easy to see that each firm's gross profits are proportional to the industry maximum gross profits with a factor of proportionality equal to the firm's bargaining power. Solving we obtain the equilibrium wholesale prices in terms of the R&D investments, $\overline{w}_i(x_i, x_j)$.

In stage 2, each D_i chooses x_i in order to maximize its profits, $\frac{1-\beta}{2}[\pi_U(x_i,x_j)+\pi^g_{D_1}(x_i,x_j)+\pi^g_{D_2}(x_i,x_j)]-x_i^2$. Solving this problem, we obtain the equilibrium R&D investments:

$$\overline{x}_i^{VS} = \frac{(a-c)(1-\beta)}{7+\beta+8\gamma}. \quad (20)$$

[14] When the negotiations of U with D_1 and D_2 are secret, U faces the "commitment problem" that does not allow him to exploit its monopoly power. The monopolist's commitment problem that has been identified by McAfee and Schwartz (1995), Rey and Vergé (2004) and de Fontenay and Gans (2005), among others, corresponds to U's inability to commit to D_i that it will not secretly offer a lower wholesale price to D_j. D_i knows that U has incentives to behave opportunistically and make D_j an aggressive competitor in the final product market, via a lower wholesale price w_j, because it can then use the fixed fee F_j in order to transfer upstream the higher gross profits of D_j. Anticipating this, D_i will never agree on a wholesale price that is not below the upstream marginal cost. As a result, if the negotiations were secret, U would have an additional reason for integrating vertically: To avoid this commitment problem. In order to abstract from such incentives, we assume that negotiations are public.

Substituting in turn, we obtain the rest of the equilibrium values under vertical separation.[15]

Under vertical integration, the equilibrium quantities of the last stage of the game coincide with the respective ones in Section 3. In the previous stage, $U - D_1$ bargains with D_2 over w_2 and F_2. We assume that D_2 is endowed with all the downstream bargaining power.[16] Given this, the Nash bargaining problem is:

$$\max_{w_2, F_2} [\pi^g_{VI}(w_2, x_1, x_2, \delta) + F_2 - \pi^{fg}_{VI}(x_1)]^{\beta} [\pi^g_{D_2}(w_2, x_1, x_2, \delta) - F_2]^{1-\beta}, \tag{21}$$

where $\pi^g_{VI}(w_2, x_1, x_2, \delta)$ and $\pi^g_{D_2}(w_2, x_1, x_2, \delta)$ are the gross (from R&D costs) profits. The term $\pi^{fg}_{VI}(x_1)$ captures the "outside option" of the vertically integrated firm. Since the vertically integrated firm always has the option to fully foreclose D_2, in case of disagreement with the latter, its profits are equal to the gross profits that it earns when it acts as a monopolist in the downstream market and are thus equal to $\frac{(a-c+x_1)^2}{4}$. The outside option of D_2 continues to be null. After maximizing (21) with respect to F_2, it is easy to see that the problem reduces to the maximization of the industry's extra joint gross profits, $\pi^g_{VI}(w_2, x_1, x_2, \delta) + \pi^g_{D_2}(w_2, x_1, x_2, \delta) - \pi^{fg}_{VI}(x_1)$, with respect to w_2 and that the latter are split between $U - D_1$ and D_2 according to their bargaining powers. Note that the last term, $\pi^{fg}_{VI}(x_1)$, is independent of w_2; thus, w_2 is chosen in order to maximize the total industry gross profits. The resulting equilibrium wholesale price is $\overline{w}_2(x_1, x_2, \delta)$.

In stage 2, the two firms choose their R&D investments in order to maximize their net profits:

$$\begin{aligned}
\max_{x_1} \overline{\pi}_{VI}(x_1, x_2, \delta) &= \pi^{fg}_{VI}(x_1) + \beta[\pi^g_{VI}(x_1, x_2, \delta) + \pi^g_{D_2}(x_1, x_2, \delta) - \pi^{fg}_{VI}(x_1)] - x_1^2, \\
\max_{x_2} \overline{\pi}_{D_2}(x_1, x_2, \delta) &= (1-\beta)[\pi^g_{VI}(x_1, x_2, \delta) + \pi^g_{D_2}(x_1, x_2, \delta) - \pi^{fg}_{VI}(x_1)] - x_2^2,
\end{aligned}$$

where $\pi^g_{VI}(x_1, x_2, \delta)$ and $\pi^g_{D_2}(x_1, x_2, \delta)$ are obtained after substituting $\overline{w}_2(x_1, x_2, \delta)$ into $\pi^g_{VI}(w_2, x_1, x_2, \delta)$ and $\pi^g_{D_2}(w_2, x_1, x_2, \delta)$. The resulting equilibrium R&D investments in

[15] These expressions are available from the authors upon request.

[16] This is the most unfavorable assumption for our main results to hold. An alternative, perhaps more easily justifiable assumption, could be that the integrated entity is endowed with a bargaining power $\beta + (1-\beta)/2$, i.e., the sum of the bargaining powers of its constituent parts before integration. Thus, leaving the non-integrated downstream firm with a power of $\beta/2$, insted of β.

terms of δ are:

$$\overline{x}_1(\delta) = \frac{(a-c)[3+\beta+4\beta\delta-4\beta(1+\delta)\gamma-(3-4\beta)\gamma^2]}{9(1-\gamma^2)+\beta[3-4(\delta-\gamma)^2]}; \quad (22)$$

$$\overline{x}_2(\delta) = \frac{(a-c)(1-\beta)(3+\delta-4\gamma)}{9(1-\gamma^2)+\beta[3-4(\delta-\gamma)^2]}. \quad (23)$$

Note that the denominator of $\overline{x}_i(\delta)$ is positive for all β only if $\gamma \leq 0.96$. Thus, we restrict attention to $\gamma \leq 0.96$ hereafter. Substituting, we obtain the rest of the equilibrium values in terms of δ.[17] It is important to note that there is full market foreclosure, i.e., $q_2(\delta) \leq 0$, as long as $\gamma > \gamma_f(\delta) \equiv (3+\delta)/4$. Assuming that $\gamma \leq \min[0.96, (3+\delta)/4]$, we find that $\frac{\partial \overline{\pi}_{VI}}{\partial \delta} > 0$. Hence, the vertically integrated firm optimally sets $\overline{\delta}^* = 1$. Clearly, when $\delta = 1$, our assumption is always satisfied and thus full foreclosure does not occur. Still, one might wonder if the integrated firm would have incentives anyway to fully foreclose its downstream rival. It is clear that there are no such incentives because the vertically integrated firm always obtains strictly higher profits when it does not fully forecloses D_2, since then its outside option during the negotiations is equal to its profits under full foreclosure.

Examining the robustness of our findings regarding the implications of vertical integration on the equilibrium R&D investments and quantities, we confirm that they are qualitatively similar to the ones stated in Proposition 4. We also confirm that incentives for vertical integration are always present. Importantly, we confirm that under two-part tariffs, vertical integration leads again to a decrease in the rival's variable cost and it increases both consumers and total welfare.

4.3 Ex-post Knowledge Disclosure

In our main analysis, we assumed that the knowledge disclosure decision is taken ex-ante: The vertically integrated firm chooses the level of δ before firms invest in R&D. One might wonder whether our results would go through if this decision was taken ex-post. In order to examine this we consider a variation of our model in which we add a stage between stage 2 and stage 3, stage 2(b), in which $U - D_1$ chooses the level of δ.

With this alternative specification, under vertical separation, the equilibrium analysis of the whole game is exactly the same as in our model with endogenous innovation. Under, vertical integration, the equilibrium analysis for the last two stages, stage 3 and 4, is also

[17] These expressions are available from the authors upon request.

the same as in our main model.

In stage 2(b), $U - D_1$ chooses δ in order to maximize its profits expressed in terms of the R&D investments and δ:

$$\max_{\delta} \ \pi_{VI}(x_1, x_2, \delta) = [q_1(x_1, x_2, \delta)]^2 + w_2(x_1, x_2, \delta) q_2(x_1, x_2, \delta) - x_1^2.$$

We note that $\frac{\partial \pi_{VI}}{\partial \delta} > 0$ if and only if the following assumption holds:

Assumption 3: $(a - c)(1 - \gamma) > x_1(\delta - \gamma) + x_2$

Interestingly, Assumption 3 coincides with the assumption which is needed in order to guarantee that $q_2(x_1, x_2, \delta) > 0$. It follows that when this assumption is satisfied, the vertically integrated firm optimally sets $\delta^*(x_1, x_2) = 1$.

We move to stage 2, where firms choose their R&D investments taking into account that, under Assumption 3, we have $\delta^*(x_1, x_2) = 1$. The resulting equilibrium R&D investments are:

$$\begin{aligned} \widehat{x}_1^{VI} &= \frac{(a-c)[92 - \gamma[64 + \gamma(28 - 3(8 - \gamma)\gamma)]]}{148 + \gamma[64 + \gamma(-164 - 3\gamma(8 - 13\gamma))]}; \\ \widehat{x}_2^{VI} &= \frac{16(a-c)(1-\gamma)}{148 + \gamma[64 + \gamma(-164 - 3\gamma(8 - 13\gamma))]}. \end{aligned}$$

The above equilibrium values always satisfy Assumption 3. Therefore, when the knowledge disclosure decision is taken ex-post, the vertically integrated firm has again incentives to fully disclosure its R&D knowledge to its downstream rival-customer.

We find again that full foreclosure never occurs. Moreover, we find that vertical integration always leads to a decrease in rival's cost just like in our main models. Our results regarding the rest of the implications of vertical integration, as well as the incentives for vertical integration are all confirmed under ex-post knowledge disclosure.

4.4 Bertrand Competition

One might wonder whether our findings continue to hold when downstream firms compete in prices, instead of quantities. To address this, we assume now that the demand function faced by each D_i is $q_i = \frac{a(1-\gamma) - p_i + \gamma p_j}{1-\gamma^2}$. In order to guarantee interior solutions under all parameter values, we restrict attention to goods which are sufficiently differentiated ($\gamma \leq 0.88$). Doing so, we conclude that all our results hold with price competition too.

Interestingly, when firms compete in prices, the equilibrium R&D investments, output and profits of the downstream non-integrated firm are always higher under vertical integration than under vertical separation.

4.5 Substitute R&D Investments

As standard in the literature on R&D investments (see e.g., d' Aspremont and Jacquemin, 1988), we assumed that firms' R&D investments - research paths are complements. We examine now what happens when, instead, firms' R&D investments are substitutes, i.e., when firms follow similar research paths that lead to substitute R&D outcomes (see e.g., Katsoulacos and Ulph, 1998). When R&D investments are substitutes, knowledge transfer from a firm to another is useful to the latter only if its own level of R&D outcome is lower than the incoming knowledge. In particular, under vertical integration, D_2's effective R&D investments are $x_2^e = \max[x_2, \delta x_1]$. Obviously then, if D_2 expects full knowledge disclosure, it has no incentives to invest in R&D as it knows that the vertically integrated firm has stronger incentives to invest in R&D. This case resembles the case with exogenous innovation. In light of this, it is not surprising that we find that the vertically integrated firm fully disclosures its knowledge to its downstream rival. It is not surprising also that we find that the non-integrated downstream firm does not invest in R&D under vertical integration. In contrast, both downstream firms invest in R&D under vertical separation. This, in principle, could make D_2 more efficient, and thus, create disincentives for vertical integration. However, this negative effect is dominated by the positive implications of vertical integration, which we also confirm here, and integration always materializes in equilibrium.

5 Concluding Remarks

We have studied vertical integration taking into account the fact that it facilitates the exchange of information between the integrated firm's units. This allows its upstream unit to learn the outcomes of its downstream unit's innovation, and in turn, to disclose it to its downstream rival-customer.

We have found that the vertically integrated firm fully discloses its knowledge to its downstream rival. By disclosing, it increases the efficiency of its downstream rival. This means, first, that it intensifies the downstream competition. And second, that it expands

the downstream market size and demand, leading, in turn, to higher upstream profits. Disclosure arises in equilibrium because it expands demand more than it intensifies competition.

We have also found that vertical integration never drives the downstream rival out of the market, and more importantly, that it decreases instead of raises the rival's cost. In particular, knowledge disclosure increases the input price, and thus, increases the rival's cost. At the same time though, knowledge disclosure reduces the rival's cost by allowing it to free-ride on the integrated firm's innovation. The reduction in rival's cost outweighs its increase.

We have pointed out throughout that if we had ignored the possibility of knowledge disclosure, then in line with the existing literature, we would have confirmed vertical integration's well known anti-competitive effect: The raising rival's cost effect. Instead, allowing for the possibility of knowledge disclosure, we have shown that an increase in input price due to vertical integration does not necessarily mean that vertical integration is anti-competitive. Importantly, we have identified a novel pro-competitive effect of vertical integration: Vertical integration by leading to knowledge disclosure, improves the efficiency of the downstream firms, increases the size of the downstream market and enhances firms' total profits and consumers' surplus. It follows that the incorporation of the fact that vertical integration can give rise to the possibility of knowledge disclosure can be an issue of great importance in the evaluation of the implications of vertical mergers.

6 Appendix A1

Equilibrium outcomes under exogenous innovation:
(i) Vertical separation:

$$\begin{aligned}
w_1^{VS} &= \tfrac{(a-c+\Delta)}{2};\quad w_2^{VS} = \tfrac{(a-c)}{2};\\
q_1^{VS} &= \tfrac{(a-c)(2-\gamma)+2\Delta}{2(4-\gamma^2)};\quad q_2^{VS} = \tfrac{(a-c)(2-\gamma)-\gamma\Delta}{2(4-\gamma^2)};\\
\pi_{D_1}^{VS} &= \tfrac{[(a-c)(2-\gamma)+2\Delta]^2}{4(4-\gamma^2)^2};\quad \pi_{D_2}^{VS} = \tfrac{[(a-c)(2-\gamma)-\gamma\Delta]^2}{4(4-\gamma^2)^2};\ \pi_U^{VS} = \tfrac{(a-c)(2-\gamma)(a-c+\Delta)+\Delta^2}{2(4-\gamma^2)};\\
CS^{VS} &= \tfrac{(q_1^{VS})^2+(q_2^{VS})^2+2\gamma q_1^{VS}q_2^{VS}}{2};\ TW^{VS} = CS^{VS}+\pi_{D_1}^{VS}+\pi_{D_2}^{VS}+\pi_U^{VS}.
\end{aligned}$$

(ii) Vertical integration:

$$\begin{aligned}
w_2^{VI}(k) &= \tfrac{(a-c)[8-(4-\gamma)\gamma^2]+[\gamma^3+4k(2-\gamma^2)]\Delta}{16-6\gamma^2};\\
q_1^{VI}(k) &= \tfrac{(a-c)(2-\gamma)(4+\gamma)+(8-2k\gamma-\gamma^2)\Delta}{16-6\gamma^2};\ q_2^{VI}(k) = \tfrac{2[(a-c)(1-\gamma)-(\gamma-k)\Delta]}{8-3\gamma^2};\\
\pi_{D_2}^{VI}(k) &= \tfrac{4[(a-c)(2-\gamma)(4+\gamma)+(8-2k\gamma-\gamma^2)\Delta]^2}{(8-3\gamma^2)^2};\\
\pi_{VI}(k) &= \tfrac{(a-c)^2(6-\gamma)(2-\gamma)+[8-4k(2\gamma-k)+\gamma^2]\Delta^2+2(a-c)[8+4k(1-\gamma)-(4-\gamma)\gamma]\Delta}{4(8-3\gamma^2)};\\
CS^{VI}(k) &= \tfrac{q_1(k)^2+q_2(k)^2+2\gamma q_1(k)q_2(k)}{2};\ TW^{VI}(k) = CS^{VI}(k)+\pi_{D_2}^{VI}(k)+\pi_{VI}(k).
\end{aligned}$$

7 Appendix A2

Proof of Proposition 1: (i) From (15) it can be checked that $\frac{\partial x_2^{VI}}{\partial \delta} > 0$ for all (γ, δ) satisfying Assumption 2.

(ii) From (14) it can be checked that $\frac{\partial x_1^{VI}}{\partial \delta} > 0$ if and only if $\gamma < \gamma_x(\delta)$, with $\frac{\partial \gamma_x}{\partial \delta} > 0$, $\gamma_x(0) = .619$, $\gamma_x(1) = 1$ and $\gamma_x(\delta) < \gamma_f(\delta)$ for all $\delta < 1$.

(iii) From (15) and (14) it can be checked that $\frac{\partial [x_2^{VI}+\delta x_1^{VI}]}{\partial \delta} > 0$ for all (γ, δ) satisfying Assumption 2.

(iv) From (16) it can be checked that $\frac{\partial w_2^{VI}}{\partial \delta} > 0$ for all (γ, δ) satisfying Assumption 2.

(v) From (16), (15) and (14) it can be checked that $\frac{\partial [c+w_2^{VI}-x_2^{VI}-\delta x_1^{VI}]}{\partial \delta} < 0$ for all (γ, δ) satisfying Assumption 2.

(vi) From (18) it can be checked that $\frac{\partial q_2^{VI}}{\partial \delta} > 0$ for all (γ, δ) satisfying Assumption 2.

(vii) From (17) it can be checked that $\frac{\partial q_1^{VI}}{\partial \delta} > 0$ if and only if $\gamma < \gamma_q(\delta)$, with $\frac{\partial \gamma_q}{\partial \delta} > 0$, $\gamma_q(0) = .502$, $\gamma_q(1) = .753$ and $\gamma_q(\delta) < \gamma_f(\delta)$ for all $\delta \leq 1$. ■

Proof of Proposition 2: Using (16), (14), (15), (17) and (18), the equilibrium profits of the vertically integrated firm in terms of δ can be expressed as:

$$\pi_{VI}(\delta) = \tfrac{(a-c)^2[15408+\delta^2(8-3\gamma^2)^2A-2\delta(8-3\gamma^2)B-\gamma(12288+\gamma\Gamma)]}{[180-176\gamma^2+39\gamma^4+4\delta(4\gamma-\delta)(8-3\gamma^2)]^2}, \tag{24}$$

where $A \equiv 4\delta^2-8\delta(1+\gamma) - 512 + 3\gamma(128+\gamma(92-48\gamma-9\gamma^2))$,

$B \equiv -192-\gamma(320-\gamma(432+\gamma(100-3\gamma(45-4\gamma)))$,

and $\Gamma \equiv 1888+\gamma(-15872+\gamma(-6944+3\gamma(2240+\gamma(149-39\gamma(8-\gamma)))))$.

Taking the first derivative of (24) with respect to δ, it can be checked that it is always positive under Assumption 2. As a consequence, $\delta^* = 1$. ■

Proof of Proposition 3: Using (24) and setting $\delta^* = 1$, it can be checked that $\pi_{VI}(1) > \pi^f_{VI} = \frac{(a-c)^3}{3}$. The latter are the vertically integrated firm's profits whenever fully forecloses its downstream rival. In the latter case, $U - D_1$ is a monopolist in the downstream market and thus sets $q(x_1) = \frac{a-c+x_1}{2}$ and obtains gross profits $\pi(x_1) = [q(x_1)]^2$. Its optimal investment level is obtained by maximizing $\pi(x_1) - x_1^2$ and is equal to $x^f_{VI} = \frac{a-c}{3}$. As a consequence, $q^f_{VI} = \frac{2(a-c)}{3}$ and $\pi^f_{VI} = \frac{(a-c)^3}{3}$. ■

Proof of Proposition 4: (i) From (9) and (14) it can be checked that $x_1^{VI}(1) > x_1^{VS}$ for all γ.

(ii) From (9) and (15) it can be checked that $x_2^{VI}(1) > x_2^{VS}$ if and only if $\gamma < 0.522$.

(iii) From (9), (14) and (15) it can be checked that $x_1^{VI}(1) + x_2^{VI}(1) > x_1^{VS}$ for all γ.

(iv) From (10) and (16) it can be checked that $w_2^{VI}(v1) > w_2^{VS}$ for all γ.

(v) From (10) and (17) it can be checked that $q_1^{VI}(1) > q_1^{VS}$ for all γ.

(vi) From (10) and (18) it can be checked that $q_2^{VI}(1) > q_2^{VS}$ if and only if $\gamma < 0.493$. ■

Proof of Proposition 5: From (10), (9), (16), (14) and (15) it can be checked that $c + w_2^{VS} - x_2^{VS} > c + w_2^{VI}(1) - x_2^{VI}(1) - x_1^{VI}(1)$ for all γ. ■

Proof of Proposition 6: (i) Using (9) and (10), the equilibrium profits of the upstream supplier and each of the downstream firms are, respectively:

$$\pi_U^{VS} = \frac{2(a-c)^2(2-\gamma)^2(2+\gamma)^3}{[15+2\gamma(4-\gamma(2+\gamma))]^2};\ \pi_{D_i}^{VS} = \frac{(a-c)^2(5-\gamma^2)(3-\gamma^2)}{[15+2\gamma(4-\gamma(2+\gamma))]^2}. \tag{25}$$

Using (24) and (25), it can be checked that $\pi_{VI}(1) > \pi_U^{VS} + \pi_{D_1}^{VS}$ for all γ. Hence, vertical integration is always profitable for $U - D_1$.

(ii) From (16), (14), (15), (17) and (18), the equilibrium profits of the non- integrated downstream firm in terms of δ can be expressed as:

$$\pi_{D_2}^{VI}(\delta) = \frac{12(a-c)^2(3+\delta-4\gamma)^2(-2+\gamma^2)(-10+3\gamma^2)}{[180-176\gamma^2+39\gamma^4+4\delta(4\gamma-\delta)(8-3\gamma^2)]^2}. \tag{26}$$

Using (25) and (26) it can be checked that $\pi_{D_2}^{VI}(1) > \pi_{D_2}^{VS}$ if and only if $\gamma < 0.491$.

(iii) It is well-known that the demand functions in (1) stem from the maximization problem of the representative consumer whose utility is $U(q_1, q_2) = a(q_1+q_2) - (q_1^2+q_2^2+2\gamma q_1 q_2)/2 + m$, where m is the composite good with its price normalized to 1. Exploiting symmetry under vertical separation, it is easy to check that $CS^{VS} = (1+\gamma)[q_i^{VS}]^2$ and $TW^{VS} = CS^{VS} +$

$2\pi_{D_i}^{VS} + \pi_U^{VS}$. Under vertical integration, the respective expressions turn out to be as follows:

$$CS^{VI} = \frac{1}{2}[q_1^{VI}(1)^2 + q_2^{VI}(1)^2 + 2\gamma q_1^{VI}(1)q_2^{VI}(1)];\ TW^{VI} = CS^{VI} + \pi_{D_2}^{VI}(1) + \pi_{VI}(1).$$

Using (10), (17), (18), (25), (26) and (24) it can be checked that $CS^{VI} > CS^{VS}$ and $TW^{VI} > TW^{VS}$ for all γ. ■

8 Appendix B: For Referees Use Only

Equilibrium values under vertical separation and two-part tariff contracts:

$$\begin{aligned}
\overline{q}_i^{VS} &= \frac{4(a-c)}{7+\beta+8\gamma}; \overline{w}_i^{VS} = \frac{4\gamma(a-c)}{7+\beta+8\gamma}; \\
\overline{\pi}_{D_i}^{VS} &= \frac{(a-c)^2(1-\beta)(15+\beta+16\gamma)}{(7+\beta+8\gamma)^2}; \overline{\pi}_U^{VS} = \frac{(a-c)^2 32\beta(1+\gamma)}{(7+\beta+8\gamma)^2}.
\end{aligned}$$

Equilibrium values under vertical integration and two-part tariff contracts:

$$\begin{aligned}
\overline{q}_1(\delta) &= \frac{(a-c)[6-\gamma(3+\delta+2\gamma)+2\beta(1-\delta^2-\gamma+\delta(1+\gamma))]}{9-\beta(4(\delta-\gamma)^2-3)-9\gamma^2}; \\
\overline{q}_2(\delta) &= \frac{2(a-c)(3+\delta-4\gamma)}{9-\beta(4(\delta-\gamma)^2-3)-9\gamma^2}; \\
\overline{w}_2(\delta) &= \frac{2(a-c)\gamma[3-(3+\delta)\gamma+\gamma^2+\beta(1+\delta-\delta^2-(1-\delta)\gamma)]}{9-\beta(4(\delta-\gamma)^2-3)-9\gamma^2}; \\
\overline{\pi}_{D_2}(\delta) &= \frac{(1-\beta)(a-c)^2(3+\delta-4\gamma)^2(3+\beta-3\gamma^2)}{[9-\beta(4(\delta-\gamma)^2-3)-9\gamma^2]^2}; \\
\overline{\pi}_{VI}(\delta) &= \frac{(a-c)^2[27(1-\gamma^2)^2+\beta[54+4(6-5\delta)\delta-16(6-\delta)\gamma-J]+\beta^2 EZ]}{[9-\beta(4(\delta-\gamma)^2-3)-9\gamma^2]^2},
\end{aligned}$$

where $J = (5+3\delta(6-7\delta))\gamma^2 + 24(3-\delta)\gamma^3 - 24\gamma^2$, $E = -3-2(3-\delta)\delta+6\gamma+2\delta\gamma-4\gamma^2$ and $Z = -1-2\gamma+2(\delta+\delta^2-3\delta\gamma+2\gamma^2)$.

9 References

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