Vertical Integration and Decreasing Rival's Cost

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Abstract

We study vertical integration in the presence of downstream R&D investments. In a setting with an upstream monopolist, downstream competition and differentiated products, we demonstrate that a vertically intgrated firm fully transfers the knowledge that it obtains from its downstream unit's R&D investments to its non-integrated downstream rival. Interestingly, due to the knowledge transfer, vertical integration reinforces firms' R&D investments incentives and decreases, instead of raises, the rival's cost.

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

JEL classification: L13; L22; L42

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1 Introduction

One of the most well-known anti-competitive effects of vertical integration is that it "raises rival's cost". That is, it leads to an increase in the input price offered to rival downstream firms. This occurs mainly because the vertically integrated firm internalizes the impact that the input price has on downstream competition. In particular, it recognizes that by raising the input price, it can foreclose its downstream rivals from the market, and thus, it can enjoy higher downstream profits. A number of theoretical papers on vertical integration develop in depth this point (see e.g., Hart and Tirole, 1990, Ordover et al., 1990 and 1992, Rey and Tirole, 2007).

In this paper, we argue that, under certain conditions, vertical integration decreases, instead of raises, the rival's cost. The conditions under which this occurs are the following. There is an industry where initially an upstream monopolist sells an essential input to two competing downstream firms. The downstream firms are symmetric, they produce differentiated final goods and invest in cost-reducing R&D. The upstream monopolist considers integrating with one of them. Vertical integration facilitates the information flow between the upstream and downstream units of the integrated firm. For instance, the merged entities may integrate their IT networks, and thus, facilitate the information exchange. As a consequence, the upstream unit of the vertically integrated firm gains access to the downstream unit's R&D knowledge, and thus, has the option of transferring this knowledge to its downstream customer-rival. If it transfers the knowledge, the downstream rival free-rides on the investments of the integrated firm. Firms trade through linear wholesale price contracts and downstream competition takes place in quantities.

We demonstrate that knowledge transfer under vertical integration can reinforce the R&D investments of both downstream firms. For the non-integrated downstream firm, this result is quite intuitive. In particular, since knowledge transfer 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 surprising since the free-riding of its rival on its own R&D investments clearly weakens its investments incentives. However, knowledge transfer has an additional effect. It increases the efficiency of the non-integrated downstream firm 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. When downstream competition is not too strong the second positive effect dominates and the integrated firm invests more in R&D.

Interestingly, we find that the vertically integrated firm instead of protecting its own R&D investments by keeping them in house, it chooses to fully transfer its R&D knowledge to its downstream rival. As mentioned above, knowledge transfer increases the input price and the output of the rival downstream firm, and as a consequence, it increases the vertically integrated entity's profits from the input sales. At the same time though knowledge transfer decreases the vertically integrated entity's profits from the downstream market. The negative impact of the knowledge transfer on the vertically integrated firm's downstream profits is always outweighed by its positive impact on its upstream profits.

It turns out that vertical integration always decreases the downstream rival's cost. Hence, it causes neither full nor partial market foreclosure. Intuitively, if the vertically integrated firm forecloses its downstream rival, its downstream profits will rise, but its upstream profits will decrease. In the absence of knowledge transfer, in line with the related literature, the negative impact of foreclosure on upstream profits is dominated by the positive impact on downstream profits and foreclosure occurs in equilibrium. In our setting though, the decrease in upstream profits from market foreclosure is more severe than in a setting without the possibility of knowledge transfer. This is so because, as mentioned above, the upstream profits increase with knowledge transfer and in equilibrium the vertically integrated firm fully transfers its knowledge to its downstream rival. Because of this, in our setting the negative impact of driving out of the market the downstream rival on the integrated firm's upstream profits dominates its positive impact on its downstream profits. Clearly, this finding points out that the incorporation of the possibility of knowledge transfer plays a crucial role.

One might wonder whether knowledge transfer could occur even in the absence of vertical integration. In order to check this, first, we consider the benchmark case of an one-tier industry that consists of simply two firms that produce differentiated goods and invest in cost-reducing R&D before they compete in quantities. We find that neither firm has incentives to share its R&D knowledge with its rival. Second, we consider a vertical industry with the same structure as the one in our basic model and examine whether in the absence of vertical integration, one of the downstream firms has incentives to let its rival free-ride on its R&D investments. The answer is negative. Therefore, the vertical structure alone is no sufficient for the knowledge transfer to take place. The existence of vertical integration is necessary.

Our paper is clearly related to the well known literature on vertical integration and market foreclosure.[1] As discussed above, this literature points out that an integrated firm increases the input price, and thus, raises the cost of its downstream rivals, in order to drive the latter out of the market. This literature abstracts from the possibility of knowledge transfer due to vertical integration. Exceptions include the papers by Hughes and Kao (2001) and Milliou (2004). 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) instead considers a market structure similar to ours and examines how the information flow from a downstream non-integrated firm to the downstream division of a vertically integrated firm via its upstream subsidiary affects downstream R&D investments, profits and welfare. Both of these papers consider knowledge transfer from the rival downstream non-integrated firm to the downstream integrated firm. We consider instead the reverse direction of knowledge transfer, from the downstream integrated firm to the downstream non-integrated firm.

There is an emerging literature on knowledge transfer in vertically related industries. Bonte and Wiethaus (2007) consider an industry where an upstream monopolist sells an input to two downstream firms that produce homogeneous goods. Both downstream firms have some exogenous R&D knowledge and choose the amount of knowledge that they will transfer to the upstream firm. 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. Harhoff et al. (2003), using a similar market structure, examine whether the downstream firms have incentives to reveal their exogenous innovation to the upstream input manufacturer. The potential advantage of revealing the innovation is that the upstream manufacturer can improve upon it or it can reduce its cost. It is assumed that the revelation automatically triggers a complete spillover to the other downstream firm. None of

[1] For a review of this literature see Rey and Tirole (2007)

these papers endogenizes innovation, and most importantly, none of these papers allows for vertical integration, and thus, examines how vertical integration affects the diffusion of the downstream R&D investments.

Our paper is also related 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) consider the incentives and the implications of vertical integration when an upstream monopolist - innovator can sell its innovation to downstream firms through a licensing contract. Our paper differs from this literature in many aspects. This literature focuses on upstream innovation instead of downstream innovation, it treats innovation as exogenous, it assumes that without licensing the upstream firm does not sell to the downstream firms, and that the technology transfer is either full (with licensing) or zero (without licensing).

The rest of the paper is organized as follows. In Section 2, we describe our modeling framework. In the following Section, Section 3, we obtain the equilibrium contract terms and R&D investments both under vertical separation and vertical integration. In Section 4, we analyze the role of the knowledge transfer and endogenize its level. We examine the impact and the incentives of vertical integration in Section 5. We discuss a number of extensions in Section 6. Finally, we conclude in Section 7.

2 The Model

An upstream monopolist, denoted by U, produces at zero cost an input which is essential for the production of two final goods. The latter are produced by two competing downstream firms, each denoted by D_i, with $i = 1, 2$. Each D_i transforms the input into its final product in a one-to-one proportion and faces the following (inverse) demand function:

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

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

When there is no vertical integration, each D_i's variable production cost is given by:

$$C_i(w_i, q_i) = (c + w_i - x_i)q_i, \tag{2}$$

where c is an exogenous constant marginal cost, w_i is the wholesale price that D_i pays per unit of input to its upstream supplier U, and x_i is the level of D_i's cost-reducing R&D investments.

When, instead, the upstream supplier U integrates vertically with one of the downstream firms, e.g. with D_1, two important changes take place. First, D_1 no longer has to pay w_1 in order to obtain the input. The input is transferred at marginal cost within the vertical integrated entity. A straightforward implication is that the variable production cost of the vertically integrated firm is now given by (2) with $w_1 = 0$. Second, due to the information flow between the upstream and downstream units of the integrated entity, U gains access to D_1's R&D investments. This access gives U the option of transferring its knowledge to its downstream customer-rival D_2. In order to capture this, we assume that under vertical integration the variable production cost of D_2 is:

$$C_2(w_2, q_2) = (c + w_2 - x_2 - \delta x_1)q_2, \tag{3}$$

where δ, with $0 \leq \delta \leq 1$, is the degree of knowledge that U transfers to D_2 regarding D_1's R&D investments.

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.

Firms play the following four-stage game with observable actions:

Stage 1: U and D_1 decide whether or not they will integrate. If they integrate, the vertically integrated firm chooses the level of δ.

Stage 2: Under vertical separation, D_1 and D_2 simultaneously and independently choose the level of their R&D investments, x_1 and x_2 respectively. Under vertical integration, the vertically integrated firm and D_2 simultaneously and independently choose x_1 and x_2 respectively.

Stage 3: Under vertical separation, U makes simultaneous "take-it-or-leave-it" offers to the downstream firms regarding the wholesale prices of the inputs, w_1 and w_2. Under vertical integration, the vertically integrated firm makes a "take-it-or-leave-it" offer to D_2 regarding the wholesale price w_2.

Stage 4: D_1 and D_2 simultaneously and independently choose their quantities, q_1 and q_2.

The above timing reflects the fact that, during the integration process, D_1 makes an agreement with U whether, and to which extent, U can transfer knowledge, through its collaboration with D_1, to its downstream rival. That is, the degree of knowledge transfer is one of the terms of vertical integration. In Section 6, we discuss an alternative specification of the timing where the knowledge transfer decision is taken after stage two.

3 Equilibrium Input Prices and R&D Investments

3.1 Vertical Separation

We start by examining what happens when U and D_1 remain separated, and thus, the variable cost of both downstream firms is given by (2).

In the last stage of the game, each D_i chooses its quantity q_i so as to maximize its profits:

$$\underset{q_i}{Max}\ \pi_{D_i}(q_i, q_j, w_i, w_j, x_i, x_j) = (a - q_i - \gamma q_j)q_i - (w_i + c - x_i)q_i - x_i^2. \tag{4}$$

Solving for the Cournot-Nash equilibrium quantities, we obtain:

$$q_i(w_i, w_j, x_i, x_j) = \frac{(a-c)(2-\gamma) + 2(x_i - w_i) - \gamma(x_j - w_j)}{4 - \gamma^2}. \tag{5}$$

In stage three, U chooses the wholesale prices in order to maximize its profits:

$$\begin{aligned} \underset{w_1, w_2}{Max}\ \pi_U(w_1, w_2, x_1, x_2) \quad = \quad & w_1 \frac{(a-c)(2-\gamma) + 2(x_1 - w_1) - \gamma(x_2 - w_2)}{4-\gamma^2} \\ & + w_2 \frac{(a-c)(2-\gamma) + 2(x_2 - w_2) - \gamma(x_1 - w_1)}{4-\gamma^2}. \end{aligned} \tag{6}$$

The solution of the system of the first order conditions yields the equilibrium wholesale prices in terms of the R&D investments:

$$w_i(x_i) = \frac{1}{2}(a - c + x_i). \tag{7}$$

Substituting (7) into (5) and then into (4), we rewrite the downstream firm's profits as a function of only the R&D investments. Maximizing the latter in terms of x_i, we obtain the equilibrium R&D investments:

$$x_i^{VS} = \frac{a-c}{15+2\gamma(4-\gamma(2+\gamma))}. \quad (8)$$

Note that $\frac{\partial x_i^{VS}}{\partial \gamma} > 0$ if and only if $\gamma > \frac{2}{3}$. In other words, there is a U-shaped relation between the R&D investments and the intensity of downstream competition. When final goods are poor substitutes, an increase in product substitutability weakens the downstream firms' R&D investment incentives. In contrast, when final goods are close substitutes, an increase in the intensity of competition reinforces the R&D investment incentives.[2]

Finally, substituting (8) into (7), (4), and (6), we obtain the equilibrium quantities, wholesale prices and profits which are included in Table 1 of the Appendix.

3.2 Vertical Integration

Next, we analyze the case of vertical integration between U and D_1. The variable production costs of the vertically integrated firm and the non-integrated downstream firm are now given respectively by $(c-x_1)q_1$ and (3).

In the last stage of the game, the two firms solve the following maximization problems:

$$\underset{q_1}{Max}\ \pi_{VI}(q_1,q_2,w_2,x_1,x_2,\delta) = (a-q_1-\gamma q_2)q_1-(c-x_1)q_1+w_2q_2-x_1^2; \quad (9)$$

$$\underset{q_2}{Max}\ \pi_{D_2}(q_1,q_2,w_2,x_1,x_2,\delta) = (a-q_2-\gamma q_1)q_2-(w_2+c-x_2-\delta x_1)q_2-x_2^2. \quad (10)$$

The solution to the first order conditions gives rise to the equilibrium quantities in terms of the wholesale price, the R&D investments and the knowledge transfer:

$$q_1(w_2,x_1,x_2,\delta) = \frac{(a-c)(2-\gamma)+x_1(2-\delta\gamma)-\gamma(x_2-w_2)}{4-\gamma^2}; \quad (11)$$

$$q_2(w_2,x_1,x_2,\delta) = \frac{(a-c)(2-\gamma)+2(x_2-w_2)-x_1(\gamma-2\delta)}{4-\gamma^2}. \quad (12)$$

In the previous stage, the vertically integrated firm solves the following problem:

$$\underset{w_2}{Max}\ \pi_{VI}(w_2,x_1,x_2,\delta) = [a-q_1(w_2,x_1,x_2,\delta)-\gamma q_2(w_2,x_1,x_2,\delta)-c]q_1(w_2,x_1,x_2,\delta) + w_2q_2(w_2,x_1,x_2,\delta)-x_1^2. \quad (13)$$

[2] This finding is in line with Sacco and Schmutzler (2009) who consider the relationship between R&D investments and product differentiation in a one-tier industry.

The resulting equilibrium wholesale price in terms of the R&D investments and δ is:

$$w_2(x_1, x_2, \delta) = \frac{(a-c)[8-(4-\gamma)\gamma^2] + 8(x_2 + \delta x_1) - \gamma^2(4x_2 + 4\delta x_1 - \gamma x_1)}{16 - 6\gamma^2}. \qquad (14)$$

One can easily verify 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 charged to the non-integrated downstream firm gets stronger when the knowledge transfer increases.

We substitute the equilibrium wholesale price (14) into (11) and (12), and then into (9) and (10). Differentiating the latter two expressions with respect to x_1 and x_2, we obtain the equilibrium R&D investments expressed in terms of δ:

$$x_1(\delta) = \frac{(a-c)[60 + 4\delta(-1+\gamma)(-8+3\gamma^2) - \gamma(32 + \gamma(16 - 3(4-\gamma)\gamma))]}{180 - 176\gamma^2 + 39\gamma^4 + 4\delta(4\gamma - \delta)(8 - 3\gamma^2)}; \qquad (15)$$

$$x_2(\delta) = \frac{4(a-c)(3 + \delta - 4\gamma)}{180 - 176\gamma^2 + 39\gamma^4 + 4\delta(4\gamma - \delta)(8 - 3\gamma^2)}. \qquad (16)$$

Substituting (15) and (16) into (14), (11) and (12), and into the firms' profits, we obtain the rest of the equilibrium values in terms of δ. These are included in Table 2.

It is important to note that $q_2(\delta) \leq 0$, i.e., there is full market foreclosure, when $\gamma \geq \gamma_f(\delta) \equiv (3+\delta)/4$. This condition implies that when there is no knowledge transfer at all ($\delta = 0$), vertical integration drives the downstream non-integrated 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 the higher is knowledge transfer, the less likely is full market foreclosure. In fact, when there is full knowledge transfer ($\delta = 1$), vertical integration never drives the downstream non-integrated firm out of the market (since $\gamma_f(1) = 1$). Some of our subsequent results hold only when both downstream firms are active in the market. Thus, we need to introduce the following assumption:

Assumption 1: $\gamma < \gamma_f(\delta) \equiv (3+\delta)/4$

In what follows, we specify which results hold under Assumption 1.

When Assumption 1 does not hold, the vertically integrated firm acts as a monopolist in the market. Its equilibrium investments, output and profits are included in Table 3.

4 Equilibrium Knowledge Transfer

In this Section, we focus on knowledge transfer under vertical integration. We examine, first, how the degree of knowledge transfer influences the firms' equilibrium behavior, and second, the incentives of the vertically integrated firm to transfer its knowledge.

We start by asking what is the effect of the knowledge transfer on R&D investments.

Proposition 1 *Under Assumption 1,*

(i) the equilibrium R&D investments of the downstream non-integrated firm $x_2(\delta)$ *always increase in* δ*,*

(ii) the equilibrium R&D investments of the vertically integrated firm $x_1(\delta)$ *increase in* δ *except if products are sufficiently close substitutes and* δ *is sufficiently low,*

(iii) the equilibrium effective R&D investments of the downstream non-integrated firm $x_2(\delta) + \delta x_1(\delta)$ *always increase in* δ*.*

Proposition 1(i) asserts that the more knowledge is transferred to the rival downstream firm, the more the latter invests in R&D. Intuitively, D_2's marginal cost is reduced due to its free-riding on the R&D investments of the vertically integrated firm. The decrease in its marginal cost results in 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, which is often referred to as *output effect*, can also be found, for instance, in Bester and Petrakis (1993) and in Milliou (2004).

Surprisingly, according to Proposition 1(ii), an increase in the knowledge transfer reinforces the investment incentives of the integrated firm. This holds unless products are sufficiently close substitutes and the degree of knowledge transfer is sufficiently low. Why is this so? An increase in knowledge transfer has two opposite effects. First, it translates into an increase in the free-riding of the rival downstream firm, and thus, it weakens the vertically integrated firm's R&D investments incentives. Second, as we saw above, it intensifies the positive impact of an increase in the vertically integrated firm's R&D investments on the input price. Therefore, it leads to higher profits from input sales and, in turn, reinforces the vertically integrated firm's investment incentives. When downstream competition is not too strong the first negative effect gets weak and it is outweighed by the second positive effect. We should point out that this result is in contrast with the respective ones in one-tier industries (see e.g., Milliou, 2009) and in vertically related industries in the absence of vertical integration.[3]

In light of the above findings, it is not surprising that the *effective R&D investments* of the downstream non-integrated firm, that is, the total cost reduction that it enjoys due to the R&D investments, $x_2(\delta) + \delta x_1(\delta)$, always increases with knowledge transfer.

Proposition 2 *Under Assumption 1, the equilibrium wholesale price charged to the downstream non-integrated firm* $w_2(\delta)$ *always increases in* δ.

One might also wonder how the transfer of knowledge affects the input price w_2. Proposition 2 above informs us that the more the vertically integrated firm transfers its knowledge to its downstream rival, the higher is the input price that it charges to the latter. This is a straightforward implication of Proposition 1(iii), according to which, the more is the knowledge transferred, the higher are D_2's effective R&D investments. The latter increase the efficiency, and in turn the gross profits of D_2. U extracts D_2' higher gross profits by charging a higher input price.

Up to now, we have seen that the impact of the knowledge transfer on the cost of the rival is, on the one hand, positive since it increases the input price (Proposition 2), and on the other hand, negative since it enhances the rival's effective R&D investments (Proposition 1(iii)). Naturally, the following question arises: What is the overall impact of knowledge transfer on the rival's cost? As Proposition 3 states, the negative impact of the knowledge transfer dominates and the more knowledge is transferred, the lower is the rival's cost.

Proposition 3 *Under Assumption 1, the downstream non-integrated firm's cost,* $w_2(\delta) - x_2(\delta) - \delta x_1(\delta)$, *always decreases in* δ.

Further, the implications of knowledge transfer on firms' output are similar to the respective ones on R&D investments. This is formally stated in the following Proposition.

Proposition 4 *Under Assumption 1,*

(i) the equilibrium output of the downstream non-integrated firm $q_2(\delta)$ *always increases in* δ,

(ii) the equilibrium output of the vertically integrated firm $q_1(\delta)$ *increases in* δ *except if products are sufficiently close substitutes.*

[3] This last point is discussed in Section 6.

Proposition 4(i) is a direct consequence of the fact that D_2's cost decreases in δ (Proposition 3). Proposition 4(ii) instead is due to the fact that, as we saw in Proposition 1(ii), an increase in δ reinforces D_1's R&D investments when goods are not sufficiently close substitutes. Thus, when δ increases and the goods are sufficiently differentiated D_1 faces a lower cost. As a consequence, it has stronger incentives to expand its output then.

Next, we turn to the analysis of the vertically integrated firm's choice of the optimal degree of knowledge that it transfers to the downstream non-integrated firm.

Proposition 5 *Under Assumption 1, the vertically integrated firm optimally sets* $\delta^* = 1$.

The vertically integrated firm instead of protecting its own downstream entity by keeping the outcome of the latter's R&D investments in house, it chooses to fully transfer it to its downstream rival. While this result seems quite surprising, it can be fully explained in light of our above mentioned findings. In particular, an increase in the knowledge transfer decreases the vertically integrated entity's profits from the downstream market. However, it increases the input price and the output of the rival downstream firm (Propositions 2 and 4), and as a consequence, it also increases the vertically integrated entity's profits from the input sales. It turns out that the negative impact of the knowledge transfer on the vertically integrated firm's downstream profits is always dominated by its positive impact on its upstream profits.

Taking into account that under vertical integration there is full knowledge transfer, we include in the following Proposition a number of observations that are very useful for the understanding of our subsequent results.

Proposition 6 *Under Assumption 1,*

(i) the R&D investments of the vertically integrated firm are higher than the respective ones of the downstream non-integrated firm, $x_1^{VI} > x_2^{VI}$,

(ii) the variable cost of the vertically integrated firm is lower than the respective one of the downstream non-integrated firm, $c - x_1^{VI} < c + w_2^{VI} - x_2^{VI} - x_1^{VI}$,

(iii) the output of the vertically integrated firm is higher than the output of the downstream non-integrated firm, $q_1^{VI} > q_2^{VI}$.

According to Proposition 6(i), the vertically integrated firm invests more in R&D than its downstream rival. This is a straightforward implication of the fact that the input is transferred at marginal cost within the vertically integrated firm, while its downstream rival has to pay the wholesale price and suffers from double marginalization. Actually, the burden of double marginalization is so heavy that the cost of the downstream non-integrated firm turns out to be higher than that of the vertically integrated firm (Proposition 6(ii)) although only the former firm free-rides on the other firm's R&D investments. 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 (Proposition 6(iii)).

5 Merger Incentives and Implications

In this Section, we examine the implications and the incentives of vertical integration.

A fundamental question we need to address before moving on is whether or not vertical integration leads to the complete market foreclosure of the rival downstream firm. According to Proposition 5, under Assumption 1, that is, under the assumption of no market foreclosure, vertical integration leads to full knowledge transfer ($\delta^* = 1$). Note though that when $\delta = 1$, Assumption 1 is always satisfied, and therefore the vertically integrated entity's profits are given by (25). However, when $\gamma \geq .75$ the vertically integrated entity might prefer instead choosing δ such that Assumption 1 is not satisfied, and thus, it might prefer to fully foreclose D_2. In the latter case, the profits of the vertically integrated entity firm are given by (28). Comparing the respective profits, we conclude that the vertically integrated entity is better off when its downstream rival is present in the market. This is formally stated in Proposition 7.

Proposition 7 *In equilibrium, the vertically integrated firm never chooses to fully foreclose the downstream non-integrated firm.*

Intuitively, if the vertically integrated firm fully forecloses its downstream rival, its downstream profits will rise, but its upstream profits will be null. However, the latter, in the absence of foreclosure, increase with knowledge transfer. This occurs because as we saw above the knowledge transfer increases both the wholesale price (Proposition 2) and the output of the downstream firm (Proposition 4(i)), and thus, increases the input sales. In our setting, the vertically integrated firm, in the absence of foreclosure, fully transfers its knowledge to its downstream rival (Proposition 5), and thus, enjoys the highest possible upstream profits. Therefore, the decrease in upstream profits, due to market foreclosure is more severe in our setting than in a setting without the possibility of knowledge transfer.

Given this, the negative impact of shutting down completely the differentiated market of the downstream rival on the integrated firm's upstream profits dominates its positive impact on its downstream profits. As a consequence, full market foreclosure is not a profitable strategy.

The following Proposition informs us about the impact of vertical integration on innovation, input price and output.

Proposition 8 *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* $\gamma < .522$*,*

(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 charged to the downstream non-integrated firm, $w_2^{VI} > w_2^{VS}$*,*

(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* $\gamma < .493$*.*

As it follows from Proposition 8, vertical integration reinforces both the R&D investments and the output of the integrated firm. Intuitively, in the absence of vertical integration 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 (Proposition 6(ii) and (iii)). 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 the free-riding on D_1's investments.

According to the same Proposition, vertical integration results into an increase in both the R&D investments and the output of the downstream non-integrated firm when downstream competition is not too strong. Intuitively, when downstream competition is strong, the above mentioned competitive advantage of the vertically integrated entity is more pronounced, and as a result, vertical integration shrinks D_2's market share then, and its subsequent incentives to invest in R&D. 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 when integration takes place.

According also to Proposition 8, vertical integration results into an increase in the input price offered to the rival downstream firm. The intuition is as follows. Proposition 8(iii) indicates that vertical integration leads to an increase in the effective R&D investments of the rival downstream firm, and thus, to a decrease in its cost. As we mentioned in the discussion of Proposition 2, when the rival downstream firm becomes more efficient, its upstream supplier has incentives to increase the input price.

Proposition 9 *In equilibrium, vertical integration leads to a decrease in the non-integrated downstream firm's cost,* $w_2^{VS} - x_2^{VS} > w_2^{VI} - x_2^{VI} - x_1^{VI}$.

In contrast to the established view in the literature that vertical integration raises the rival's cost, Proposition 9 states that vertical integration *always* decreases the rival's cost. As we saw in Proposition 3, the more knowledge is transferred to the rival downstream firm, the lower is the latter's cost. From Proposition 5, we know that in the equilibrium under vertical integration, the integrated firm optimally chooses to transfer all its knowledge to the rival downstream firm, and thus, to decrease the latter's cost. At the same time though, the vertically integrated firm increases the wholesale price, and thus, it raises the rival's cost. The decrease in the rival's cost turns out to be larger because, as we saw in Proposition 8, vertical integration enhances the effective R&D investments of the downstream rival.

It is important to note that an obvious implication of Propositions 8 and 9 is that in our setting, vertical integration leads neither to full nor to partial market foreclosure. As we discuss in Section 6, this is mainly due to the fact that we allow for the possibility of knowledge transfer. In the absence of such possibility, in line with the related literature, foreclosure incentives can dominate. In particular, 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 $\delta_{cr}(1) = .14$. Thus, in the benchmark case in which by assumption knowledge transfer is impossible, i.e., $\delta = 0$, vertical integration does raise the rival's cost.

Given the above mentioned implications of vertical integration, do U and D_1 integrated or not? If they integrate, their joint profits are given by (25) after setting $\delta = 1$. If they remain separated, their profits are given respectively by the sum of (20) and (19). Taking the difference $\pi_{VI}(1) - (\pi_U^{VS} + \pi_{D_1}^{VS})$ we note that is its always positive. Therefore, merger incentives are always present. This is formally stated in the following Proposition.

Proposition 10 *Vertical integration always arises in equilibrium.*

The intuition of Proposition 10 is straightforward. Vertical integration not only solves the double marginalization problem among U and D_1, but it also increases D_1's sales (Proposition 7(iv)) and the resulting downstream profits of the integrated entity at the expense sometimes of lower upstream profits.

Finally, regarding the desirability of the vertical integration from the non-integrated downstream firm's perspective, as mentioned above, vertically integration leads neither to its full nor to its partial foreclosure (Propositions 7 and 9). And in fact, vertical integration increases the profitability of the downstream rival when downstream competition is not sufficiently strong, and in particular, if and only if $\gamma \leq .491$. Intuitively, vertical integration increases the efficiency of the non-integrated downstream firm (Proposition 9) and this effect causes the expansion of its output and profits unless downstream competition is not too fierce (Proposition 8(vi)). When instead downstream competition is strong, the competitive advantage of the integrated entity gets pronounced and vertical integration leads then to a decrease in D_2's output and profits.

6 Discussion - Extensions

We have based our analysis so far on the assumption that vertical integration creates the possibility of knowledge transfer from D_1 to D_2 and have demonstrated that in equilibrium such transfer takes place. Naturally, one might wonder whether indeed vertical integration is necessary for such transfer to occur. In order to check this and to better understand our findings, we have examined two modifications of our basic model.

First, we have considered the benchmark case of an one-tier industry that consists of simply two firms, firm 1 and firm 2. The two firms produce differentiated goods without the use of an input and invest in cost-reducing R&D before they compete in quantities. We have examined whether or not firm 1 has incentives to share its R&D knowledge with firm 2, i.e., to let the outcome of its R&D investments spillover to firm 2. We have found that such incentives are always absent in a one-tier industry.

Second, we have considered a vertical industry with the same structure as the one in our basic model and have checked whether in the absence of vertical integration D_2 has incentives to let D_1 free-ride on its R&D investments. We have found that D_2 chooses not to transfer its knowledge. Therefore, it is not the vertical structure alone that leads to the knowledge transfer.

It follows from the above that the existence of vertical integration is necessary for knowledge transfer to take place. In our model, it is also sufficient. Is it though also sufficient under a number of variations of our model? In order to answer this it would be interesting to examine the robustness of our main findings under alternative contract types such as two-part tariffs. A complication that arises then is that with two-part tariff contracts the upstream monopolist extracts all the downstream profits. Thus, the downstream firms have no incentives to invest in R&D. In order to solve the problem, we would have to include bargaining over the terms of the two-part tariff contracts. An additional interesting extension would be to consider what happens when the downstream firms' R&D investments are research substitutes (as e.g., in Katsoulacos and Ulph, 1998) rather than research complements as in our basic model. Finally, it would be useful to examine whether our results hold under an alternative specification of the timing of decisions. In particular, when the decision regarding knowledge transfer is taken after the R&D investments, i.e., after stage two.

7 Concluding Remarks

We have investigated the incentives and the implications of vertical integration in the presence of downstream R&D investments. We have done so taking into account the fact that vertical integration facilitates the information exchange between the vertical units of the integrated firm, and thus, gives to its upstream unit access to the R&D of its downstream unit. The former can in turn transfer this knowledge to its downstream customer-rival.

We have shown that the vertically integrated firm has incentives to transfer its R&D knowledge to its downstream rival, and more importantly, that due to this knowledge transfer, vertical integration decreases instead of raises its rival's cost. This occurs mainly because knowledge transfer increases the efficiency of the non-integrated downstream firm, and thus, allows the integrated firm to charge a higher input price and enjoy higher profits from the upstream market. At the same time though, knowledge transfer and thus the free-riding of the non-integrated downstream firm on the integrated firm's R&D investments, reinforces firm's R&D investment incentives that decrease the rival's cost.

Finally, we have shown that vertical integration has a positive impact on the profits of the integrated firms, and thus, that it is desirable from the firms' point of view. As part of our future research, we plan to examine the desirability of vertical integration from a social point of view too, as well as to extend our analysis in the directions discussed in Section 6.

8 Appendix

The following Tables include the equilibrium values under vertical separation, as well as the respective ones under vertical integration for given values of δ.

$q_i^{VS} = \frac{(a-c)(4-\gamma^2)}{15+2\gamma(4-\gamma(2+\gamma))}$ (17)
$w_i^{VS} = \frac{(a-c)(2-\gamma)(2+\gamma)^2}{15+2\gamma(4-\gamma(2+\gamma))}$ (18)
$\pi_{D_i}^{VS} = \frac{(a-c)^2(5-\gamma^2)(3-\gamma^2)}{[15+2\gamma(4-\gamma(2+\gamma))]^2}$ (19)
$\pi_U^{VS} = \frac{2(a-c)^2(2-\gamma)^2(2+\gamma)^3}{[15+2\gamma(4-\gamma(2+\gamma))]^2}$ (20)

Table 1: Equilibrium values under vertical separation

$q_1(\delta) = \frac{(a-c)[(2-\gamma)[60+\gamma(10-3\gamma(9+2\gamma))]-\delta(8-3\gamma^2)(2\delta-2-\gamma)]}{180-176\gamma^2+39\gamma^4+4\delta(4\gamma-\delta)(8-3\gamma^2)}$ (21)
$q_2(\delta) = \frac{2(a-c)(3+\delta-4\gamma)(8-3\gamma^2)}{180-176\gamma^2+39\gamma^4+4\delta(4\gamma-\delta)(8-3\gamma^2)}$ (22)
$w_2(\delta) = \frac{2(a-c)[48+\delta^2\gamma(-8+3\gamma^2)-\delta(2+\gamma)(-8+3\gamma^2)+\gamma[-4+\gamma(-50+\gamma(8-3(-4+\gamma)\gamma))]]}{180-176\gamma^2+39\gamma^4+4\delta(4\gamma-\delta)(8-3\gamma^2)}$ (23)
$\pi_{D_2}(\delta) = \frac{12(a-c)^2(3+\delta-4\gamma)^2(-2+\gamma^2)(-10+3\gamma^2)}{[180-176\gamma^2+39\gamma^4+4\delta(4\gamma-\delta)(8-3\gamma^2)]^2}$ (24)
$\pi_{VI}(\delta) = \frac{(a-c)^2[15408+\delta^2(8-3\gamma^2)^2A-2\delta(8-3\gamma^2)B-\gamma(12288+\gamma\Gamma]}{[180-176\gamma^2+39\gamma^4+4\delta(4\gamma-\delta)(8-3\gamma^2)]^2}$ (25)
where $A \equiv 4\delta^2 - 8\delta(1+\gamma) - 512 + 3\gamma(128+\gamma(92-48\gamma-9\gamma^2))$
$B \equiv -192+\gamma(-320+\gamma(432+\gamma(100+3\gamma(-45+4\gamma))))$
$\Gamma \equiv 1888+\gamma(-15872+\gamma(-6944+3\gamma(2240+\gamma(149-39\gamma(8-\gamma)))))$

Table 2: Equilibrium values under vertical integration without foreclosure

$x_1^f = \frac{a-c}{3}$ (26)
$q_1^f = \frac{2(a-c)}{3}$ (27)
$\pi_{VI}^f = \frac{(a-c)^3}{3}$ (28)

Table 3: Equilibrium values under vertical integration with foreclosure

9 References

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