Collusive Strategic Buying of a Necessary Input

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Abstract

In this paper, we highlights conditions under which R&D agreements may have anti-competitive effects. We focus on cases where two strategic firms compete with each other and with a competitive fringe. R&D activities need a specific input available to all firms on a common market and in limited quantities. In such a context, if a firm increases its R&D expenses, it makes R&D less available and more costly to other firms. This increases concentration on the final market and may increase the final price. Therefore, cooperation between strategic firms on the upstream market may induce more R&D by strategic firms, in order to exclude firms from the fringe and increase the final price. Such strategies neither occur when members of the agreement face no competition, nor when the cost of R&D for one firm is independent of its rivals' R&D decisions. This result calls for a rule of reason to allow research agreements.

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1 Introduction

Horizontal agreements in general are considered to have anti-competitive effects, and as such, are strictly forbidden by Article 81 of the EU Treaty. However, some specific agreements, such as research and development (R&D) agreements, benefit from a 'block exemption', because the efficiency gains that result from such agreements are likely to offset their potential anti-competitive effects.

In this paper, we assume that R&D activities need a specific input called capital, available to all firms on a common market and in limited quantities. In such a context, a firm that has market power on the capital market can exclude some rivals by increasing its capital purchase, which eventually increases final prices. Then, when firms cooperate on R&D, they may have incentives to buy more capital than when they compete. However,

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although the resulting increased R&D enhances the total efficiency of the industry, it also softens competition on the final market, hence increasing final prices. This result calls for a rule for reason rather than for a block exemption as far as horizontal R&D agreements are concerned.

To our knowledge, the economic literature does not take into account that firms engaging in similar R&D activities (which is likely to be the case for firms that compete to sell the same final good) need some common inputs that are sometimes only available on a common market. For instance, this is the case of workers with specific skills or of very rare machineries. In such cases, the more one firm uses of a given asset, the least available it is for its rivals. In particular, this may be a serious issue in markets in which large firms compete against small rivals, as it is likely that large firms may have better access to such assets than small firms.[1]

Besides analyzing whether and to what extent R&D agreements indeed lead to efficiency gains (D'Aspremont and Jacquemin, 1988; Kamien, Muller and Zang, 1992), the economic literature on joint-ventures has already studied several potential anti-competitive effects of such agreements. These effects usually result from the fact that firms engaging in a joint-venture usually compete on other markets, and in particular on the final market. Then, joint-ventures may harm welfare in several ways. Chen and Ross (2000, 2003) show for instance that an input joint venture may enable members of the joint venture to compete less on the final market. Noticing that members of such joint-ventures may be in contact in markets that are not even related to their joint activity, Cooper and Ross (2009) show that joint-ventures may have anti-competitive effects on such other markets too.

Such anti-competitive effects of joint ventures may occur in an industry where all the firms take part in the joint-venture. On the contrary, we focus on situations where only part of the firms competing on the final market are members of the joint-venture. We consider that firms cannot produce without a specific input called capital, and show that by reducing rivals' access to capital (and hence to R&D), the joint-venture may reduce competition on the final market. Besides, we are not interested in the spreading of cooperation to the output and price setting phase. It should be noted that in our framework, collusion on the final market may not be profitable for members of the R&D agreement.

Several articles already focus on the potential anti-competitive effects of joint-ventures through exclusionary practices. More precisely, they analyze the effects of access rules to the joint-venture. In particular, Carlton and Salop (1996) highlight that joint-ventures may harm competition by preventing some (possibly more efficient) firms from entering the joint-venture or by reducing rival input producers' incentives to enter the input market.

[1] Focusing not on competition between firms but on competition between countries, Nuttal (2005) describes this concern for skilled workers in the nuclear industry: "A particular example might be that a firm US resolve to embark on a nuclear renaissance might lead the US to recruit nuclear engineers from other countries, such as the UK. [...] this might jeopardize UK capacity to meet its existing nuclear skills needs [...] and thereby prevent any UK nuclear renaissance."

Both these effects of joint ventures lead rivals of the joint-venture members on the final market to have reduced access to some inputs, and therefore tends to reduce competition.

In this paper, contrary to the previous literature, we assume that capital is available to all firms on the same market. An agreement between two firms does not give them any privilege on the access to capital; It may only induce spillovers between the two firms.

We consider a framework in which two strategic firms compete with each other and with a competitive fringe. While strategic firms have market power both on the final market and on the market for capital, fringe firms are price-takers on the two markets. Buying capital enhances a firm's efficiency. However, it is costly and the price of capital is increasing in demand for capital. At the limit, capital may be capacity constrained. Then, strategic firms anticipate that purchasing capital will increase the cost of fringe firms, thus inducing part of them to leave the market and softening competition on the final market. To this extent, this article is related to the literature on "raising rivals' costs" strategies, first studied by Salop and Scheffman (1983, 1987), in a framework with one dominant firm and a competitive fringe. More generally, several articles such as Riordan (1998) study potential exclusionary practices in a framework with a dominant firm and a competitive fringe.

This article contributes to the literature on R&D cooperation by showing that two elements strongly affect the effect of such cooperation on competition. First, when firms buy at least one input necessary for R&D on a common market, the cost of all firms are interdependent, which may induce anti-competitive behaviour from some of the firms. Second, when members of the R&D cooperation face no rival, they will soften competition on the final market by purchasing less capital than in competition. On the contrary, in the presence of rivals, members of the agreement may want to buy more capital than in competition, so as to exclude rivals. Depending on which effect harms competition on the final market more, members of an R&D joint-venture may therefore buy more capital than if they were competing in R&D as well as on the final market.

Finally, in this context, although buying more capital, i.e. increasing R&D expenses, enhances the total efficiency of the industry, it also increases final price. Indeed, dominant firms only buy more capital when they cooperate than when they compete if this strategy enables them to reduce competition on the final market and increase final price. As a consequence, R&D agreements that result in more capital purchase than would have occurred without the agreement harm consumer surplus, and can thus be considered as"overbuying strategies".

The structure of the paper is as follows. In Section 2, we present the general model. In Section 3, we analyze under what conditions the increase of R&D expenses may lead to increased final prices. In Section 4, we determine the capital purchase decisions of strategic firms in the presence of a competitive fringe, and compare our results to two benchmark cases: when the size of the competitive fringe is exogenous and when R&D costs are independent from one firm to another. We finally study collusion on both markets. Section

5 concludes.

2 Model

Consider a market where two strategic firms denoted by 1 and 2 compete in quantity with each other and with a competitive fringe to sell a homogeneous good. We denote by $p(Q)$ the inverse demand function, where Q is the total quantity sold on the final market. The inverse demand function p is twice differentiable and such that $p' < 0$ and $p''q_i + p' < 0$. Fringe firms are price-takers on the final market.

In order to produce the final good, all firms need at least one unit of a fixed input, which we call capital. Prior to the purchase of capital, firms cost functions are as follows. A fringe firm has a cost $C(q_f)$ associated with producing quantity q_f. The cost function C is assumed twice differentiable, increasing and convex. A strategic firm has a cost function $\gamma C(q)$ associated with producing quantity q. The parameter $\gamma \in [0, 1]$ represents the efficiency advantage of strategic firms over fringe firms: the lower γ, the better this efficiency advantage.

Assume that the more capital a firm owns, the more efficient it is. Capital can thus be interpreted as an input which is necessary for research and development, and the use of which can accelerate the R&D process. If firm i purchases an amount k_i of capital, its cost function becomes $\gamma k_i C\left(\frac{q_i}{k_i}\right)$. A fringe firm can only purchase one unit of capital. Then, the size of the fringe is equal to the amount of capital bought by the fringe, and the price of capital is equal to the entry cost of fringe firms.

Capital is sold on a market represented by the supply function $R(K)$, where K is the total demand of capital. R is assumed twice differentiable, increasing and convex. Strategic firms can then compete both on the input and output markets, or cooperate on the input market. Such a cooperation can be interpreted as a research joint venture and is thus legal. For simplicity, we assume for now that there are no spillovers due to research cooperation. However, we will show later that our results hold even if such spillovers exist. Assuming that cooperation on the input market is legal allows us to consider only the static game, as firms can design a contract that defines the terms of cooperation and of the punishment in case of a deviation, and can be enforced by law. Fringe firms are price-takers on the input market.

The timing of the game is as follows:

1. Strategic firms simultaneously set their demands for capital. Firm i's capital demand is denoted by k_i ($i = 1, 2$).

2. Fringe firms decide whether or not to enter the market by purchasing one unit of capital. Entry is free and n denotes the size of the fringe at the end of this stage.

3. Strategic firms simultaneously set their output on the final market. Firm i's output is denoted by q_i.

4. Fringe firms simultaneously set their output on the final market.

Finally, we assume that their exists a unique equilibrium in which the two strategic firms behave identically, and make the following assumption regarding the equilibrium of the subgame including stages 3 and 4 of the game.

Assumption 1. *The equilibrium of the quantity setting stage is such that* $\frac{\partial q_i^*}{\partial n}+\frac{\partial q_j^*}{\partial n}+q_f^* > 0$.

Assumption 1 ensures that in equilibrium, total output $Q^* = q_1^* + q_2^* + nq_f^*$ increases when the size of the fringe increases. This assumption is satisfied for instance when the demand function is linear and the cost function of fringe firms is $C(q) = \frac{q^2}{2}$. Assumption 1 is reasonable assuming that the cost advantage of the strategic firms over the fringe firms is not too high.

3 Price increasing effect of R&D

In this section, we determine conditions under which final price is increasing in the capital purchase of strategic firms. We solve the subgame composed of stages 2 to 4 by backward induction.

3.1 Quantity setting

The fringe firms are price takers on the final market and therefore all set their output so that the final price is equal to their marginal cost. Denoting by $q_f(Q_s, n)$ the resulting output of one fringe firm, we thus have $p(Q_s + nq_f) = C'(q_f)$, where $Q_s = q_1 + q_2$ is the total output of strategic firms. It is immediate that q_f is decreasing in Q_s: as the output of strategic firms increases, the price decreases and each fringe firm must thus set a lower output to reduce its marginal cost. However, an increase of the strategic firms' output still always leads to an increase of total output (and hence a decrease of the final price). Indeed, as $p = C'(q_f)$, we have the following equality:

$$p'\left(1+\frac{\partial q_f}{\partial q_i}\right) = C''(q_f)\frac{\partial q_f}{\partial q_i} \quad \Rightarrow \quad 1+\frac{\partial q_f}{\partial q_i} > 0. \tag{1}$$

In the third stage of the game, strategic firms then set their output anticipating the fringe firms' decision. Firm i's programme is then:

$$\max_{q_i} \pi_i = p(q_1 + q_2 + nq_f(q_1, q_2, n))q_i - \gamma k_i C\left(\frac{q_i}{k_i}\right).$$

and the corresponding first order condition is:

$$\frac{\partial \pi_i}{\partial q_i} = p + p'\left(1 + n\frac{\partial q_f}{\partial q_i}\right) q_i - \gamma C'\left(\frac{q_i}{k_i}\right) = 0$$

In the following, we use exponent (*) for all values of the parameters that correspond to the equilibrium of the quantity-setting subgame. Determining the comparative statics of these values with regards to capital purchase allows us to highlight the effect of R&D when the size of the fringe is exogenous.

Comparative statics with regards to capital endowment. First, it is immediate that firm i's best reply output is increasing in its own capital endowment since $\frac{\partial^2 \pi_i}{\partial q_i \partial k_i} = \frac{\gamma}{k_i^2} C''(\frac{q_i}{k_i}) > 0$. On the contrary, the best reply output of i's rival is not affected by a change in i's capital endowment: $\frac{\partial^2 \pi_j}{\partial q_j \partial k_i} = 0$. As a consequence, assuming that there exists a unique equilibrium of the quantity-setting subgame, and given that the strategic firms' outputs are strategic substitutes, the equilibrium output choices are such that $\frac{\partial q_i^*}{\partial k_i} > 0$, $\frac{\partial q_j^*}{\partial k_i} < 0$ and $\frac{\partial q_i^*}{\partial k_i} + \frac{\partial q_j^*}{\partial k_i} > 0$. In other words, for a given size of the fringe, the output of a strategic firm increases with its capital endowment more than the parallel decrease of its strategic rival's output.

Consider now the effect of k_i on a fringe firm's output q_f^* and consequently on the final price p^*. Indeed, it should be noted that since $p^* = C'(q_f^*)$, it is immediate that p^* and q_f^* vary similarly with k_i (as well as with all other parameters). As $q_f^* = q_f(q_1^* + q_2^*, n)$, the output of each fringe firm decreases with the capital endowment of any strategic firm.

Therefore, for a given size of the competitive fringe, the final price decreases with k_i. This effect is straightforward and can be explained as follows: when the marginal cost of production of a firm is reduced, everything being equal, the industry becomes globally more efficient and consequently, the final price decreases while the total output increases. We denote this effect *efficiency enhancing effect*.

Obviously, if we assume that cooperation in R&D implies that a strategic enjoys spillovers from its rival, this effect becomes stronger: Indeed, in that case, the costs of both strategic firms decrease, which leads to an even fiercer competition on the output market.

Comparative statics with regards to the size of the fringe. The effect of the number of fringe firms on the final price is given by the following equation:

$$\frac{\partial p^*}{\partial n} = p'\left(1 + n\frac{\partial q_f}{\partial Q_s}\right)\left(q_f^* + \frac{\partial q_i^*}{\partial n} + \frac{\partial q_j^*}{\partial n}\right)$$

Given Equation (1) and Assumption 1, the final price p^* is thus decreasing in the size of the fringe. This is a direct consequence of Assumption 1, which ensures that total output increases with the number of fringe firms.

3.2 Entry decision of the fringe firms

Consider now Stage 2 of the game. Competition on the upstream market determines the number of fringe firms that enter the market. Indeed, in order to enter the market, a fringe firm must buy one unit of capital at the market price R. Fringe firms enter as long as this entry cost is lower than their profits on the output market. As a consequence, for a given pair (k_1, k_2), the size of the fringe is determined by the following equation:

$$p^* q_f^* - C(q_f^*) = R(K) \tag{2}$$

where $K = k_1 + k_2 + n$. We denote the equilibrium size of the fringe by $n^*(k_1, k_2)$.

Lemma 1. *Under Assumption 1, the size of the fringe decreases with the capital endowment of a strategic firm.*

Proof. Equation (2) is satisfied for all values of k_i. In particular, if k_i changes, the equilibrium size of the fringe n^* changes so that equation (2) is still satisfied. Therefore, the derivative of expression (2) gives us the following equation:

$$\left(\frac{\partial p^*}{\partial k_i} + \frac{\partial p^*}{\partial n}\frac{\partial n^*}{\partial k_i}\right) q_f^* = R' \left(1 + \frac{\partial n^*}{\partial k_i}\right). \tag{3}$$

which we can rewrite:

$$\frac{\partial n^*}{\partial k_i} = -\frac{R' - p' q_f^*(n^*) \left(1 + n^* \frac{\partial q_f}{\partial Q_s}\right)\left(\frac{\partial q_i^*}{\partial k_i} + \frac{\partial q_j^*}{\partial k_i}\right)}{R' - p' q_f^*(n^*) \left(1 + n^* \frac{\partial q_f}{\partial Q_s}\right)\left(\frac{\partial q_i^*}{\partial n} + \frac{\partial q_j^*}{\partial n} + q_f^*(n^*)\right)}. \tag{4}$$

Given that $R' > 0$, $p' < 0$, $1 + n\frac{\partial q_f}{\partial q_i} > 0$ and $\frac{\partial q_i^*}{\partial k_i} + \frac{\partial q_j^*}{\partial k_i} > 0$, it is immediate from the previous equation that if Assumption 1 is satisfied, then $\frac{\partial n^*}{\partial k_i} < 0$. □

When firm i increases its capital purchase, it has two parallel effects on fringe firms. First, for a given size of the fringe, the final price and the output of each fringe firm decrease: The industry becomes globally more efficient, but only firm i benefits from it as all its rivals become less efficient relative to i. As a consequence, the "short-term" profit of a fringe firm, *i.e.* its profit on the final market, decreases. Parallel to this, as the total demand of capital increases, the market price of capital, hence the cost of entry on the market $R(K)$, increases.

The consequence of these two effects is that less firms enter the fringe when strategic firms purchase more capital. Therefore, the purchase of capital by a strategic firm has a second effect parallel the efficiency enhancing effect highlighted previously: its leads to market concentration. Finally, as the final price decreases when the size of the fringe shrinks, the efficiency enhancing effect and *market concentration effect* are contradictory. We thus have to determine the conditions that ensure that the final price raises following an increase of capital purchase.

3.3 Effect of capital purchase on final price

In order to determine the effect of k_i on final price p^*, we determine the effect of k_i on $q_f^*(n^*) = q_f^{**}$, as we know that $p^*(n^*) = C'(q_f^*(n^*))$ and C' is increasing in q_f. Noticing first that $q_f^{**} = q_f(q_1^*(k_1, k_2, n^*),\ q_2^*(k_1, k_2, n^*), n^*)$, where $n^* = n^*(k_1, k_2)$, the derivative of q_f^{**} with regards to k_i is thus given by:

$$\begin{aligned}\frac{\partial q_f^{**}}{\partial k_i} &= \frac{\partial q_f}{\partial Q_s}\left(\left(\frac{\partial q_i^*}{\partial k_i} + \frac{\partial q_j^*}{\partial k_i}\right) + \frac{\partial n^*}{\partial k_i}\left(\frac{\partial q_i^*}{\partial n} + \frac{\partial q_j^*}{\partial n} + q_f^{**}\right)\right) \\ &= \frac{R'\left(\left(\frac{\partial q_i^*}{\partial k_i} + \frac{\partial q_j^*}{\partial k_i}\right) - \left(\frac{\partial q_i^*}{\partial n} + \frac{\partial q_j^*}{\partial n} + q_f^{**}\right)\right)}{R' - p' q_f^{**}\left(1 + n^*\frac{\partial q_f}{\partial Q_s}\right)\left(\frac{\partial q_i^*}{\partial n} + \frac{\partial q_j^*}{\partial n} + q_f^{**}\right)}\frac{\partial q_f}{\partial Q_s}.\end{aligned} \tag{5}$$

Given that $q_f^{**} > 0$, $R' > 0$, $\frac{\partial q_f}{\partial Q_s} \in \left[-\frac{1}{n}, 0\right]$ and $p' > 0$, the output of a fringe firm increases with k_i when Assumption 1 is satisfied and:

$$\frac{\partial q_i^*}{\partial k_i} + \frac{\partial q_j^*}{\partial k_i} < \frac{\partial q_i^*}{\partial n} + \frac{\partial q_j^*}{\partial n} + q_f^{**}, \tag{6}$$

i.e. when the total output gain incurred by the efficiency enhancing of the industry is offset by the output loss resulting from market concentration.

Proposition 1. *Under Assumption 1, the equilibrium of the subgame composed of stages 2 to 4 of the game is such that the final price p^* is increasing in k_i as long as* $\frac{\partial q_i^*}{\partial k_i} + \frac{\partial q_j^*}{\partial k_i} < \frac{\partial q_i^*}{\partial n} + \frac{\partial q_j^*}{\partial n} + q_f^{**}$.

Two assumptions regarding the price of capital are crucial for this result to hold: First, the price of capital must be increasing in capital purchase; Second, the price of capital for fringe firms must depend on strategic firms' capital purchase. This leads to several corollaries to Proposition 1.

Corollary 1. *The price increasing effect of R&D is only possible if the firms practicing R&D all need to purchase an input on a common market.*

Indeed, assume that the cost of capital for a fringe firm is independent of capital purchase by all other firms. In that case, equation (2) becomes simply $p^* q_f^* - C(q_f^*) = R$, and equation (3) becomes $\left(\frac{\partial p^*}{\partial k_i} + \frac{\partial p^*}{\partial n}\frac{\partial n^*}{\partial k_i}\right) q_f^* = 0$, as neither the increase of k_i nor the entry of a new fringe firm raises the price of capital. Given that $q_f^* > 0$, the effect of an increase of capital purchase on the size of the fringe is simply:

$$\frac{\partial n^*}{\partial k_i} = -\frac{\frac{\partial p^*}{\partial k_i}}{\frac{\partial p^*}{\partial n}} = -\frac{\frac{\partial q_i^*}{\partial k_i} + \frac{\partial q_j^*}{\partial k_i}}{\frac{\partial q_i^*}{\partial n} + \frac{\partial q_j^*}{\partial n} + q_f^{**}}. \tag{7}$$

Obviously, it is still negative as the short-term profit of fringe firms is still reduced following an increase of k_i. However, it is straightforward from equation (5) that we now have $\frac{\partial q_f^{**}}{\partial k_i} = 0$. In other words, when the fringe firms' cost of entry is not affected by other firms' purchases, the market concentration effect exactly offsets the efficiency enhancing effect.

As a consequence, as long as R&D decisions of one firm on the market has an impact on its rivals' R&D decisions, the price increasing effect of R&D may arise. This may be the case when R&D needs specific inputs such as high skilled workers or a given amount of time spent using a specific facility. Therefore, although an increase of R&D expenses following the creation of a joint-venture is considered desirable, as it increases efficiency on the market, such an increase of expenses, shall it occur, may not have the expected competitive effects. In particular, it should be noted that if Assumption 1 is satisfied, it is always the case that more R&D will lead to more concentration on the final market and higher final price.

Corollary 2. *Assume that there is a capacity constraint on capital and this constraint is binding for a given size of the fringe n. Then, if firm i increases its capital purchase by one unit, it excludes one firm from the fringe. This results in higher final price as long as* $\frac{\partial q_i^*}{\partial k_i} + \frac{\partial q_j^*}{\partial k_i} < \frac{\partial q_i^*}{\partial n} + \frac{\partial q_j^*}{\partial n} + q_f^{**}$.

Capacity constraint on capital is a specific case where R' tends to infinity as the constraint becomes binding. We can then deduce from equation (4) that $\frac{\partial n^*}{\partial k_i}$ tends to -1 as R' tends to infinity. The price increasing effect of R&D thus exists in particular when one of the inputs necessary for R&D is available in limited quantity. This is the case in particular for the time spent using a given facility, as one cannot extend the time available.

4 R&D Decisions

In this section, we give some insights as to what factors lead to more capital purchasing when strategic firms cooperate rather than compete on the upstream market. We then compare the results obtained with the model described in Section 2 to alternative frameworks: We assume first that the size of the fringe is fixed, second that the cost of R&D for one firm only depends on its own R&D expenses and finally that strategic firms collude on the final market in addition to cooperating on the upstream market.

4.1 Capital purchase in the presence of a competitive fringe

Anticipating decisions in the following stages of the game, strategic firms make their capital purchase decisions by each maximizing its individual profit in the competitive case, and maximizing the joint-profit of the two strategic firms in the cooperative case. Thus, firm i maximizes π_i in the competitive case and $\pi_i + \pi_j$ in the cooperative case, where profits of strategic firms are given by:

$$\pi_i = p(q_1^{**} + q_2^{**} + n^* q_f^{**})q_i^{**} - \gamma k_i C\left(\frac{q_i^{**}}{k_i}\right) - k_i R(k_i + k_j + n^*).$$

Assume now that firm i's capital purchase is the competitive best reply to k_j, which we denote by $BR(k_j)$. Then, the difference between marginal profits in the competitive and cooperative cases is given by:

$$\begin{aligned}\frac{\partial \pi_j}{\partial k_i}(BR(k_j), k_j) &= p' q_i^{**}\left(1 + \frac{\partial q_f}{\partial Q_s}\right)\left[\frac{\partial q_i^*}{\partial k_i} + \frac{\partial q_j^*}{\partial k_i} + \frac{\partial n^*}{\partial k_i}\left(\frac{\partial q_i^*}{\partial n} + \frac{\partial q_j^*}{\partial n} + q_f^{**}\right)\right] \\ &\quad + \left[p^{**} - \gamma C'\left(\frac{q_j^{**}}{k_j}\right)\right]\left(\frac{\partial q_j^*}{\partial k_i} + \frac{\partial q_j^*}{\partial n}\frac{\partial n^*}{\partial k_i}\right) - k_j R'\left(1 + \frac{\partial n^*}{\partial k_i}\right). \quad (8)\end{aligned}$$

Using the first order condition of Stage 3 for firm j, we can simplify (8) as follows:

$$\frac{\partial \pi_j}{\partial k_i}(BR(k_j), k_j) = p' q_i^{**}\left(1 + \frac{\partial q_f}{\partial Q_s}\right)\left(\frac{\partial q_i^*}{\partial k_i} + \frac{\partial n^*}{\partial k_i}\left(\frac{\partial q_i^*}{\partial n} + q_f^{**}\right)\right) - k_j R'\left(1 + \frac{\partial n^*}{\partial k_i}\right). \quad (9)$$

The first term of the right-hand side of equation (9) is positive if and only if the positive effect of purchasing more capital on firm i's output is more than offset by its negative effect on the fringe's output. In other words, if the joint output of firm i and the fringe decreases with k_i, the first term of the right-hand side of equation (9) is positive. Therefore, putting aside the variation of firm j's output following an increase of k_i, firm i is more likely to purchase more capital in cooperation than in competition in cases where final price increases with capital purchase.

The second term of equation (9) is negative if and only if $\frac{\partial n^*}{\partial k_i} > -1$. From equation (4) we deduce that this is true if and only if Assumption 1 is satisfied. Cases where this term is positive correspond to situations where capital purchase by strategic firms highly increases their efficiency as compared to the fringe firms. As a result, the size of the fringe (and hence the fringe's purchase of capital) decreases more than firm i's purchase of capital, and the capital price then decreases following an increase of k_i. In that case, the final price also decreases, because the efficiency enhancing effect offsets the market concentration effect. As a consequence, when Assumption 1 is not satisfied, the effects of k_i on equation (9) are reverse: the first term is negative whereas the second term is positive.

Finally, it is not obvious that strategic firms buy more capital in cooperation than in collusion only when their purchase induces an increase of the final price. However, consider a more specific case, we will show in the following that values of k_i such that $\frac{\partial n^*}{\partial k_i} < -1$ are usually very low and do not occur at equilibrium.

4.2 Capital purchase when the size of the fringe is exogenous

In this subsection, we show that free entry is necessary for strategic firms to buy more capital in cooperation than in collusion. We consider a benchmark in which there is no competitive fringe, and the two strategic firms thus only compete against each other. The results we obtain are then robust to the presence of a competitive fringe with a fixed size.

In this framework, the game has only two stages: first, the two firms simultaneously set their demand for input on the market for input; second, they simultaneously set their quantities on the final market. As in the case with free entry, we consider two possible frameworks: In the first framework, firms compete on the upstream market; In the second framework, firms enforce collusion on the market for capital and each firm i thus sets k_i so as to maximize the joint profit of the industry. We denote respectively by k^* and k^c the amount of capital purchased by one firm in the symmetric equilibrium, when firms are competing colluding on the market for capital.

Lemma 2. *In the absence of a competitive fringe, firms buy less capital in the cooperative equilibrium than in the competitive equilibrium: $k^c < k^*$.*

We show this result in the following. However, we first give the intuition for the result. In both cases (endogenous or exogenous competitive fringe), the purpose of cooperating strategic firms is the same: They seek to reduce competition on the final market in order to increase final prices. However, the means to reduce competition are different, depending on whether the size of the fringe is exogenous or endogenous. If it is exogenous, then strategic firms can only reduce competition among themselves. In order to do so, they buy less capital than in the competitive equilibrium, hence decreasing their production cost less and finally, softening competition on the final market as compared to the competitive case. On the contrary, when the size of the fringe is endogenous, strategic firms have an incentive to reduce competition by increasing market concentration. They do so by increasing their capital purchase, hence driving firms out of the competitive fringe. If the effect of k_i on fringe firms is high enough relative to its effect on i's strategic rival, strategic firms buy more capital in cooperation than in competition. Obviously, this can never happen when buying more capital has no effect on the size of the fringe.

Competition on the output market. The outcome of the second stage of the game is the same for both frameworks, as we always consider that there is Cournot competition on this market.

Each firm i ($i = 1, 2$) sets its output q_i in order to maximize its individual profit, and thus solves the problem:

$$\max_{q_i} \pi_i = p(Q_s)q_i - k_i R(k_1 + k_2)$$

First order conditions are given by:

$$p + q_i p' = \gamma C' \left(\frac{q_i}{k_i} \right).$$

As in the case with free entry, i's best reply output is increasing in k_i whereas j's best reply output does not depend on k_i. Therefore, we still have that $\frac{\partial q_i^*}{\partial k_i} > 0$, $\frac{\partial q_j^*}{\partial k_i} < 0$ and $\frac{\partial q_i^*}{\partial k_i} + \frac{\partial q_j^*}{\partial k_i} > 0$. A capital expansion by one firm amounts to an increase of the cost asymmetry between the firms, to the expense of the firm whose capital remains unchanged. However, the global efficiency of the industry is always improved by more capital purchasing and therefore, total output increases while final price decreases with k_i.

Equilibrium on the market for capital. In the first stage of the game, the difference between cooperation and competition is given by the effect of firm i's capital purchase on its rival's profit. In particular, if for all pair (k_1, k_2) we find that this effect is negative, then firm i's capital purchase is always lower in cooperation than in competition. Indeed, assume that $\frac{\partial \pi_j}{\partial k_i}(q_1^*, q_2^*) < 0$. Then, it is true in particular if i sets k_i as the competitive best reply to k_j, which we denote $BR_i(k_j)$. As a consequence, for any k_j, i has an incentive to buy less capital in cooperation than in competition. As firms' best-reply functions are symmetric, this implies that k^c is lower than k^*.

Consider now the effect of k_i on firm j's profit $\pi_j = p(q_i^* + q_j^*)q_j^* - \gamma k_j C\left(\frac{q_j^*}{k_i}\right)$:

$$\frac{\partial \pi_j}{\partial k_i} = p' \frac{\partial q_i^*}{\partial k_i} q_j^* + \frac{\partial q_j^*}{\partial k_i} \left(p + p' q_j^* - \gamma C' \left(\frac{q_j^*}{k_j} \right) \right) - k_j R'.$$

Using the first order condition of the second stage, we simplify this expression to $\frac{\partial \pi_j}{\partial k_i} = p' \frac{\partial q_i^*}{\partial k_i} q_j^* - k_j R'$. As $p' < 0$ and $R' > 0$, it is immediate that it is negative for all values of k_i and k_j. Hence Lemma 2. Since increasing i's capital purchase simultaneously reduces final price and firm j's output, and increases the input price R, buying more capital always harms the rival firm. As a consequence, in collusion, firms always buy less capital than in competition: $k^c < k^*$. In this framework, collusion enables firms to soften competition on the final market, which they can only do by enhancing their efficiency less than in the competitive case. This is consistent with the result that the price increasing effect of R&D only occurs if entry on the market is free.

4.3 R&D choices with independent costs of R&D

In this subsection, we show that strategic firms never buy more capital in cooperation than in competition if the cost of capital for a firm is independent of other firms' capital purchase, *i.e.* if firms do not all have to buy an input on the same market in order to implement R&D.

Assume that the cost of capital for a firm is only a function of its own capital purchase, which we denote by $R(k)$, where k is the capital purchase by the concerned firm. Then, equation (8) becomes:

$$\frac{\partial \pi_j}{\partial k_i}(BR(k_j), k_j) = \left[p^{**} - \gamma C'\left(\frac{q_j^{**}}{k_j}\right)\right]\left(\frac{\partial q_j^*}{\partial k_i} + \frac{\partial q_j^*}{\partial n}\frac{\partial n^*}{\partial k_i}\right),$$

as the increased capital purchase of k_i has no effect on fringe firms' and j's cost of capital anymore, and the final price is unchanged following an increase of k_i, as stated in Corollary 1. Then, using equation (7) and the inequality $-\frac{\partial q_j^*}{\partial k_i} < \frac{\partial q_i^*}{\partial k_i}$, we find that $\frac{\partial \pi_j}{\partial k_i}(BR(k_j), k_j) < 0$ for all values of k_j.

When the cost of capital of one firm is independent of other firms' capital purchase, firm j cannot benefit form an increase of k_i: If firm i buys more capital, final price remains unchanged but firm j's output decreases because of its relative loss of efficiency. Besides, the size of the fringe never shrinks so much that this offset j's output loss.

As a consequence, by not taking into account that many inputs necessary for R&D processes are available in limited quantity and sold at a common price to all the firms in an industry, one will miss the potential price increasing effect of capital purchase. Nevertheless, if large firms have easier access to some necessary facilities than small firms, increasing R&D efforts may be perceived as an over-buying strategy by large firms, in an attempt to prevent or reduce the access of small rivals to the same facilities.

4.4 The role of firms' relative efficiency

We assume in the following that the inverse demand function on the downstream market is $p(Q) = 1 - Q$ where $Q = q_1 + q_2 + nq_f$ is total output. The cost function of a fringe firm is quadratic and given by $C(q_f) = \frac{q_f^2}{2}$, and consequently, we have $k_i C\left(\frac{q_i}{k_i}\right) = \frac{q_i^2}{2k_i}$. Finally, we assume that the capital supply function is $R(K) = \frac{1}{2}\left(\frac{K}{a}\right)^2$, where a is a positive parameter and $K = k_1 + k_2 + n$ is the total purchase of capital. As previously, we compare capital purchase decisions when strategic firms are competing and cooperating on the market for capital.

It is first worth noting that in the framework specified formerly, Assumption 1 is always satisfied. Consider first the output decision of fringe firms. Each fringe firm sets q_f so that its marginal cost is equal to final price, which implies $q_f = p$. The resulting residual demand for strategic firms is then given by $RD(p) = 1 - p - nq_f$ and the associated inverse demand function is $\widetilde{p}(Q_s) = \frac{1-Q_s}{n+1}$. Firm i ($i = 1, 2$) then sets output q_i to maximize its profit $\pi_i = \widetilde{p}(Q_s)q_i - \gamma k_i C(\frac{q_i}{k_i}) - k_i R(K)$. The equilibrium outputs and final price are thus given by:

$$\begin{aligned} q_i^* &= \frac{k_1(\gamma + k_2 + \gamma n)}{3k_1k_2 + 2\gamma(k_1 + k_2)(1+n) + \gamma^2(1+n)^2}, \\ p^* = q_f^* &= \frac{(\gamma + k_1 + \gamma n)(\gamma + k_2 + \gamma n)}{(1+n)\left(3k_1k_2 + 2g(k_1 + k_2)(1+n) + \gamma^2(1+n)^2\right)}. \end{aligned}$$

The equilibrium of the quantity setting subgame is such that $\frac{\partial q_i^*}{\partial n} + \frac{\partial q_j^*}{\partial n} + q_f^* > 0$, and hence satisfies Assumption 1.

The equilibrium size of the fringe firm is given by $\frac{p^2}{2} = \frac{(k1+k2+n)^2}{2a^2}$. Because of computation issues, we only simulate the resulting capital choices in the two relevant cases. We set $a = 1000$ and determine the values of k^* and k^c for various values of $\gamma \in [0, 1]$. Table 1 summarizes the results.

Table 1: Capital purchase, size of the fringe, final price and strategic firm's profit when strategic firms are competing ($*$) and cooperating (c) on the market for capital.

γ	k^*	n^*	$10^3 \times p^*$	$10^3 \times \pi_1$	k^c	n^c	$10^2 \times p^c$	$10^3 \times \pi_1$
0.01	3.52	14.75	21.79	6.17	5.30	13.23	23.83	6.27
0.02	4.26	14.29	22.81	6.07	5.56	13.18	24.30	6.13
0.05	5.39	13.77	24.55	5.73	6.10	13.14	25.34	5.75
0.10	6.34	13.53	26.21	5.18	6.66	13.23	26.54	5.19
0.20	7.26	13.64	28.16	4.21	7.26	13.64	28.16	4.21
0.50	7.74	15.42	30.90	1.95	7.51	15.72	30.73	1.96
0.99	1.75	27.71	31.21	57.13×10^{-4}	1.72	27.77	31.21	57.17×10^{-4}

Then, we observe that k^c is higher than k^* as long as γ is low enough (here lower than 0.2). When γ is low, the efficiency advantage of strategic firms over fringe firms is high, and therefore, a strategic firm benefits more from an increase of its capital endowment. The fringe thus suffers all the more from an increase of k_i that γ is higher. The overbuying strategy of cooperative strategic firms is thus more likely to occur when they are very efficient relative to their smaller rivals. However, although one would then expect final price to decrease due to the enhancing of global efficiency, this never happens. Cases where $k^c > k^*$ in the case we describe are always cases where the final price increases with k_i.

4.5 Downstream collusion

It is interesting to note that in this case, we do not assume that cooperative R&D increases the risk of collusion. The price increase is thus simply a result of the contact of all firms both on the final market and on the market for capital. Moreover, we will show in the following that enforcing collusion on the final market would not be profitable for strategic firms.

Consider again the specific framework described in the previous subsection. Assume that strategic firms now maximize the joint profit of the strategic duopoly both on the capital market and on the final market, *i.e.* enforce collusion on the final market.

Output decisions of the fringe firms are again given by $p = q_f$ and the residual inverse demand function is still $\widetilde{p}(Q_s)$. Then, firm i sets output q_i to maximize profit $\pi_i + \pi_j = \widetilde{p}(Q_s)Q_s - \gamma(k_i C(\frac{q_i}{k_i}) + k_j C(\frac{q_j}{k_j})) - (k_i + k_j)R(K)$. The collusive outputs and final price are thus given by:

$$
\begin{aligned}
q_i^M &= \frac{k_i}{\gamma(n+1) + 2(k_1 + k_2)}, \\
p^M &= \frac{\gamma(n+1) + k_1 + k_2}{(n+1)(\gamma(n+1) + 2(k_1 + k_2))}.
\end{aligned}
$$

Unsurprisingly, for a given size of the fringe, the resulting final price (and hence the output of a fringe firm) is higher than in the competitive equilibrium. Besides, if strategic firms both buy the same amount of capital, firm i's output is reduced in collusion as compared to competition. The direct consequence however is that more firms enter the fringe than in the competitive case: $n^M(k,k) > n^*(k,k)$ for any $k > 1$, which reduces the final price as well as the output of strategic firms. Then, if the difference between n^M and n^* is high enough, the profit of strategic firm is higher in competition than in collusion for any value of k.

For $a = 1000$, it is always the case that the profit of a strategic firm in competition is higher than its profit in collusion: $\pi_i^*(k,k) > \pi_i^M(k,k)$. In particular, since $\pi_i^*(k^c,k^c) > \pi_i(k,k)$ for all $k > 1$, we always have $\pi_i^*(k^c,k^c) > \pi_i^M(k,k)$. In other words, it is impossible for strategic firms to earn a higher profit when they enforce collusion successively on the market for capital and on the final market than when they only cooperate on the market for capital. Indeed, when collusion on the final market increases the final price and therefore facilitates entry in the competitive fringe. Eventually, the increased competition on the final market more than offsets the initial price increase.

The usual concerns regarding the potential anti-competitive effects of R&D agreements are that cooperation at any stage of the production process (here, R&D) can facilitate cooperation in other stages, and in particular at the pricing stage. Interestingly enough, in our case, collusion on the final market would not be profitable for strategic firms. More importantly, the anti-competitive effect of R&D we observe thus does not result from softer competition between strategic firms on the final market: It results from softer competition between strategic firms and the competitive fringe, which has been analyzed in the previous Section.

5 Conclusion

In this paper, we highlight an anti-competitive effect of R&D agreements that had not been pointed out in the previous literature. In order to engage in R&D, firms must purchase specific inputs including high skilled workers or time using a rare facility. Such inputs are necessary to all the firms engaging in the same type of research. Consequently, firms that compete to sell a final good are also likely to compete to purchase the inputs necessary to R&D.

We show that in such situations, if there are large asymmetries between firms on the market, large firms with market power may engage in R&D cooperation for anti-competitive purposes. Cooperation may then induce them to overbuy the input, *i.e.* to buy more input than they would otherwise, so as to increase the input price or make it less available to small firms, and thus to exclude them from the final market. This strategy is all the more likely to occur that large firms are very efficient relative to their small rivals. In such a context, while one would expect final prices to decrease due to enhanced efficiency, the market concentration effect induces an increase in the final price. Such agreements thus harm consumer surplus.

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