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1 Introduction

Although horizontal agreements are generally forbidden by Article 101 of the Treaty on the Functioning of the European Union, research and development (R&D) agreements benefit from a “block exemption” as long as the market share of participants is lower than 25%, and are more generally often considered to fall under paragraph 3 of Article 101, that is to benefit final consumers.\footnote{See the European Guidelines (2011).}

In this paper, we highlight conditions under which R&D agreements may actually harm consumers by increasing final prices, and therefore do not fit the requirements of paragraph 3 of Article 101. This occurs although members of the R&D agreement increase their R&D efforts.

We consider a framework where firms compete both on the final market and to buy an input necessary for R&D. The industry consists in a competitive fringe and two strategic firms that enjoy a first mover advantage on both markets. Then, if a strategic firm increases its R&D input purchase, it increases the cost of all its rivals and in particular deters entry in the fringe. This reduces downstream competition and eventually increases the final price. Therefore, an R&D agreement between the leading firms...
may induce firms to increase their individual R&D efforts at the expense not only of rival firms but also of consumers.

Firms engaging in (similar) R&D activities usually need specific and often scarce inputs for which they also have to compete, such as time slots in highly specialized industrial facilities or skilled workers: the R&D costs of such firms are thus not as independent from one another as is usually assumed. To a certain extent, this “R&D input” could be viewed as essential in R&D intensive industries\(^2\). For instance, there is empirical evidence that skilled workers is a scarce resource in many R&D oriented industries. According to a survey by the US National Science Foundation, wages and related labor costs accounted for 46.6% of the US industrial R&D costs in 2006. In particular, they account for 28.8% of all R&D costs in pharmaceuticals and medicine, 51.9% in the industry for computer and electronic products and 55.3% in computer systems designing\(^3\). Parallel to this, concerns are often raised both by firms in innovative markets and by governments as to the need for more research personnel\(^4\).

Although Grossman and Shapiro (1986) argue that R&D agreements may create barriers to entry both on the downstream market and on the “upstream research market”, most of the literature on R&D agreements focuses only on their direct effects on product markets (D’Aspremont and Jacquemin, 1988; Kamien, Muller and Zang, 1992; Simpson and Vonortas, 1994), and considers industry wide R&D agreements, while we want to analyze the entry deterrence effect of partial agreements. D’Aspremont and Jacquemin (1988) find, as we do, conditions under which R&D cooperation increases R&D efforts as compared to competition. In their case however, it results from an internalization of R&D spillovers, and hence increases social welfare and consumer surplus. By contrast, we assume no spillovers from R&D. In our framework, increasing R&D efforts in an R&D agreement is essentially a way to prevent rivals from accessing the R&D input, and as such can be considered as an “overbuying strategy” that reduces consumer surplus and may reduce welfare. To this extent, our work is related to the literature on ‘raising rivals’ costs” first studied by Salop and Scheffman (1983, 1987).

Banerjee and Lin (2003) already highlighted the raising rivals’ costs effect of R&D. They consider an oligopoly in which firms need an input

\(^2\) Motta (2004) defines an essential facility as “any input which is deemed necessary for all industry participants to operate in a given industry and which is not easily duplicated”. The main concern then is the “refusal to supply” when a firm competing downstream owns the essential facility. In our framework, strategic firms are not vertically integrated, but they take into account how their investment decisions will affect the access of fringe firms to the R&D input.


supplied by a monopoly to produce output, and can engage in parallel in
cost-reducing R&D. A firm engaging in R&D increases its output, hence
its input demand, and finally induces the monopoly to increase the input
price. The standard hold-up problem is then lessened by the raising rivals’
costs effect. Our paper is different from theirs in two ways. First, Banerjee
and Lin (2003) do not focus on horizontal R&D agreements but rather on
the means to solve the hold-up problem that arises when R&D intensive
industries belong to a vertical chain. Second, and more importantly, al-
though in both our frameworks R&D investment yields a raising rivals’
costs mechanism, in Banerjee and Lin (2003) this never induces an increase
of the final price and therefore does not harm consumers, as the cost reduc-
tion of the firm that invests in R&D always offsets the cost increase of its
rivals. By contrast, in our framework, the final price may increase following
an increase of R&D efforts, because this induces firms to leave the fringe
and therefore increases market concentration.

Yi (1998) shows how an horizontal R&D agreement including only
part of the firms in the industry imposes a cost disadvantage on firms out-
side the agreement, for members of the agreement enjoy synergies unavail-
able to outsiders. However, as Yi (1998) focuses on a one-layer industry,
the raising rivals’ costs effect does not result from strategic behavior on the
input market. In his framework, this raising rivals’ costs effect is actually
an increase of the cost difference between insiders and outsiders, but not an
absolute cost increase for the outsiders. Therefore, although an agreement
harms outsiders, it never increases final prices.

The two last papers both consider initially symmetric industries and
a fixed market structure, which is not the case of our paper. In fact, the
harmful effect of R&D agreements is the result of anti-competitive behavior
by large firms. To this extent, our work is related to Riordan (1998), who
analyzes a raising rivals’ costs problem with an endogenous market struc-
ture, in a framework with one dominant firm and a competitive fringe. We
extend this framework to consider a duopoly facing a fringe, which allows
us to balance the raising rivals’ costs effect on the strategic rival on the one
hand and on the competitive fringe on the other hand. In order to isolate
the two effects, we consider a benchmark in which there is no competitive
fringe and show that in this case, strategic firms have no incentive to in-
crease R&D efforts when they cooperate.

This paper thus contributes to the literature on R&D agreements by
taking into account the role of the R&D input market when a subset of the
firms in the industry decide cooperatively on R&D and when the market
structure is endogenous. It also contributes to the literature on raising ri-
vals’ costs by balancing the effect of R&D on a strategic rival on the one
hand, and on the competitive fringe on the other hand. In our framework,
not only do large firms invest more in R&D when they enter an agreement,
but this behavior harms both their rivals and consumers. Our results have
important implications in terms of competition policy as this potential effect of R&D agreements is not taken into account by competition authorities, the main concern of which is the direct restriction of competition on the final market that may result from such agreements.

The structure of the paper is as follows. In Section 2, we present the general model. In Section 3 we determine the R&D input purchase decisions of strategic firms in the presence of a competitive fringe and compare two cases: when strategic firms are competing on both markets and when they are cooperating in R&D. We then compare our results to two benchmarks: when the size of the competitive fringe is exogenous and when R&D costs are independent from one firm to another. In Section 4, we derive a welfare analysis. 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 \( p''Q + p' < 0 \). Fringe firms are price-takers on the final market.

As we focus on R&D intensive industry such as biotechnology or software designing, we assume that R&D investment is a sine qua non condition for entering the market. Therefore, a firm enters the market by buying at least one unit of R&D input. Besides, buying more than one unit of R&D input increases the firm’s productive efficiency. We denote by \( k_i \in [1, +\infty) \) the amount of R&D input purchased by strategic firm \( i \), and we assume that a fringe firm can only buy 1 or 0 unit of R&D input. Then, the cost of a fringe firm producing \( q_f \) is \( C(q_f) \), whereas the cost of producing \( q_i \) for strategic firm \( i \) is given by \( \gamma k_i C(q_i / k_i) \). The parameter \( \gamma \in [0,1] \) thus represents the efficiency advantage of strategic firms over fringe firms: the lower \( \gamma \), the higher this efficiency advantage. The function \( C \) is assumed twice differentiable, increasing and convex. Using similar cost functions for the fringe and the strategic firms allows us to reduce the difference between the two types of firms to one parameter and simplifies the analysis. Besides,
as far as the fringe is concerned, it is reasonable to assume convex costs as it represents the capacity constraint of these firms. In that sense, the parameter $\gamma$ is a measure of the difference between the capacity constraint of the fringe firms and the strategic firms. Indeed, the lower $\gamma$, the flatter the cost function of the strategic firms relative to the fringe firms.

All firms buy the R&D input on a common market represented by the supply function $R(K)$, where $K = k_1 + k_2$ is the demand for R&D input of strategic firms. $R$ is assumed twice differentiable, increasing and convex, which reflects the existence of a capacity constraint on the input. We assume that fringe firms are price-takers on the R&D input market. As a fringe firm either buys one unit of R&D input and enters the market or buys no R&D input and stays out, $R(K)$ can be interpreted as the entry cost of fringe firms. Finally, the size of the fringe $n$ is thus equal to the total amount of R&D input bought by fringe firms, and is assumed continuous.

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 that there are no spillovers from R&D and that research cooperation does not induce synergies between the two firms. 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.

The timing of the game is as follows. The outcome of each stage is subsequently observed.

1. Strategic firms simultaneously invest in R&D. Firm $i$’s R&D input demand is denoted by $k_i$ ($i = 1, 2$). If they are competing in R&D, then $i$ sets $k_i$ to maximize its own profit. If however they are cooperating in R&D, then $i$ sets $k_i$ to maximize the joint profit of the two strategic firms.

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

---

7 In order to simplify computations, we assume that the R&D input purchase of fringe firms does not affect the price of R&D. Our results are however qualitatively the same if we assume that fringe firms’ R&D purchase similarly affects $R$ (that is if we instead assume that $K = k_1 + k_2 + n$), as we show in Christin (2011) with specified inverse demand and input supply functions.

8 We can show that our main result holds when there are spillovers between the two strategic firms. Assume that the cost function of a strategic firm is actually $(k_1 + k_2)\gamma C(\theta/(\theta + k_2))$, i.e. there are full R&D spillovers between the two firms. Then, we still find, as in D’Aspremont and Jacquemin (1988) that strategic firms invest more in R&D in cooperation than competition, but by contrast to D’Aspremont and Jacquemin (1988) the final price may increase following this increase in R&D efforts in cooperation than in competition.

9 Similarly, we show in Christin (2011) that our main result holds with synergies. Assume that when strategic firms enter an R&D agreement, they enjoy full synergies from each other’s R&D investment. The effect of an R&D agreement then is similar to the effect of a merger in Perry and Porter (1985). Then, we can show that strategic firms invest more in R&D in cooperation than competition for low enough values of $\gamma'$, and that when they do buy more, the final price is higher in cooperation than in competition.
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.

The game is solved by backward induction.

Note that we do not endogenize the decision of strategic firms to cooperate or not, but merely compare their purchasing behavior when they are competing and cooperating on the upstream market. However, considering the numerical example of Section 4, cooperation is always profitable for the strategic firms. Thus were the choice of cooperation endogenous, firms would always choose cooperation. We assume that this is also the case in the more general model presented here.

Note also that we do not consider collusion on the final market, for as in Yi (1998), we want to focus on the exclusionary effect of R&D agreements. Besides, in this particular setting downstream collusion may not even be profitable for members of an R&D agreement. Indeed, downstream collusion relies on output reduction, which does not necessarily lead to a final price increase here, since fringe firms increase their output as a response to strategic firms’ decisions. Consequently, while one usual concern regarding R&D agreements is that they may facilitate collusion on final markets, it is not what we are interested in here: the anti-competitive effect of R&D agreements that we observe does not result from softer competition between strategic firms on the final market.\(^{10}\)

### 3 R&D Decisions

In this section, we determine conditions under which final price is increasing in the R&D input purchase of strategic firms, and conditions under which strategic firms buy more R&D input when they form an R&D agreement than when they compete on the R&D market.

#### 3.1 Quantity setting

We show here that for a given size of the fringe, the total efficiency of the market increases when strategic firm i increases its R&D expenses $k_i$.

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. We denote by $q_f(q_i + q_z, n)$ the resulting output of one fringe firm. In stage 4, by symmetry, we thus have:\(^{11}\)

---

\(^{10}\) See Christin (2011) for a more developed analysis of this point.

\(^{11}\) Obviously, we must also ensure that fringe firms earn a positive total profit (taking into account the cost of purchasing R&D). As we will see later on however, firms only enter the fringe if they are sure to earn a positive profit, and the equilibrium size of the fringe is given by a 0 profit condition.
It is immediate that $q_i$ is decreasing in $q_i$ ($i \in \{1, 2\}$): 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, deriving equation (1) with respect to $q_i$ yields:

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

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

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

and the corresponding first order condition is:

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

In the following, we define the equilibrium outcome of the quantity-setting subgame by the use of an asterisk (for instance the equilibrium price is $p^*$). A comparative statics analysis of these values with respect to R&D input purchase allows us to highlight the effect of R&D when the size of the fringe is given. We also determine the effect of $n$ on prices and outputs.

**Comparative statics with respect to R&D input endowment.**

First, it is immediate that firm $i$’s best reply output is increasing in its own R&D input endowment since $\frac{\partial^2 \pi_i}{\partial k_i \partial q_i} = \gamma / k_i^2 C''(q_i / k_i) > 0$. By contrast, the best reply output of $i$’s rival is not affected by a change in $i$’s R&D input endowment: $\frac{\partial^2 \pi_i}{\partial k_i \partial q_i} = 0$. Besides, we show in Appendix A that the strategic firms’ output decisions are strategic substitutes. As a consequence, assuming that there exists a unique equilibrium of the quantity-setting subgame, the equilibrium output choices are such that $\partial q_i^* / \partial k_i > 0$, $\partial q_j^* / \partial k_i < 0$ and $\partial q_i^* / \partial k_i + \partial q_j^* / \partial k_i > 0$. In other words, for a given size of the fringe, the output of a strategic firm increases with its R&D input endowment more than the parallel decrease of its strategic rival’s output and of the fringe’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, 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
\( q^*_i = q_i(q^*_i + q^*_j, n) \), the output of each fringe firm decreases with the R&D input 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 else 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.

Comparative statics with respect to the size of the fringe. Noticing that \( q^*_i(n, k_i, k_j) = q_i(q^*_i(n, k_i, k_j) + q^*_j(n, k_i, k_j), n) \) and \( p^* = p(q^*_i + q^*_j + nq^*_j) \), the effect of the number of fringe firms on the final price is given by the following equation:

\[
\frac{\partial p^*}{\partial n} = \left( \frac{\partial q^*_i}{\partial n} + \frac{\partial q^*_j}{\partial n} + n \left( \frac{\partial q^*_i}{\partial q_i} \frac{\partial q^*_i}{\partial n} + \frac{\partial q^*_j}{\partial n} \right) + q^*_j \right) p'(q^*_i + q^*_j + nq^*_j),
\]

Besides, deriving equation (1) with respect to \( n \) yields:

\[
\left( q_i + n \frac{\partial q_i}{\partial n} \right) p' = \frac{\partial q_i}{\partial n} C''(q_i)
\] (4)

Finally, from (2) and (4), we deduce that \( \frac{\partial q_i}{\partial n} = \frac{\partial q^*_i}{\partial q_i} \frac{\partial q_i}{\partial n} + \frac{\partial q^*_j}{\partial n} + q^*_j \), which gives us a simpler expression of the variation of \( p^* \) with respect to \( n \):

\[
\frac{\partial p^*}{\partial n} = \left( 1 + n \frac{\partial q_i}{\partial q_i} \right) \left( \frac{\partial q^*_i}{\partial n} + \frac{\partial q^*_j}{\partial n} + q^*_j \right) p'.
\]

We then find as in Riordan (1998) that the final price \( p^* \) is decreasing in the size of the fringe \( n \). Indeed we show in Appendix B that the additional output produced by one more firm in the fringe is higher than the output loss of incumbent firms following this entry, and therefore total output \( Q^* = q^*_i + q^*_j + nq^*_j \) increases when the size of the fringe increases. However, as shown in Appendix B, the output of a strategic firm always decreases with \( n \) : the direct effect of \( n \) on \( q^*_i \) is always stronger than its indirect effect through reducing the rest of the fringe’s output.
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 R&D input at the market price $R$. Fringe firms enter as long as this entry cost is lower than their profits on the output market. Thus for a given pair $(k_i,k_j)$, the size of the fringe is given by:

$$p^* q_j^* - C(q_j^*) = R(K)$$

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

**Lemma 1.** The size of the fringe decreases with the R&D input endowment of any strategic firm.

**Proof.** Equation (5) is satisfied for all values of $k_i$. Therefore, the derivative of expression (5) gives us the following equation:

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

which we can rewrite:

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

Given that $R' > 0$, $p' < 0$, $1 + n \frac{\partial q_i}{\partial n} + \frac{\partial q_i}{\partial n} > 0$, $\frac{\partial q_i}{\partial n} + \frac{\partial q_j}{\partial n} > 0$, and $\frac{\partial q_i^*}{\partial n} + \frac{\partial q_j^*}{\partial n} + q_j^*(n^*) > 0$, it is immediate that $\frac{\partial n^*}{\partial k_i} < 0$.

An increase in firm $i$’s R&D input purchase 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 profit of a fringe firm on the final market decreases. In parallel, as the total demand for R&D input increases, the market price of the input, 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 R&D input. Therefore, the purchase of R&D input by a strategic firm has a second effect parallel to the efficiency enhancing effect highlighted previously: it increases market concentration. Finally, as the final price increases when the size of the fringe shrinks, the efficiency enhancing and market concentration effects are contradictory. We thus have to determine the conditions that ensure that the final price rises following an increase of R&D input purchase. From here on, we use
Comparative statics with respect to R&D input endowment.

Equation (6) gives a simple expression of the price variation following R&D input purchase: \( \partial p^{**} / \partial k_i = R' / q_i^{**} \), from which we immediately deduce the following proposition. This proposition is an extension of Riordan (1998) to a framework with two strategic firms.

**Proposition 1.** In the subgame composed of Stages 2 to 4, the equilibrium final price \( p^{**} \) is increasing in \( k_i \).

In particular, assuming that there is a capacity constraint on the amount of R&D input available and that fringe firms buy all the remaining R&D inputs after strategic firms’ purchasing decision, then if firm \( i \) increases its R&D input purchase by one unit, it excludes one firm from the fringe, which results in a higher final price.

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 slots to use a specific facility. Therefore, although an increase of R&D expenses following the creation of a R&D agreement 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.

Focusing now on firms’ output decisions, it is immediate that the output of strategic firm \( i \) increases with \( k_i \). This results both from the efficiency enhancing and from the market concentration that follow an increase of \( i \)’s R&D investment. Paradoxically, an increase of \( k_i \) may also increase the output of firm \( i \)’s strategic rival: this happens when the market concentration effect offsets the efficiency enhancing effect, which happens under the conditions described in the following proposition.

**Proposition 2.** If we assume that \( C \) is three times differentiable and \( p''(C'')^2 - (p')^2C''' \) is not too negative, then the output of strategic firm \( j \) \((j \in \{1,2\})\) increases with \( k_i \) \((i \in \{1,2\}, i \neq j)\).

Proof. See Appendix C.

Note that this condition only needs to be true in equilibrium. This is the more likely to happen that the cost function of fringe firms is convex enough and the inverse demand function is convex. In that case, an increase of \( k_i \) tends to reduce fringe firms’ revenue more, and therefore the number of fringe firms decreases faster with \( k_i \) than when the cost function is not too convex. In other words, the market concentration effect is all the stronger that the cost function \( C \) is more convex. It is also more likely that one strategic firm’s output increases with its strategic rival’s R&D
endowment when the inverse demand function is not too steep, for the efficiency enhancing effect is weaker than with a steep inverse demand curve, which benefits \( i \)'s strategic rival.

Finally, this condition is satisfied with rather standard demand and cost functions. For instance, it is satisfied when the cost function is quadratic and demand is linear or iso-elastic.

### 3.3 R&D decisions of strategic firms

We now determine conditions that ensure that strategic firms invest more in R&D when they cooperate than when they compete on the upstream market.

Anticipating decisions in the following stages of the game, strategic firm \( i \) makes its R&D input purchase decision by maximizing its individual profit \( \pi_i \) in the competitive case, and maximizing the joint-profit of the two strategic firms \( \pi_i + \pi_j \) in the cooperative case, where profits of strategic firms are given by:

\[
\pi_i = p(q_i^{**} + q_j^{**} + n^*q_j)q_i^{**} - \gamma kC\left(\frac{q_i^{**}}{k_i}\right) - k_i(R(k_i + k_j)).
\]

The only difference between competition and cooperation on the upstream market is that firm \( i \) takes into account the effect of its own investment on the profit of firm \( j \) in addition to its effect on its own profit. In particular, assuming that firm \( i \)'s R&D investment is equal to its competitive best reply to \( k_j \), which we denote \( BR(k_i) \), the additional effect that \( i \) must take into account is given by the following equation:

\[
\frac{\partial \pi_i}{\partial k_i}(BR(k_i),k_j) = \frac{\partial p^{**}}{\partial k_i}q_i^{**} + \left[p^{**} - \gamma C'\left(\frac{q_i^{**}}{k_i}\right)\right]\frac{\partial q_j^{**}}{\partial k_i}\frac{R'}{R}.
\]  

Then a firm will buy more R&D input in cooperation than in competition if and only if \( \frac{\partial \pi_i}{\partial k_i}(BR(k_i),k_j) > 0 \).

This effect can be decomposed into three parts that may be contradictory: the final price effect (I), the output effect (II) and the cost effect (III). The comparative statics of (I) and (II) with respect to \( k_i \) are described in the previous subsection: the final price increases with \( k_i \) and so does firm \( j \)'s output under some conditions. By contrast, it is straightforward that the cost effect is negative: an increase of \( k_i \) increases the unit cost of R&D and thus \( j \)'s R&D expenses (at \( k_j \) given). The following proposition gives some insights as to the effect of cooperation on strategic firms’ R&D investments.

**Proposition 3.** Strategic firms invest more in R&D in cooperation than in competition when:
(i) The demand for firm $i$’s good does not decrease to much with $j$’s ($j \neq i$) R&D input purchase (i.e. $p''(C''')^2 - (p')^2 C'''$ is not too negative),

(ii) The cost advantage of strategic firms is high enough (i.e. $\gamma$ is low enough).

Proof. The first condition is immediate and derives from Proposition 2: $\frac{\partial \pi_i}{\partial w}(BR(k_i),k_j)$ is more likely to be positive if an increase of $k_i$ increases $q_j$, which happens under the first condition.

The second condition ensures that the price effect is high enough relative to the cost effect. Indeed, we know that $\frac{\partial p''}{\partial k_i} = R' / q_j''$. Therefore, the sum of these two effects is given by $\frac{\partial p''}{\partial k_i} - k_j R' = R' \left(\frac{q_j''}{q_j''} - k_j \right)$. This implies that the price effect offsets the cost effect if and only if $q_j'' > k_j q_j''$, which is equivalent to $C' \left(\frac{q_j''}{k_j} \right) > C' \left(\frac{q_j''}{k_j} \right)$. Besides, from equations (1) and (3), we find that $p'' = C' \left(\frac{q_j''}{k_j} \right) > \gamma C' \left(\frac{q_j''}{k_j} \right)$. Therefore, there exists $\gamma' \in [0,1)$ such that the price effect offsets the cost effect if $\gamma < \gamma'$ and the opposite happens otherwise.

When determining how much to invest in R&D in cooperation relative to the competitive level, a strategic firm must solve the trade-off between its effect on both the fringe firms and its strategic rival. Increasing $k_i$ allows strategic firm $i$ to increase the competitive pressure faced by fringe firms, but at the same time increases competition between the two strategic firms. This trade-off is essentially described by (II), that is the output effect: On the one hand, for a given number of fringe firms, an increase of $k_i$ reduces $i$’s production cost and leads to a decrease of firm $j$’s output. On the other hand, as $k_i$ increases, the size of the fringe decreases, which is beneficial to firm $j$. Then, depending on which of these two effects prevails, the effect of $k_i$ on output can be either positive or negative, as shown in the previous subsection. This effect corresponds to the first condition in Proposition 3.

Similarly, increasing $k_i$ both increases fringe firms’ entry costs and the rival strategic firm’s R&D expenses. Again, depending on which of the two effects prevails, the effect of $k_i$ on firm $j$’s profit can be either positive or negative. This effect corresponds to the second condition in Proposition 3. Indeed, increasing fringe firms’ entry costs results in less entry, which increases the final price. Then, the more $R$ increases with $k_i$, the faster the final price increase following an increase of $k_i$. The effect on strategic firm $j$ is however symmetrical: the higher $R'$, the more $j$’s R&D expenses increase with $k_i$. Finally, the latter effect offsets the former only when strategic firms are efficient enough relative to fringe firms, which implies that a strategic firm’s output per unit of R&D is higher than a fringe firm’s output (per unit of R&D).

Finally, it is important to note that in cases where strategic firms indeed buy more R&D input in cooperation than in competition, they do so in the sole purpose of excluding fringe firms and increasing final price.
As a consequence, despite the efficiency gains resulting from more R&D, the effect of R&D cooperation on consumer surplus is negative when the condition given in Proposition 3 are satisfied. In that case, the strategy of strategic firms can be described as “over-buying” or strategic buying.

3.4 Benchmarks

We have shown that under free entry in the competitive fringe, the strategic firms may buy more R&D input in cooperation than in competition. We now disentangle the different effects explaining this result by comparing our model to two benchmarks.

Assume first that there is no competitive fringe, and the two strategic firms only compete against each other. This benchmark gives some insight as to the effect of an R&D agreement in the framework of Banerjee and Lin (2003), focusing on the duopoly case and replacing the upstream monopoly by an increasing inverse supply function. The game has only two stages: First, the two firms simultaneously invest in R&D, and firm i’s R&D input demand is still denoted by $k_i$. Second, they simultaneously set output on the final market.

**Lemma 2.** In the absence of a competitive fringe, firms invest less in R&D in the cooperation than in the competition.

**Proof.** See Appendix D.

In both cases (endogenous or exogenous competitive fringe), the purpose of cooperating strategic firms is to reduce competition on the final market. However, if the size of the fringe is exogenous, strategic firms can only reduce competition among themselves. In order to do so, they buy less R&D input and thus decrease their production costs less than in competition. By contrast, when the size of the fringe is endogenous, strategic firms reduce competition by increasing their R&D input purchase, hence driving firms out of the competitive fringe.

Assume now that the cost of the R&D input for a firm is only a function of its own R&D input purchase $k$, which we denote by $R(k)$.

**Lemma 3.** When the R&D cost of a firm only depends on its own R&D investment and not on its rivals’, then:

(i) the final price $p^*$ is constant with $k$, and,

(ii) strategic firms invest less in R&D in cooperation than in competition.

---

12 The results we obtain are robust to the presence of a competitive fringe with a fixed size.

13 It is actually possible to show that in the framework of Banerjee and Lin (2003), for any number of firms in the industry, an R&D agreement between two firms would lead to less R&D investment by the two cooperating firms and more investment by the outsiders than in the purely competitive case. In fact there needs to be a large enough initial asymmetry between the firms inside the agreement and the outsiders for our result to hold. In particular, this can be cost asymmetry or the fact that some firms have easier access to the input market.
Proof. See Appendix E.

It is a standard result that in the absence of spillovers, firms invest less in R&D when they cooperate than when they compete (D’Aspremont and Jacquemin, 1988). A crucial assumption for this result to hold is that the cost of R&D of one firm is independent of other firms’ R&D input purchase. Indeed, in that case firm $j$ cannot benefit from an increase of $k_i$: If firm $i$ buys more R&D input, final price remains unchanged but firm $j$’s output decreases because of its relative loss of efficiency.

4 Welfare analysis

We now illustrate our result with a numerical example. We show that in our framework, R&D cooperation decreases consumer surplus as well as total welfare.

We assume in the following that the inverse demand function on the downstream market is $p(Q) = 1 - Q$ where $Q = q_i + q_j + nq_f$. The cost function of a fringe firm is quadratic and given by $C(q_f) = q_f^2 / 2$, and consequently, we have $kC(q_f / k) = q_f^2 / (2k)$. Finally, we assume that the R&D input inverse supply function is $R(K) = K^2 / z$, where $z$ is a positive parameter.

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 residual demand for strategic firms is then $RD(p) = 1 - p - nq_f$ and the associated inverse demand function is $\tilde{p}(q_i + q_j) = (1 - (q_i + q_j)) / (n + 1)$. Firm $i$ ($i = 1, 2$) then sets output $q_i$ to maximize its profit $\pi_i = \tilde{p}(q_i + q_j)q_i - \gamma k_i C(q_i / k_i) - k_i R(K)$. The equilibrium outputs and final price are thus given by:

$$q^*_i = \frac{k_i (\gamma + k_i + \gamma n)}{3k_i k_j + 2\gamma (k_i + k_j)(1 + n) + \gamma^2 (1 + n)^2},$$

$$p^* = q^*_f = \frac{(\gamma + k_i + \gamma n)(\gamma + k_j + \gamma n)}{(1 + n) \left( 3k_i k_j + 2\gamma (k_i + k_j)(1 + n) + \gamma^2 (1 + n)^2 \right)}.$$

The equilibrium size of the fringe firm such that $p^2 / 2 = (k_i + k_j)^2 / z$. Because of computation issues, we only simulate the resulting R&D input purchases in the two relevant cases. We set $z = 2.10^8$ and determine the values of competitive R&D $k^*$ and cooperative R&D $kc^*$ for various values of $\gamma \in [0, 1]$. Figure 1 summarizes the effect of cooperation on R&D investment and final price.
Figure 1  R&D investment (left-hand) and final price (right-hand) with respect to strategic firms cost advantage $\gamma$, with competition (full line) and cooperation (dotted line)

We see on the left-hand side of Figure 1 that strategic firms always invest more in R&D in cooperation than in competition here and that the difference between $k^c$ and $k^*$ decreases with $\gamma$. When $\gamma$ 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 R&D input endowment. The over-buying strategy of cooperative strategic firms is thus stronger 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, as is predicted by Proposition 1: the cooperative final price is also higher than the competitive final price for all $\gamma \in [0,1)$.

Consumer surplus here is simply $SC = (1 - p)^2 / 2$, from which we deduce that consumer surplus is always lower when strategic firms cooperate in R&D than when they compete in R&D. Total welfare is $W = \pi^*_c + \pi^*_c + SC$. As Figure 2 shows, welfare is lower with R&D cooperation than competition for all values of $\gamma$.

Figure 2  Welfare with respect to strategic firms cost advantage $\gamma$, in the competitive equilibrium (full line) and in cooperation (dotted line)
The inverted U-shape of R&D purchase, and consequently of final prices, comes from two different effects. When $\gamma$ is close to 1, the cost advantage of a strategic firm over the fringe is very low. Then, an increase of i’s R&D purchase does not increase its cost advantage so much. This explains why as $\gamma$ decreases, strategic firms increase their R&D effort in competition as well as in cooperation. By contrast, when $\gamma$ is close to 0, the cost advantage of a strategic firm is already so high that strategic firms sell most of the output. Then, an increase of i’s R&D effort, while highly increasing its cost advantage, cannot lead to a very high output increase and hence does not benefit the strategic firm. This explains why R&D input purchase decreases as $\gamma$ tends to 0.

5 Conclusion

In this paper, we highlight an anti-competitive effect of R&D agreements that has 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 slots for the use of 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 size or cost asymmetries between firms on the market, as can be the case in industries such as software designing or pharmaceutical R&D, 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, and are thus in contradiction with Paragraph 3 of Article 101 of the TFEU. As such, they should not benefit from a block exemption.
6 Appendix

A Strategic substitutes

We show here that when the size of the fringe \( n \) is fixed, the output decisions of the strategic firms are strategic substitutes. Deriving equation (3) with respect to \( q_j \) yields:

\[
\frac{\partial q_j^{MR}}{\partial q_j} = -\frac{\left( p' + \left(1 + n \frac{\partial q_j}{\partial q_j}\right) p'' q_j \right) \left(1 + n \frac{\partial q_j}{\partial q_j}\right)}{\left(2p' + \left(1 + n \frac{\partial q_j}{\partial q_j}\right) p'' q_j \right) \left(1 + n \frac{\partial q_j}{\partial q_j}\right) - \frac{C''}{\bar{C}}}. 
\]

As \( 1 + n \frac{\partial q_j}{\partial q_j} \in [0,1] \), and since \( p' + Qp'' < 0 \), it is immediate that the numerator is negative. Besides, since \( p' < 0 \) and \( C'' > 0 \), the denominator is higher in absolute terms than the numerator. Therefore, \( \frac{\partial q_j^{MR}}{\partial q_j} \in [-1,0] \), for any \( i, j \in \{1,2\} \) and \( i \neq j \).

From this, we can deduce the variation of strategic firms’ output with respect to \( k_i \), noticing first that:

\[
\frac{\partial q_j^*}{\partial k_i} = \frac{\partial q_j^{MR}}{\partial q_j} + \frac{\partial q_j^{MR}}{\partial q_i} \frac{\partial q_i^*}{\partial q_i} = \frac{\partial q_j^{MR}}{\partial q_i} \frac{\partial q_i^*}{\partial q_i}, \tag{9}
\]

\[
\frac{\partial q_j^*}{\partial k_i} = \frac{\partial q_j^{MR}}{\partial k_i} + \frac{\partial q_j^{MR}}{\partial q_i} \frac{\partial q_i^*}{\partial q_i} \frac{\partial q_j^{MR}}{\partial q_i} = \frac{\partial q_j^{MR}}{\partial k_i} + \frac{\partial q_j^{MR}}{\partial q_i} \partial_{q_i^{MR}} \frac{\partial q_j^*}{\partial q_i} \frac{\partial q_i^*}{\partial q_i} \tag{10}
\]

for \( \frac{\partial q_j^{MR}}{\partial q_i} > 0 \) and \( \frac{\partial q_j^{MR}}{\partial q_i} \in [0,1] \). From (9) and (10), it is immediate that \( \frac{\partial q_j^*}{\partial k_i} < 0 \). Finally, we have:

\[
\frac{\partial q_j^*}{\partial k_i} + \frac{\partial q_j^*}{\partial k_i} = \frac{\partial q_j^{MR}}{\partial q_i} \left(1 + \frac{\partial q_j^{MR}}{\partial q_i}\right) > 0.
\]

B Comparative statics over \( n \)

We prove here that \( \frac{\partial q_i^*}{\partial n} < 0 \) for any \( i \in \{1,2\} \), and:

\[
\frac{\partial q_i^*}{\partial n} + \frac{\partial q_j^*}{\partial n} + q_f^* > 0, \tag{11}
\]
which implies that when the size of the fringe increases, total output also increases, while the output of strategic firms decreases.

We first show that total output increases with $n$. We consider two possible cases: either strategic firms’ output increases or decreases with $n$.

Assume first that $\frac{\partial C''}{\partial n} + \frac{\partial q^*}{\partial n} > 0$. Then it is immediate that (11) is satisfied. Assume now that on the contrary $\frac{\partial C''}{\partial n} + \frac{\partial q^*}{\partial n} < 0$. Then there exists $i$ such that $\frac{\partial q^*}{\partial n} < 0$. Consider the derivative of $\frac{\partial C}{\partial n}$ with respect to $n$:

$$\frac{\partial^2 \pi}{\partial q \partial n} = \left[ \frac{\partial q^*}{\partial n} + \frac{\partial q^*_i}{\partial n} + q^*_i \right] \left[ 1 + n \frac{\partial q_i}{\partial q_i} \right] \left( p' + \left( 1 + n \frac{\partial q_i}{\partial q_i} \right) p'' q_i^* \right) + n q_i^* p' \frac{\partial^2 q_i}{\partial q_i^2}$$

(12) since for any value of $n$, we always have that $\frac{\partial C''}{\partial q} \left( q_i^*, q_i^*, q_i^* \right) = 0$. Besides, we know that $C'' > 0$, $p' < 0$ and $\frac{\partial q_i}{\partial q_i} < 0$. As we also have $\frac{\partial q^*_i}{\partial n} < 0$, we can write that $\left( 1 + n \frac{\partial q_i}{\partial q_i} \right) \left( \frac{\partial q_i}{\partial n} + \frac{\partial q_i^*}{\partial n} \right) p' - \frac{\partial q_i}{\partial n} C'' \left( q_i^* \right) > 0$, and consequently, we have the following inequality:

$$\left\{ \frac{\partial q^*}{\partial n} + \frac{\partial q^*_i}{\partial n} + q^*_i \right\} \left[ 1 + n \frac{\partial q_i}{\partial q_i} \right] \left( p' + \left( 1 + n \frac{\partial q_i}{\partial q_i} \right) p'' q_i^* \right) + n q_i^* p' \frac{\partial^2 q_i}{\partial q_i^2} < 0.$$  

(13)

Therefore, if we find that the right term of this product is always negative, it immediately follows that $\frac{\partial q^*}{\partial q} + \frac{\partial q^*_i}{\partial q} + q^*_i > 0$. In order to show that this is true, we now differentiate $\frac{\partial C}{\partial q}$ with respect to $k_j$. Using the same reasoning, we find:

$$\frac{\partial^2 \pi}{\partial q_k \partial k_j} = \left( \frac{\partial q^*}{\partial k_j} + \frac{\partial q^*_i}{\partial k_j} \right) \left[ 1 + n \frac{\partial q_i}{\partial q_i} \right] \left( p' + \left( 1 + n \frac{\partial q_i}{\partial q_i} \right) p'' q_i^* \right) + n q_i^* p' \frac{\partial^2 q_i}{\partial q_i^2}$$

(14)

Since $p' < 0$, $C'' > 0$ and $\frac{\partial q^*_i}{\partial q} < 0$, we have the following inequality:

$$\left( \frac{\partial q^*}{\partial k_j} + \frac{\partial q^*_i}{\partial k_j} \right) \left[ 1 + n \frac{\partial q_i}{\partial q_i} \right] \left( p' + \left( 1 + n \frac{\partial q_i}{\partial q_i} \right) p'' q_i^* \right) + n q_i^* p' \frac{\partial^2 q_i}{\partial q_i^2} < 0.$$
Entry Deterrence Through Cooperative R&D Over-Investment

\[ (1 + n \frac{\partial q_i}{\partial q_n}) \left( p' + \left( 1 + n \frac{\partial q_i}{\partial q_n} \right) p'' q_i^* \right) + n q_i' p' \frac{\partial^2 q_i}{\partial q_n^2} < 0. \]  

(15)

From this and (13), we deduce that (11) is satisfied.

We now show by contradiction that we always have \( \frac{\partial q_i^*}{\partial n} \leq 0 \): the output of strategic firm \( i \) decreases with \( n \). Assume that there exists \( i \) such that \( \frac{\partial q_i^*}{\partial n} > 0 \). This implies that:

\[ \left( 1 + n \frac{\partial q_i}{\partial q_n} \right) \frac{\partial q_i}{\partial q_n} q_i^* + \frac{\partial q_i}{\partial n} \left( 1 + n \frac{\partial q_i}{\partial q_n} \right) p' - \frac{\gamma}{k_i} C'' \left( q_i^* \right) < 0. \]

It follows from (12) and (15) that \( \frac{\partial q_i}{\partial n} + \frac{\partial q_i}{\partial n} + q_i^* < 0 \), which as we have shown is not true. Finally, we always have \( \frac{\partial q_i^*}{\partial n} \leq 0 \), and therefore \( \frac{\partial q_i}{\partial n} + \frac{\partial q_i}{\partial n} + q_i^* \in [0, q_i^*] \).

C Proof of Proposition 2

We show here that the output of strategic firm \( j \) may increase with its strategic rival’s R&D investment. The variation of \( q_j^* \) with respect to \( k_i \) is

\[ p''(Q^*)C''(q_j^*)^2 - C''(q_j^*)p'(Q^*)^2 > \frac{p'(Q^*)}{n q_j^* + \frac{\partial q_j}{\partial q_n}} \left( \frac{B X^2 q_j^* q_i^* - R' X q_j^*}{R' A} - \frac{X (p'\gamma) + X p''(Q^*) q_i^*}{\frac{\partial q_j}{\partial q_n}} \right). \]

given by:

\[ \frac{\partial q_j^*}{\partial k_i} = \frac{\partial q_j^*}{\partial k_i} + \frac{\partial q_j^*}{\partial n} \frac{\partial n^*}{\partial k_i}. \]

In order to simplify expressions, we use the following notations:

\[ A = \frac{\partial q_j^*}{\partial n} + \frac{\partial q_j^*}{\partial n} + q_j^*, \quad B = \frac{\partial q_j^*}{\partial k_i} + \frac{\partial q_j^*}{\partial k_i}, \quad X = 1 + n \frac{\partial q_j}{\partial q_n}, \quad T = X (p' + X p'' q_i) + n q_i p' \frac{\partial q_j}{\partial q_n}. \]

Equations (7), (12) and (14) yield:

\[ \frac{\partial q_j^*}{\partial k_i} = -\frac{BT}{X p' - \frac{\gamma}{k_i} C'' \left( q_j^* \right)} - \frac{R' - B X q_j^* p' - A T + X \frac{\partial q_j}{\partial q_n} q_j^*}{A X q_j^* p'} \frac{X p' - \frac{\gamma}{k_i} C'' \left( q_j^* \right)}{X p' - \frac{\gamma}{k_i} C'' \left( q_j^* \right)}. \]

Since \( X p' - \frac{\gamma}{k_i} C'' \left( q_j^* \right) < 0 \), \( \frac{\partial q_j^*}{\partial k_i} \) is of the sign of

\[ -R' (A T + X \frac{\partial q_j}{\partial q_n} q_j^*) + B X^2 q_j p' \frac{\partial q_j}{\partial q_n}, \] and is thus positive as long as:

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\[ \frac{\partial^2 q_i}{\partial q_i^2} > \frac{1}{nq_i^* p'} \left( \frac{\partial q_i}{\partial q_i} \frac{BX^* q_i^* p' - R' Xq_i^*}{R'A} - X(p' + Xp'' q_i'^* ) \right). \]

Besides, from (2) we find that:
\[ \frac{\partial^2 q_i}{\partial q_i^2} = \left( \frac{\partial q_i}{\partial q_i} \right)^2 \frac{p''(Q)C''(q_i)^2 - C'''(q_i)p'(Q)^2}{p'(Q)^2}. \]

Therefore, the condition for \( \frac{\partial^i q_i}{\partial k_i} \) to be positive is:

The right-hand side of the latter inequality is negative. In particular, if \( p''(Q)C''(q_i)^2 - C'''(q_i)p'(Q)^2 > 0 \), then it is true \( \frac{\partial^i q_i}{\partial k_i} > 0 \).

**D Proof of Lemma 2**

Consider first the second stage of the game, which corresponds to Stage 3 in the main framework. Each firm \( i \) (\( i = 1, 2 \)) sets \( q \) to maximize its individual profit, and thus solves the problem: \[ \max_{q_i} \pi_i = p(q_i + q_j)q_i - k_i R(k_i + k_j), \]
and the first order conditions are thus given by:
\[ p + q_i p' = rC' \left( \frac{q_i}{k_i} \right). \] (16)

Following the same reasoning as in the previous section, we find \( \frac{\partial^i q_i}{\partial k_i} > 0 \), \( \frac{\partial^j q_j}{\partial k_i} < 0 \) and \( \frac{\partial^j q_j}{\partial k_i} + \frac{\partial^j q_j}{\partial k_j} > 0 \).

In the first stage of the game, the difference between cooperation and competition is given by:
\[ \frac{\partial \pi_i}{\partial k_i}(q_i^*, q_j^*) = p' q_j^* \frac{\partial q_j^*}{\partial k_i} + \frac{\partial q_j^*}{\partial k_i} \left( p + p' q_j^* - rC' \left( \frac{q_j^*}{k_j} \right) \right) - k_j R'. \]

We can simplify this expression using (16) and find that \( \frac{\partial \pi_i}{\partial k_i} = p' q_j^* \frac{\partial^j q_j}{\partial k_i} - k_j R' \). 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.

**E Proof of Lemma 3**

When the cost of a firm only depends on its own R&D investment, equation (5) becomes simply \( p^* q_j^* - C(q_j^*) = R \), and equation (6) becomes \( \left( \frac{\partial^i q_i}{\partial k_i} + \frac{\partial^j q_j}{\partial k_i} \right) q_j^* = 0 \), as neither the increase of \( k_i \) nor the entry of a new fringe firm raises the price of the R&D input. Given that \( q_j^* > 0 \), the effect of an increase of R&D input purchase on the size of the fringe is simply:
\[
\frac{\partial n^*}{\partial k_i} = -\frac{\partial p^*}{\partial k_i} = -\frac{\partial q_i^*}{\partial n} + \frac{\partial q_j^*}{\partial k_i} - q_j^{**}.
\] (17)

Obviously it is still negative as the short-term profit of fringe firms is still reduced following an increase of \( k_i \). However, since \( q_j^{**} > 0 \), it is straightforward that we now have \( \frac{\partial q_j^{**}}{\partial k_i} = 0 \).

Equation (8) becomes:
\[
\frac{\partial \pi_j}{\partial k_i} (BR(k_j),k_j) = \left[ p^{**} - rC\left(\frac{q_j^*}{k_j}\right)\right] \left(\frac{\partial q_j^*}{\partial k_i} + \frac{\partial q_j}{\partial n} \frac{\partial n^*}{\partial k_i}\right),
\]
for the increased R&D input purchase of \( k_i \) has no effect on fringe firms’ and \( j \)'s cost of buying R&D input anymore, and the final price is unchanged following an increase of \( k_i \). Then, using equation (17) and the inequality \( -\frac{\partial q_j^{**}}{\partial k_i} < \frac{\partial q_j^{**}}{\partial k_i} \), we find that \( \frac{\partial \pi_j}{\partial k_i} (BR(k_j),k_j) < 0 \) for all values of \( k_j \).

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