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Richard Ruble* and Bruno Versaevel†

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Current EU policy exempts horizontal R&D agreements from antitrust concerns when the combined market shares of participants are low enough. This paper argues that existing theory does not support limiting the exemption to low market shares. This is done by introducing a set of non-innovating outside firms to the standard framework to assess what link might exist between the market share of innovating firms and the product market benefits of cooperation. With R&D output choices, the market share criterion, while it rules out the most socially harmful R&D cooperation agreements, also hinders the most beneficial ones. With R&D input choices, cooperation may actually be desirable in concentrated industries, and harmful in more competitive ones. If R&D cooperation does have anti-competitive effects in product markets, it seems that these are therefore best addressed by other tools than market share criteria.

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1 Introduction

European competition law regulates so-called "horizontal" research and development (R&D) agreements, whereby firms coordinate their R&D operations and jointly exploit the results, while still competing in the marketplace. These agreements have pro-competitive virtues, in that they permit participating firms to avoid the duplication of budgets, or to combine complementary resources, toward innovative products and lower production costs. On the other hand, antitrust authorities are concerned that horizontal R&D agreements may also facilitate anti-competitive behavior at the market level, including the concerted formation of prices. The current regime for the assessment of R&D cooperation agreements will expire on 31st December 2010. In order to prepare the new regime to be applied after that date, the European Commission has recently invited stakeholders to present their views on their experiences in applying the existing rules. In the spirit of this consultation, in this paper we offer an economic assessment of a key feature of the regulation, which is the use of a market share criterion to discriminate firms that will be exempted or not from the burden of assessing the compatibility of their contractual relationships with the legislation.

In order to let consumers benefit from the pro-competitive effects of horizontal R&D cooperation, under the constraint that anti-competitive ones are filtered out, the European Commission adopted the Regulation (EC) No 2659/2000.[1] It sets limits to the application of Article 81(1) of the Treaty on European Union that prohibits in principle all agreements "which have as their object or effect the prevention, restriction or distortion of competition within the common market." Regulation 2659 offers a block exemption for R&D agreements. It then establishes that "Article 81(1) *shall not apply* to agreements entered into between two or more undertakings (...) which relate to the conditions under which those undertakings pursue: (a) joint research and development of products or processes and joint exploitation of the results of that research and development; (b) joint exploitation of the results of research and development of products or processes jointly carried out pursuant to a prior agreement between the same parties; or (c) joint research and development of products or processes excluding joint exploitation of the results" (art. 1, added emphasis).

However, an important proviso of the regulation is that the block exemption applies "*only if,* at the time the research and development agreement is entered into, the combined market share of the participating undertakings does not exceed 25 % of the relevant market for the

[1] Commission Regulation (EC) No 2659/2000 of 29 November 2000 on the application of Article 81(3) of the Treaty to categories of research and development agreements.

products capable of being improved or replaced by the contract products" (Article 4(2), added emphasis). It follows that only firms with little market power, typically small and medium-sized businesses, benefit from a guarantee of legal validity. Larger companies must submit to self-assessment the R&D cooperation they envisage, in order to evaluate compliance with antitrust rules and decide to go ahead with the agreement.

The obligation for large firms to conduct their own assessment of the legality of R&D cooperation agreements, in the light of the legislation in force, Commission guidelines, and case-law, is a costly and uncertain process.[2] Since it is not possible to seek legal protection by notifying in advance the terms of the agreement to the competition authority, an existing or candidate agreement must be proved not to infringe Article 81(1) in order to be valid and enforceable. This occurs when the agreement can be shown to fulfil the conditions of Article 81(3). These conditions are that (i) it contributes to improving the production or distribution of products or to promoting technical or economic progress; (ii) it allows consumers a fair share of the resulting benefit; and it does not (iii) impose restrictions which are not indispensable to the attainment of the above listed objectives; nor does it (iv) afford the possibility of eliminating competition in respect of a substantial part of the products in question. The parties to a horizontal R&D agreement, with a combined market share above the 25% threshold, bear the burden of proving that all four conditions are satisfied in order to claim the benefit of Article 81(3).[3] This is detailed in the accompanying guidelines, issued by the Commission in 2001, on the applicability of Article 81 of the EC Treaty to horizontal cooperation agreements.[4]

The guidelines indicate clearly what is meant by economic progress: cooperation may enable firms to offer existing products "at lower prices" or result in a "better quality" (§32). As for the fair share to consumers, they assert: "[g]enerally, the transmission of the benefits to the consumers will depend on the intensity of competition within the relevant market. Competitive pressures will normally ensure that cost-savings are passed on by way of lower prices or that companies have an incentive to bring new products to the market as quickly as possible. Therefore, *if sufficient competition which effectively constrains the parties to the agreement is maintained* on the market, the competitive process will normally ensure that

[2]For a detailed discussion on the legal uncertainty and the costs for the undertakings entailed by the current EC antitrust enforcement rules, see Di Federico and Manzini (2004).

[3]See Müller (2004) for a detailed analysis of the applicability of Article 81(3) under the current antitrust regime, and of the individual responsability of the parties to a horizontal agreement in assessing the compliance of their practices with competition law.

[4]See European Commission (2001).

the consumers receive a fair share of the economic benefits" (§34, added emphasis). This describes a deep underlying motivation of the regulator for excluding large firms from the block exemption. In more economic terms, R&D agreements are beneficial because of the impact on consumer surplus. And according to the guidelines this impact is much more likely to occur with a high degree of competition.

The market share criterion used by the regulator affects the decision process of large firms that may either rely exclusively on their proprietary R&D assets or opt for cooperation. It is not easy for firms to show that they satisfy the conditions of Article 81(3). For example, General Electric and Pratt & Whitney, which formed an alliance to develop an innovative aircraft engine, had to go through a number of important obligations to respond to the observations of the Commission, although the new product was designed to meet an uncertain demand on a market that did not exist yet.[5] The regulatory pressure can also lead firms to give up initial plans. Microsoft and Time Warner abandoned their project to jointly control ContentGuard, a US entity specializing in the development and licensing of intellectual property rights, after the Commission opened an in-depth investigation and expressed concerns about anti-competitive aspects of the operation.[6]

In addition to self-assessment costs, before engaging unrecoverable resources the firms excluded from the block exemption must weigh the risk of seeing the legality of an agreement challenged by a client or a non-participating competitor. Should an infringement of Article 81(1) be detected, the competition authorities of the Member States and the Commission may impose non-negligible fines or periodic penalty payments. The pecuniary sanctions can attain up to 10 per cent of a firm's total turnover in the preceding business year, and daily penalties up to 5 per cent of the average daily turnover to secure compliance with a cease-and-desist order.[7] This forms negative incentives, as faced by firms with high market shares, to participate in a horizontal R&D cooperation agreement under the current antitrust rules.[8]

[5]The obligations included a limitation of the design of the engine for only precisely identified aircrafts, the yearly submission of accounting and auditing records to the Commission, and other safeguards to prevent the exchange of competitively sensitive information among the parties. See the Official Journal, 2000 L58/16, and Van Bael & Bellis (2005) for comments.

[6]See the initiation of proceedings, in Case COMP/M.3445 Microsoft/Time Warner/ContentGuard/JV, Official Journal, 2004 C245/5.

[7]See articles 23 and 24 in the Council Regulation (EC) No 1/2003 of 16 December 2002 on the implementation of the rules on competition laid down in Articles 81 and 82 of the Treaty.

[8]Law experts also point to the costs of the regulation for firms that are excluded from the block exemption. For example, Anderman (2002) observes that EC competition law "acts as a detailed regulator of R&D agreements with a aim of discouraging cooperation that is a tool to engage in disguised cartel or to foreclose markets

The main issue of this paper is whether the market share criterion successfully facilitates the R&D agreements that are most beneficial to consumers. In particular, we ask whether this criterion is consistent with the most standard theory of R&D cooperation (d'Aspremont and Jacquemin (1988), Kamien, Muller, and Zang (1992), Amir, Evstigneev, and Wooders (2003), among others).[9] Ex-ante symmetric firms, in a Cournot oligopoly, compete on a market for homogeneous products. A subset of these firms may engage in R&D activity to enhance the quality of their products or reduce the marginal costs of production (satisfying the condition of "economic progress"). These firms may choose R&D decisions either cooperatively or non-cooperatively, before selling to consumers (whose surplus is shown to increase with R&D levels, hence they receive a "share of the resulting benefit").[10]

Our finding is that existing theory does not support limiting the exemption to low market shares. We derive a necessary and sufficient condition for cooperation to result in more R&D than competition, consequently in more consumer surplus, and apply it to several specifications of the R&D stage of the model. In the simplest setup that theory provides, where firms' decisions are R&D results (or "outputs"), we obtain that the regulation actually hinders the best agreements, where R&D cooperation is most beneficial to consumers, by only exempting from regulatory control those collaborations whose impact on consumer surplus is relatively negligible. Then, turning to cases where firms choose the level of R&D expenditure (or "inputs"), we see that the relationship between market share and the relative benefit of R&D cooperation can in fact be the opposite of what Regulation 2659 presumes. R&D cooperation can actually penalize consumers when the market share of the cooperating firms is lower than the regulatory threshold. Beyond the threshold, the higher the ex-ante market share of the cooperating firms, the greater the benefit of the agreement for consumers. In that case the regulation penalizes cooperation precisely when economic analysis indicates such agreements would benefit consumers.

The remainder of the paper is as follows. Section 2 presents the model and offers the necessary and sufficient condition for consumer surplus to be higher under R&D cooperation than competition. Section 3 applies the condition to standard specifications to reveal non-univocal connections between consumer surplus and innovating firms' ex-ante market share.

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but ending up possibly *discouraging investments in such joint ventures* that might have been encouraged by a more user-friendly legal framework" (p. 305, added emphasis).

[9]Thus, we model firms that do not collude tacitly. For an analysis of the connection between R&D cooperation and collusion, see Martin (1996).

[10]As there is no collusion, and we focus on equilibria in which non-innovating firms participate by selling positive outputs, conditions (iii) and (iv) of Article 81(3), as listed above, are satisfied.

2 R&D and Market Shares

The industry consists of n firms indexed on $N = \{1, \dots, n\}$, $n \geq 2$. Firms face inverse demands, $p_i = \alpha_i - q_i - \sum_{j \neq i} q_j$, $i, j \in N$, where the parameter α_i measures the vertical quality of firm i's product, and there is a constant marginal cost c_i.[11] Initially, both α_i and c_i are the same across firms. The variable profit of a given firm i is thus $\widehat{\pi}^i(\mathbf{q}) = \left(a_i - q_i - \sum_{j \neq i} q_j\right) q_i$, with $\mathbf{q} = (q_1, \dots, q_n)$ and $a_i = \alpha_i - c_i$. A subset $M = \{1, \dots, m\}$ of firms engages in research and development activity ex-ante, by each choosing a decision variable $z_i \in \mathbb{R}_+$. Below, we successively consider the cases where z_i is an R&D output and where it is an R&D input. The choice $\mathbf{z} = (z_1, \dots, z_m)$ acts on the parameters a_i, hereafter $a_i(\mathbf{z})$. It can be interpreted as either a quality improvement or a cost reduction. There are non-negative technological spillovers, not only between the m firms that conduct R&D, but also from the firms that conduct R&D to those that do not, although these are lesser.[12] R&D effects are symmetric within the two groups of firms M and $N \setminus M$. Finally, the R&D decision z_i has a cost, symmetric across the m innovating firms, $g(z_i)$. The full profit functions are therefore $\pi^i(\mathbf{q}, \mathbf{z}) = \left(a_i(\mathbf{z}) - q_i - \sum_{j \neq i} q_j\right) q_i - g(z_i)$, $i \in M$, and $\pi^k(\mathbf{q}, \mathbf{z}) = \left(a_k(\mathbf{z}) - q_k - \sum_{j \neq k} q_j\right) q_k$, $k \in N \setminus M$.

Two games are compared. In the first game, *R&D competition*, firms play a two-stage non-cooperative game. The timing of the non-cooperative game is as follows. In the first stage, the m innovating firms simultaneously decide their levels of z_i. In the second stage, given the variable profit intercepts $a_i(\mathbf{z})$, all n firms engage in quantity competition. The equilibrium of the quantity competition stage is denoted by $\mathbf{q}^*(\mathbf{z})$, and assumed to be differentiable in $\mathbf{z}$. Assume that sufficient conditions in the style of Amir et al. (2003) hold, so that this first game has a unique symmetric equilibrium in R&D decisions that we denote by $\mathbf{z}^{\mathrm{n}}$. In the second game, *R&D cooperation*, the R&D decision is made collectively by all innovating firms. The timing of the cooperative game is as follows. As a first stage, these m firms

[11] This inverse demand function can be derived as a limit case, as $\gamma \to 1$, of a utility function described in Häckner (2000), that is: $U(q, I) = I + \sum_{i \in N} \alpha_i q_i - \frac{1}{2}\left(\sum_{i \in N} q_i^2 + 2\gamma \sum_{i \neq j} q_i q_j\right)$, which is quadratic in the consumption of q-products and linear in the consumption of the composite I-good (i.e., the numeraire). The parameter $\gamma \in (0, 1)$ measures product horizontal substitutability.

[12] At least a part of the spillovers received by firms, including non-innovating entities, are involuntary leakages. In a seminal empirical paper, Mansfield (1985) has found that information concerning the detailed nature and operation of a new product or process generally leaks out to competitors within about a year. However, when firms engage in R&D, Cohen and Levinthal (1989) have shown that they increase the effectiveness of incoming spillovers. This is captured here by the inequality $\beta \geq \beta_0$. See Cassiman and Veugelers (2002) for the empirical evidence.

choose $\mathbf{z}$ to maximize the sum of their profits. In a second stage, non-cooperative quantity competition ensues. Finally, assume that the joint profits $\Pi(\mathbf{z}) = \sum_{i\in M} \pi^i(\mathbf{q}^*(\mathbf{z}), \mathbf{z})$ are a twice differentiable, strictly quasiconcave function of $\mathbf{z}$ with a unique symmetric optimum that we denote by $\mathbf{z}^{\mathrm{c}}$.[13]

We may now characterize the difference between $\mathbf{z}^{\mathrm{c}}$ and $\mathbf{z}^{\mathrm{n}}$. The following proposition gives a necessary and sufficient condition for cooperation to result in more R&D than competition, therefore in more consumer surplus, which is presumably the objective of the regulator.[14]

Proposition 1. *Consumer surplus is higher under R&D cooperation than under competition if and only if*

$$(1-s)\left(\frac{\partial a_i}{\partial z_j}(\mathbf{z}^{\mathrm{n}}) - \frac{\partial a_k}{\partial z_j}(\mathbf{z}^{\mathrm{n}})\right) + \frac{1}{n}\left(2\frac{\partial a_i}{\partial z_j}(\mathbf{z}^{\mathrm{n}}) - \frac{\partial a_j}{\partial z_j}(\mathbf{z}^{\mathrm{n}})\right) > 0, \tag{1}$$

with $i \neq j$, $i, j \in M$, $k \in N \setminus M$, *and* $s = \frac{m}{n}$.

Proof. See the appendix. ■

In the specifications that follow we shall see that $\mathbf{z}^{\mathrm{n}}$ in fact often drops out. There are two terms in (1). The second term depends on the difference $2\frac{\partial a_i(\mathbf{z})}{\partial z_j} - \frac{\partial a_j(\mathbf{z})}{\partial z_j}$, which is standard in the literature, where most papers feature a model with $m = n$. It becomes less and less important as the total number of firms n rises. The first term appears whenever $N \backslash M$ is non-empty, as in many real-world situations. This suggests that the influence of firm numbers, and thereby market share $s = \frac{m}{n}$, rests largely on the sign of the difference $\frac{\partial a_i(\mathbf{z})}{\partial z_j} - \frac{\partial a_k(\mathbf{z})}{\partial z_j}$. One might think that R&D decisions have more impact on innovators in M than on other firms, so that the latter difference is positive. This holds in particular when the impact of firms' decisions on product quality or the marginal cost is linear, as commonly assumed in many models. However, as the latter part of analysis with R&D inputs will show, this is not always true.

The logic of the proposition is actually more general. In fact, as detailed in the proof, the comparison of z^{c} and z^{n} depends on the sign of a derivative, which can be broken down into

[13] For sufficient conditions toward a symmetric optimum in R&D decisions, see Leahy and Neary (2005).

[14] In the prolegomena of Regulation (EC) No 2659/2000, enhanced consumer satisfaction is clearly established as the motivation for exempting cooperation agreements that result in more R&D: "*Consumers* can generally be expected to benefit from the increased volume and effectiveness of research and development through the introduction of new or improved products or services or the reduction of prices brought about by new or improved processes" (para. 12, added emphasis).

a direct and indirect effect, that is $\frac{\partial \pi^i}{\partial z_j} + \sum_{l \neq i} \frac{\partial \pi^i}{\partial q_l^*} \frac{\partial q_l^*}{\partial z_j}$, with $i \neq j$, $i, j \in M$. The sign of the first term, a direct effect, is always positive. On the other hand the sign of the second term, an indirect effect, is indeterminate without more information on the impact of R&D on cost and demand parameters. An economic rationale for current exemption policy would be an assertion regarding the sensitivity of the sign of the derivative to the ex-ante market share of the innovating firms, that is s. We do not see on what grounds such an assertion would be made, in particular with regards to the indirect effect term, which is not clearly related to market share.

Before focusing on more specified versions of the model, as encountered in the literature, note that the decomposition into direct and indirect effects is fairly general as it relates to many second stage product market interactions. In the case of homogeneous goods and cost-reducing R&D, the second (indirect) effect would be $q_i^* D'(Q^*) \frac{\partial Q_{-i}^*}{\partial z_j}$, where $Q_{-i}^* = \sum_{k \in N \setminus \{i\}} q_k^*$, for an arbitrary inverse demand function $D(Q)$. Moreover, a similar condition arises with price instead of quantity competition in the second stage.

3 R&D Cooperation Impact is Independent of Market Shares

In this section we concentrate on standard specifications. This authorizes tractable computations that reveal counter-intuitive connections, in Regulation 2659, between consumer surplus and innovating firms' ex-ante market share. Two specifications of the R&D process are considered successively in the rest of this section. The first is output choice, in the style of d'Aspremont and Jacquemin (1988). The other one is input choice, as in Kamien et al. (1992), and Amir et al. (2003).

3.1 Cooperation in output choices

Following d'Aspremont and Jacquemin (1988), let x_i denote firm i's R&D output decision.[15] The cost function is $\frac{\gamma}{2} x_i^2$ for the purpose of obtaining the example in Figure 1, although the nature of results (condition (3)) is unaffected if a more general cost function, as suggested in Amir et al. (2008), is adopted. The $a_i(\mathbf{x})$ functions are specified as

$$a_i(\mathbf{x}) = a + x_i + \beta \sum_{j \neq i} x_j,\ i \in M \text{ and } a_k(\mathbf{x}) = a + \beta_0 \sum_M x_j,\ k \in N \setminus M, \tag{2}$$

[15] Recalling that $a_i = \alpha_i - c_i$, in order to circumvent the issue of non-negative marginal cost, assume here that R&D is of the product kind (it impacts α_i).

where $\beta_0 \in [0,1]$ is a technological "natural" spillover rate in the industry (see Amir et al. (2003)), and $\beta \in [\beta_0, 1]$ is the spillover rate between innovating firms. With this specification, a unique symmetric Nash equilibrium exists, and a unique cooperation outcome can be computed, for γ sufficiently high.[16] Then (1) becomes,

$$(1-s)(\beta-\beta_0) + \frac{2\beta-1}{n} > 0. \tag{3}$$

For sufficiently high spillovers ($\beta > \frac{1}{2}$), R&D cooperation always dominates R&D competition. For a given industry size n, (3) is less likely to hold as the market share s of R&D collaborating firms increases. This would seem to provide support for Regulation 2659. However, fixing m and letting industry size vary illustrates how the relationship between market share and the relative consumer surplus $\frac{CS^{\mathrm{c}}}{CS^{\mathrm{n}}}$ is not monotonic.

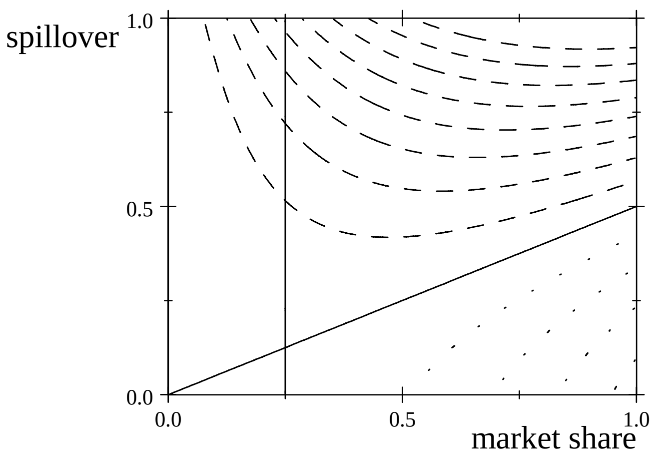

Figure 1: Level curves of $\frac{CS^{\mathrm{c}}}{CS^{\mathrm{n}}}$ at 1% intervals. (i) For $\beta = 1$, an increase in s results in relative gains to cooperation for consumers; (ii) For β in the neiborhood of 1/2, the relationship between s and the relative consumer surplus is non monotonic; (iii) If innovating firms may not collaborate for $s > 0.25$, the most desirable level curves are ruled out.

Figure 1 plots the level curves of the relative consumer surplus with R&D cooperation, $\frac{CS^{\mathrm{c}}}{CS^{\mathrm{n}}}$ (for $\beta_0 = 0$, $m = 2$ and $\gamma = 10$). The solid line represents values for which $\frac{CS^{\mathrm{c}}}{CS^{\mathrm{n}}} = 1$.

[16] Taking $m = 2$ and $\beta_0 = 0$, as in Figure 1, the symmetric equilibrium values are $x^{\mathrm{n}} = \frac{2(n-\beta)a}{\gamma(n+1)^2 - 2(n-\beta)(n-1)(\beta+1)}$ and $x^{\mathrm{c}} = \frac{2(n-1)(\beta+1)a}{\gamma(n+1)^2 - 2(n-1)^2(\beta+1)^2}$, in the non-cooperative and cooperative cases, respectively, with $n \geq 2$, $\beta \in [0,1]$, $a > 0$ and $\gamma > 2$.

Its slope is positive throughout, indicating that, for $\beta < \frac{1}{2}$, the lower the market share, the more likely it is that R&D cooperation dominates. The dashed (dotted) curves indicate values for which $\frac{CS^{\mathrm{c}}}{CS^{\mathrm{n}}} = 1 + 0.01k$ $(-0.01k)$, $k \in \mathbb{N}$. We can make three remarks that cast doubt on Regulation 2659. Consider first the case $\beta = 1$ for clarity. Then an increase in s results in relative gains to cooperation for consumers.[17] Next, consider the spillover rate β in the neighborhood of $\frac{1}{2}$. Then the relationship between s and the relative consumer surplus is non monotonic. Finally, consider the vertical line at $s = 0.25$, which represents the threshold beyond which innovating firms may not benefit from the exemption of Regulation 2659. Clearly the most desirable level curves, in the North-East of the figure, are ruled out. In order to avoid the worst outcomes, the regulation actually impedes the best, only allowing those whose impact on consumer welfare is relatively negligible.

3.2 Cooperation in input choices

Consider next R&D competition in input choice (that is, where R&D expenditure is the strategic variable), in the style of Kamien et al. (1992). Input and output choices are compared in Amir (2000) and Amir et al. (2008), the former being found to satisfy a general criterion regarding R&D technology and the spillover process. Let y_i denote firm i's R&D input decision. The R&D cost function is then simply y_i. Here the $a_i(\mathbf{y})$ functions are specified as

$$a_i(\mathbf{y}) = f\left(y_i + \beta \sum_{j \neq i} y_j\right), \; i \in M \text{ and } a_k(\mathbf{y}) = f\left(\beta_0 \sum_{M} y_j\right), \; k \in N \setminus M, \tag{4}$$

where $\beta_0 \in [0,1]$ is a natural spillover rate and $\beta \in [\beta_0, 1]$ is now the rate at which R&D spending spills over between innovating firms. The R&D production function f is generally assumed to satisfy a number of Inada-like conditions Amir et al. (2003), Kamien et al. (1992). In particular, f is assumed to be twice differentiable, increasing, concave, and bounded. Let $Y_j^{\mathrm{n}} = (1 + \beta(m-1))\, y^{\mathrm{n}}$ denote the equilibrium effective R&D spending for innovating firms in the non-cooperative game, and $Y_k^{\mathrm{n}} = \beta_0 m y^{\mathrm{n}}$ denote the equilibrium effective R&D spending for non-innovating firms. Then, with this specification, (1) becomes

$$(1-s)\left[\beta f'\left(Y_j^{\mathrm{n}}\right) - \beta_0 f'\left(Y_k^{\mathrm{n}}\right)\right] + \frac{2\beta - 1}{n} f'\left(Y_j^{\mathrm{n}}\right) > 0. \tag{5}$$

[17] Recent theoretical analyses of R&D joint-ventures in which firms may control information flows predict a high endogenous level of spillovers (see for example Amir et al. (2003)). This is also well empirically documented in the European economy (see in particular Belderbos et al. (2004)).

This condition is more elaborate than its analog (3) above, and reveals a key difference between the two frameworks. An increase in market share s had an unambiguous effect on the left-hand term of the inequality (3). In the case of R&D input choice as generally modeled, this is no longer true. Higher industry size (or lower market share for the innovating firms) can lead to *reversal*, whereby cooperation is desirable at high market share but harmful at low market share. This consideration goes squarely against the apparent rationale of Regulation 2659. It is related to the nature of competition in R&D, via the term $\beta f'\left(Y_j^{\mathrm{n}}\right) - \beta_0 f'\left(Y_k^{\mathrm{n}}\right)$. Because of differing spillovers the effective R&D spending is lower for non-innovating firms ($\beta_0 m < (1 + \beta(m-1))$), and since R&D production is a concave function, the marginal productivity of R&D spending at y^{n} can be higher for non-innovating firms. This can result in a negative coefficient for $1 - s$, hence in a reversed sensitivity of (1) to market share. Note that, without introducing more specification, in principle this effect can arise for β_0 arbitrarily small so long as it is non zero.

The next example illustrates reversal for a common specification of the R&D production function (see Amir (2000), Amir et al. (2003) and Amir et al. (2008)).

Example: R&D production *à la* **Amir** The following specification for an R&D production process, suggested by Amir (2000), fits much of the spirit of the assumptions of Kamien et al. (1992), although the shift of the variable profit intercept is not a bounded function of $\mathbf{y}$:

$$a_i = a + \sqrt{\frac{2}{\gamma}\left(y_i + \beta \sum_{j \neq i} y_j\right)},\ i \in M \text{ and } a_k = a + \sqrt{\frac{2}{\gamma}\beta_0 \sum_M y_j},\ k \in N \setminus M. \qquad (6)$$

There is a unique symmetric Nash equilibrium, and a unique cooperative octane, for β_0 and β close to 1.[18] Here, condition (5) reduces to

$$(n-m)\left[\beta - \beta_0\sqrt{\frac{1+(m-1)\beta}{m\beta_0}}\right] + 2\beta - 1 > 0. \qquad (7)$$

[18]Note that innovating firms' profit is a piecewise-defined function. Because of the asymmetry between innovating and non-innovating firms, the profit functions of the former may be non-differentiable when the non-negativity constraint binds the latter in the quantity stage. Taking $m = 2$ and $\beta_0 = \beta$, as in Figure 2, the symmetric equilibrium values are $y^{\mathrm{n}} = \left(\frac{a\Gamma_1}{1-\Gamma_1\Gamma_2}\right)^2$ and $y^{\mathrm{c}} = \left(\frac{a\Gamma_3}{1-\Gamma_2\Gamma_3}\right)^2$ in the non-cooperative and cooperative cases, respectively, with the algebraic expressions $\Gamma_1 = (n+1)^{-2}\left(\frac{n-\beta}{\sqrt{1+\beta}} - (n-2)\sqrt{\frac{\beta}{2}}\right)\sqrt{\frac{2}{\gamma}}$, $\Gamma_2 = (n-1)\sqrt{\frac{2}{\gamma}(1+\beta)} - 2(n-2)\sqrt{\frac{\beta}{\gamma}}$, and $\Gamma_3 = (n+1)^{-2}\left((n-1)\sqrt{\beta+1} - (n-2)\sqrt{\beta}\sqrt{2}\right)\sqrt{\frac{2}{\gamma}}$. For y^{n} and y^{c} to be well defined, it must be the case that $\Gamma_1\Gamma_2 < 1$ and $\Gamma_2\Gamma_3 < 1$, respectively.

Here the coefficient of n can be negative, so that reversal arises. This occurs if $\beta_0 \in \left(\frac{m\beta^2}{1+(m-1)\beta}, \beta\right]$, with $\beta < 1$. Figure 2 illustrates such a reversal. R&D cooperation penalizes consumers when the market share of the cooperating firms is lower than the regulatory threshold ($s < 0.25$). Beyond the threshold, the higher the ex-ante market share of the innovative firms, the greater the benefit of R&D cooperation for consumers. Regulation 2659 hinders cooperation precisely when economic analysis indicates such agreements would benefit consumers.

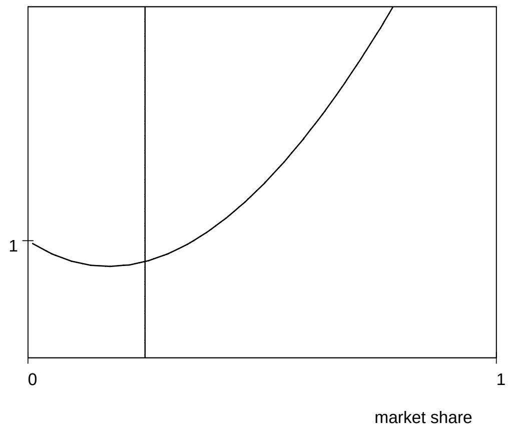

Figure 2: $\frac{CS^{\text{c}}}{CS^{\text{n}}}$ for s in $(0, 1]$, with $\gamma = 4$, $\beta = \beta_0 = 0.65$, $m = 2$. R&D cooperation is never beneficial to consumers when $s < 0.25$. It is beneficial to consumers only beyond the threshold.

4 Conclusion

Regulation (EC) No 2659/2000, and accompanying guidelines, reflect the laudable objective to make consumers benefit from the virtues of R&D cooperation, while filtering out arrangements that may result in anti-competitive behavior. By introducing a market share criterion, so that only firms with limited sales may collaborate in R&D within "safe harbours", the regulation hinders the technological collaboration of larger suppliers. When firms have a high combined market share, horizontal R&D agreements take place in a more uncertain legal environment. The parties bear the burden of self-assessing the compatibility of their contractual relationships vis-à-vis the legislation, and face the risk of incurring severe pecuniary sanctions in case of infringement.

In order to test the regulation from a theoretical economic viewpoint, we have established by means of a standard model that the connection between market shares and the benefit of R&D cooperation to consumers, is not univocal. It can actually be the opposite of what the regulation presumes. A low combined market share, for the cooperating firms, is no guarantee of better products or lower costs, hence of more consumer surplus. R&D cooperation can penalize consumers, in comparison to R&D competition, when the market share of the cooperating firms is lower than the regulatory threshold. Moreover, more competition in an industry can even lead to lower benefits of R&D cooperation to consumers.

The current regime for the assessment of horizontal R&D agreements aims to make consumers benefit from the virtues of inter-firm cooperation, by guaranteeing that "sufficient competition which effectively constrains the parties to the agreement is maintained" (European Commission (2001) guidelines, §32), and under the constraint not to facilitate anti-competitive behavior at the market stage. Our message is that the regulation by focusing too closely on the competition dimension, via market shares, loses sight of the raison d'être of the R&D block exemption. When it discourages the formation of the most efficient agreements, it institutionalizes an adverse selection mechanism.

In terms of policy implications, our analysis calls for both simplification and specialization. The simplification of the R&D block exemption by withdrawing the market share criterion would eliminate the disincentives to R&D cooperation faced by large firms. In that case the regulation would specialize on the objective that motivates its revision, leaving aside the detection and prosecution of welfare-reducing behavior to other dedicated competition rules.

5 Appendix

5.1 Equilibrium of the Cournot subgame and consumer surplus

Given $\mathbf{z}$, each firm chooses output to maximize its gross profits. Assuming an interior equilibrium, this yields a set of n symmetric first-order conditions, which we use to solve for each firm's subgame Cournot-Nash equilibrium output, that is

$$q_i^* (\mathbf{z}) = a_i (\mathbf{z}) - \frac{\sum_N a_j (\mathbf{z})}{n+1}, \tag{8}$$

all $i \in N$. The total equilibrium quantity is

$$Q^*(\mathbf{z}) = \frac{\sum_N a_j(\mathbf{z})}{n+1}, \tag{9}$$

and the resulting consumer surplus is

$$CS(\mathbf{z}) = \frac{1}{2}\left(\frac{\sum_N a_j(\mathbf{z})}{n+1}\right)^2. \tag{10}$$

5.2 Proof of Proposition 1

The consumer surplus, as in (10), is an increasing function of z_i, all $i \in M$. For a comparison of the consumer surplus in equilibrium across the R&D competition and cooperation games, compute the total derivative of $\Pi : R_+^m \to R$, that is

$$\mathrm{d}\Pi(\mathbf{z}) = \sum_{i \in M} \frac{\partial \pi^i}{\partial z_i} \mathrm{d}z_i + \sum_{i \in M} \sum_{j \in M, j \neq i} \frac{\partial \pi^i}{\partial z_j} \mathrm{d}z_j. \tag{11}$$

Next, evaluate at $\mathbf{z} = \mathbf{z}^{\mathrm{n}}$ the two partial derivatives that appear in the expression above, for $\pi^i = \pi^i(\mathbf{q}^*(\mathbf{z}), \mathbf{z})$, to get

$$\left.\frac{\partial \pi^i}{\partial z_i}\right|_{\mathbf{z}=\mathbf{z}^{\mathrm{n}}} = 0 \text{ and } \left.\frac{\partial \pi^i}{\partial z_j}\right|_{\mathbf{z}=\mathbf{z}^{\mathrm{n}}} = q_i^* \left(\frac{\partial a_i}{\partial z_j} - \sum_{k \in N \setminus \{i\}} \frac{\partial q_k^*}{\partial z_j}\right), \tag{12}$$

all $i, j \in M$, $i \neq j$. The zero value of $\frac{\partial \pi^i}{\partial z_i}$ results directly from the first-order condition for a NE in R&D decisions. The value of $\frac{\partial \pi^i}{\partial z_j}$ is obtained by recalling that $\frac{\partial \pi^i}{\partial q_i^*}\frac{\partial q_i^*}{\partial z_j} = 0$ from the first-order condition for a NE in quantities, and also by observing that $\frac{\partial \pi^i}{\partial a_i}\frac{\partial a_i}{\partial z_j} = q_i^* \frac{\partial a_i}{\partial z_j}$ and $\frac{\partial \pi^i}{\partial q_j^*}\frac{\partial q_j^*}{\partial z_j} = -q_i^* \frac{\partial q_j^*}{\partial z_j}$ from the specification of demand functions. Next, recall that firms are ex-ante symmetric to focus on the R&D vectors $\mathbf{z}$ verifying $z_1 = \ldots = z_m = z$, so that joint profits on M can be expressed as a function $\Pi : R_+ \to R$, which is strictly quasi-concave in z. In that case the maximizer z^{c} is strictly greater than z^{n} if and only if $\left.\frac{\mathrm{d}\Pi(z)}{\mathrm{d}z}\right|_{z=z^{\mathrm{n}}} > 0$. From (11) and (12) the latter condition can now be rewritten as

$$\left.\frac{\partial a_i}{\partial z_j} - \sum_{k \in N \setminus \{i\}} \frac{\partial q_k^*}{\partial z_j}\right|_{z_j = z^{\mathrm{n}}} > 0, \tag{13}$$

all $i, j \in M$, $i \neq j$, and all $q_i^* > 0$. Concentrate on the second term in (13). We have $\sum_{k \in N \setminus \{i\}} \frac{\partial q_k^*}{\partial z_j} = \frac{\partial Q^*}{\partial z_j} - \frac{\partial q_i^*}{\partial z_j}$, with $\frac{\partial q_i^*}{\partial z_j} = \frac{\partial a_i}{\partial z_j} - \frac{\partial Q^*}{\partial z_j}$ from (8-9). Then observe, again from (9), that

$\frac{\partial Q^*}{\partial z_j} = \frac{1}{n+1}\sum_N \frac{\partial a_l}{\partial z_j}$, and that $\frac{\partial a_l(\mathbf{z})}{\partial z_j} = \frac{\partial a_i(\mathbf{z})}{\partial z_j}$ for all $l \in M\backslash\{j\}$ by symmetry. It follows that the condition in (13) simplifies to

$$\frac{\partial a_i}{\partial z_j} - \frac{1}{n+1}\left(\frac{\partial a_j}{\partial z_j} + (m-1)\frac{\partial a_i}{\partial z_j} + (n-m)\frac{\partial a_k}{\partial z_j}\right)\bigg|_{z_j=z^{\mathrm{n}}} > 0,$$

all $i, j \in M$, $i \neq j$, and $k \in N \setminus M$. Multiplying by $n+1$ and rearranging terms gives the desired result. ■

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