

**Research joint ventures and price collusion:
Joint analysis of the impact of R&D
subsidies and antitrust fines**

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**Evgenia Motchenkova
Olgerd Rus**

Research Joint Ventures and Price Collusion: Joint Analysis of the Impact of R&D Subsidies and Antitrust Fines

Evgenia Motchenkova¹ and Olgerd Rus²

Abstract

This paper analyzes the joint design of innovation and competition policy. It focuses on collusion sustainability changes due to implementation of antitrust fines and R&D subsidies in an extension of a model by Miyagiwa (2009). Generic subsidies for R&D are found not to facilitate collusion, while additional subsidization to research joint ventures (RJVs) can be collusion facilitating. We also find that proper joint design of RJV subsidies and antitrust fines may cancel out the negative effects of such subsidization. Comparison of welfare effects shows that in some cases additional RJV-promoting subsidies may induce the choice of RJV together with increasing social welfare.

Keywords: R&D, Subsidies, Antitrust, Collusion.

JEL classification: L13, L43, K21, O32.

¹ Assistant Professor, VU University Amsterdam, e-mail: emotchenkova@feweb.vu.nl

² Transaction Management and Restructuring, European Investment Bank, e-mail: o.rus@eib.org

1. Introduction

The number of instances of cooperation in research activities has been growing steadily since mid 20th century.³ Firms have noticed the advantages of improved information flow, abolishment of effort duplication, synergies and innovation sharing, they have commenced establishing research partnerships via creating new companies or allocating their joint resources contractually. On the other hand, this type of cooperation raised great concerns of the antitrust authorities, which were eager to punish any type of horizontal cooperation. However, as a response to the diminishing competitiveness of the US and EU R&D markets, new policies allowing these partnerships needed to be formulated in order not to lose the competitive technological edge to the emerging economies.

Currently, public authorities explicitly prohibit collusive market behavior.⁴ At the same time they seldom discourage cooperation in R&D activities due to e.g. Block Exemption Regulations (see Appendix D). On the contrary, there are numerous examples of policy measures meant to stimulate the formation of research joint ventures (RJVs).⁵ However, as mentioned also in Lambertini et al. (2002), encouraging cooperative R&D and discouraging market collusion can be inconsistent if cooperation in R&D tends to induce collusion in the product market. This inconsistency can be further aggravated by the improper design of innovation and competition policy instruments, such as R&D subsidies and antitrust fines.

This paper analyzes the relationship between the current innovation and competition policies, implemented through R&D subsidies for independent or cooperative research activities and antitrust fines. We aim to answer the question whether two policies contradict each other and what the governments should be aware of when formulating both policies. The main contribution of our paper is analysis of collusion sustainability changes due to implementation of antitrust fines and R&D subsidies in an existing framework. The model based on a stochastic grim trigger strategy patent race of Miyagiwa (2009) is constructed implementing the aforementioned policy tools, and analyzed for various ranges of antitrust fines and subsidies. Additional subsidies given to research partnerships or RJVs are found to facilitate collusion, while antitrust fines are found to be usable to remedy this collusion facilitating effect. However, it is shown that the combined usage of these policies may not always have a welfare enhancing effect and each case needs to be thoroughly analyzed by antitrust authorities based on the market and research conditions.

We are not the first to look at the interaction between R&D cooperation and product market collusion. Other references include Martin (1993, 1995), van Wegberg (1995), Cabral (2000), Lambertini et al. (2002, 2003) and Miyagiwa (2009). The effects of R&D subsidies also have been analyzed by some researchers (see e.g. Katz (1986), Romano (1989), Folster (1995) or Hinloopen (1997, 2000)) but never in the context of collusion sustainability. Filling in this gap in the literature is the main contribution of the current paper.

The paper is organized as follows. Section 2 gives an overview of the related literature. Section 3 outlines the model. Section 4 examines the collusive equilibrium under competitive and cooperative

³ See e.g. Caloghirou et al. (2003) for stylized facts.

⁴ See e.g. EC (2006), Articles 101 and 102 of the EC Treaty or DOJ (2010).

⁵ See the National Cooperative Research Act in the US or EU Research and Innovation DG, FP7 (2011).

R&D. In section 5 we discuss policy implications. Some model extensions and robustness of the results are discussed in section 6. Section 7 concludes.

2. Literature review

In the mid 20th century the antitrust authorities have been vicious with regard to any cooperation between firms, even at the development levels. However, the legislation towards regulating cooperative research and development agreements has become milder now. In both the US and EU competition law cooperative R&D agreements are not prohibited but even encouraged. The discussion of whether cooperatively carried out R&D is dangerous for competition in the product market, however, is still being raised. In this section an overview of how the R&D choices of firms have been modeled is provided, covering the highlights of both deterministic and stochastic innovation, under price and quantity competition.

The topic of R&D and innovation has been appealing to the IO audience for quite a long time. Conversely, it has not been until the paper by D'Aspermont and Jaquemin (1988) when it took a new turn in the direction of cooperative R&D agreements. The sparked interest has continued and the deterministic innovation with spillover effects has been thoroughly researched through the 90's (see e.g. Kamien et al. (1992), Brood and Shivakumar (1997), Hinloopen (1997, 2000), Amir (2000)).

Later Lambertini et al. (2002, 2003) adds to this literature by introducing deterministic *product* innovation in contrast to *process* innovation employed by the previously mentioned authors. Contrary to the case of stochastic innovation models, which are discussed in the following paragraph, here it is assumed that firms are not active in the product market prior the involvement in the development stage. Also, the product is successfully developed with probability 1. This assumption is credible due to the nature of *product* innovation because it may be perceived as more of a marketing effort than a high-tech one, and thus the cost of positioning a newly developed product can be generally known and fixed. Analysis in Lambertini et al. (2002) concentrates on firms' choices of product position in horizontal or vertical product space and generally finds that for horizontal product differentiation it can actually destabilize collusion if firms develop the product jointly. This happens mainly due to the fact that after the joint innovation which homogenizes the product, the horizontal product differentiation is lost and firms cannot collude for some values of discount factors, for which they could have colluded in the independent product development case. They show that in the independent product development case, firms can sustain collusion for lower discount factors even if they do not position their products as prescribed by full collusion under the cooperative R&D. In the independent R&D case firms have the luxury of colluding even when placing their products farther apart from each other. Therefore, with deterministic product innovation and horizontal product differentiation, the authors show that collusion is actually hindered by the formation of an RJV, which is a very desirable result. In the vertical product differentiation setting Lambertini et al. (2002) do not find a collusion hindering or facilitating effects stemming from firms' R&D choices.

Another way of modeling cooperative versus non-cooperative R&D is through stochastic innovation. The outcome of R&D cannot be determined to succeed with 100 percent probability, while the models of d'Aspermont and Jaquemin (1988) and Kamien et al. (1992) imply that firms

can achieve any cost reduction level given that they want to spend resources on it. Hence, another aspect of the R&D modeling stems from the fact that firms cannot with certainty say whether a particular amount of investment will result in definite cost reduction. It is rather through either continuous or discrete time stochastic modeling that we can estimate the expected time or expected expenses of an R&D. Furthermore, the deterministic models tend not to be able to provide implications about collusion sustainability, while it is possible to do within a stochastic framework.

The pioneering research in this field was that of Martin (1995), who used continuous time discounting to estimate the implications of forming an RJV for sustainability of collusion. He introduced patent protection and continuous choice of research inputs. In his original model, both costs of research and the success probability (defined through exponential probability distribution) depended on the research investments. There are no spillovers in his model, but as he uses a general research cost function, they can be easily added via introducing them through the effort levels.⁶ His main result was that, all else equal, firms will be able to sustain product market collusion more easily if they form an RJV. As a means to prove this he uses discounted expected profits from investing in innovation either alone or in alliance with the partner. While there is place for product market collusion in the development stage, he does not model collusion implications for the post discovery collusion, stating that the qualitative implications will be similar. The beauty of his approach lies in the usage of exponential distribution function for discounting, which transforms the complicated integrals over time into static expressions for values. Therefore, a collusive value of a research joint venture outweighs the deviation value with RJV more than it does for collusion without forming an RJV, which is also shown for a general case of the R&D cost function. The only assumption that Martin imposes is that the research effort in an RJV is going to be smaller than in the case with independent R&D, which contradicts the deterministic innovation results, which, for instance, Brood and Shivakumar (1997) get with a general D'Aspermont and Jaquemin (1988). On the other hand, Martin states that such relationship is mainly due to stochastic nature of the game with patent protection and that firms are going to reduce their research effort with an RJV mainly due to the expectation that they cannot lose the patent race and they will not be trying to reduce the probability of the rival winning the patent first. An additional Martin's assumption of perfect effort observability is criticized by Cabral (2000).

Cabral (2000) offers a slightly different approach on modeling of the collusion sustainability, his main focus being kept on differentiated probabilities of success through unobservable research efforts. That is, he incorporates the choice of deviation from the agreed research effort in his modeling of cooperative R&D. Ultimately he speaks in favor of product market competition. He finds equilibria where firms choose full research effort and compete below monopoly prices. He generally shows that for specific set of assumptions there exist stationary equilibria in which firms will find it optimal to set prices below the monopoly level in order to sustain high investments in R&D. One of the more constraining assumptions is that R&D output spillovers are complete, i.e. the newly discovered technology is a public good and there is no patent protection. From the modeling standpoint, Cabral (2000) is the first one to present RJVs in the discrete time trigger strategy setting. His other innovation is introduction of different success probabilities if firms are working together or independently.

⁶ See section on stochastic innovation in Martin (2001).

Our paper utilizes a different model offered by Miyagiwa (2009), which is also based on a price setting super-game. Miyagiwa (2009) approach is more versatile in the sense that it includes both patent protection in a stochastic setting and a proper market competition model with comparable profits, where it is easy to incorporate the focal policy tools. In general, Miyagiwa's (2009) findings confirm those of Martin (1995) extending them to collusion in post-discovery markets. Formation of an RJV in general facilitates collusion, and collusion in the RJV regime is easier prior the discovery than post discovery, while in the independent R&D regime it is in general easier post discovery than prior. A welfare comparison between the two regimes of independent R&D and RJV revealed that welfare gains with the formation of RJV can occur when the switch happens from collusion under independent R&D to collusion under RJV.

Finally, literature on the effects of various policy tools in the presence of cooperative R&D is generally very scarce. In this paragraph we review three papers in which these issues are addressed. Hinloopen (1997) extends the model of d'Aspermont and Jaquemin (1988) with R&D cost subsidies, where firms are also taxed from their profits. Lambertini et al. (2003) address the issue through the possibility of subsidizing or taxing the research expenses so as to optimize the critical discount factor levels in the presence of the substitutability parameter of the product that the firms are developing. Ruble and Versaevel (2009) examine the validity of the combined market share threshold below which the EU firms are allowed to form horizontal agreements. Note that neither of the policy tools were ever addressed within stochastic R&D framework, which is the main innovation of our paper. In the following section we are extending the stochastic innovation framework of Miyagiwa (2009) with innovation and competition policy tools, such as R&D subsidies and antitrust fines, and derive the policy implications with respect to the fine-subsidy interaction.

3. The model

As was pointed out in the previous section, it is generally found that forming the Research Joint Ventures (RJVs) in itself has implications for collusion sustainability. As is shown by e.g. Miyagiwa (2009) and Martin (1995), formation of an RJV facilitates collusion. A stochastic innovation framework is followed in our paper as the R&D subsidization implications have already been researched in the deterministic models by Hinloopen (1997, 2000)..

In our analysis of subsidies grantable for the R&D investments on one side, and antitrust fine enforcement on the other, we combine the setup by Miyagiwa (2009) with elements of Cabral (2000). In his model, Miyagiwa (2009) explains the concept of RJVs in a broader sense than through formation of a single R&D department of all the participants: rather through full innovation *sharing* after the discovery has been achieved.⁷ The following analysis adapts a similar assumption.⁸

⁷ For analysis in this paper we will compare the impact of policy instruments on collusion sustainability under independent R&D regime and under cooperative RJV (research joint venture) regime. Hagedoorn et al. (2000) classifies RJV's as formal R&D contracts or consortia created to pool up R&D resources without involving in joint equity agreements. Miyagiwa (2009) cites RJVs as technology-sharing arrangements including royalty-free cross-licensing agreements, meaning that all the outcomes of research are completely shared among the participants (a similar view towards cooperative research is employed by the European Union legislation, see EU (2011)). The latter implies that RJV may also be seen as a risk diminishing endeavor, especially if we are looking at dynamic stochastic models of R&D. In their favor, the costs of forming and dissolving RJVs are much lower than those related to equity partnerships.

The model uses a discrete time grim trigger strategy set-up in order to investigate the problem of fine-subsidy interaction taking place in the cooperative versus independent R&D environment. We model a repeated game with an infinite time horizon and analyze the collusion sustainability differences.

Introduction of variables and timing of the game: The market consists of two ex-ante symmetric firms, which are involved in a patent race for making a cost reducing innovation. The product market is characterized by the oligopolistic price competition model. If firms are successful in carrying out the innovation, they reduce their costs from $\bar{c}$ to $\underline{c}$. A cost c_d marks the threshold for drastic innovation, in which a successful firm acts as an unconstrained monopolist by undercutting its rival, or it satisfies $\bar{c} = p_m(c_d)$. The function $p_m(c)$ maximizes an unconstrained monopolist's profit given his marginal cost, i.e. $p_m(c) = \operatorname{argmax} D(p)(p - c)$. The demand $D(p)$ is twice differentiable, with $D'(p) < 0$ and $D''(p) \leq 0$.

There also exists a system of patent protection, where a patent's lifespan is infinite. If both firms make the discovery simultaneously, each of them has an equal chance of obtaining the patent first. The time is discrete and at time $t = 1$ each firm possesses identical technology and produces homogenous products at symmetric and constant marginal cost $\bar{c}$. In each period $t \geq 1$ firms decide whether to invest in R&D in order to invent a new cost reducing technology to produce at $\underline{c} < \bar{c}$. Prior to the discovery firms incur the costs k of running their R&D departments. If the research is conducted cooperatively (in an RJV), the probability of simultaneous success is denoted by $\alpha + \beta$, and if separately (independent R&D regime), the probability of simultaneous success is lower and equal α , where $0 \leq \alpha + \beta \leq 1$ and $0 \leq \beta \leq \alpha \leq 1$.⁹ Firms make their choices subject to their time preferences defined through the common discount factor δ .

Policy instruments: The primary novelty of this paper lies in the introduction of subsidies covering the costs of innovation on one end, and antitrust fines imposed to punish collusive behavior on the other. Taking current regulations of the EU Framework Program for research and technological development as a reference (see e.g. EU Research and Innovation DG, FP7 (2011) or Eureka Program (2011)), subsidies are modeled as a fraction of the research costs sk given to firms to cover part of their expenses k , making the overall R&D expenditures by each firm equal $k(1 - s)$. Current EU innovation policy focuses on promoting cooperative R&D; therefore, we assume that if firms form an RJV, they receive higher subsidies than independently innovating ones $(s + r)k$, where r denotes the subsidy difference between independent R&D and RJV regimes. This implies that the research expenditures per firm are given by $k(1 - s - r)$ if a research joint venture is formed. The antitrust fines for collusion are assumed to be fixed and the expected fine is given by qf , where q is

In the model extensions section, we also show that the OE (operating entity) joint ventures can be more dangerous to competition integrity than RJVs.

⁸ As a matter of fact, if we imagine modern research cooperation it is very plausible that due to advanced communication technologies it is unlikely that companies would be willing to incur additional costs of moving their R&D facilities.

⁹ For simplicity of showing our results and for their comparability with the model of Miyagiwa (2009), in the model solution section we assume that $\beta = 0$, i.e. the knowledge spillovers are complete or the R&D know-how is shared by all firms. This assumption is relaxed in the model extensions section and it is shown that the main implications of the analysis still hold in that setting. The detailed derivation of this result are available from authors upon request.

the probability of detection by the antitrust authority and f is the fine itself. We assume that firms are notorious and continue collusion even after they are discovered by the antitrust authorities.¹⁰

Price leadership hypothesis: As already mentioned, there exists a cost c_d , at which the innovator may act as an unconstrained monopolist. Let us assume hereafter that the innovation is non-drastic, and the implemented innovation leads to the cost reduction in the range $\underline{c} \in [c_d, \bar{c})$. This is one of the cornerstones of the analysis by Miyagiwa (2009), because it implies that there is room for collusion in the case of non cooperative R&D, while otherwise the innovating firm would drive out the non-innovator and enjoy the full monopoly profits.¹¹

The price leadership hypothesis proposed by Miyagiwa (2009) implies that the innovator rather than limit pricing his runner-up opponent, decides to offer him an opportunity to share the market at the innovator's terms. In particular, the low cost firm communicates its market sharing rule d which it chooses so as to maximize its profits and to keep the non-innovating firm from deviating from this collusive agreement. Miyagiwa (2009) finds that the collusive price p^c and market sharing rule d are $p^c = p_m(\underline{c})$ and $d = \delta \geq \frac{1}{2}$ with δ being the discount factor. We will further consider what happens to this market sharing rule when fines and subsidies are introduced.

3.1. Non-collusive game after the breakdown of the cartel

First, let us describe the non-collusive game that firms play after the collusion breaks down. In this game, the firms set their prices to $\bar{c}$ prior and after the discovery. We denote this strategy profile by P (where P stands for punishment). In the post-discovery case, setting the price to $\bar{c}$, the innovator limit-prices his rival driving him out of the market and earns $\pi_L = D(\bar{c})(\bar{c} - \underline{c}) > 0$. Since firms both race for obtaining the patent in this case, each period they both have a chance α of making the discovery, and if it is made, an equal probability ($\frac{1}{2}$) of obtaining the patent. We assume that k is sufficiently low so that the expected payoff of playing the strategy P , V_P , is non-negative and investment in R&D is meaningful. The expected payoff of a firm can be thus summarized as

$$V_P = -k(1 - s) + \frac{\delta\alpha}{2} \left(\frac{\pi_L}{1 - \delta} \right) + \delta(1 - \alpha)V_P. \quad (1)$$

The first term in the above expression denotes the total amount of R&D expenditures after subsidies in the period before the discovery. In the next period, the discovery is made with probability α and one of the firms becomes the innovator with probability $\frac{1}{2}$ and limit prices the opponent earning π_L forever thereafter. The third term reflects that with probability $(1 - \alpha)$ the discovery is not made and then the game repeats until the innovation is developed. Collecting terms, this recursive expression can be rewritten as

$$V_P = \frac{-k(1 - s) + \frac{\delta\alpha}{2} \left(\frac{\pi_L}{1 - \delta} \right)}{1 - \delta(1 - \alpha)}.$$

¹⁰ Similar assumption is adopted in e.g. Motta and Polo (2003).

¹¹ Note that limit-pricing an opponent due to decreased marginal costs does not necessarily mean abuse of dominant position. The latter implies acting absolutely independently of the competitors in raising price above marginal costs, while non-drastic innovation means *not* being able to do so.

4. Analysis of collusive strategies

In this section we examine what does the introduction of fines and subsidies do to the collusion sustainability prior and after the discovery in case of Independent R&D and RJV. In each case we focus on the modifications that the introduction of these policy tools brings to the payoff functions and critical discount factors for collusion sustainability outlined in Miyagiwa (2009).

4.1. Independent R&D in the presence of subsidies and antitrust fines

4.1.1. Post discovery collusion and impact of antitrust fines on the market-sharing rule

First, we analyze the post-discovery collusion. After the discovery has taken place, there are only two possible cases: either the observed price is p_c (the agreed collusive price) or it is different. After the different price has been observed, a firm adopts the punishment strategy P . Otherwise, maintaining the collusive price will be sub-game perfect if both firms will not have profitable deviations. Now, let us analyze how our extensions affect the equilibrium collusive market sharing rule d introduced by Miyagiwa (2009) such that post-discovery collusion is sustainable. The innovator maximizes his profit by setting $p_c = p_m(\underline{c})$. Thus the per-period payoff for the innovator (patent-holder) taking into account per-period expected penalty of qf is given by

$$\pi_I = dD(p_m(\underline{c}))(p_m(\underline{c}) - \underline{c}) - qf.$$

And for the non-innovator this payoff is given by

$$\pi_N = (1 - d)D(p_m(\underline{c}))(p_m(\underline{c}) - \bar{c}) - qf.$$

Let us denote the profit of the non-innovator at the innovator's monopoly price as $\pi_{NS} = D(p_m(\underline{c}))(p_m(\underline{c}) - \bar{c})$ and the monopoly profit of the innovator as $\underline{m} = D(p_m(\underline{c}))(p_m(\underline{c}) - \underline{c})$. Then one period deviation is not profitable for the non-innovator if

$$\frac{(1 - d)\pi_{NS} - qf}{1 - \delta} \geq \pi_{NS}.$$

This can be rearranged to

$$\delta - \frac{qf}{\pi_{NS}} \geq d.$$

Since the innovator is seeking to maximize his payoff π_I subject to the above constraint, he will basically set the proposed market share to the highest value possible, i.e. $d^* = \delta - qf/\pi_{NS}$. We can immediately observe that compared to the case with no fine enforcement discussed in Miyagiwa (2009), the market share that the innovator enjoys is smaller than δ , since the term qf/π_{NS} is positive and increasing in qf . This implies that in this setting the innovator enjoys a smaller market share compared to the case where antitrust enforcement is absent, because he is aware that fines make deviation more attractive to the non-innovator. Thus the leader is required to increase the share of the follower in this collusive contract. In the remainder of the paper we call the optimal market sharing rule d^* .

Finally, the innovator also should not have profitable deviations. Collusion for the innovator yields $d^*\underline{m}$ with possibility of receiving a fine each period, while deviation yields full monopoly profits $\underline{m}$

for one period and the limit-pricing profits π_L in all subsequent periods. So, the non-deviation condition for the innovator can be written as follows

$$\frac{d^* \underline{m} - qf}{1 - \delta} \geq \underline{m} + \frac{\delta \pi_L}{1 - \delta}.$$

Recall that $d^* = \delta - \frac{qf}{\pi_{NS}}$. Rearranging we get

$$\delta \geq \frac{\underline{m} \left(1 + \frac{qf}{\pi_{NS}}\right) + qf}{2\underline{m} - \pi_L} \equiv \delta^A. \quad (2)$$

The critical discount factor δ^A , which is the minimum discount factor necessary to sustain collusion in the post discovery periods with independent R&D is unambiguously larger with enforcement than without, and is increasing in expected fine qf . Importantly, we can observe that fine enforcement has a double effect on collusion sustainability in this setting expressed through the terms qf and qf/π_{NS} . Firstly, fines directly decrease the expected payoffs of the non-innovator, which would make it harder to collude in any setting. Secondly, fines decrease the market share d^* that the innovator is optimally offering to the non-innovator thus directly decreasing the collusive profits of the leading firm. Through decreased collusive profits, the innovator now requires a higher discount factor than before to make collusion sustainable. This critical discount factor δ^A is illustrated in the schematic $(\delta, \underline{c})$ -diagram in Figure 1, where it is represented by the solid line A_2A_2 .

4.1.2. Pre-discovery collusion in the presence of antitrust fines and R&D subsidies

Next, we continue with analyzing collusion prior the discovery. Here we will be able to examine the role of subsidies in determining the collusion sustainability. In every period before discovery, both firms observe each other's prices and whether there has been a discovery in the period before. The collusive strategy prior the discovery can be described as follows (assuming current period is τ). There are four cases: (I) no discovery in $\tau - 1$ and no price deviations to date; (II) no discovery in $\tau - 1$ and a price deviation has been observed before; (III) discovery in $\tau - 1$ and no price deviations to date; (IV) discovery in $\tau - 1$ and a price deviation has been observed before. In cases (II) and (IV) firms adopt the punishment strategy P forever after due to grim trigger strategy profile. In case of (III) firms adopt post discovery collusive strategy described before. Only case (I) has to be checked for profitable deviations. If the collusive price is unchanged and discovery has not been made, the firms will be able to sustain collusion if their collusive expected profits are higher than the one-shot deviation and the expected profits from taking part in the patent race independently. We define the collusive payoffs as V_{IC} (where IC stands for Independent R&D Collusion). Also, the per-period present discounted values of the post discovery profits of the innovator and non-innovator are as $v_I = \frac{d^* \underline{m} - qf}{1 - \delta}$ and $v_N = \frac{(1 - d^*) \pi_{NS} - qf}{1 - \delta}$, where the profits $\underline{m}$ and π_{NS} and the optimal market sharing rule (d^*) were defined before. Then the value of collusion is given by the collusive per period profits $\bar{m}/2$ minus the expected fine qf and development costs reduced by an R&D subsidy $k(1 - s)$, where $\bar{m}$ is the monopoly profit under the old technology. In the subsequent periods firms become either the patent race winners or losers with equal probability, thus the expected discounted payoffs if the discovery is made are $\frac{\delta \alpha}{2}(v_I + v_N)$, and if no discovery is made, the cycle is repeated.

$$V_{IC} = \frac{\bar{m}}{2} - qf - k(1 - s) + \frac{\delta \alpha}{2}(v_I + v_N) + \delta(1 - \alpha)V_{IC}$$

Rearranging the above expression implies

$$V_{IC} = \frac{\frac{\bar{m}}{2} - qf - k(1-s) + \frac{\delta\alpha}{2}(v_I + v_N)}{1 - \delta(1-\alpha)}.$$

The one shot deviation payoffs are given by V_{ID} (where ID stands for Independent R&D Deviation). A deviating firm earns $\bar{m} - k(1-s)$ for one period but finds itself in state (II) and (IV) in the following period. Hence, the deviation yields the expected profit

$$V_{ID} = \bar{m} - k(1-s) + \frac{\delta\alpha}{2}\left(\frac{\pi_L}{1-\delta}\right) + \delta(1-\alpha)V_P.$$

Where the firms revert to the punishment strategy P in the subsequent periods. Recalling the expression (1) this can be rewritten as $V_{ID} = \bar{m} + V_P$. In other words, the collusion will be sustainable prior the discovery if $V_{IC} \geq V_{ID}$ or if

$$V_{IC} - V_P \geq \bar{m}.$$

Substituting expressions for V_{IC} , V_P and d^* in the above inequality and rearranging we get

$$\frac{\frac{\bar{m}}{2} - qf + \frac{\delta\alpha}{2(1-\delta)}\left(\left(\delta - \frac{qf}{\pi_{NS}}\right)\underline{m} + \left(1 - \delta + \frac{qf}{\pi_{NS}}\right)\pi_{NS} - \pi_L - 2qf\right)}{1 - \delta(1-\alpha)} \geq \bar{m}. \quad (3)$$

The expression for δ which equalizes the above inequality is tedious algebraically. However, it is verified in the Appendix A that this discount factor is between $\frac{1}{2}$ and 1. We implicitly define the discount factor at which (3) holds with equality by $\delta^B(qf, \underline{c})$, where it is the critical discount factor for collusion sustainability in pre-discovery periods of the Independent R&D regime. For certain parameter ranges this discount factor can be smaller or larger than the discount factor δ^A derived in (2). Consequently, we arrive at the following results.

Lemma 1. *The critical discount factor before discovery in the Independent R&D regime is always larger than $\frac{1}{2}$.*

Proof: See Appendix A. ■

Result 2. *If the common discount factor δ exceeds $\max(\delta^A, \delta^B)$, collusion can be sustained in both post and pre discovery phases in the Independent R&D regime.*

The implications of Lemma 1 and Result 2 are illustrated graphically in Figure 1. Whenever firms find themselves in the Area 1 (above both loci A_2A_2 and B_2B_2 , which denote δ^A and δ^B , respectively) they may easily maintain collusion prior and after the discovery in the regime of Independent R&D.

4.1.3. Collusion sustainability in the presence of antitrust fines and R&D subsidies

Our main aim is to analyze what does the introduction of antitrust fines and R&D subsidies do to the collusion sustainability both prior and after the discovery. Collusion sustainability here is defined through critical discount factors prior and after discovery, δ^A and δ^B , respectively. The results of Miyagiwa (2009) suggest that it can be hard to sustain collusion prior the discovery for high $\underline{c}$ and easier to sustain it for low $\underline{c}$ and sufficiently high δ (the slope of δ^B is negative). Similar to Miyagiwa (2009), we can plot the critical discount factors δ^A, δ^B in the $(\delta, \underline{c})$ space (see Figure 1). For reference, the discount factors without fine enforcement and subsidies are also illustrated by dotted lines, A_1A_1 and B_1B_1 , respectively.

Inequality (2) also implies that fine enforcement unambiguously increases the critical discount factor of post-discovery collusion throughout the entire range of cost reductions $\underline{c}$ through the appearance in the numerator of terms $\underline{m} \frac{qf}{\pi_{NS}}$ and qf . Effectively, we can conclude that the critical discount factor δ^A with fine enforcement will appear above the curve without fine enforcement for all values of $\underline{c}$ except for $\underline{c} = c_d$, where it merges with unity. δ^A with fine enforcement is plotted in Figure 1 as solid line A_2A_2 together with the same locus absent fine enforcement (dotted line A_1A_1).

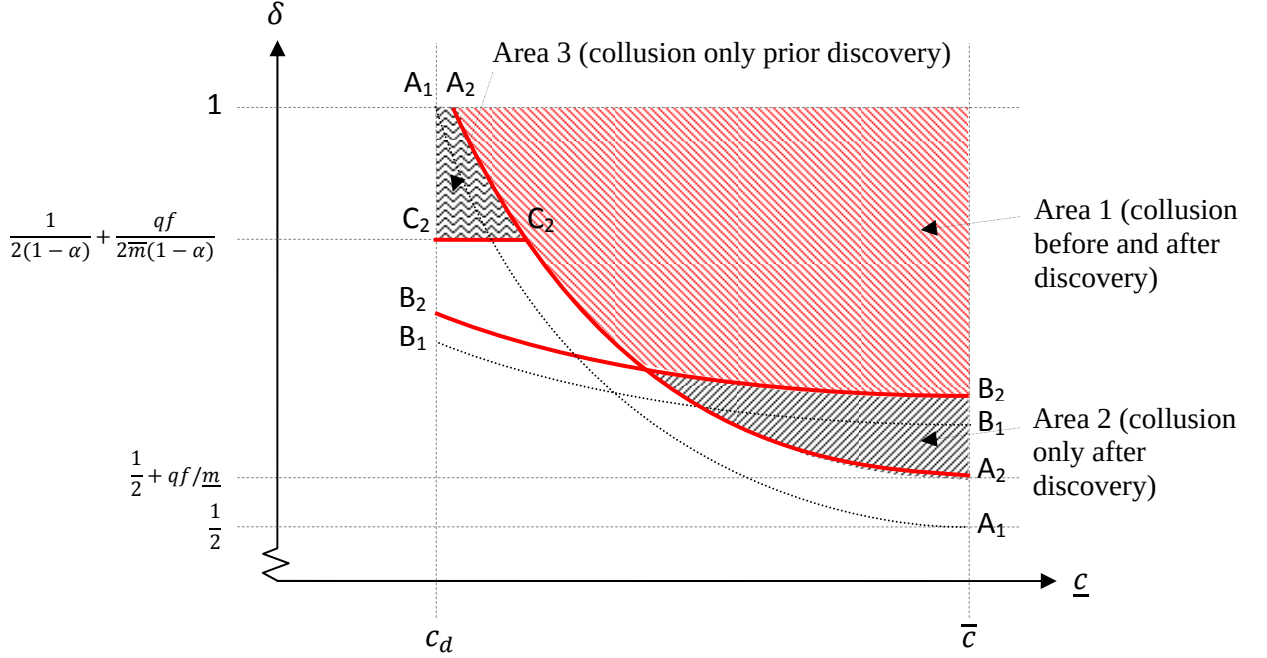


Figure 1: Loci of critical discount factors in the $(\delta, \underline{c})$ -space and changes in areas of collusion sustainability. (Independent R&D regime)

Dotted lines A_1A_1 and B_1B_1 represent critical discount factors without enforcement. Solid lines A_2A_2 and B_2B_2 : with enforcement. Horizontal line C_2C_2 represents the critical discount factor δ^{IC2} .

Next, recall the inequality (3). It is the inequality for the critical discount factor before discovery. Before the invention, firms make investments in R&D, which are also subsidized by the government. It would seem that it might make collusion easier; however, it is not the case, for the term $k(1-s)$ cancels out from two sides of the equation, thus concluding that neither the size of R&D investments, nor the size of subsidies has any impact for the collusion sustainability before discovery in the case of independent R&D with complete spillovers. The expected fine, on the other hand, will have a collusion destabilizing effect, which is proven in Proposition 4. Plotting this new discount factor requires to put it above the analogous δ^B without fine enforcement B_1B_1 . In Figure 1 the solid curve B_2B_2 represents δ^B with fine enforcement and is above B_1B_1 through the entire range of cost parameters $\underline{c}$. In summary, both prior and after discovery critical discount factors increase in the presence of antitrust fines.

The area above both solid lines in Figure 1 represents the analogue of Region 1 of Miyagiwa (2009). It shows the pairs of $(\delta, \underline{c})$ at which firms can collude both before and after the discovery. Note that

because of the introduction of expected fines qf , the area shrunk. I.e. there are less pairs of $(\delta, \underline{c})$ at which firms can collude both before and after the discovery. Careful analysis of expressions (2) and (3) implies the following propositions.

Proposition 3. *In the case with independent R&D, subsidies do not facilitate collusion.*

Proof: See Appendix A. ■

Proposition 4. *Fines effectively hinder collusion both prior and after the discovery in independent R&D regime.*

Proof: See Appendix A. ■

Let us now also consider the situations where firms collude only after the discovery and not prior or vice versa. First, if $\underline{c}$ is such that $\delta^A < \delta < \delta^B$, then firms can effectively collude after the discovery but not before it. This pair of $(\delta, \underline{c})$ is reflected by the Area 2 in Figure 1. On the other hand, it can also be the case that $\underline{c}$ is such that $\delta^B < \delta < \delta^A$, which means that firms do not collude after the discovery, but can do that before. However, we need to re-check for the sustainability of such a strategy, since the payoffs change. As now firms revert to competition after the discovery, in this case collusion payoff prior discovery V_{IC2} becomes

$$V_{IC2} = \frac{\frac{\bar{m}}{2} - qf - k(1-s) + \frac{\delta\alpha}{2} \left(\frac{\pi_L}{1-\delta} \right)}{1 - \delta(1-\alpha)}.$$

While deviation payoffs stay the same. Inequality (3) in effect can be rewritten as $\frac{\frac{\bar{m}}{2} - qf}{1 - \delta(1-\alpha)} \geq \bar{m}$.

Isolating the discount factor, this implies

$$\delta \geq \frac{1}{2(1-\alpha)} + \frac{qf}{2\bar{m}(1-\alpha)} \equiv \delta^{IC2}.$$

Let us call this critical discount factor δ^{IC2} . The term $\frac{qf}{2\bar{m}(1-\alpha)}$ appears only due to enforcement and is unambiguously positive. The entire RHS of the above equation is below 1 only for $\alpha < \frac{1}{2} - \frac{qf}{2\bar{m}}$. Hence, it can be concluded that for high enough probability of success the firms will never collude prior the discovery. Assuming that α is low enough, let us plot the line $\delta^{IC2} = \frac{1}{2(1-\alpha)} + \frac{qf}{2\bar{m}(1-\alpha)}$ in the Figure 1 and call the area above it and below δ^A the Area 3. This critical discount factor δ^{IC2} is denoted by C_2C_2 in the Figure 1.

Area 3 the analogue of the Region 3 of Miyagiwa (2009), and it marks the pairs of the discount factor and costs at which collusion is possible only prior discovery but not after. Moreover, the range of success probabilities α , for which collusion prior discovery is feasible, is also smaller compared to the findings in Miyagiwa (2009). This implies that in the presence of antitrust fines it is more difficult to sustain collusion before discovery as well.

4.2. Research joint ventures in the presence of R&D subsidies and antitrust fines

Let us now move on to the analysis of product market collusion in an RJV setting. Following the current EU R&D co-financing rules, we assume that if firms form an RJV, they can get a higher

level of subsidization, given by $k(s + r)$, than the firms undertaking the R&D independently, which is ks for independent developers. Note that $r \in [s, 1]$, where r denotes the subsidy difference between independent R&D and RJV regimes and s denotes a normal fraction of the research costs covered under independent R&D regime.¹²

There are several factors which lure firms to form Research Joint Ventures in our model. First, the invention is shared and there is no chance of being driven out of the market in case the rival is first to finish the patent race. Second, firms remain symmetric and can sustain collusion more easily, which guarantees half monopoly profits with more efficient production. Third, joining forces facilitates the information flow between the R&D departments of two firms and it makes research more efficient. There are several ways to capture this effect: either through increased success probability or through research cost reductions, both of which are addressed in the model extension section.

As before, we begin by analyzing the post discovery collusion. In this case both firms share the technology of the same efficiency level and can enjoy collusive profits more easily, while on the other hand the punishments are harsher due to symmetry. Recall that with symmetric firms the Nash expected competitive per period profits are equal to 0 rather than $\pi_L/2$. Here we shall check whether firms will collude at the monopoly prices. Setting such prices is subgame perfect if firms' time preferences are correct, i.e. if the common discount factor is high enough. This subgame follows a generic grim trigger strategy analysis and the critical discount factor without fine enforcement would be $\delta \geq \frac{1}{2}$. Considering a case with fine enforcement we can conclude that collusion post discovery is more profitable than deviation if

$$\delta \geq \frac{1}{2} + \frac{qf}{m} \equiv \delta^R. \quad (4)$$

It is straightforward to show that δ^R is always below δ^A , its independent R&D analogue. Hence, similar to the conclusion of Miyagiwa (2009) we obtain that formation of an RJV in itself facilitates collusion after discovery through post-discovery symmetry. We define the post-discovery collusive strategy by R and assume that it is characterized by standard grim trigger strategies, where any deviation from the prescribed monopoly prices $p_m(\underline{c})$ triggers a marginal cost pricing.

Now consider collusion prior the discovery. The timing is similar as in the case with independent R&D. We start at $t = 1$ when firms set monopoly prices $p_m(\bar{c})$ under the old technology. Then in any subsequent period τ there are four possible states: (I) no discovery in $\tau - 1$ and no price deviations to date; (II) no discovery in $\tau - 1$ and a price deviation has been observed before; (III) discovery in $\tau - 1$ and no price deviations to date; (IV) discovery in $\tau - 1$ and a price deviation has been observed before. In cases (II) and (IV) firms adopt a punishment strategy P . In case (III) firms adopt the post-discovery collusive strategy R . The collusive strategy prior the discovery in RJV case (call it RC) is subgame perfect except for the case (I) in which it is not clear if the collusive payoff prior discovery is higher than payoff from the one shot deviation. To check that, we write down the collusion expected payoffs within a joint venture (in the recursive form)

¹² The current Seventh Framework guidelines suggest that subsidies are granted to international research consortia rather than to independently researching organizations. We assume that if independent companies seek funding elsewhere, they can get a smaller subsidy, or even none.

$$V_{RC} = \frac{\bar{m}}{2} - qf - k(1 - s - r) + \frac{\delta\alpha}{1 - \delta} \left(\frac{m}{2} - qf \right) + \delta(1 - \alpha)V_{RC}.$$

Here firms receive half of the monopoly profits each before and after discovery and incur the subsidized R&D costs prior discovery. They also face a threat of being detected and penalized by the antitrust authorities in every period. If firms are successful, they enjoy the collusive profits with the new technology. This can be rewritten as

$$V_{RC} = \frac{\frac{\bar{m}}{2} - qf - k(1 - s - r) + \frac{\delta\alpha}{1 - \delta} \left(\frac{m}{2} - qf \right)}{1 - \delta(1 - \alpha)}.$$

Whereas a one-shot deviation before discovery can lead to the old technology monopoly profits less R&D costs for one period and then reverting to the punishment strategy P as long as discovery is not successful. If the discovery takes place, the firms follow the deviating strategy with Bertrand Nash profits equal 0. This strategy is denoted RD (RJV Deviation case) and its value is specified below

$$V_{RD} = \bar{m} - k(1 - s - r) + \delta(1 - \alpha)V_P.$$

The firm will find it profitable to collude prior discovery if $V_{RC} \geq V_{RD}$ or if (5) is satisfied.

$$\frac{\delta\alpha}{1 - \delta} \frac{m}{2} + \frac{\delta(1 - \alpha)}{1 - \delta(1 - \alpha)} \left(\frac{\bar{m}}{2} + \frac{\delta\alpha}{1 - \delta} \left(\frac{m}{2} - \frac{\pi_L}{2} \right) \right) - qf \left(\frac{2 - \delta(1 - \alpha)}{1 - \delta} \right) + kr \left(\frac{1}{1 - \delta(1 - \alpha)} \right) \geq \frac{\bar{m}}{2} \quad (5)$$

This inequality implicitly defines $\delta^{RC}(qf, r)$ critical discount factor, for collusion to be sustainable in RJV regime prior discovery. By analyzing the inequality (5) several results can be observed regarding fine enforcement and subsidization differences in the case of RJV.

Proposition 5. *Fines hinder collusion both before and after discovery in case of RJV.*

Proof: See Appendix A. ■

Proposition 6. (i) *Subsidy differences between independent R&D and RJV facilitate collusion prior discovery, but do not have an effect on collusion sustainability after discovery in the case of RJV.*

(ii) *Generic subsidies given to both independent and cooperative R&D do not have an effect on collusion sustainability both before and after discovery.*

Proof: See Appendix A. ■

5. Results and policy implications

Miyagiwa (2009) finds that pre-discovery collusion under RJV is subgame perfect for $\delta \geq 1/2$. It is also implied in his paper that under the RJV regime the critical discount factor prior discovery is below 1/2 (without fine enforcement). This means that under the RJV regime firms find it easier to collude prior the discovery. It is possible to show (see Appendix B) that without fine enforcement and with positive subsidy differences this result still holds. It is thus clear that formation of RJV has collusion stabilizing effect prior the discovery, assuming there are no competition policy tools in place.

5.1. Analysis of the fine - subsidy interaction

Let us now return to the issue of subsidization. As we can observe from the analysis of Proposition 5 above, without the differences in subsidies grantable for RJVs, the effect of expected fines is unilateral and collusion-destabilizing. However, as was shown in the Proposition 6, high subsidy differences can have a collusion facilitating effect in case of RJV, basically bringing the δ^{RC} thresholds back down. It needs to be analyzed to what extent can the subsidies for cooperative R&D be higher than for independent R&D in order for the overall policy not to facilitate collusion. Recall the inequality (5) which had the two terms related to these policy tools collected at the left hand side: $-qf \left(\frac{2-\delta(1-\alpha)}{1-\delta} \right) + kr \left(\frac{1}{1-\delta(1-\alpha)} \right)$. Since we have shown that in the pre-discovery stage fines hinder collusion and subsidy differences facilitate it, and that the LHS of (5) is strictly increasing in δ , we can write down the condition for “non-facilitation”. The competition and innovation policy pair of expected fine and subsidy difference (qf, r) will not facilitate pre-discovery collusion if:

$$r \leq \frac{qf}{k} \left(\frac{2-\delta(1-\alpha)}{1-\delta} \right) (1-\delta(1-\alpha)) \equiv r^x(qf).$$

Let us define the value of r , at which the above holds with strict equality by $r^x(qf)$. We can plot $r^x(qf)$ in the (r, qf) -space. This simple linear dependence with a positive slope is illustrated in the Figure 2. The possible positive subsidy difference is bounded from above by $1-s$, since we assume that governments do not grant subsidies above the costs of development.

Some implications can be derived from the analysis of the slope of $r^x(qf)$. The slope of this line decreases with k , or the R&D costs, meaning that the higher the costs are, the more difficult it is to hinder collusion with fine enforcement, given some level of r . It is logical, since as the costs of development increase, the additional subsidies become more important than before. On the other hand, the slope of the line increases with α , meaning that the higher is the probability of making the discovery, the more effective fines are to hinder collusion when there are higher than normal subsidies given to firms involved in RJV. The effect of α can be explained as follows: as firms are aware that the probability of making a discovery is higher, they also anticipate that they are going to spend less for the development of their cost reducing technology. Thus, subsidies become less important and the collusion hindering effect of fines outweighs the collusion facilitating effect of RJV subsidies more easily.¹³

A proposition consequently can be formulated with regard to the fine / subsidy interplay, which in fact serves as a remedy to the negative results of Proposition 6, where we have shown that subsidy differences can facilitate collusion prior discovery.

Proposition 7. *In a setting with subsidy differences r and expected fines qf , additional subsidies do not facilitate prior discovery collusion compared to the case without these policy instruments, as long as r does not exceed $r^x(qf) = \frac{qf}{k} \left(\frac{2-\delta(1-\alpha)}{1-\delta} \right) (1-\delta(1-\alpha))$.*

¹³ Recall equations for δ^R and δ^{RC} specified in (4) and (5). One of further implications for this setting is that even if we “cancel out” the prior discovery collusion hindering effects of fines with additional subsidies for RJV or vice versa, there will always remain the unaltered increase in the critical discount factor post discovery δ^R . Therefore, the effect of fines does not nullify entirely if there are high subsidy differences, since in the product market after discovery collusion will still be destabilized.

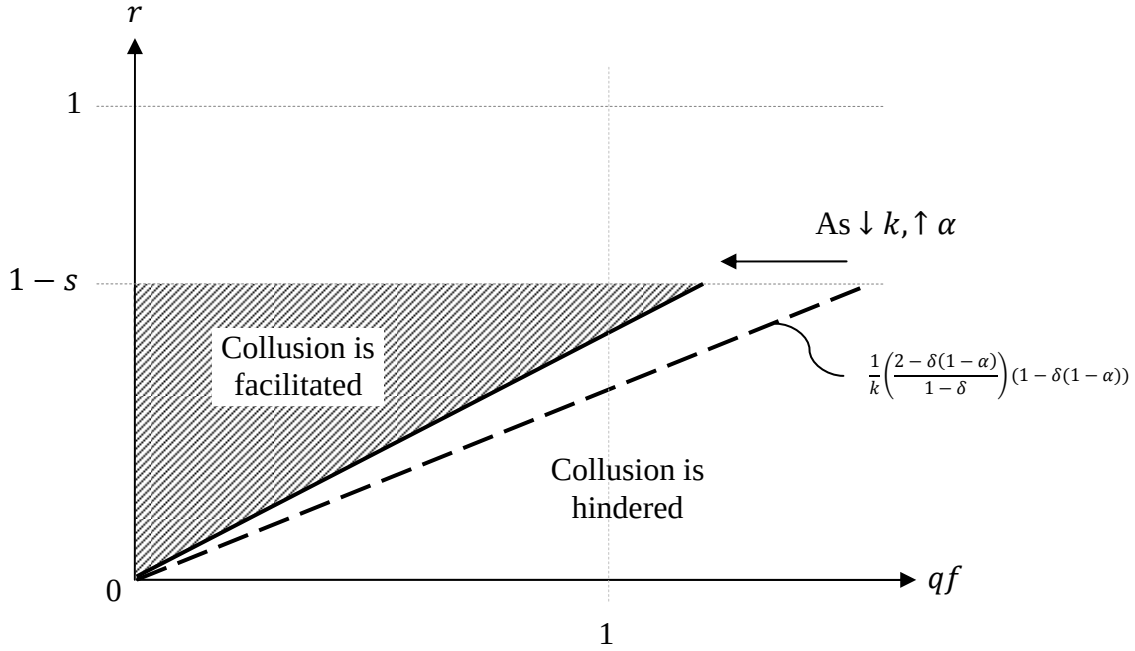


Figure 2. Collusion implications in the (qf, r) -space. Cooperative R&D regime.

The above figure and proposition imply that policymakers should consider designing the competition and innovation policy jointly if they wish to grant additional subsidies to research consortia. Governments which aim to maintain high levels of cooperative R&D but make sure not to facilitate collusion, should design subsidy programs such that percentages of additional subsidies for research consortia above general R&D subsidies would not exceed r^x . Note that r^x can be estimated and calibrated based on market characteristics (such as δ, k, α) and expected fines, implied by existing antitrust sentencing guidelines.

5.2. Optimal policies and characterization of SPNE

5.2.1. Optimal policies under independent R&D regime

Some implications can also be derived in the (qf, r) -space with regard to firms' collusion choices under both Independent R&D and RJV regimes. Under Independent R&D, firms do not receive additional R&D subsidies; therefore, only the expected fine qf is relevant as means of collusion sustainability control. Recall expressions for $\delta^A(qf, \underline{c})$ and $\delta^B(qf, \underline{c})$ or inequalities (2) and (3) respectively. It is straightforward to express qf from both of them. Expression (2) implies

$$qf \leq \frac{\pi_{NS}(2\delta\underline{m} - \delta\pi_L - \underline{m})}{\pi_{NS} + \underline{m}} \equiv qf^A.$$

While expression (3) implies

$$qf \leq \frac{\frac{\delta\alpha}{2(1-\delta)}(\delta\underline{m} + (1-\delta)\pi_{NS} - \pi_L) - \overline{m}(1-\delta(1-\alpha))}{1 + \frac{\delta\alpha}{2(1-\delta)}(\frac{\underline{m}}{\pi_{NS}} + 1)} \equiv qf^B.$$

The above inequalities show the minimum levels of expected fines, above which sustaining collusion is not possible after discovery (qf^A) and before discovery (qf^B) under the Independent R&D regime. These expressions imply that knowing the market structure it is feasible to tune the expected fines so as to hinder collusion specifically prior or post discovery. Recalling Figure 1 several points can be made regarding the relationship between qf^A and qf^B . As cost reduction is low, i.e. difference between $\bar{m}$ and $\underline{m}$ is quite low, collusion before discovery is more difficult than after discovery, hence $qf^A > qf^B$. This means that collusion is more easily prevented with fines before the discovery than after the discovery. However, as cost reduction becomes higher, the relationship may reverse to $qf^B > qf^A$, since collusion prior discovery may be easier, and thus larger expected fine will be required to prevent collusion before discovery than after discovery.

5.2.2. Optimal policies under cooperative RJV regime

Similar analysis can be done for the RJV case. Here it is also possible to control the variable of subsidy differences r which influences the prior discovery critical discount factor $\delta^{RC}(qf, r, \underline{c})$. We also denote the critical value of qf post discovery by qf^R . This is the value of the expected fine above which post discovery collusion is not possible in the product market. We also derive the subsidization rule $r^{RC}(qf)$ above which collusion is sustainable prior discovery. From inequalities (4) and (5) we can isolate the critical value of the expected fine for collusion sustainability post discovery and the critical value of the subsidy difference pre-discovery. Expression (4) implies

$$qf \leq \underline{m} \left(\delta - \frac{1}{2} \right) \equiv qf^R.$$

While expression (5) implies

$$r \geq \frac{1 - \delta(1 - \alpha)}{k} \left(\frac{\delta\alpha}{1 - \delta} \frac{\underline{m}}{2} + \frac{\bar{m}}{2} - \frac{\delta(1 - \alpha)}{1 - \delta(1 - \alpha)} \left(\frac{\bar{m}}{2} + \frac{\delta\alpha}{1 - \delta} \left(\frac{\underline{m}}{2} - \frac{\pi_L}{2} \right) \right) + \left(\frac{2 - \delta(1 - \alpha)}{1 - \delta} \right) qf \right) \equiv r^{RC}.$$

The relationship between these values is illustrated in the Figure 3. Above the line $r^{RC}(qf)$ the subgame perfect Nash equilibrium (SPNE) is to collude in the pre-discovery phase. Below this line collusion cannot be sustained, therefore, it can be shown that it is a SPNE to set competitive prices prior discovery. To the left of the vertical line qf^R firms find it optimal to collude after discovery because enforcement is too weak. To the right of this value they do not collude post discovery, since enforcement is too strict for the collusion to be maintained. The above discussion and ideas illustrated in the Figure 3 can be summarized in the following proposition.

Proposition 8. *Optimal policies that implement fully competitive outcome require $qf > qf^R$ and $r < r^{RC}(qf)$.*

This proposition implies that in cases when fine enforcement is very strong and additional subsidies are low, firms will not collude at all. Partially competitive outcome still can be achieved with low expected fines and low subsidy differences. High subsidy differences in combination with low fines implement the worst for society outcome with collusion both before and after discovery.

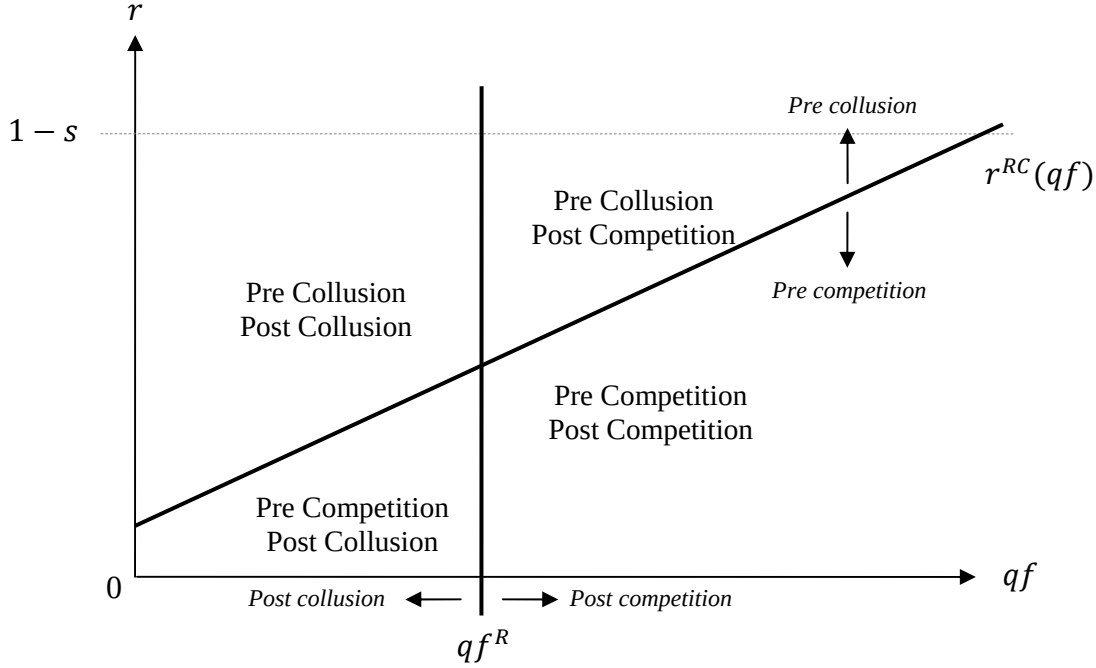


Figure 3. SPNE choices pre- and post-discovery in the (qf, r) -space. Cooperative RJV regime.

5.3. Welfare Implications

In the absence of fine enforcement, formation of an RJV has quite clear welfare implications.¹⁴ In the case of RJV, firms can freely collude for all $\delta \geq \delta^R = 1/2$ and formation of an RJV is explained as a switch from one of the Areas of Figure 1 (without enforcement) to a case where collusion is always sustainable. Therefore, if we switch from full collusion in independent R&D regime to full collusion in RJV, social welfare is increased only due to an increase in total profits. Forming an RJV in that region, firms become more symmetric when colluding and, hence, sum of their profits increases. Hence, if the firms are encouraged to form RJVs, governments need to make sure that this increases also consumer welfare.

In the model with competition policy through fine enforcement, we observe the following. Fines in independent R&D reduce areas 1, 2 and 3 at the same time increasing the set of pairs of $\delta, \underline{c}$ at which firms cannot collude at all. In addition, the RJV case has very different results than Miyagiwa (2009). Now there exist pairs of $\delta, \underline{c}$ for which collusion is not possible above $\delta = 1/2$ and hence there appear to be areas for which switching from Independent R&D to RJV can have positive social welfare implications without collusion in the RJV case compared to the same constitution of $\delta, \underline{c}$ in case with no enforcement.

Plotting critical discount factors $\delta^A, \delta^B, \delta^R, \delta^{RC}$ described in expressions (2), (3), (4), and (5) simultaneously in $(\underline{c}, \delta)$ -diagram, we obtain Figure 4. Figure 4 specifies 3 zones which are of particular interest due to their appearance in effect of the combined competition and innovation

¹⁴ We define total social welfare as a sum of consumer surplus and firms' profits minus R&D costs (it does not matter who pays these costs).

policy. Zone A in Figure 4 represents the state when setting monopoly prices can never be a SPNE for firms within the RJV. In Zone B it is a subgame perfect Nash equilibrium for firms to set monopoly prices and share the market equally after the discovery, while playing a competitive game prior the discovery. In zone C, vice versa, an SPNE is to set monopoly prices before the discovery, but to set price equal marginal costs after the discovery.¹⁵

Several policy implications may be drawn from this analysis. Firstly, since competition post discovery under RJV regime implies symmetry, firms will be aware of the occurring profit losses. The expected profits in the Independent R&D case are positive and the formation of an RJV implies nil profits. The best thing that a policymaker can do in this case (when firms' time preferences are relatively short-sighted or δ is relatively low) is to make them indifferent between choosing to innovate within an RJV or not, with 100% subsidization. However, this may only happen, when the firms' payoffs of playing the competitive strategy within the Independent R&D are negative, meaning $V_p < 0$. Secondly, formation of an RJV in Zone B is not always profitable for firms, even though they get a chance to collude in the post discovery stage. Moreover, the total welfare is decreasing in Zone B with the formation of RJV. Therefore, the governments should not try to promote RJVs in that case. Thirdly, formation of an RJV in Zone C implies collusion only prior discovery and competition in the post discovery state. Here the welfare effect is ambiguous, since the policymaker has to weigh whether it is better to allow one firm to limit-price the other in the outcome of discovery or to afford some collusion under the old technology in the pre-discovery stage in order to enjoy infinite horizon competition within RJV in the post-discovery periods.

The abovementioned results imply the following with respect to subsidization / enforcement. The implemented competition policy may not be largely effective in increasing welfare in Zones A or C if firms will not be willing to form an RJV. If the governments suspect that the time preferences of the firms are characterized by a low discount factor, i.e. we are in either of the Zones A, B or C and firms are willing to form RJVs, then several scenarios are possible: either the firms are aiming at (1) large cost reductions in Zone B or (2) at low cost reductions in Zone C. In the case (1) additional subsidies for RJVs should not be granted since formation of RJV in that region implies welfare losses. Thus the antitrust authorities should pay stricter attention to the post discovery duopoly. In case (2) governments should not be cautious of increasing subsidization if they believe that the RJV will have an overall welfare increasing effect. Giving additional subsidies pulls δ^{RC} down and "expands" Zone C, making it more likely that firms will be willing to form an RJV, and also increases the range of $\underline{c}$ for which the welfare effect of forming an RJV is at least ambiguous and not negative.

Lastly, if we observe that firms are not willing to form an RJV at all, then we may suspect that they are in Zone A or the fines are too large in Zones B or C. Zone A is the first best, since it induces social welfare maximization as firms are producing at the new technology and set price equal marginal costs. In that case, however, governments need to impose innovation by fully subsidizing the costs of development, or else the firms will not be willing to innovate. If costs of development are fully subsidized, then the expected fines need to be very high in order to "create" the Zone A. It then boils down to evaluation, which situation is the best for the government: no collusion, but full subsidization and a very expensive enforcement policy (through Zone A) or a less strict fine enforcement policy and an ambiguous welfare effect through RJV formation (Zone C). In general, if

¹⁵ More detailed derivations are provided in Appendix C.

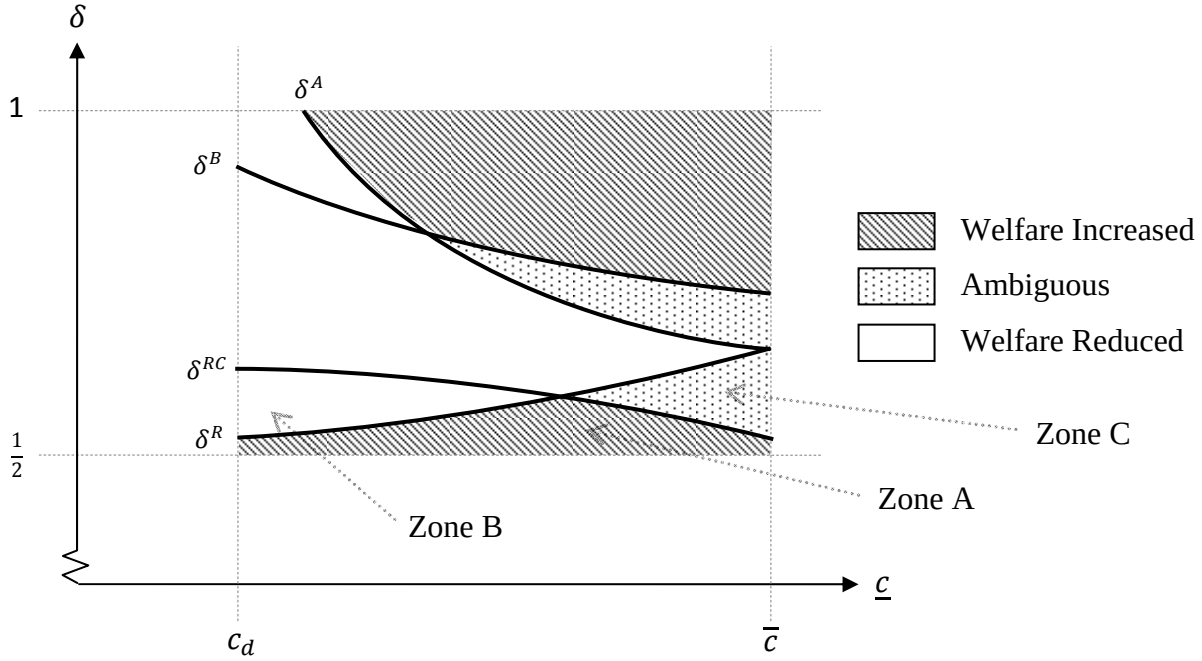


Figure 4: Zones of welfare effects of RJV formation. Example when enforcement is moderate.

the government is aiming at maximizing the Zone C, then it is better to keep the subsidies high but enforcement moderate. This will increase the chances that firms will be willing to form an RJV.

6. Model extensions

Until now we have assumed that the input spillovers were complete and that firms enjoyed equal success probabilities in the development stage both in Independent R&D and RJV. Let us now introduce incomplete input spillovers first in the form of different costs of research and then in the form of different success probabilities. In the following analysis we distinguish different success probabilities in a stochastic discrete time environment, which we call the effect of “spillovers”. If we carry on with the reasoning by Miyagiwa (2009), where he points out that firms retain their R&D units, then a probability of success in execution of the research implies that when firms join forces, the information flow between them becomes more efficient or even perfect (in other words, spillover rate equals one, as in Kamien, Muller and Zang (1992)). We assume in our model that the lower is the difference between these two probabilities, the higher are the “spillovers” in the independent environment.

6.1. R&D cost spillovers, OE joint ventures, and different success probabilities

Firstly, assume that the costs of research are different for independent and cooperative R&D. We implement it in our model by introducing an additional exogenous cost reducing variable (call it j). Hence, forming an RJV means that costs of development reduce additionally by jk , making the total costs $k(1 - s - r - j)$. It is very straightforward that this variable bears an effect only on the critical discount factor prior discovery δ^{RC} . This effect is exactly the same as of r , except that it cannot be controlled by the regulator. We can thus say that the higher the spillovers are (the closer j is to 0),

the higher is the critical discount factor of RJV prior the discovery. Introduction of incomplete knowledge spillovers does not change many of the implications in our model, except that if we want to maintain the status quo, governments have to either give lower subsidies to RJVs than to independent researchers or increase the expected fines. In other words it diminishes the r^x by a constant value, bringing some part of it below 0, meaning it is harder now not to facilitate collusion.

A formation of an OE (operating entity) joint venture is usually accompanied by equal sharing of the costs development. It can also be modeled as an “R&D cost spillovers” case described above with $j = \frac{1-s-r}{2}$. The latter means that δ^{RC} will be lower compared to the situation within an RJV, thus implying that formation of an OE joint venture is more collusion stabilizing. Moreover, under OE joint ventures the generic R&D subsidy term s does not cancel out from the inequality (5) and, therefore, they bear collusion facilitating effects too.

Different success probabilities also have a similar effect. If we assume that the probabilities of success are different for RJV versus independent R&D, the inequality (5) can be rewritten with higher success probability. Denoting the probability of success under RJV by $\alpha + \beta$, while probability of success in independent R&D case is still α , we can analyze a modified version of inequality (5). Similarly as with the R&D cost spillovers, critical discount factor δ^{RC} is increasing in both α and β , and the bigger the difference in probability of success between the independent R&D regime and RJV regime, the higher the critical discount factor for RJV prior discovery, δ^{RC} , which is similar to the effect of higher R&D cost spillovers discussed above.

6.2. Block exemption regulations

Following the legislation of the European Commission with regard to competition rules on horizontal co-operation agreements, it is also possible to briefly comment on the so-called block exemption regulations and their general implications for collusion sustainability. According to the current block exemption rules, firms cooperating in R&D can enjoy 7 years of exemption from the actions of competition authorities. Let us try to incorporate it within our model, let the period of exemption be T . The condition for no-deviation from collusion in post-discovery (RJV case) then becomes

$$\frac{\frac{m}{2} - \delta^T qf}{1 - \delta} \geq \underline{m}$$

Since δ is below 1, from the inequality above we can observe that with larger T firms expect less strict punishments, and thus the critical discount factor will fall with T . This would be reflected through shallower increase of δ^R with higher qf . Before discovery the picture would be similar. With positive T , we would observe a lower multiplier of the term qf in inequality (5) and a decrease the slope of r^x , meaning that it would be more difficult to cancel the collusion sustainability effects of additional subsidies for RJVs, if they are given. It would also mean that firms would be more eager to form an RJV.

7. Conclusions

This paper has examined the paradox of encouraging cooperation in R&D while at the same time prohibiting other types of horizontal agreements, most notably collusion. A fixed expected fine and

R&D subsidization were employed to analyze the interaction between the innovation and competition policy adopting a framework of Miyagiwa (2009).

Stochastic trigger strategy setting was chosen to carry out the analysis, trying to fill the existing gap in the current research on cooperative innovation policy, which up to date has mainly been concentrating on deterministic innovation. The focus has been kept on non-drastic innovation, which implied the possibility of collusion in the ensuing post discovery markets under the Independent R&D regime. Additional R&D subsidies have been shown to facilitate collusion prior discovery in the RJV setting, whereas subsidies per se had no effect on collusion sustainability under Independent R&D. The rationale behind this result is that under independent R&D firms receive the same R&D subsidies no matter whether they collude or not. Under RJV collaboration, which is promoted by the EU, the innovating firms may be enjoying larger subsidies when innovating together and thus not willing to deviate from collusive agreements if such were formed. The problem that additional subsidies to RJVs could facilitate collusion prior discovery can be remedied by simultaneous joint design of innovation and competition policy. Governments which aim to maintain high levels of cooperative R&D but make sure not to facilitate collusion, should design subsidy programs such that percentages of additional subsidies for research consortia above general R&D subsidies would not exceed certain threshold levels, which should depend on market characteristics and expected fines, implied by existing antitrust sentencing guidelines.

The role of expected fines was shown to be collusion destabilizing both prior and after the discovery. More importantly, the result that fines are more effective in hindering collusion post discovery than after the discovery has shown that the paradox found by Miyagiwa (2009) can be remedied with the use of antitrust policy tools. In general, the paradox constituted a situation in which collusion prior discovery would become easier with the formation of RJV, while independent innovation had reverse results. Therefore, the implementation of antitrust fines could make the RJV collusion prior discovery more difficult than after the discovery. However, the general result that collusion is easier under cooperative RJV remained true even after the implementation of the competition policy. The validity of this effect is only amplified if firms are allowed to form OE joint ventures.

The implications for the joint design of competition and innovation policy depend on the aims of the policymakers. Article 101 of the EC Treaty is explicit with respect to collusion prevention; however, the innovation is also promoted through subsidies given out to RJVs. We show that competition and innovation policy may be implemented together, however, the authorities should be aware not to over-subsidize the industry and induce collusion where it is undesirable. We also point out that the best welfare-wise outcome, achievable through the formation of an RJV, is only possible when firms are not willing to innovate under the independent R&D regime and only through full subsidization and strict fine enforcement. In other words, such policy might be too expensive for the government and thus it may be better to strive for the second best solution, where some joint exploitation is allowed to the mutually innovating firms. If the government sees the RJV as socially desirable in that case, it is then plausible to subsidize the joint innovation, which might induce collusion at the development stage. However, as the antitrust fines successfully hinder collusion in the period after discovery, the total welfare effect of allowing RJVs might be still positive.

Unfortunately, in such a model formation of an RJV does not improve welfare for all cost reduction and discount factor levels. Furthermore, the general policy result of Miyagiwa (2009) that

governments should watch more closely innovating firms that are aiming at high cost reductions remains true after the implementation of subsidization and antitrust enforcement. Therefore, the practice of evaluating firms prior to allowing them to form cooperative research agreements still should be utilized by the European Commission.

Further research could be carried out in the direction of this paper, implementing a higher number of firms with only a subset of innovating ones in order to evaluate the effects of Block Exemption regulations more thoroughly (particularly with regard to the market share threshold rule). As a general fact, the empirical support for theoretical findings on collusion is extremely difficult to obtain; however, some behavioral patterns might be discovered when evaluating the propensity of firms to form RJVs under the presence of antitrust fines and R&D subsidies. A dynamic panel data analysis of concentration index changes overtime in subsidized high-tech industries could also be evaluated in order to confirm the finding that subsidies for cooperative R&D may induce collusion, and higher market concentration.

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Appendices

Appendix A:

Proof of Lemma 1:

First, note that the left hand side of inequality (3) is differentiable and increasing in δ (since $\underline{m} \geq \pi_{NS}$). Furthermore, it goes to infinity as δ approaches 1. Thus, if we prove that the inequality fails to hold at $\delta = \frac{1}{2}$, it would confirm that there exists a $\delta \in (\frac{1}{2}, 1)$ at which (2) holds with strict equality. Evaluating the equation at $\delta = \frac{1}{2}$ and rearranging we get:

$$\frac{1}{2}\alpha \left(\left(\frac{1}{2} - \frac{qf}{\pi_{NS}} \right) \pi_{IS} - \left(\frac{1}{2} + \frac{qf}{\pi_{NS}} \right) \pi_{NS} - 2qf - \pi_L - \underline{m} \right) \geq qf.$$

Rearranging further implies

$$\frac{1}{2}\pi_{IS} + \frac{1}{2}\pi_{NS} - \pi_L - \overline{m} \geq \frac{2qf}{\alpha} + qf + \frac{qf}{\pi_{NS}}\pi_{IS}.$$

First, let us point out that the right hand side of the equation is positive. It is then possible to show that the left hand side of the equation above is in fact negative, which in turn makes the above inequality false and proves that there exists a δ , at which (3) holds with equality. The following result shows that the left hand side of (3) is always negative.

$$\begin{aligned} & \frac{1}{2}\pi_{IS} + \frac{1}{2}\pi_{NS} - \pi_L - \overline{m} = \\ &= \frac{1}{2}D(p_m(\underline{c}))(p_m(\underline{c}) - \underline{c}) + \frac{1}{2}D(p_m(\underline{c}))(p_m(\underline{c}) - \overline{c}) - D(\overline{c})(\overline{c} - \underline{c}) \\ & - D(p_m(\overline{c}))(p_m(\overline{c}) - \overline{c}) < \\ & < \frac{1}{2}D(\overline{c})(2p_m(\underline{c}) - \underline{c} - \overline{c} - \overline{c} + \underline{c}) - D(p_m(\overline{c}))(p_m(\overline{c}) - \overline{c}) - \frac{1}{2}D(\overline{c})(\overline{c} - \underline{c}) = \\ &= D(\overline{c})(p_m(\underline{c}) - \overline{c}) - D(p_m(\overline{c}))(p_m(\overline{c}) - \overline{c}) - \frac{1}{2}D(\overline{c})(\overline{c} - \underline{c}) < 0. \blacksquare \end{aligned}$$

Proof of Proposition 3:

Proof is straightforward, since subsidy variable s is absent from both expression (2) and expression (3). ■

Proof of Proposition 4:

(i) δ^A in (2) unambiguously increases in qf , thus positive expected fines destabilize post-discovery collusion.

(ii) The left hand side of the inequality (3) unambiguously increases in δ and decreases in the expected fine qf . Hence, if we fix the level of the LHS of expression (3) at $\overline{m}$, with larger qf larger δ will be required to sustain the same level of the LHS of (3) in the range of $\delta \in (0,1)$. Hence, δ^B is also increasing in qf and thus destabilizes pre-discovery collusion. ■

Proof of Proposition 5:

Proof: (i) The critical discount factor to sustain collusion after the discovery, δ^R , is described by the inequality (4). It is clear that δ^R is increasing in qf , and thus an increase in expected fine hinders collusion after discovery.

(ii) To prove the same for the case before discovery, note that the left hand side of (5) is increasing in δ and decreasing in qf , since the multiplier of the expected fine $\left(\frac{2-\delta(1-\alpha)}{1-\delta}\right)$ is strictly positive for the entire range of α and δ . Now, if we keep the value of the left hand side fixed at $\frac{\bar{m}}{2}$ and let qf increase, we have to require higher δ to sustain the same level of the LHS. It is thus the case that critical discount factor preceding discovery is increasing in qf . This provides the proof that increase in qf hinders collusion before discovery as well. ■

Proof of Proposition 6:

Proof: (i) After the discovery, firms do not invest in R&D any longer, and do not receive subsidies. Due to the backward induction solution of this game, there is no lingering effect of subsidization when either of the firms has made a discovery. We can see thus that neither s , nor r enter the inequality (4), which proves that subsidies and subsidy differences have no effect on the post discovery collusion stability.

On the other hand, differences in subsidization seem to help to sustain collusion prior the discovery. By examining the inequality (5) we can notice the LHS is strictly increasing in r . The LHS is also strictly increasing in δ , thus for (5) to hold with strict equality δ needs to drop in order to maintain the same levels of the LHS. This concludes the proof that the critical discount factor of RJV prior the discovery is decreasing in r , having facilitating effects for collusion.

(ii) The generic subsidy parameter is absent from both (4) and (5). Hence, subsidies do not affect critical discount factors δ^R and δ^{RC} . We can conclude that subsidies per se do not have an effect on collusion sustainability both prior and after the discovery in the RJV case. ■

Appendix B:

In this appendix we show that with additional subsidies granted to firms if they form RJVs, or without subsidies, firms do not have profitable deviations for $\delta \geq \frac{1}{2}$ prior the discovery. Recall inequality (5) but set antitrust fines to 0, $qf = 0$. Then it can be rewritten as

$$\frac{\delta\alpha}{1-\delta} \frac{\bar{m}}{2} + \frac{\delta(1-\alpha)}{1-\delta(1-\alpha)} \left(\frac{\bar{m}}{2} + \frac{\delta\alpha}{1-\delta} \left(\frac{\bar{m}}{2} - \frac{\pi_L}{2} \right) \right) + kr \left(\frac{1}{1-\delta(1-\alpha)} \right) \geq \frac{\bar{m}}{2}$$

The left hand side is going to infinity as δ approaches 1, so the inequality always holds when $\delta = 1$. Showing that this inequality also holds at $\delta = \frac{1}{2}$ would imply that deviation is not profitable with or without additional subsidies for RJVs in the range $\delta \in \left[\frac{1}{2}, 1\right]$. Evaluating the inequality at $\delta = \frac{1}{2}$

$$\alpha \frac{\bar{m}}{2} + \frac{(1-\alpha)}{2} \left(\frac{\bar{m} + \alpha(\frac{\bar{m}}{2} - \pi_L)}{(1+\alpha)} \right) \geq \frac{\bar{m}}{2} - \frac{2kr}{(1+\alpha)}$$

Now, we can show that $\frac{\bar{m} + \alpha(\underline{m} - \pi_L)}{(1 + \alpha)} > \bar{m}$

$$\frac{\bar{m} + \alpha(\underline{m} - \pi_L) - \bar{m} - \alpha\bar{m}}{(1 + \alpha)} > 0$$

Therefore, if $\underline{m} - \pi_L - \bar{m} > 0$, then $\frac{\bar{m} + \alpha(\underline{m} - \pi_L)}{(1 + \alpha)} > \bar{m}$.

$$\begin{aligned} \underline{m} - \pi_L - \bar{m} &> D(p_m(\underline{c}))(p_m(\underline{c}) - \underline{c}) - D(\bar{c})(\bar{c} - \underline{c}) - D(\bar{c})(p_m(\bar{c}) - \bar{c}) > \\ &= D(p_m(\underline{c}))(p_m(\underline{c}) - \underline{c}) - D(\bar{c})(p_m(\bar{c}) - \underline{c}) > 0 \end{aligned}$$

By obtaining this result, the following holds

$$\alpha \frac{\underline{m}}{2} + \frac{(1 - \alpha)}{2} \left(\frac{\bar{m} + \alpha(\underline{m} - \pi_L)}{(1 + \alpha)} \right) > \alpha \frac{\underline{m}}{2} + (1 - \alpha) \frac{\bar{m}}{2} > \frac{\bar{m}}{2} - \frac{2kr}{(1 + \alpha)}$$

Consequently, firms have no profitable deviations in the RJV case prior discovery for the range of $\delta \in \left[\frac{1}{2}, 1\right]$ both with or without positive additional RJV subsidies.

Appendix C

Through straightforward comparison of payoffs we can come to several conclusions about firm's R&D choices. The first question is will firms be willing to form an RJV if they find themselves in Zone A of Figure 4. In Zone A firms *have* profitable deviations from the collusive agreement and thus it will be a SPNE for them to compete both prior and post discovery, both under the Independent R&D and RJV regimes. The expected profits of competition under Independent R&D are equal to the payoffs of the "punishment" strategy V_P defined before, whereas the RJV competition expected payoffs V_{RZA} (for RJV Zone A) if firms innovate are below or equal 0, since firms are symmetrical both prior and after the collusion. As a result we have

$$\begin{aligned} V_P &= \frac{-k(1 - s) + \frac{\delta\alpha}{2} \left(\frac{\pi_L}{1 - \delta} \right)}{1 - \delta(1 - \alpha)} \\ V_{RZA} &= \frac{-k(1 - s - r)}{1 - \delta(1 - \alpha)} \leq 0 \end{aligned}$$

Therefore, firms will form an RJV in Zone A if $V_P > V_{RZA}$ or will be indifferent if $V_P = V_{RZA}$. Our former assumption stated that costs firms pay for development are low enough so that $V_P > 0$. Let us relax this assumption, since otherwise firms will never form an RJV. Actually, the best a policymaker can do in this case is to make firms indifferent between investing in R&D and forming RJVs by giving full subsidies if firms form an RJV, thus setting $r = (1 - s)$.

Firstly, we can conclude that firms will always be willing to form an RJV if fine enforcement is high enough and cost reduction is high enough (Zone B of Figure 4). If firms are in Zone B, then they can collude only after the discovery. In that case their payoffs V_{RZB} are

$$V_{RZB} = \frac{-k(1 - s - r) + \frac{\delta\alpha}{2} \left(\frac{\underline{m} - qf}{1 - \delta} \right)}{1 - \delta(1 - \alpha)}$$

Firms will be forming an RJV in Zone B if

$$kr + \frac{\delta\alpha}{2} \left(\frac{\underline{m} - qf}{1 - \delta} \right) > \frac{\delta\alpha}{2} \left(\frac{\pi_L}{1 - \delta} \right)$$

If firms find themselves in Zone C of the Figure 4, it is a SPNE for them to collude prior discovery, but set competitive prices after the discovery. In other words, their payoffs of forming an RJV in Zone C are

$$V_{RZC} = \frac{-k(1-s-r) + \frac{\bar{m}}{2} - qf}{1 - \delta(1 - \alpha)}$$

Forming an RJV will be more profitable than innovating independently if $V_{RZC} > V_P$ or if

$$kr + \frac{\bar{m}}{2} - qf > \frac{\delta\alpha}{2} \left(\frac{\pi_L}{1 - \delta} \right)$$

In other words, it will depend on series of parameters such as the discount factor, demand function parameters, probability of success, level of R&D investments and subsidy differences. All else equal, the *higher* are the R&D expenditures and the subsidy differences and the *lower* is the discount rate and probability of success are, the more likely the firms will be to form an RJV if they find themselves in Zone C (Figure 4).

Appendix D:

Brief overview of the EU competition and innovation policies with the focus on cooperative R&D

D.1. Antitrust enforcement and cooperative R&D

The attitude of antitrust authorities to any kind of cooperation between firms was not particularly lenient when they have first started appearing. However, around 1970s and 1980s both the US and European legislators had to change their perspectives on the research partnerships. According to Caloghirou et al. (2003) this was due to several reasons. Firstly, the policy-makers acted driven by the alarm that their home R&D markets would start failing as a result of increasing global competition in the field of hi-tech research, where cooperative agreements were quite abundant. There has been evidence of benefits extracted from such agreements, through the possibility of accessing within-alliance superior technologies and having better opportunities of developing more efficient technologies on their own. In hand with these developments, the general perception of the research partnerships as seen by the policy-makers and analysts has started to shift dramatically. Previously, the research agreements were viewed as mechanisms to support falling industries, while now the view was moving towards supporting them as effective drivers of competition in the *emerging* industries. Such a change was accompanied by the fact that prior 1970s a huge shares of cooperative agreements have been implemented within low-to-medium tech industries, whereas late 1970s have seen the rise of high tech RJV and equity venture formation.

This in turn has served as a stimulus for the governments to create RJV-friendly legal and policy frameworks that would propel the industries to compete on an international level in the hi-tech field. The cooperative R&D has gained political support in both EU countries and the US. The latter have mainly been focusing on introducing stronger patent protection and weakening the antitrust laws in order to promote RJVs. European Union was in general moving in the same direction, with the exception that it had an additional problem to cope with: the huge technological gaps within its borders, or among the member states. As a response to this issue, EU created a pioneering program called ESPRIT to encourage the international (inter-member) cooperation in R&D and public support for pre-competitive cooperative R&D. The ESPRIT program evolved into what we know

today as the Framework Programs for Research and Technological Development. These 4-year (recently the period has been extended) programs encompassed the entire policy bundle through which the EU supports its R&D activities in concrete areas of focus. The following subsection will present the EU research promoting programs in more detail.

D.2. Characteristics of the EU research promoting programs

As already has been mentioned, the EU Framework Programs for Research and Technological Development were established as a response to the emerging competitiveness of the global R&D markets. Indeed, as is stated by the EU Research and Innovation Directorate General, the main aims of the Framework Program are “to strengthen the scientific and technological base of European Industry and to encourage its international competitiveness, while promoting research that supports EU policies”. In its current 7th incarnation, the Framework Program is endowed with a huge budget of Euro 50 billion to promote EU-beneficial research and development. However, it claims not to be constrained entirely to the EU countries, even though the latter enjoy broader rights of obtaining the support. For instance, if Russian or Central Asian states intended to form a research consortium under the support of the FP program, they would need to make sure that enough European Union member states were involved.

The funding is provided on the principle of co-financing, or in other words subsidizing a part of the research costs. The subsidies are given mostly for *collaborative* research, under the condition that all the results are freely available among the participants. The size of the subsidy may vary according to the type of the project undertaken, but the standard reimbursement is set at 50%. Legal entities such as non-profit public organizations, SMEs, research organizations may receive grants of up to 75%. A subsidy of 100% may also be reimbursed for a narrow range of activities, such as consortium management, training coordination, or participation in the “frontier research” programs on the grounds of scientific excellence. The current FP is set to last for 7 years from 2007 until 2013, which is a change in both breadth and scope, since preceding programs have been covering 4 years each with significantly lower funds. The research policy carried out by the FP programs is of a top-down nature, meaning that the companies apply for the grants that are available for specific fields of research chosen by the EU.

Due to the vast budgets of the FPs, they have also been subject to criticism because of their administrative complexity. Marin and Siotis (2008) argue that the tendering procedures that companies applying for the subsidies must undergo are time consuming and burdensome in nature. Furthermore, being an institution to encompass the execution of the entire EU research policy, it also tries to pursue multiple, sometimes inconsistent goals. For instance, the FP programs emphasize the adherence of all the participants’ conduct to EU competition law, and hence subjects many of its granting decisions based on the competition considerations. At the same time the programs try to promote *competitiveness* in the international high technology markets, where big corporations in concentrated industries are more likely to make a stand.

D.3. General EU competition law

The part of the competition policy of the European Union that covers the issues relevant to this paper can be addressed through several major Articles of EC Treaty: Article 101 (ex 81 Treaty of European Communities or TEC) and Article 102 (ex 82 TEC) and their consequent modifications,

which address the horizontal and vertical agreements and the abuse of dominant position by the firms. This subsection aims to summarize the general implications of the legislation with regard to price collusion; therefore, we are mostly interested in the Article 101 and not Article 102, which deals with exclusionary practices and market power abuse.

D.3.1. Block exemption regulations for cooperative R&D

Even though the innovation policy allowing the formation of RJVs was in place since the commencement of the ESPRIT program, the European Commission still had to routinely check through all of the R&D cooperatives for possible anti-competitive effects. It has been a burdensome and inefficient process, since the limited resources had to be disseminated to analyze hundreds of minor cooperative agreements instead of focusing on the most important ones. Amendments to the Block Exemption regulations implemented in the early 2000s have made it easier for the Commission to filter the cooperative R&D agreements. The application of the block exemption implies automatic approval of the agreement and an exemption of the involved agents from anti-competitive concerns for a certain period of time. The changes in the legal framework of the exemptions throughout the years have been towards the liberalization upon the previous regimes (Topping, 2001). According to the most recent regulation No 1217/2010 covering the block exemptions, several notable conditions need to be fulfilled for the agreement to be eligible for the application of the block exemption:

[1] The research and development agreement must stipulate that all the parties have full access to the final results of the joint research and development or paid-for research and development, including any resulting intellectual property rights and know-how. [2] The research and development agreement must stipulate that each party must be granted access to any pre-existing know-how of the other parties, if this know-how is indispensable for the purposes of its exploitation of the results. [3] Any joint exploitation may only pertain to results which are protected by intellectual property rights or constitute know-how and which are indispensable for the manufacture of the contract products or the application of the contract technologies¹⁶.

Where the conditions labeled [1]-[3] correspond directly to factual formation of an RJV, due to the requirement of full information (or R&D outcome) sharing. An additional requirement for the block exemption is the market share threshold, which is currently set at 25%. It implies that the exemption shall apply only to research and development agreements, where the combined market share of the involved parties in the relevant markets shall not exceed 25%. The period of exemption is currently set at the duration of research plus additional 7 years of joint exploitation, meaning that during this period the participants are exempted from the enforcement of Articles 101 and 102. If after the end of this period the combined market share of the parties does not exceed 25%, the block exemption may be extended.

¹⁶ Numbers in squared brackets do not correspond to actual paragraphs of the regulation. Conditions for exemption are covered by Article 2 paragraphs 2-5.

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