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Downstream Research Joint Venture with Upstream Market Power

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Abstract

In this paper, we examine how the structure of an imperfectly competitive input market affects final-good producers' incentives to form a Research Joint Venture (RJV), in a differentiated duopoly where R&D investments exhibit spillovers. Although a RJV is always profitable, downstream firms' incentives for R&D cooperation are non-monotone in the structure of the input market, with incentives being stronger under a monopolistic input supplier, whenever spillovers are low. In contrast to the hold-up argument, we also find that under non-cooperative R&D investments and weak free-riding, final-good producers invest more when facing a monopolistic input supplier, compared with investments under competing vertical chains. Integrated innovation and competition policies are also discussed.

JEL classification: L13; O31

Keywords: Oligopoly; Process Innovations, Research Joint Ventures

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1 Introduction

The critical role of innovation on the competitiveness of firms, industries and national economies has by far been established by academics and recognized by policy-makers. However, Research and Development (R&D hereafter) activities generate knowledge spillovers that may lead to free-riding and underinvestment.[1] In order to overcome these weaknesses, policy-makers and business practitioners moved towards new organizational forms of R&D investments. As Vonortas (1997) notes, Research Joint Ventures (RJV hereafter) were regarded as "the cure for a number of failures in innovation markets" as far as knowledge spillovers are internalized and thus incentives for R&D investments are restored.[2]

The economic literature in the field of RJVs has mainly been inspired by the seminal papers of d' Aspremont and Jacquemin (1988) and Kamien et al. (1992) that have been generalized and extended towards several directions.[3] Caloghirou Ioannides and Vonortas (2003), surveying a great volume of available theory and empirical evidence, conclude on some robust incentives for firms to participate in RJVs: Internalizing R&D spillovers, sharing the cost and avoiding the duplication of R&D activities, having access to complementary resources and skills, exploiting economies of scale and scope, distributing the investment risk to more investors, creating new investment options and promoting technical standards are strong incentives that lead to R&D cooperation.[4]

[1] D' Aspremont and Jacquemin (1988) mention that "R&D externalities or spillovers imply that some benefits of each firm's R&D flow without compensation to other firms and this may cause free-riding behavior and underinvestment problems".

[2] Recent papers establish the growing trend of RJVs. Caloghirou Ioannides and Vonortas (2003), exploring the existing databases (MERIT-CATI, NCRA-RJV, CORE, STEP TO RJV), demonstrate that the number of the new world-wide partnerships set up annually increased from about 30-40 in the early seventies to 100-200 in the late seventies. Starting from around 200 per year, the number of new partnerships announced every year reached around 600 or more in the eighties and nineties. Most partnerships are established between multinational firms from OECD countries and high-tech industries. Hagedoorn and van Kranenburg (2003), exploring the MERIT-CATI databank for the period 1960-1998, confirm a growth pattern in RJVs. Focusing on the EU case, Benfratello and Sembenelli (2002) mention that 1031 RJVs were sponsored under the EUREKA project over the 1985-1996 period and 3874 RJVs were financed under the 3rd and 4th Framework Programs for Science and Technology (FPST) over the 1992-1996 period.

[3] The papers of Suzumura (1992), Ziss (1994), Poyago-Theotoky (1995), Salant and Shaffer (1998) and Katsoulacos and Ulph (1998) have contributed much in the literature. More recent contributions contain the papers of Yi and Shin (2000), Cabral (2002), Miyagiwa and Ohno (2002), Lambertini et al. (2002) and Amir et al. (2003).

[4] The empirical literature for RJVs is growing too. Cassiman and Veugelers (2002), using data from the Community Innovation Survey for the Belgian manufacturing industry in 1993, find that although cost-sharing is an important incentive for cooperation, risk-sharing is not. They also find that the probability of cooperation increases in the size of the firms and when incoming spillovers are high while outgoing spillovers are low. Benfratello and Sembenelli (2002), find that firms participating in the EUREKA program over the 1985–1996 period have experienced a significant improvement in their "adjusted" performance measures between the "pre" and the "post" period. Labor productivity and price cost margins for participating firms show a lower than average in the pre-period but a higher than average performance in the post-period. Hernan et al. (2003), find that the probability of forming a RJV, under

Although the research on RJVs is growing, formal models have focused on horizontal settings, assuming that the firms that form a RJV buy their inputs from perfectly competitive input markets. The purpose of this paper is to investigate the effects of an imperfectly competitive input market where input suppliers do have market power and extract rents. Regarding a two-tier market structure, where downstream firms, that undertake R&D investments, buy inputs from input suppliers that capture mark-up rents, issues from the "hold-up" literature have to be taken into account.[5] In this setting, cost-reducing innovations by downstream firms increase the demand for the final good and subsequently, the demand for the inputs sold by suppliers also increases. Thus, suppliers increase the price that they charge and the stronger the suppliers' market power, the higher the rents that they capture and the lower the downstream firms' profits and returns on R&D investments. Downstream firms know this ex ante and as a result they invest low amounts in R&D.

In this vertical framework, we address the following questions: Firstly, "how does the structure of the input market affect downstreams' incentives to form a RJV?" and secondly, "how does the coexistence of R&D spillovers and suppliers' rent-extracting affect downstreams' amounts invested in case of non-cooperative and cooperative R&D investments?"

In order to answer these questions, we consider a two-tier market structure consisting of two downstream firms - final-good producers while the upstream industry can be either duopolistic or monopolistic. For the duopolistic case, we follow the *competing vertical chains regime*, where each downstream firm has an exclusive relationship with one of the two upstream firms. In the monopolistic case, there is a *common input supplier* for both downstream firms. Downstream firms, endowed with symmetric technologies, produce a differentiated final-good and invest in R&D for cost-reducing process innovations. Firms may invest either non-cooperatively, or by forming a RJV, while R&D activities exhibit spillovers.

The present paper contributes to the literature in several ways. First of all, it is found that downstream firms' incentives to form a RJV are non-monotone in the structure of the input market. Although a RJV is always profit-enhancing

the EUREKA and EU Framework Programmes, is influenced positively by sectoral R&D intensity, industry concentration, firm size, technological spillovers and past RJV participation. Caloghirou, Hondroyiannis and Vonortas (2003), investigating data from the STEP TO RJVs databank, suggest that partnership success depends significantly on the closeness of the cooperative research to the in-house R&D effort of the firm, on the firm's effort to learn from the partnership and its partners and on the absence of problems of knowledge appropriation between partners. Moreover, they find that firms use partnerships as vehicles of risk and uncertainty reduction by collaborating with competitors and suppliers. Finally, Belderbos et al. (2004), using data from the Community Innovation Survey for the Netherlands during 1996-1998, examine the determinants of innovating firms' decisions to establish cooperation with competitors (horizontal), suppliers or customers (vertical) and with universities and research institutes (institutional cooperation). They find that incoming spillovers from universities and research institutes stimulate cooperation of all types. Risk, organizational constraints in the firm's innovation process and firm size have a positive impact on all four types of cooperation, while R&D intensity has a positive impact on vertical and institutional cooperation.

[5] See Banerjee and Lin (2003) and the references therein.

for downstream firms, whether the input supplier(s) extract(s) rents from the downstream firms depends on the structure of the input market, the degree of spillovers that are internalized under the RJV and the degree of product differentiation. Whenever internalized spillovers are *low,* the efficiency of the RJV is fully exploited by the final-good producers and no efficiency is transferred to the upstream market, only if downstream firms face a monopolistic input supplier. Thus, downstreams' incentives for a RJV are stronger in case of a single supplier, compared with incentives under competing vertical chains. Whenever internalized spillovers are *high,* the single supplier captures higher rents than suppliers under competing vertical chains do and thus, incentives for a RJV are stronger in case of competing vertical chains. The analysis also reveals that the more homogeneous the products are, the higher the spillovers that must be internalized under the RJV in order incentives under a single supplier to be stronger than incentives under a duopolistic input market.

In the second part of the paper we restrict our attention on the amounts invested in R&D. The present paper is among the first in the theoretical R&D literature that incorporates R&D spillovers into a vertical setting. In contrast to the hold-up argument, the analysis reveals that whenever firms invest non-cooperatively, investments are higher under a monopolistic supplier, compared with investments under competing vertical chains, if the free-riding is not intense. We argue that it is the combination of the low spillovers, that favor, and the single supplier's strong pressure, that forces, downstream firms to increase R&D investments. This result contradicts with the conventional argument, which indicates that, the stronger the rent-extracting that downstream firms face, the lower the amounts that they invest per se. In case of a RJV, investments are higher under competing vertical chains. In this case, downstreams invest cooperatively, avoid the free-riding and internalize the spillovers. As a result, there is no strategic interactions between firms in the investments stage. As far as a single supplier always extracts a higher input price it discourages downstreams' R&D investments. We argue that the effect of the input market structure on R&D investments depends on whether spillovers lead to free-riding or being internalized. We also find that the critical spillover rate increases as products become more homogeneous, indicating that the fiercer the competition becomes, the higher the spillovers that firms must internalize in order the RJV to be investment enhancing.

The welfare analysis suggests that a single supplier depresses social welfare under both non-cooperative and cooperative R&D investments. In addition to that, the minimum internalized spillovers in order the regulator to approve the RJV are lower under the competing vertical chains regime, compared with the single supplier regime, for every degree of product differentiation. These results underline that a single supplier hinders the transfer of the efficiency created by a RJV to consumers. Existing literature on RJVs, assuming perfectly competitive input markets, suggests that if spillovers exceed a critical level, a RJV results in enhanced social welfare and thus, cooperation will be preferable from the regulator's point of view. This paper contributes to the relevant literature as we prove that the regulator, when deciding to approve or not the formation

of a RJV, should also take into account the structure of the input market. Policy-implications contain the encouragement of RJVs and the institution of antitrust enforcement for the input markets of R&D intensive industries. This combination of innovation and competition policies leads to the more preferable outcomes in terms of social welfare.

We are aware of two papers that study downstream firms R&D investments in two-tier vertically related industries. However, the questions addressed in these papers differ from ours. Attalah (2002) considers two vertically related duopolistic industries, with horizontal spillovers within each industry and vertical spillovers between the two industries. All firms can engage in cost-reducing R&D activities. In the first stage of the game all firms decide on their R&D simultaneously, while in the second and the third stage, suppliers and final-good producers compete in quantities respectively. He studies four different schemes of R&D investments: *No cooperation*, *intraindustry cooperation* only, *interindustry cooperation* only and *simultaneous interindustry and intraindustry cooperation*. Cooperative settings are compared in terms of R&D solely. The comparison shows that no setting uniformly dominates the others, while the type of cooperation that yields more R&D depends on horizontal and vertical spillovers, and market structure.[6] Although we examine the case of horizontal cooperation solely, the present paper departs from Attalah (2002) and Ishii (2004) in several ways. First of all, they examine only the case of an upstream duopoly, while in the present paper, the case of a single supplier is also examined. Thus, we gauge the antitrust issues of different input market structures. In addition to that, Attalah (2002) and Ishii (2004) consider that input suppliers compete in input quantities. However, in our model suppliers set input prices. By doing so, the effects of supplier rent-extracting behavior is also taken into account. Thirdly, both of the above papers focus on R&D investments, while no attention is given in firms' incentives to cooperate between different types of organization modes of R&D.

The rest of the paper is organized as follows: In section 2 we present the model and in sections 3 we examine final-good producers' incentives to form a RJV. In section 4 the attention is restricted on R&D investment levels and in section 5 we carry out a welfare analysis and present policy implications. In section 6 some extensions of the basic model are discussed and finally, section 7 concludes.

[6] In an identical setup and sequence of decisions, Ishii (2004) extends the analysis of Attalah. Ishii (2004), following the taxonomy of Kamien et al. (1992), considers input R&D spillovers rather than output spillovers considered by Attalah (2002). He compares R&D investments under four vertical R&D organization modes: Non-cooperative R&D, vertical R&D cartels, vertical non-cooperative RJVs, and vertical RJV cartels. He finds that vertical R&D cartels attain a higher technological improvement and a larger social welfare than non-cooperative R&D and that vertical R&D cartels yield a larger social welfare than horizontal R&D cartels if the horizontal spillover rate between upstream firms is not sufficiently high.

2 The model

We consider a two-tier industry. There are two downstream firms, final-good producers, while the input market can be either duopolistic or monopolistic. The structure of the input market is assumed to be exogenously given. In case of a duopolistic input market, we follow the *competing vertical chains* regime (CV): Each downstream firm has an exclusive relationship with one of the two upstream firms and buys its input only from that particular upstream firm. In the monopolistic case, there is a *single supplier* (S) for both downstream firms. We also assume that the production cost for the supplier(s) is normalized to zero and that supplier(s) unilaterally set(s) the price w of the input that is sold to final-good producers.[7]

Each downstream firm, denoted by $i, j = 1, 2, i \neq j$, produces a differentiated final good (goods 1 and 2 respectively) and the inverse demand for that good is linear: $P_i = \alpha - q_i - \gamma q_j$. The parameter $\gamma \in [0, 1]$ is a measure of substitutability in demand. If $\gamma \to 0$ the goods are regarded as (almost) unrelated, whereas $\gamma \to 1$ corresponds to the case of (almost) homogeneous goods. Each downstream firm produces its final-good with a fixed-coefficient technology -one unit of final product requires exactly one unit of the input- and the marginal cost of transforming the input into the final-good is c. We further consider that firm i can invest in R&D for cost-reducing process innovations. The overall marginal cost of transforming inputs into the final-good is given by $w_i + c - y_i - \delta y_j$. y_i is the cost reduction due to firm i's R&D investment, while y_j is the benefits that leak from firm j to firm i without compensation, due to the spillovers of R&D activities. δ is the spillover rate, indicating the R&D externalities, with $0 \leq \delta \leq 1$. Following d' Aspremont and Jacquemin (1988), we assume that spillovers are exogenous and industry-wide. The cost of R&D is $\frac{1}{2}ky_i^2$, reflecting the existence of diminishing returns to R&D expenditures. Parameter k captures the relative effectiveness of R&D.[8] Thus, downstream firm i has a total cost function, $C_i = (w_i + c - y_i - \delta y_j)\, q_i - \frac{1}{2}y_i^2, i, j = 1, 2, i \neq j$.

We consider that in this industry, R&D can be carried out under two alternative organizational forms:

I. Non-cooperatively, where downstream firms carry out their R&D activities strategically. Formally speaking, firms act non-cooperatively in both R&D and output stage.

II. Cooperatively, where the downstream firms form a RJV and each enjoys the common R&D output. In this case, firms coordinate their activities so as to maximize their joint profits in the R&D stage. Under a RJV, although firms internalize spillovers and avoid free-riding, duplication of effort is not eliminated.[9]

In order to answer the questions addressed above, we consider a four stage game with the following timing:

[7] In section 6.2 we allow for bargaining over the input price.

[8] $k \geq 1$ guarantees that the second order conditions are satisfied. For simplicity, we assume that $k = 1$.

[9] In section 6.3 we examine the case where firms invest cooperatively in one common lab.

Stage 1: Downstream firms decide simultaneously, whether to invest in R&D non-cooperatively (nc) or to form a RJV (c).

Stage 2: Downstream firms invest in R&D.

Stage 3: Upstream firm(s) set(s) input price.

Stage 4: Downstream firms set quantities of the final-good.

We solve the game using Backwards Induction, in order to define the Subgame Nash Perfect Equilibrium (SPNE).

3 Incentives to form a Research Joint Venture[10]

3.1 The case of Competing Vertical Chains

We begin our analysis by examining the case where downstream firms invest in R&D non-cooperatively (denoted by nc) .[11] In the last stage of the game, downstreams compete in a Cournot fashion, so as to maximize their profits:

$$\Pi_i\left(q_i, q_j, w_i, y_i, y_j, \delta\right) = \left(a - q_i - \gamma q_j\right) q_i - \left(w_i + c - y_i - \delta y_j\right) q_i - \frac{1}{2} y_i^2 \quad (1)$$

Solving the first order conditions of eq. (1), we compute the Nash-Cournot quantity levels:[12]

$$q_i^* = \frac{\left[(2-\gamma)(a-c) - 2w_i + \gamma w_j + y_i(2-\gamma\delta) + y_j(2\delta-\gamma)\right]}{4-\gamma^2} \quad (2)$$

q_i^* decreases in w_i and increases in w_j. Note also that q_i^* increases not only with firm i's R&D investment but with firm j's as well, indicating the positive spillover effect of R&D on the final-good quantity. For $\gamma \in [0,1]$ and $\delta \in [0,1]$, firm i's R&D investment has larger impact on its output than j's R&D impact has, as $2 - \gamma\delta > 2\delta - \gamma$ always holds. In the case of perfect spillovers ($\delta = 1$), firm i's and j's R&D investments have equal impact on each firm's output.

Given q_i^* and q_j^*, in the third stage of the game input suppliers set input prices simultaneously and non-cooperatively so as each supplier to maximize its profits:

$$\pi_i = q_i^* w_i \quad (3)$$

Thus, each supplier charges an input price equal to:

$$w_i = \frac{\left[\left(\gamma^2 + 2\gamma - 8\right)(a-c) + y_i\left(\gamma^2 + 2\gamma\delta - 8\right) + y_j\left(2\gamma + \gamma^2\delta - 8\delta\right)\right]}{\gamma^2 - 16} \quad (4)$$

[10] Our benchmark is the paper of d' Aspremond and Jacquemin (1988), who consider a perfectly competitive input market. In this benchmark case, they find that a RJV increases investments if $\delta > 0.5$, while it is always profitable for downstream firms, regardless the magnitude of spillovers.

[11] This can be the case where an antitrust law forbids the formation of RJVs among competitors in order to deter a possible cartel in the market of the final good.

[12] We assume that $c \leq a$.

In the second stage of the game, downstream firms set non-cooperatively their R&D investments (y_1, y_2) in order to maximize their profits:

$$\underset{y_i}{Max}\Pi_i = \frac{4\left[\left(\gamma^2+2\gamma-8\right)(a-c)+y_i\left(\gamma^2+2\gamma\delta-8\right)+y_j\left(\gamma^2\delta+2\gamma-8\delta\right)\right]^2}{\left(64-20\gamma+\gamma^4\right)^2}-\frac{1}{2}y_i^2 \tag{5}$$

Solving eq. (5), the symmetric R&D investment in equilibrium is:

$$y_{inc}^{CV*} = \frac{8\left(\gamma^2+2\gamma\delta-8\right)(a-c)}{A_1} \tag{6}$$

where $A_1 = 40\gamma^3-28\gamma^4-2\gamma^5+\gamma^6-8\gamma^2(\delta-27)+64(\delta-7)-16\gamma\left(8+\delta+\delta^2\right)$.

Using eq. (1)-(6), equilibrium total R&D investment $\left(Y_{nc}^{CV} = y_1^* + y_2^*\right)$, final-good quantity $\left(Q_{nc}^{CV}\right)$, downstream firm i's profits $\left(\Pi_{inc}^{CV}\right)$ and each upstream's profits $\left(\pi_{inc}^{CV}\right)$, are given by:

$$Y_{nc}^{CV} = \frac{16\left(\gamma^2+2\gamma\delta-8\right)(a-c)}{A_1} \tag{7}$$

$$Q_{nc}^{CV} = \frac{4\left(-\gamma^4+20\gamma^2-64\right)(a-c)}{A_1} \tag{8}$$

$$\Pi_{inc}^{CV} = \frac{\left[\gamma^4\left(520-40\gamma^2+\gamma^4\right)+256\gamma\delta-23\gamma^3\delta-32\gamma^2\left(76+\gamma^2\right)+3584\right](a-c)^2}{\left(A_1\right)^2} \tag{9}$$

$$\pi_{inc}^{CV} = \frac{-2\left(\gamma^2-16\right)^2\left(\gamma^2-4\right)^3(a-c)^2}{\left(A_1\right)^2} \tag{10}$$

Qualitative analysis of the results in equilibrium indicates that, as far as downstream firms invest non-cooperatively and spillovers lead to free-riding, R&D investments and final-good quantity decrease in spillovers ($\frac{dY_{inc}^{CV}}{d\delta} < 0$ and $\frac{dq_{inc}^{CV}}{d\delta} < 0$). However, downstream and input suppliers' profits increase in spillovers ($\frac{d\Pi_{inc}^{CV}}{d\delta} > 0$ and $\frac{d\pi_{inc}^{CV}}{d\delta} > 0$), because increases in the spillovers that leak from firm j to firm i, decrease i's marginal cost. Finally, downstream and input suppliers' profits decrease in the degree of product differentiation $\left(\frac{d\Pi_{inc}^{CV}}{d\gamma} < 0 \text{ and } \frac{d\pi_{inc}^{CV}}{d\gamma} < 0\right)$, because the more homogeneous that products are, the fiercer the competition, and as a result, final-good producers' and input suppliers' profits decrease.

Let us now examine the case where downstream firms form a RJV under competing vertical chains. In the last stage of the game, output is given by eq. (2) and in the third stage input suppliers charge a price given by eq. (4). In the second stage of the game downstream firms invest cooperatively in R&D so as to maximize their joint profits:

$$\underset{y_i,y_j}{Max}\Pi = \frac{4\left[\left(\gamma^2+2\gamma-8\right)(a-c)+y_i\left(\gamma^2+2\gamma\delta-8\right)+y_j\left(\gamma^2\delta+2\gamma-8\delta\right)\right]^2}{\left(64-20\gamma+\gamma^4\right)^2} + \frac{4\left[\left(\gamma^2+2\gamma-8\right)(a-c)+y_i\left(\gamma^2\delta+2\gamma-8\delta\right)+y_j\left(\gamma^2+2\gamma\delta-8\right)\right]^2}{\left(64-20\gamma+\gamma^4\right)^2} - \frac{1}{2}y_i - \frac{1}{2}y_i \tag{11}$$

In equilibrium, the symmetric R&D investment is given by:

$$y_{ic}^{CV*} = \frac{8(1+\delta)(a-c)}{32\gamma-12\gamma^2-4\gamma^3+\gamma^4-8\left(7+2\delta+\delta^2\right)} \tag{12}$$

We set $A_2 = 32\gamma-12\gamma^2-4\gamma^3+\gamma^4-8\left(-7+2\delta+\delta^2\right)$ and it is found that results in equilibrium are given by:

$$Y_c^{CV} = \frac{16(1+\delta)(a-c)}{A_2} \tag{13}$$

$$Q_c^{CV} = \frac{4\left(-\gamma^2+2\gamma+8\right)(a-c)}{A_2} \tag{14}$$

$$\Pi_{ic}^{CV} = \frac{4(a-c)^2}{A_2} \tag{15}$$

$$\pi_{ic}^{CV} = \frac{2\left(\gamma^2-4\right)(\gamma-2)^4(a-c)^2}{(A_2)^2} \tag{16}$$

R&D investments, total output, upstream and downstream profits increase in δ, as far as spillovers are internalized. Moreover, the comparative positive effect of spillovers on upstream and downstream profits in the case of a RJV is higher than the corresponding negative in case of strategic investments, due to spillovers' internalization (that is, $\left|\frac{d\Pi_{ic}^{CV}}{d\delta}\right| > \left|\frac{d\Pi_{inc}^{CV}}{d\delta}\right|$ and $\left|\frac{d\pi_{ic}^{CV}}{d\delta}\right| > \left|\frac{d\pi_{inc}^{CV}}{d\delta}\right|$ always hold). Results for the role of γ are identical with the corresponding in the non-cooperative case.

Now, consider that the formation of a RJVs is permitted. Do final-good producers have incentives (I^{CV}) to form a RJV under competing vertical chains? Thus, we investigate downstream firms' strategies in the first stage of the game and we answer the first question addressed in the introduction of this paper. Downstream firm i has incentives to cooperate in R&D with firm j if each firm's profits under the RJV are higher than profits under non-cooperation ($I^{CV} = \Pi_{ic}^{CV} - \Pi_{inc}^{CV} > 0$). We state our findings in the following proposition:

Proposition 1 *(i)Downstream firms have incentives to form a RJV under competing vertical chains. (ii) R&D investments, input price, upstream profits and*

final-good quantities are higher under a RJV, if $\delta > \widehat{\delta}_{CV}(\gamma)$ *with* $\frac{d\widehat{\delta}_{CV}(\gamma)}{d\gamma} > 0$ *and* $\widehat{\delta}_{CV}(0) = 0$ *(*$\widehat{\delta}_{CV}(1) = 0.29$*).*

Intuitively, firm i's profits increase in spillovers in case of non-cooperation $\left(\frac{d\Pi_{inc}^{CV}}{d\delta} > 0\right)$and under a RJV $\left(\frac{d\Pi_{ic}^{CV}}{d\delta} > 0\right)$ too. However, $\frac{d\Pi_{ic}^{CV}}{d\delta} > \frac{d\Pi_{inc}^{CV}}{d\delta}$ because $\frac{dy_{ic}^{CV}}{d\delta} > 0$, while $\frac{dy_{inc}^{CV}}{d\delta} < 0$ and as a result, decreases in marginal cost under a RJV are higher than the corresponding decreases in case of non-cooperation. We further find that R&D investments are higher under a RJV, if spillovers exceed a critical rate (δ_{CV}). In case of non-cooperation, free-riding discourages firms to invest in R&D and $\frac{dy_{inc}^{CV}}{d\delta} < 0$. On the contrary, by forming a RJV, firms internalize spillovers and as a result, R&D investments increase $\left(\frac{dy_{ic}^{CV}}{d\delta} > 0\right)$.[13] Results for investments are presented in figure 1a. Note that δ_{CV} increases from 0 to 0.29, as products become more homogeneous ($\gamma \to 1$), indicating that the fiercer the competition becomes, the higher the spillovers that firms must internalize in order the RJV to be investment enhancing. According to upstream profits, as marginal cost and the price of the final-good decrease, the demand of the final-good increases. Subsequently, the demand for inputs increases, suppliers increase the input price that they charge and their profits increase too.

3.2 The case of a Single Supplier

Let us now examine the case where final-good producers face a single supplier (S). In the last stage of the game they compete in quantities trying to maximize their profits:

$$\Pi_i(q_i, q_j, w_i, y_i, y_j, \delta) = (a - q_i - \gamma q_j)\, q_i - (w_i + c - y_i - \delta y_j)\, q_i - \frac{1}{2} y_i^2 \quad (17)$$

Solving first order conditions of eq. (17), the Nash-Cournot quantity level is given by:

$$q_i^* = \frac{(a-c)(2-\gamma) + (\gamma - 2)\, w + y_i (2 - \gamma\delta) + y_j (2\delta - \gamma)}{4 - \gamma^2} \quad (18)$$

In the third stage, the monopolistic supplier maximizes:

$$\pi = \left(q_i^* + q_j^*\right) w \quad (19)$$

by setting the input price, equal to:

$$w = \frac{1}{4}\left[2(a-c) + (y_i + y_j)(1+\delta)\right] \quad (20)$$

Input price increases in firm i's and firm j's R&D investments, due to the R&D spillover effects.

[13] The same critical spillover rate holds for input price, upstream profits and final-good quantities.

In the second stage of the game, downstream firms set simultaneously their R&D investments so as each firm to maximize its profits:

$$\underset{y_i}{Max}\Pi_i = \frac{\left[2\left(2-\gamma\right)\left(a-c\right)+y_i\left(6+\gamma-2\delta-3\gamma\delta\right)+y_j\left(-2-3\gamma+6\delta+\gamma\delta\right)\right]^2}{16\left(\gamma^2-4\right)^2}-\frac{1}{2}y_i^2 \tag{21}$$

Solving eq. (21), the optimal non-cooperative R&D investment level for firm i is given by:

$$y_{inc}^{S*} = \frac{\left(-6-\gamma+2\delta+3\gamma\delta\right)\left(a-c\right)}{A_3} \tag{22}$$

where $A_3 = 8\gamma^2+4\gamma^3-2\left(13-2\delta+\delta^2\right)-\gamma\left(15+2\delta+3\delta^2\right)$. Subsequently, equilibrium outcomes are given by:

$$Y_{nc}^{S} = \frac{2\left(-6-\gamma+2\delta+3\gamma\delta\right)\left(a-c\right)}{A_3} \tag{23}$$

$$Q_{nc}^{S} = \frac{\left(4\gamma^2-16\right)\left(a-c\right)}{A_3} \tag{24}$$

$$\Pi_{inc}^{S} = \frac{\left[8\left(\gamma^2-4\right)^2-\left(6+\gamma-2\delta-3\gamma\delta\right)^3\right]\left(a-c\right)^2}{\left(A_3\right)^2} \tag{25}$$

$$\pi_{nc}^{S} = \frac{8\left(\gamma-2\right)^2\left(\gamma+2\right)^3\left(a-c\right)^2}{\left(A_3\right)^2} \tag{26}$$

Qualitative analysis for the role of γ and δ reveals that the results obtained in the case of non-cooperative R&D, under competing vertical chains, hold under a single supplier as well.

We now solve for the case where downstream firms form a RJV while facing a single supplier (S). Output in the last stage is given by eq. (18) and in the third stage the single supplier charges an input price given by eq. (20). Downstream firms invest in R&D so as to maximize their joint profits:

$$\begin{aligned}\underset{y_i,y_j}{Max}\Pi \quad = \quad & \frac{\left[2\left(2-\gamma\right)\left(a-c\right)+y_i\left(6+\gamma-2\delta-3\gamma\delta\right)+y_j\left(-2-3\gamma+6\delta+\gamma\delta\right)\right]^2}{16\left(\gamma^2-4\right)^2} \\ & \frac{\left[2\left(2-\gamma\right)\left(a-c\right)+y_j\left(6+\gamma-2\delta-3\gamma\delta\right)+y_i\left(-2-3\gamma+6\delta+\gamma\delta\right)\right]^2}{16\left(\gamma^2-4\right)^2} \\ & -\frac{1}{2}y_i-\frac{1}{2}y_j \end{aligned} \tag{27}$$

The optimal firm i's R&D investment in case of a RJV is:

$$y_{ic}^{S*} = \frac{\left(4+2\gamma\right)\left(a-c\right)}{7+8\gamma+2\gamma^2-2\delta-\delta^2} \tag{28}$$

Setting $A_4 = 7 + 8\gamma + 2\gamma^2 - 2\delta - \delta^2$, it is found that results in equilibrium are as follows:

$$Y_c^S = \frac{(8+4\gamma)(a-c)}{A_4} \tag{29}$$

$$Q_c^S = \frac{(2\gamma+4)(a-c)}{A_4} \tag{30}$$

$$\Pi_{ic}^S = \frac{(a-c)^2}{2A_4} \tag{31}$$

$$\pi_c^S = \frac{\left(31 + 40\gamma + 16\gamma^2 + 2\gamma^3 - 2\delta - \delta^2\right)(a-c)^2}{(A_4)^2} \tag{32}$$

The effects of γ and δ on equilibrium outcomes reached for the case of RJV under competing vertical chains, hold for the present case as well. Note also that $\left|\frac{d\Pi_{ic}^S}{d\delta}\right| > \left|\frac{d\Pi_{inc}^S}{d\delta}\right|$ and $\left|\frac{d\pi_{ic}^S}{d\delta}\right| > \left|\frac{d\pi_{inc}^S}{d\delta}\right|$ always hold. Investigating downstream firms' incentives to form a RJV ($I^S = \Pi_{ic}^S - \Pi_{inc}^S$) when facing a single supplier, we state the following proposition:

Proposition 2 *(i)Downstream firms have incentives to form a RJV under a single supplier. (ii) R&D investments, input price, upstream profits and final-good quantities are higher under a RJV, if* $\delta > \widehat{\delta}_S(\gamma)$ *with* $\frac{d\widehat{\delta}_S(\gamma)}{d\gamma} > 0$ *and* $\widehat{\delta}_S(0.33) = 0$ *(*$\widehat{\delta}_S(1) = 0.72$*).*

The intuition behind these results goes precisely as in the case of competing vertical chains and the results for investments are presented in figure 1b. However, a novel argument is that the critical spillover rate $\delta_S(\gamma)$ is higher than $\delta_{CV}(\gamma)$ for every degree of product differentiation, with $\delta_S(\gamma)$ increasing from 0.33 to 0.72, as $\gamma \to 1$. The reason for that lays on the comparative shift of investments and the subsequent point of intersection of the R&D investment curves. If firms invest non-cooperatively, as spillovers increase and the free-riding effect becomes stronger, the decreasing rate of investment in case of a single supplier exceeds the corresponding under competing vertical chains $\left(\left|\frac{dy_{inc}^S}{d\delta}\right| > \left|\frac{dy_{inc}^{CV}}{d\delta}\right|\right)$. Thus, R&D investments in case of a single supplier are more steep in δ than investments under competing vertical chains. On the contrary, under a RJV, as spillovers increase, the increasing rate of investment under competing vertical chains exceeds the corresponding under a single supplier. $\left(\left|\frac{dy_{ic}^{CV}}{d\delta}\right| > \left|\frac{dy_{ic}^S}{d\delta}\right|\right)$. Thus, the point of intersection between y_{inc}^{CV} and y_{ic}^{CV} lays on the left of the point of intersection between y_{inc}^S and y_{ic}^S.

The analysis reveals that a single supplier increases the minimum spillovers that must be internalized in order the RJV to enhance investments and final-good quantity. Therefore, we argue that a single supplier hinders the transfer of the efficiency created by a RJV to consumers.

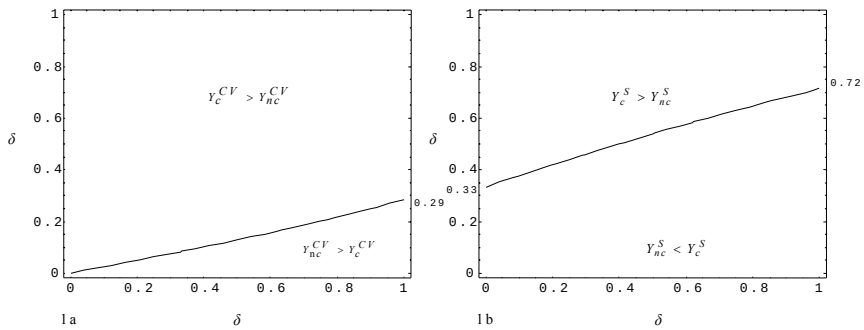

Figure 1: 1a: R&D investments under competing vertical chains in case of non-cooperation $\left(Y_{nc}^{CV}\right)$ and under a RJV $\left(Y_{nc}^{S}\right)$. 2b: R&D investments under a single supplier in case of non-cooperation $\left(Y_{nc}^{CV}\right)$ and under a RJV $\left(Y_{nc}^{S}\right)$.

3.3 Comparing firms' incentives to form a Research Joint Venture

The previous analysis suggests that final-good producers do have incentives to form a RJV in case of competing vertical chains and under a single supplier too. In order to examine how does the structure of the input market affect downstreams' incentives to form a RJV, we compare the magnitude of the incentives under competing vertical chains $\left(I^{CV}\right)$ with the corresponding in case of a single supplier $\left(I^{S}\right)$. We state the following proposition:

Proposition 3 *Downstream firms incentives to form a Research Joint Venture are stronger under a single supplier compared with incentives under competing vertical chains, if* $\delta < \widehat{\delta}(\gamma)$ *with* $\frac{d\widehat{\delta}}{d\gamma} > 0$, $\widehat{\delta}(0) = 0.24$ *and* $\widehat{\delta}(1) = 0.55$.

Results are presented in figure 2. Interestingly, it is found that although a RJV is always profitable for downstream firms, their incentives to form a RJV are non-monotone in the structure of the input market. The intuition behind this result goes as follows: A RJV is always profit-enhancing for downstream firms. However, whether the input supplier(s) extract(s) part of the increased downstream firms' profits due to the RJV, depends on the structure of the input market, the degree of spillovers that are internalized under the RJV and the degree of product differentiation.

Assume first that products are perfect substitutes ($\gamma = 1$). Whenever internalized spillovers are *low* ($\delta < 0.55$), the RJV increases downstreams' profits. In case of a duopolistic input market, in order upstreams' profits to increase, the magnitude of the internalized spillovers must be $\delta > 0.29$. Only in this case, part of the efficiency created by the RJV is captured by the input suppliers. In case of a monopolistic input market, the RJV never increases the single supplier's profits. The efficiency of the RJV is fully exploited by the downstream

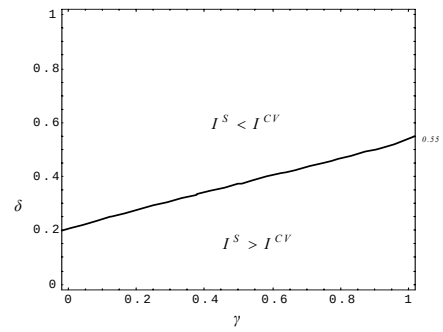

Figure 2: Downstream firms incentives to form a RJV under competing vertical chains $\left(I^{CV}\right)$ and a single supplier $\left(I^{S}\right)$.

firms and no efficiency is transferred to the monopolistic input supplier. As a result, if internalized spillovers are *low,* downstreams' incentives to form a RJV are stronger compared with the incentives under a duopolistic input market $\left(I^{S} > I^{CV}\right)$.

Assume now that the magnitude of spillovers that are internalized under the RJV is *high* ($\delta > 0.55$). In case of competing vertical chains, a RJV always increases downstreams' and input suppliers' profits, suggesting that part of the RJV's efficiency is exploited by the input suppliers. In contrast to that, under a monopolistic upstream market, the supplier exploits higher profits only if the magnitude of the internalized spillovers is $\delta > 0.72$. But, as far as the profits that the monopolistic supplier captures are higher than the profits that each supplier in competing vertical chains does, downstreams' incentives to form a RJV are weakened, with $I^{CV} > I^{S}$.

Incorporating the product differentiation parameter and assuming that products can not be perfect substitutes, that is $\gamma \in [0, 1)$, we state the following result: In order the downstream firms' incentives for a RJV under a single supplier to be stronger than incentives under a duopolistic input market, the minimum internalized spillovers under the RJV should increase the more homogeneous the products become, that is $\gamma \to 1$. This result suggests that the more homogeneous the products are, the more fierce the competition between the final-good producers' becomes and subsequently, the higher the spillovers that must be internalized under the RJV in order incentives under a single supplier to be stronger than incentives under a duopolistic input market. Observe in figure 2 that $\frac{d\widehat{\delta}}{d\gamma} > 0$,with $\widehat{\delta}(0) = 0.24$ and $\widehat{\delta}(1) = 0.55$.

4 Investments in R&D

In this part of the paper, the attention is restricted on the amounts invested in R&D. We examine how the coexistence of upstream rent-extracting and spillovers of R&D activities affects investments under different vertical relations regimes, in case of non-cooperative and cooperative R&D. The present paper is among the first in the theoretical R&D literature that incorporates R&D spillovers into a vertical setting.

4.1 The case of non-cooperation

Let us begin the analysis with the case of non-cooperative R&D investments. Total R&D investment under competing vertical chains is given by eq. (7), and the corresponding under a single supplier is given by eq. (23). Comparing these, we state the following proposition:

Proposition 4 *R&D investments are higher under a single supplier, compared with the corresponding under competing vertical chains, if* $\delta < \widehat{\delta}(\gamma)$ *with* $\frac{d\widehat{\delta}}{d\gamma} < 0$, $\widehat{\delta}(0) = 1$ *and* $\widehat{\delta}(1) = 0.55$.

This result contradicts with the conventional argument which predicts that investments under a single supplier should be lower, as far as a single supplier extracts higher rents. The intuition behind the result goes as follows: When downstream firms invest in R&D non-cooperatively, investments depend on the *free-riding effect* and the *supplier rent-extracting effect*. In case of no free-riding ($\delta = 0$), investments under a single supplier are higher than investments under competing vertical chains ($Y^s > Y^{cv}$). Although a single supplier extracts higher rents $\left(\pi_{nc}^S > \pi_{inc}^{CV} \text{ always hold}\right)$, its comparative stronger pressure increases R&D investments, rather than to decrease them. As free-riding arises, ($\delta > 0$), only if it is weak ($\delta < \delta^*$) the single supplier pressure's effect overcomes the negative effect of free-riding and thus $Y^s > Y^{cv}$. We argue that when competition is fierce, in terms that downstream firms behave strategically in both R&D and output stages, the stronger single supplier's pressure increases R&D investments, if free-riding is weak. It is the combination of low spillovers, that favor, and single supplier's strong pressure, that forces, downstream firms to increase R&D investments.

Observe in figure 3a the inverse relation between the critical spillover rate δ^* and the degree of product differentiation. The more unrelated the products are, that is $\gamma \to 0$, the higher the profits that downstream firms capture and subsequently, the negative effect of free-riding must be very intense (high values of δ) to offset the single supplier's stronger pressure. In case of unrelated goods ($\gamma = 0$) free-riding has no effect and $Y^s > Y^{cv}$, while in case of homogeneous goods ($\gamma = 1$), downstream firms invest more when facing a single supplier only if $\delta^* < 0.55$.

Note also that firm i's profits are higher under competing vertical chains, compared with the case of a single supplier, unless $\gamma = 0$ and $\delta > 0.2$ (figure

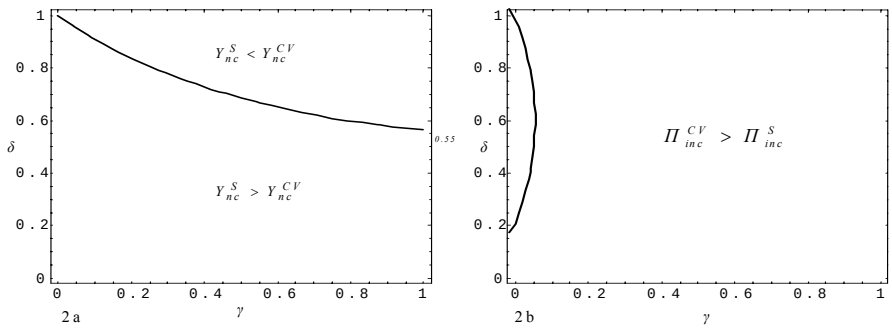

Figure 3: 3a: Total R&D investments under competing vertical chains $\left(Y_{nc}^{CV}\right)$ and a single supplier $\left(Y_{nc}^{S}\right)$. 3b: Firm i' s profits under competing vertical chains $\left(\Pi_{inc}^{CV}\right)$ and a single supplier $\left(\Pi_{inc}^{S}\right)$.

3b). In addition to that, a single supplier's profits are always higher than each supplier's under competing vertical chains. Intuitively, downstream firms invest in R&D and as a result the marginal cost falls. The price of the final-good decreases and its demand increases. Demand for input increases too and supplier(s) extract(s) rents through setting higher input price. A single supplier always extracts more rents, than a supplier in competing vertical chains does ($w_{nc}^{S} > w_{inc}^{CV}$ and $\pi_{nc}^{S} > \pi_{inc}^{CV}$ always hold). But, the higher the price that suppliers charge, the lower the input quantities that downstream firms buy and the lower their profits. This is the rational why downstream firms' profits are higher in competing vertical chains $\left(\Pi_{inc}^{CV} > \Pi_{inc}^{S}\right)$. However, for $\gamma = 0$ and $\delta > 0.2$, each downstream earns more when facing a single supplier, which is a counterintuitive result. In case of no free-riding, downstreams earn more under competing vertical chains, regardless the degree of product differentiation. As free-riding arises ($\delta > 0.2$), only if final-goods are unrelated and subsequently downstream firms act as monopolists, their profits are higher when facing a single supplier.

4.2 The case of a Research Joint Venture

Let us now proceed in the analysis of the case where firms invest in R&D under a RJV. Investments under competing vertical chains are given by eq. (13) and the corresponding under a single supplier are given by eq. (29). Comparing these results, we state the following proposition:

Proposition 5 *R&D investments are always higher in case of competing vertical chains.*

In case of a RJV, downstream firms invest cooperatively, they internalize spillovers and avoid the free-riding. In this case, there is no strategic interac-

tion between firms in the R&D investment stage. Given that a single supplier extracts higher rents $\left(\pi_c^S > \pi_{ic}^{CV} \text{ always holds}\right)$, investments are higher under competing vertical chains $\left(Y_c^{CV} > Y_c^S\right)$.[14] The previous analysis suggests that the effect of the input market structure on R&D investments depends on whether spillovers lead to free-riding or being internalized.

According to upstream and downstream profits, the findings for the case of RJV coincide with the corresponding in case of non-cooperation. However, in the present case, downstreams' profits are always higher under competing vertical chains. This result comes also from the fact that as far as spillovers are being internalized, they do not affect downsteams' strategic interactions.

5 Welfare analysis

In this section we conduct a welfare analysis and suggest some policy implications. For the purposes of the analysis we assume that there exists a regulator who can approve the formation of a RJV if it enhances social welfare. The appropriate measure of welfare consists of three parts: Consumers' surplus, downstream firms' profits and suppliers' profits. We have two alternative organizational forms of R&D activities (non-cooperative: nc and cooperative: c) and two downstreams-supplier(s) regimes: Single supplier (S) and competing vertical chains (CV). Thus, social welfare is defined as:

$$SW_A^B = \frac{1}{2}\left(Q_A^B\right)^2 + 2\Pi_A^B + 2\pi_{iA}^{\ B}, \quad A = nc, c, \quad B = CV, S \tag{33}$$

$\frac{1}{2}\left(Q_A^B\right)^2$ indicates consumers' surplus and $2\Pi_A^B$ and $2\pi_A^B$ indicate overall downstream and upstream profits respectively. Social welfare for each case is given in the Appendix.

Interestingly, it is found that $SW_{nc}^{CV} > SW_{nc}^S$ and $SW_c^{CV} > SW_c^S$ always hold. Downstream profits and consumers' surplus are higher under the CV regime. On the contrary, a single supplier always earns more than each supplier does under competing vertical chains. However, the sum of downstream profits and consumers' surplus overcome the single supplier's depression in social welfare.

We now turn to the core issue of the social welfare analysis: How does the structure of the input market affect the regulator's decision to approve the RJV?

[14] Banerjee and Lin (2003), following a setup where n final-good producers, that face a monopolistic upstream supplier setting the input price, undertake cost-reducing R&D investments, prove that downstream firms may overcome underinvestment through a fixed input price contract, signed before R&D is undertaken. They also suggest that this type of arrangement can be viewed as a long-term contractual relationship where the upstream firm commits to a prespecified input price even if the demand conditions for the input change in the future. We depart from their paper as we examine the case of a duopolistic input market as well and we incorporate R&D spillovers. In addittion to that, the reversal of timing that they suggest does not correspond to the planning horizon usually associated with the respective decisions, as investment decisions are mostly long-run while input price contracts are usually negotiated for a much shorter time horizon.

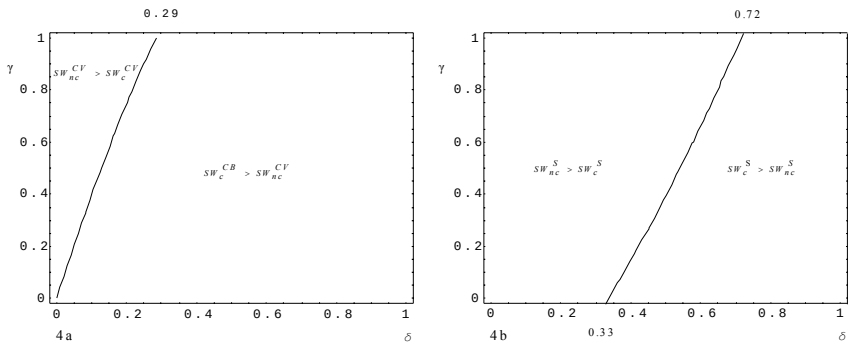

Figure 4: 4a: Social welfare under competing vertical chains in case of non-cooperation $\left(SW_{nc}^{CV}\right)$ and under a RJV $\left(SW_{nc}^{S}\right)$. 4b: Social welfare under a single supplier in case of non-cooperation $\left(SW_{nc}^{CV}\right)$ and under a RJV $\left(SW_{nc}^{S}\right)$.

In order to answer this question, we compare -for every *regime*- social welfare under non-cooperative R&D investments with welfare under a RJV, and we state the following proposition:

Proposition 6 *(i) The regulator will approve the Research Joint Venture under the competing vertical chains regime if* $\delta > \widehat{\delta}_{CV}(\gamma)$ *with* $\frac{d\widehat{\delta}_{CV}(\gamma)}{d\gamma} > 0$ *and* $\widehat{\delta}_{CV}(0) = 0$ *(*$\widehat{\delta}_{CV}(1) = 0.29$*). (ii) The regulator will approve the Research Joint Venture under the single supplier regime if* $\delta > \widehat{\delta}_{S}(\gamma)$ *with* $\frac{d\widehat{\delta}_{S}(\gamma)}{d\gamma} > 0$ *and* $\widehat{\delta}_{S}(0.33) = 0$ *(*$\widehat{\delta}_{S}(1) = 0.72$*).*

Results are presented in figures 4a and 4b. According to the economic rationale behind these results, a RJV always leads to increased downstream profits. However, the minimum internalized spillovers in order the RJV to increase consumers' surplus and suppliers' profits are lower under the competing vertical chains regime, for every degree of product differentiation, as we have already proven in section 3. In case of competing vertical chains, the minimum spillover rate increases from 0 to 0.29, as products become more homogeneous, while in case of a single supplier the corresponding rate increases from 0.33 to 0.72. Thus, although a RJV always increases downstream profits, it is not always preferable from the social welfare point of view. The more concentrated the input market is, the higher the spillovers that have to be internalized through a RJV, in order downstream firms' and regulator's incentives for a RJV to be aligned. This result underlines the difficulties for the alignment between firms' and regulators' preferences and the rigidities for the transfer of the efficiency created by a RJV to consumers, that a single supplier causes.

In the relevant literature, although Ishii (2004) conducts a welfare analysis he does not suggest any policy implications for reaching socially preferable outcomes. On the contrary, the previous analysis offers some directions for R&D

and antitrust policy implications. According to the first one, policy-makers should move towards the encouragement of RJVs (e.g. through subsidization) in R&D intensive industries where input suppliers do have market power. A RJV leads to more preferable outcomes for firms and consumers given that a minimum degree of spillovers are internalized. The second policy implication comes from the depressing effects of a single supplier on social welfare. We suggest that policy-makers should extend the antitrust rules to input markets of R&D intensive final-good industries. Thus, possible anticompetitive situations should be investigated in the suppliers' market, beyond the market of the final-good.

Existing literature on RJVs, assuming perfectly competitive input markets, suggests that if spillovers exceed a critical level, a RJV results in enhanced social welfare and thus, the cooperation should be approved by the regulator. This paper contributes to the relevant literature as we prove that the regulator, when deciding to approve or not the formation of a RJV, should also take into account the structure of the input market. The analysis shows that it is the combination of the above R&D and antitrust policies that leads to the more preferable outcomes in terms of social welfare. Through the above integrated policy-mix, policy-makers can overturn not only free-riding (through the encouragement of RJVs), but also rent-extracting (through blocking high concentration in input suppliers for R&D intensive final-good industries), and this is not only an contributional argument in the relevant literature, but also a straightforward applicable policy. Especially for the case of European Union, given the wide asymmetries across Member States' innovation policies, our analysis suggests that the above policy-mix can be an effective framework for integrated policies that will sufficiently increase European competitiveness.

6 Extensions

The basic model is rather stylized, so it is natural to check the robustness of our results. Thus, we extend the basic model in three different directions.[15]

6.1 Bertrand competition

The question addressed in this subsection is whether results demonstrated under Cournot competition, hold under price competition as well. The corresponding profit function for downstream firm i, has the form:[16]

$$\begin{aligned}\Pi_i\left(P_i, P_j, w_i, y_i, y_j, \delta, \theta\right) &= \left[Pi - \left(w_i + c - y_i - \delta y_j\right)\right] \times \\ &\quad \frac{\alpha\left(1-\gamma\right) + \gamma P_j - P_i}{1-\gamma^2} - \frac{1}{2}kx_i^2 \qquad (34)\end{aligned}$$

[15] Due to space limits, the results are presented in brief. A detailed derivation of the results is available from the authors upon request.

[16] As in the case of Cournot competition, we set $k = 1$ a condition which guarantees that the second order conditions are satisfied.

It can be shown that results obtained in the previous sections, hold for the case of Bertrand competition as well. The reason is that although the nature of product market competition is altered, competition in prices does not alter the interactions between downstream firms and supplier(s) that drive the results.

6.2 Bargaining over input price

In the previous analysis, it was assumed that supplier(s) unilaterally set(s) the input price. It is then natural to check whether our results still hold if we allow downstream firms to have bargaining power over the input price. It has already been showed that results obtained under Cournot competition hold for the case of Bertrand competition as well and that although the product differentiation γ affects the results, it is not the main factor that drives them. Therefore, we allow for bargaining over the input price, considering homogeneous products ($\gamma = 1$) and Cournot competition. In the case of competing vertical chains, under the general asymmetric Nash Bargain over input price between each input supplier - downstream firm pair i solves:

$$w_i = \arg\max \left\{ B_i = \pi_i^{\beta} \Pi_i^{1-\beta} \right\} \tag{35}$$

We consider that input suppliers are endowed with the same bargaining power ($\beta_1 = \beta_2 = \beta_{CV}$). It is found that downstream firms do have incentives to form a RJV even if the input price is determined through bargaining. In addition to that, the critical spillover rate that guarantees investments, input price, upstream profits and final-good quantity enhancement due too the RJV, decreases in the bargaining power of the input suppliers $\left(\frac{d\widehat{\delta}_{CV}(\beta)}{d\beta_{CV}} < 0\right)$.[17] In the second case, a single supplier (with bargaining power β_S), bargains with downstream firms' federation over the input price and the federation acts so as to maximize overall industry's profits. We also find that downstream firms do have incentives for a RJV. Interestingly, the critical spillover rate that guarantees investments, input price, upstream profits and final-good quantity enhancement due too the RJV, increases in the bargaining power of the monopolistic supplier $\left(\frac{d\widehat{\delta}_S(\beta)}{d\beta_S} < 0\right)$.[18]

It turns out that our qualitative results are robust. Thus, it is mainly the structure of the input market rather than the distribution of bargaining power between upstream(s) and downstreams that drives the results. The trade-off between suppliers' bargaining power and the critical spillover rate, depends on the regime between supplier(s) final-good producers. The economic rationale behind this result is that the distribution of bargaining power, between final-good producers and input suppliers, affects suppliers' rent-extracting potential and

[17] The case of bargaining in competing vertical chains was analytically solved, while results for the case of bargaining between a single supplier and the federation were obtained after numerical simulations. A detailed file is available from the authors upon request.

[18] In all of the above cases, the fall-back payoffs for downstream firms and input suppliers are zero.

downstream R&D investments as spillovers vary and subsequently, the critical spillover rate is also influenced.

6.3 The case of a RJV cartel

Our formal modeling for the case of the RJV was based on two key assumptions: According to the first one, the magnitude of spillovers is industry-wide and the sharing of information in case of a RJV remains the same as when R&D is conducted non-cooperatively. According to the second one, when firms form a RJV, R&D activities are conducted in two different labs. Thus, although free-riding is avoided, firms do not eliminate the duplication of effort. It is logical then to examine the case where firms form a RJV and undertake their R&D activities in one common lab. In this case, information sharing is maximized, that is, the formation of the RJV leads to $\delta = 1$. This is the case of a *RJV cartel*, in the taxonomy proposed by Kamien et al. (1992), where firms avoid not only the free-riding but the duplication of effort as well.

Analysis of pure-strategy subgame-perfect Nash equilibria discloses that a RJV cartel gives more preferable results, in terms of investment levels, final-good quantity, input price, consumers' surplus and social welfare. However, downstream firms' incentives to form a RJV cartel are always stronger under the competing vertical chains regime, compared with incentives in case of a single supplier.

7 Concluding remarks

Although the research on RJVs is growing, formal models have focused on horizontal settings. However, vertical market structures are critical because they may hinder downstream R&D investments. The purpose of this paper was to investigate final-good producers' incentives to form a RJV and R&D investments in vertically related industries where input suppliers extract rents. The analysis suggests that downstream firms' incentives to form a RJV are non-monotone in the structure of the input market. Although a RJV is always profit-enhancing for downstream firms, whether the input supplier(s) extract rents from the downstream firms depends on the structure of the input market, the degree of spillovers that are internalized under the RJV and the degree of product differentiation. In addition to that, it was showed that the intense hold-up of a single supplier, in case of non-cooperative R&D, increases investments if free-riding is weak. The welfare analysis suggests that the regulator, when deciding to approve or not the formation of a RJV, should take into account the structure of the input market and the regime that relates input suppliers with final-good producers. We suggest that the encouragement of RJVs between downstream firms jointly with the strict antitrust in input market leads to the more preferable outcomes in terms of social welfare.

The results obtained in this paper could guide future research in the field of empirical investigation of RJVs participation determinants and participants'

performance. An empirical test should start with a detailed study for the discrimination in the data material between process R&D intensive industries with low and high concentration of input suppliers. Based on the previous analysis, a first testable hypothesis is the participation probability of final-good producers in RJVs depending on the concentration ratio in input suppliers' industries. In final-good industries with low spillovers, the higher the concentration in input suppliers' industries, the higher the probability of final-good producers' participation in RJVs. Empirical results consistent with our argument would indicate that firms participate in RJVs in order to overcome their suppliers' rent-extracting.

8 Appendix

Social walfare for each case is given by:

$$SW_{nc}^{CV} = \frac{4\left[31744 + 6768\gamma^4 - 848\gamma^6 + 48\gamma^8 - \gamma^{10} + 512\gamma\delta - 64\gamma^3\delta - 64\gamma^2\left(380 + \delta^2\right)\right](a-c)^2}{\left[40\gamma^3 - 28\gamma^4 - 2\gamma^5 + \gamma^6 - 8\gamma^2(\delta - 27) + 64(\delta - 7) - 168\gamma\left(8 + \delta + \delta^2\right)\right]^2} \tag{a1}$$

$$SW_{c}^{CV} = \frac{4\left[256\gamma - 160\gamma^2 - 64\gamma^3 + 20\gamma^4 + 4\gamma^5 - \gamma^6 - 16\left(\delta^2 + 2\delta - 31\right)\right]^2(a-c)^2}{\left[32\gamma - 12\gamma^2 - 4\gamma^3 + \gamma^4 - 8\left(7 + 2\delta + \delta^2\right)\right]^2} \tag{a2}$$

$$SW_{nc}^{S} = \frac{\left[476 - 64\gamma^3 + 32\gamma^4 + 8\gamma^5 + 4\delta(6-\delta) + \gamma\left(116 + 40\delta - 12\delta^2\right) + \gamma^2\left(-257 + 6\delta - 9\delta^2\right)\right](a-c)^2}{\left[8\gamma^2 + 4\gamma^3 - 2\left(13 - 2\delta + \delta^2\right) - \gamma\left(15 + 2\delta + 3\delta^2\right)\right]^2} \tag{a3}$$

$$SW_{c}^{S} = \frac{\left(31 + 40\gamma + 16\gamma^2 + 2\gamma^3 - 2\delta - \delta^2\right)(a-c)^2}{\left(7 + 8\gamma + 2\gamma^2 - 2\delta - \delta^2\right)^2} \tag{a4}$$

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