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RJVs in Product Innovation and Cartel Stability

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Abstract

We characterise the interplay between ¯rms' decision in product development undertaken through a research joing venture (RJV), and the nature of their ensuing market behaviour. Participant ¯rms in an RJV face a trade-o® between saving the costs of product innovation by developing similar products to one another, e.g. by sharing most of the basic components of their products, and investing higher initial e®orts in product innovation in order to develop more distinct products. We prove that the more the ¯rms' products are distinct and thus less substitutable, the easier their collusion is to sustain in the marketing supergame, either in prices (Bertrand) or in quantities (Cournot). This gives rise to a non-monotone and discontinuous relationship between ¯rms' product portfolio and their intertemporal preferences.

Keywords : R&D, supergame, collusion, optimal punishment, critical discount factor.

JEL classi¯cation : D43, L13, O31.

1 Introduction

Both the current antitrust legislation and the literature appear to adopt a schizophrenic attitude towards cooperation amongst firms in R&D activities on one side, and collusion in marketing on the other. Whilst public authorities explicitly prohibit collusive market behaviour, there is scarce evidence that they discourage cooperation in R&D activities. As to the latter, there indeed exist several examples of policy measures meant to stimulate the formation of research joint ventures (RJVs henceforth).[1] Analogous considerations in favour of RJVs have been put forward by several authors (Grossman and Shapiro, 1986; Brodley, 1990; Jorde and Teece, 1990; Shapiro and Willig, 1990; and, for a general appraisal, Tao and Wu, 1997). If cooperation in innovation activities may induce collusion in the product market, then the above mentioned tendency to encourage cooperative R&D but to discourage market collusion will render itself inconsistent.

In this paper, we model an RJV as a noncooperative two-stage game played by participant firms. The first stage ($t = 0$) concerns product development. The second ($t = 1, 2, \cdots$) is a supergame concerning market competition, either in quantities or in prices, with time discounting with a constant factor δ. In particular, unlike most of the existing literature on market supergames with heterogeneous products, we explicitly take into account the effort-saving effects of the RJV in our model. Namely, even though each firm develops its own product, multiple firms can develop some, if not all, of the components of their products jointly in attempt to save innovative efforts. It is inevitable that such an attempt makes their products partly similar, thereby increasingly substitutable. The two polar cases are a full RJV in which the participant firms develop all components of their product jointly, and a null RJV where each firm develops the whole of its product independently. General cases are somewhere in between these two extremes, each firm developing some parts of its product independently.[2] A full RJV minimises the initial innovative effort exerted by each participant firm, while it results in an entirely identical product across firms, making their ensuing market competition the most strenuous. As the RJV becomes less and less "joint", involving each firm's partially independent in-

[1] See the National Cooperative Research Act in the US; EC Commission (1990); and, for Japan, Goto and Wakasugi (1988).

[2] Partially joint product development can also be achieved without an explicit "venture" agreememt negotiated between firms. For example, almost all the leading PC (personal computer) manufacturers (e.g., IBM, Compaq, Hewlett Packard) buy one main component, the pentium processer, from Intel Corporation. These PC manufacturers do not invest seperately to produce such processors for their machine. Yet one firm differentiates its product from rival products by investing effort to develop other features that makes its product distinct from rival firms.

novative e®orts, the initial cost of product development increases on one hand, and the severity of the ensuing market competition decreases on the other because ¯rms are now selling mutually distinct products.

Our game is fully noncooperative in that each ¯rm independently decides the degree of its involvement in the RJV in the ¯rst stage.[3] This choice variable having been exercised by every ¯rm, both the amount of each ¯rm's initial innovative e®ort cost and the degree of substitutability between ¯rms' products are automatically determined. Namely, in this paper we abstract the joint process of multiple ¯rms' product development into one strategic variable which is each ¯rm's involvement in the RJV, and two exogenous functions of the pro¯le of the strategic variable across ¯rms: one determines the cost of product development, which decreases in each ¯rm's involvement, and the other determines the degree of substitutability between ¯rms' products perceived on the demand side, which obviously increases in each ¯rm's involvement in the RJV. The second stage, the market supergame, is also fully noncooperative in that we consider only subgame perfect equilibrium paths, whether the resulting prices and/or quantities are collusive or generated by the one-shot Nash equilibrium.

Hereby intuitively, each ¯rm would decrease its involvement in the RJV as ± increases. Each ¯rm's initial e®ort exerted in product development can be viewed as an investment in attempt to ease the competition in the ensuing marketing stage. However, there is a counterforce, which is the fact that the degree of product substitutability a®ects the required level of ± in order for subgame perfection of collusive price and/or quantity paths in the market supergame.

1. When ± is very low, ¯rms have no hope in sustaining implicit collusion in the marketing supergame. Therefore, each ¯rm's involvement in the RJV decreases in ±.

2. When ± is intermediate, ¯rms have a strong incentive to keep up the degree of product substitutability at that level which is su±cient in order to sustain a collusive subgame perfect equilibrium in the ensuing market supergame. Since the threshold in ± decreases in product substitutability, the higher ± is, the more substitutable the ¯rms' products are allowed to be, which allows each ¯rm to increase its involvement in the RJV.

[3] In this paper we do not interpret an RJV as a uni¯ed decision making body who strives to maximise the joint discounted pro¯ts among all participant ¯rms. Each ¯rm remains as a purely sel¯sh decision maker irrespective of its involvement in the RJV.

3. When δ is high enough for firms to sustain collusion in the marketing supergame irrespective of their product substitutability, each firm's involvement in the RJV again decreases in δ.

Hence we establish that each firm's initial decision in product development is non-monotone in δ.

The paper is organised as follows. The basic model is laid out in section 2. Firms' interaction is closely analysed in section 3 in an equilibrium comparative statics framework, focusing on symmetric pure-strategy subgame perfect equilibrium outcomes. Then, welfare implications are discussed in section 4. Section 5 concludes the paper, summarising our main qualitative findings and locating it in the context of the existing literature.

2 The setup

We consider the following two-stage game, played by two *a priori* identical firms. Each firm sells only one product. The first stage ($t = 0$) is for product innovation, where the degree of substitutability between the two firms' products is endogenously determined as a result of the R&D decisions exercised noncooperatively by the two firms. The second stage is a supergame in marketing ($t = 1; 2; \cdots$), either in prices or in quantities. Throughout the game, the discount factor δ is common to both firms.

2.1 Second stage (super)game : Marketing with optimal punishment

In the second stage ($t = 1; 2; \cdots$), each firm faces the following inverse demand function:

$$p_i = 1 - q_i - \gamma q_j \tag{1}$$

in which $\gamma \in (0; 1]$ measures the degree of substitutability between the two firms' products (see Dixit, 1979; Singh and Vives, 1984). By inverting (1), the direct demand function obtains:

$$q_i = \frac{1}{1+\gamma} - \frac{1}{1-\gamma^2} p_i + \frac{\gamma}{1-\gamma^2} p_j :$$

Marginal production cost is constant and thus normalised to zero.

Let π^M denote cartel profit, and π_K^N one-shot Nash equilibrium profit per firm per period, under the type of competition K. For future reference, it is useful to derive explicitly here the threshold levels of the discount factor $\delta_K^*(\gamma)$ under both quantity and price competition. Straightforward calculations are needed to derive the per period per firm noncooperative profits (see Singh and Vives, 1984):

$$\pi_C^N = \frac{1}{(2+\gamma)^2}; \qquad \pi_B^N = \frac{1-\gamma}{(2-\gamma)^2(1+\gamma)}. \tag{2}$$

Obviously, the cartel profit is the same in both settings, i.e., half the monopoly profit:[4]

$$\pi^M = \frac{1}{4(1+\gamma)}. \tag{3}$$

In establishing the critical threshold of the discount factor stabilising collusion under either price or quantity competition, we apply Abreu's (1986, 1988) rule. Finding the optimal punishment quantity q^p or price p^p, as well as the critical threshold of the discount factor $\delta_K^*(\gamma)$, involves solving the following system of simultaneous equations in the case of Bertrand behaviour:

$$\pi_B^D(p^M) - \pi^M = \delta_B^*(\gamma)(\pi^M - \pi_B(p^p)); \tag{4}$$
$$\pi_B^D(p^p) - \pi_B(p^p) = \delta_B^*(\gamma)(\pi^M - \pi_B(p^p)); \tag{5}$$

where $\pi_B^D(p)$ is the profit resulting from the one-shot best response when the other firm plays p, and $\pi_B(p^p)$ denotes the profit during the symmetric punishment period. The solution to (4)-(5) is:

$$p^p = \frac{2-3\gamma}{2(2-\gamma)}; \quad \delta_B^*(\gamma) = \frac{(2-\gamma)^2}{16(1-\gamma)} \qquad \forall \gamma \in (0, \sqrt{3}-1];$$

$$\left.\begin{array}{l} p^p = \dfrac{(1-\gamma)\gamma + \sqrt{2\gamma - 1 - \gamma^3}}{\gamma(2-\gamma)} \\ \delta_B^*(\gamma) = \dfrac{(2-\gamma)^2(1-\gamma-\gamma^2)}{4 - 8\gamma + 4\gamma^3 - \gamma^4 + 4\gamma^2\sqrt{2\gamma-1-\gamma^3}} \end{array}\right\} \qquad \forall \gamma \in \left(\sqrt{3}-1, \frac{3\sqrt{5}-5}{2}\right];$$

$$p^p = \frac{1}{2} - \frac{\sqrt{2\gamma^2+\gamma-1}}{2\gamma}; \quad \delta_B^*(\gamma) = \frac{\gamma^2+\gamma-1}{2\gamma^2+\gamma-1} \qquad \forall \gamma \in \left(\frac{3\sqrt{5}-5}{2}, 1\right].$$

The functional forms of both p^p and $\delta_B^*(\gamma)$ shift at $\gamma = \sqrt{3}-1$, due to a non-negativity constraint on the quantity being supplied by the cheated firm during the deviation period (see Deneckere, 1983; and Ross, 1992). Then, they shift again at $\gamma = (3\sqrt{5}-5)/2$, due

[4] In this paper we formally do not consider partial collusion, i.e., any collusion not at the monopoly level. Taking partial collusion into consideration would not qualitatively affect our results, even though it would considerably complicate algebraic operations.

to the fact that a deviation in the punishment phase would never take place at a negative price. When $\gamma = 1$, firms are providing homogeneous products, so that $\pi_B^D = 2\pi_B^M$ and $\pi_B^N = 0$; hence, $\delta^*_B(\gamma) = 1/2$. Note that, at $\gamma = 1$, the punishment price p^p is still strictly negative (see Lambson, 1987).

Under Cournot competition, solving the system (in which the notation is analogous to the previous Bertrand case)

$$\begin{aligned} \pi_C^D(q^M) - \pi^M &= \delta^*_C(\gamma)(\pi^M - \pi_C(q^p)); \\ \pi_C^D(q^p) - \pi_C(q^p) &= \delta^*_C(\gamma)(\pi^M - \pi_C(q^p)) \end{aligned}$$

yields the optimal punishment quantity as well as the critical level of the discount factor for all $\gamma \in (0,1]$:

$$q^p = \frac{2 + 3\gamma}{2(1 + \gamma)(2 + \gamma)}; \quad \delta^*_C(\gamma) = \frac{(2 + \gamma)^2}{16(1 + \gamma)}.$$

2.2 First stage game : RJV in product development

Unlike previous contributions, we consider the choice of γ as a costly commitment. A full RJV, where the two firms jointly develop one product, economises R&D costs, while leading to homogeneous products ($\gamma = 1$) marketed in the future. The more independent R&D efforts each firm exerts, the more distinct their resulting products will be. Therefore, when firms invent their new products at $t = 0$, they face a tradeoff between the cost of innovative investment and the increase in the stream of operative profits they may obtain from the ensuing market supergame.

We abstract the negotiation process undertaken by the two firms in deciding the extent of jointness of the product innovation, e.g. which components of the two firms' products should be developed jointly and which else independently, into one strategic variable exercised noncooperatively by each firm. This variable, denoted by ν_i $(i = 1, 2)$ hereinafter, can be conceptualised as the degree of firm i's intended involvement in the RJV between the two firms. Once ν_1 and ν_2 have been submitted by the two firms mutually independently and noncooperatively, the negotiation between these two firms entails uniquely to the cost of product innovation per firm $\Phi[\nu_1, \nu_2]$ and the product substitutability $\gamma[\nu_1, \nu_2]$. These two functions, determined exogenously by given R&D technology, satisfy symmetry, i.e.

$$\Phi[\nu', \nu''] = \Phi[\nu'', \nu']; \quad \gamma[\nu', \nu''] = \gamma[\nu'', \nu'] \quad \text{for any } \nu', \nu'';$$

as well as

$$©_1 \; · \; 0 ; \; ©_2 \; · \; 0 ; \; ©_{11}©_{22} \; ¸ \; ©_{12}©_{21} ; \qquad °_1 \; ¸ \; 0 ; \; °_2 \; ¸ \; 0 ; \; °_{11}°_{22} \; ¸ \; °_{12}°_{21} \tag{6}$$

which ensures asymptotic stability. It is also natural to assume constants $k > 0$ and θ such that

$$\min_{º_1;º_2} °[º_1 ; º_2] = \theta ; \qquad \max_{º_1;º_2} °[º_1 ; º_2] = 1 ;$$
$$\max_{º_1;º_2} ©[º_1 ; º_2] = k ; \qquad \min_{º_1;º_2} ©[º_1 ; º_2] = \frac{k}{2} ;$$

and that

$$°[º_1 ; º_2] = \theta \quad \text{if and only if} \quad ©[º_1 ; º_2] = k ; \tag{7}$$
$$°[º_1 ; º_2] = 1 \quad \text{if and only if} \quad ©[º_1 ; º_2] = \frac{k}{2} ; \tag{8}$$

where obviously (7) corresponds to the case of a null RJV, and (8) corresponds to the case of a full RJV.

Note that these conditions on $©[¢; ¢]$ and $°[¢; ¢]$ ensure the existence of a symmetric pure strategy equilbrium $º_1 = º_2$. Even though there does not necessarily exist a one-to-one relation between $°$ and $©$, there is indeed a strictly monotone one-to-one relation between them given $º_1 = º_2$. We denote this monotone relation by $°(©)$ hereinafter, which is a strictly decreasing function.

3 Comparative statics results

At the development stage ($t = 0$), ¯rms choose their intention to be involved in the RJV, $º_1$ and $º_2$, simultaneously and mutually independently through non-cooperative decisions. The game trees are as illustrated in ¯gures 1 and 2, in which the market supergame is suppressed into a binary description of collusive and competitive outcomes. Discounted pro¯ts are computed based upon (2) and (3) in the previous section.

Figure 1 : RJV-Cournot game.

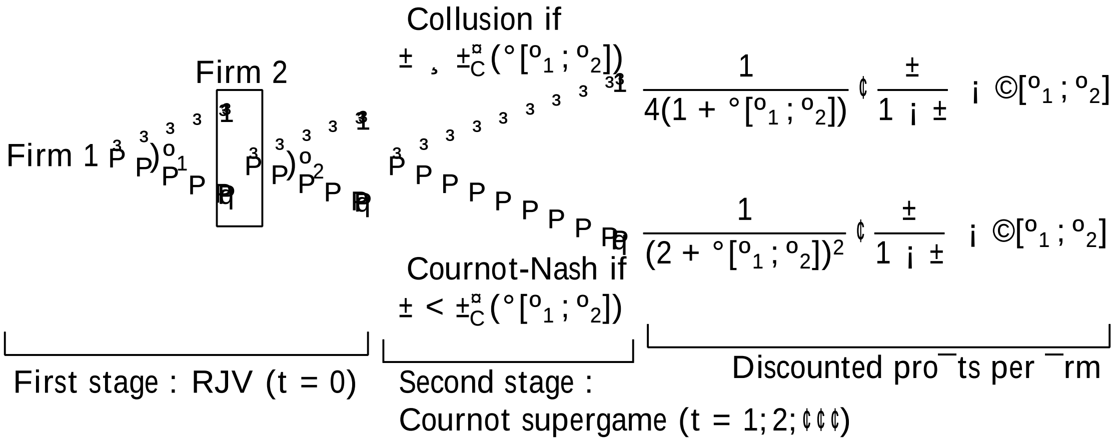
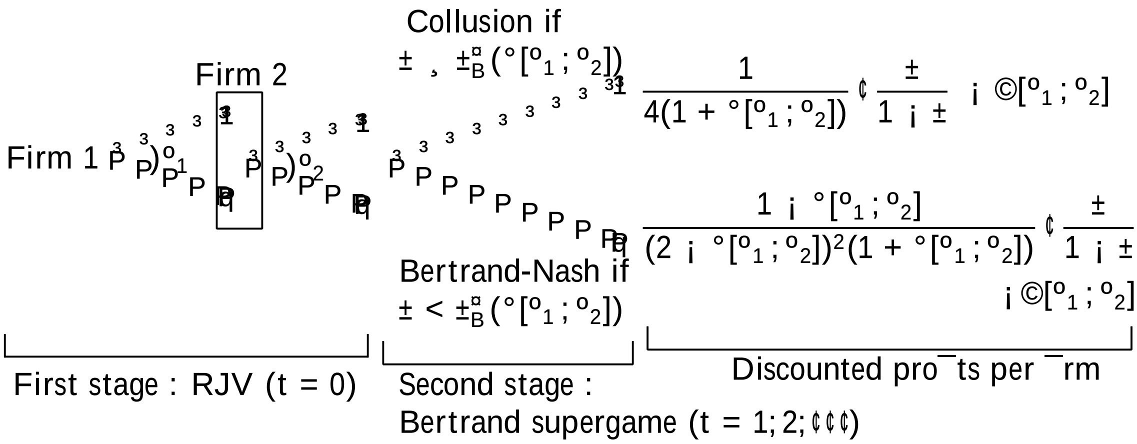


Figure 2 : RJV-Bertrand game.



In any symmetric pure-strategy equilibrium, each firm incurs the cost $\Psi[\kappa_1;\kappa_2]$ in the R&D stage ($t = 0$). In the marketing stage ($t = 1, 2, \cdots$), each firm's profits per period

$$\pi^M = \frac{1}{4(1+\gamma[\kappa_1;\kappa_2])}; \qquad \pi_C^N = \frac{1}{(2+\gamma[\kappa_1;\kappa_2])^2}; \qquad \pi_B^N = \frac{1-\gamma[\kappa_1;\kappa_2]}{(2-\gamma[\kappa_1;\kappa_2])^2(1+\gamma[\kappa_1;\kappa_2])}$$

(see equations (2) and (3) in section 2) decrease monotonically in $\gamma[\kappa_1;\kappa_2]$. Hence, by assumption (6), the equilibrium κ_i decreases monotonically, although it may or may not be continuous, in δ. This observationally implies the following.

• Firms can sustain implicit collusion if and only if $\delta \geq \delta_K^*(\gamma[\kappa_1;\kappa_2])$. Over this parametric range, the equilibrium $\Psi[\kappa_1;\kappa_2]$ increases and the equilibrium $\gamma[\kappa_1;\kappa_2]$ decreases monotonically in δ.

² Firms cannot sustain implicit collusion over the range $\pm < \pm^{¤}_{K}(°[º_1; º_2])$. Within this range, again, the equilibrium $©[º_1; º_2]$ increases and the equilibrium $°[º_1; º_2]$ decreases monotonically in $\pm$.

Figure 3 schematically plots the equilibrium venture investment © and the equilibrium degree of substitutability °, respectively, against ±. Both Cournot and Bertrand cases lead to qualitatively similar diagrams.

In the left diagram, the relationship between © and ± is described. The whole space is divided by the downward sloping locus $\pm = \pm^{¤}_{K}(°(©))$. To the north-east of this locus, collusion is sustainable in the marketing stage. Within this region, the candidate equilibrium level of innovative e®orts © increases monotonically, either continuously or discontinuously, in ±. The diagram depicts the case where the graph TU of © smoothly increases in ±. On the other hand, to the south-west of the critical locus $\pm = \pm^{¤}_{K}(°(©))$, ¯rms repeat one-shot Nash equilibria in the marketing stage.[5] Within this region (note that this region does not include the critical boundary), the candidate equilibrium level of initial investment © increases monotonically in ±. Once again, the diagram represents the graph of © with a smooth curve VW although © need not always be continuous in ±.

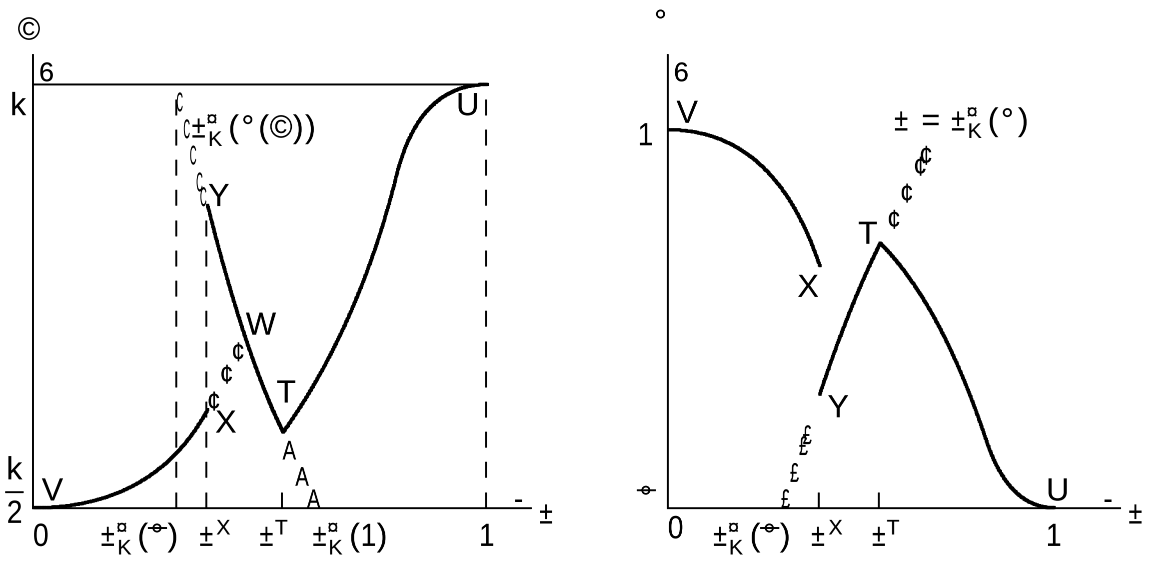
It is qualitatively clear that W should be situated to the north-west of T, and therefore that the kinked locus WTU is an unambiguous part of the optimal © in response to ±. To the west of W, ¯rms face the choice whether to sustain collusion by paying high initial e®orts. The break-even point, denoted by $\pm^{X}$ where each ¯rm's discounted pro¯t at X equals that at Y, must lie between W and $\pm^{¤}_{K}(\overline{\ominus})$.

Hereby the optimal locus VX-YTU is established. Overall, the venture investment increases as ¯rms become more forward looking, which is the reason why both loci TU and VW are up-sloping. However, in an intermediate range of ±, where venture decisions can a®ect future cartel stability, ¯rms choose the minimum level of © ensuring collusion sustainability, unless the initial investment is excessively costly (to the upper-left of Y) compared to discounted future gains.

[5] Our qualitative diagrams would stay similar even if we took into account partial collusion, in which case the following scenario would arise. Firms collude at the monopoly level whenever possible, which preserves our diagram intact to the north-east of the locus $\pm = \pm^{¤}_{K}(°(©))$. To the south-west of the locus where they are unable to sustain monopoly-level collusion, they choose partial collusion, i.e., the most pro¯table collusion sustainable given ± and °. Note that this makes marginal gains from $º_i$ jump discontinuously between these two regions. Hence, as long as ° and © are smooth in $º_i$, the graphs of candidate equilibrium ° and © will always jump at the boundary $\pm = \pm^{¤}_{K}(°(©))$.

This analysis is translated in terms of the equilibrium degree of product substitutability ° in the right diagram. The degree of substitutability generally decreases in ±, except in a small region to the right of $± = ±^X$, where the equilibrium ° rapidly increases in ± (the interval $[±^X; ±^T)$ in the diagrams). This is due to the fact that it is only in this region that the sustainability of future collusion, be that in prices or in quantities, becomes the binding factor in determining the degree of substitutability.

Figure 3 : Venture costs and substitutability as a function of ±.



Hence, ¯rms' endogenous choice of $°_1$, $°_2$, and therefore the resulting amount of R&D investment © and the degree of product substitutability °, are both non-monotone and discontinuous in their time discount factor ±.

Proposition 1 : There exist $±^X$ and $±^T$, where $±^¤_K(ⓞ) < ±^X < ±^T < ±^¤_K(1)$, such that:[6]

² ¯rms' R&D investment increases and the endogenous degree of product substitutability decreases in $± 2 [0; ±^X)$ as well as in $± 2 (±^T; 1)$, and vice versa in $± 2 (±^X; ±^T)$;

² both © and °(©) have a discontinuous jump at $±^X$, and a kink at $±^T$.

[6] The latter half of this proposition does not preclude the possibility that the loci of © and ° may have jumps and kinks elsewhere.

4 Policy and welfare implications

In essence, the only component of social welfare which is neglected by ¯rms is consumer surplus, computed as (per period $t = 1; 2; ¢¢¢$) :

$$
\begin{aligned}
S^M &= \frac{1}{4(1 + °(©))} && \text{in collusion;} \\
S_C^N &= \frac{1 + °(©)}{(2 + °(©))^2} && \text{in Cournot-Nash;} \\
S_B^N &= \frac{1}{(2 \text{ ¡ } °(©))^2(1 + °(©))} && \text{in Bertrand-Nash,}
\end{aligned}
$$

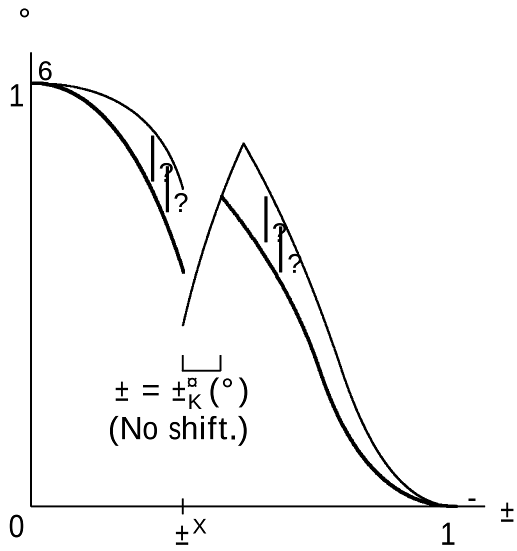
all of which decrease in $°(©)$ and thus increase in ©. Therefore ceteris paribus, consumer surplus tends to be higher as the degree of product substitutability decreases.

4.1 An overview

When functions $°[º_1; º_2]$ and $©[º_1; º_2]$ shift due to a technological progress or a policy change, ¯rms' R&D decisions are a®ected accordingly. If R&D is subsidised, which shifts $©[¢; ¢]$ downward, ¯rms are encouraged to choose a lower $º_i$ in the parametric region where they would collude in the marketing stage, as well as in the region where they play one-shot Nash in the market. This results in a decrement in the equilibrium level of °.

The welfare implications can be illustrated in ¯gure 4. When the discount factor ± takes an intermediate value with which the equilibrium ° is critically regulated by the sustainability of later collusion, any intervention either encouraging or discouraging the jointness of the RJV will induce no a±rmative reaction. On the other hand, if ± takes those values with which ¯rms' market behaviour is una®ected by their initial choice of $º_i$, the only determinant to the social welfare that is neglected by ¯rms' decentralised decisions is the increment in consumer surplus due to product substitutability. Hence, encouraging a decrement in product substitutability may represent a welfare improving measure.

Figure 4 : Reaction to a reduction in ©[¢; ¢].



Hence, the following welfare characterisation can be given.

Proposition 2 : Total surplus can be improved by a downshift in ©[¢; ¢] when ± 2 [0; ±^{X}) and when ± 2 (±^{T}; 1).

Refer to section 3 and Proposition 1 about the de¯nition of ±^{X} and ±^{T}.

Proposition 2 recommends that R&D investment be encouraged through public policy. This is indeed consistent with those commonly implemented policy measures to stimulate product development, such as investment tax credits. Consequently, enhanced innovative e®orts exerted by each ¯rm reduces the degree of product substitutability. In this sense, the more R&D is encouraged, the less \joint" it becomes. This seems to contradict with the widely observed tendency that public authorities often favour RJVs.

A natural curiosity here is: is there any situation where the jointness of the RJV should be encouraged by policy measures?

4.2 A closer insight

As shown in Proposition 1, the locus of the equilibrium © has a discontinuous jump at ± = ±^{X}. This indicates the possibility that an incremental change in R&D subsidisation or taxation could bring a substantial impact on ¯rms' venture decisions and on the resulting social welfare when ± is in the neighbourhood of ±^{X}. Even though Proposition 2 is operative over greater portions of the parametric space $\delta \in [0;1)$, any marginal policy alteration entails only a marginal perturbation in product development wherever the loci of equilibrium ψ, γ are continuous.

By definition, when $\delta = \delta^X$, firms are indifferent between points X and Y in figure 3. Let ψ^X and ψ^Y denote the levels of investment per firm at X and Y, respectively, where obviously

$$\psi^X < \psi^Y. \tag{9}$$

Namely, in the Cournot game,

$$\frac{1}{(2+\gamma(\psi^X))^2} \cdot \frac{\delta^X}{1-\delta^X} - \psi^X = \frac{1}{4(1+\gamma(\psi^Y))} \cdot \frac{\delta^X}{1-\delta^X} - \psi^Y. \tag{10}$$

In the Bertrand game,

$$\frac{1-\gamma(\psi^X)}{(2-\gamma(\psi^X))^2(1+\gamma(\psi^X))} \cdot \frac{\delta^X}{1-\delta^X} - \psi^X = \frac{1}{4(1+\gamma(\psi^Y))} \cdot \frac{\delta^X}{1-\delta^X} - \psi^Y. \tag{11}$$

The implications of inequality (9), equations (10) and (11) to the welfare rank between outcomes X and Y are indecisive, depending upon the technological conditions incorporated in the specific R&D cost function $\gamma(\cdot)$. Therefore we must exhaust both possibilities:

- X welfare-dominates Y if the social benefit of market competition outweighs that of product variety. There are two ways to encourage outcomes near X as opposed to those near Y.

  One is to induce a positive shift in δ^X. This is made possible by a policy that either subsidises path VW or taxes on path YW in figure 3. Since the latter incurs higher R&D expenditures than the former, the policy is to make the costs of partial independence in the RJV more progressive and thereby to encourage the jointness of the RJV.

  The other alternative is to induce a reduction in firms' discount factor δ. This can be attained either by a macroeconomic contraction policy that raises the interest rate, or by an industrial regulation tightening corporate finance.

- Y welfare-dominates X if the social benefit of reducing product substitutability outweighs that of market competition. In this case it enhances welfare to encourage outcomes in the neighbourhood of Y relative to those in the vicinity of X.

  To this end, it is effective to induce a decrement in δ^X. This is attained by a policy that either penalises path VW or rewards path YW. Such a policy is to make the costs of partial independence in the RJV more regressive and thereby to discourage the jointness of the RJV.

Alternatively, an increment in firms' discount factor δ can bring a similar effect. This can be attained either by an expansionary macro policy that lowers the interest rate, or by an industrial measure subsidising corporate finance.

These observations should be summarised as follows, to complement the previous proposition.

Proposition 3 : In the neighbourhood of $\delta = \delta^*$, a small perturbation either in the function $\gamma(\cdot)$ or in δ can bring a substantial change in welfare.

We hereby understand that the commonly observed tendency of seemingly schizophrenic legislation, encouraging RJV on one hand while strictly discouraging market cartels on the other (see section 1), may render itself either consistent or inconsistent depending crucially upon two factors :

1. whether the benefit from reducing product substitutability is socially more important than market competition, or vice versa,
2. whether the policy is to encourage overall efforts in product innovation, or to encourage the jointness of R&D. Note that these two kinds of policy work in opposite directions : the latter is to reduce the overall R&D expenditures.

Hence, whenever there is good reason to believe that the status quo is reasonably close to δ^*, the public authority should either :

- encourage overall R&D investment to reduce product substitutability, or
- encourage the jointness of product development to stimulate market competition.

5 Concluding remarks

We avail of a large number of contributions concerning firms' incentives to undertake RJVs in order to avoid effort duplication (Katz, 1986 ; d'Aspremont and Jacquemin, 1988, 1990 ;

Katz and Ordover, 1990; Kamien et al., 1992; Suzumura, 1992; inter alia). Besides, there exists a wide literature concerning the effects of product differentiation on the stability of implicit collusion either in output levels or in prices (Deneckere, 1983; Chang, 1991, 1992; Rothschild, 1992; Ross, 1992; Friedman and Thisse, 1993; Häckner, 1994, 1995, 1996; Lambertini, 1997; inter alia). So far, however, few serious attempts have been made to interconnect these two streams of research, except for Martin (1995) and Cabral (1996). The former takes into account an RJV aimed at achieving a process innovation for an existing product which is marketed by firms through Cournot behaviour. Cabral proves the existence of cases where competitive pricing is needed to sustain more efficient R&D agreements. On the other hand, Martin's analysis shows that cartel stability is enhanced by the presence of cooperation in process innovation, so that the welfare advantage of the RJV by eliminating effort duplication can be jeopardised by the arising of collusion in the ensuing market phase. Our effort in this paper serves to clarify potential implications of Martin's work to the case of product innovation, in lieu of process innovation.

The particular benefit from discussing product innovation is that we can interlink the strategic aspects of R&D with the effect of inter-firm product portfolios in the ensuing marketing stage. In this paper we have mapped the effects of both intertemporal preferences and the technology of product development on firms' venture decisions as well as on their market behaviour over the entire parameter space. Contrary to some of the earlier beliefs, we have established that the relationship between product substitutability and the discount factor can indeed be both non-monotone and discontinuous. This seemingly counterintuitive result stems from the balance between cost considerations in product development and firms' concern towards future cartel stability.

Note also that product innovation, unlike process innovation, has a direct effect on consumers' surplus by affecting the product portfolio in the market. In fact, our non-monotonicity and discontinuity results carry over to welfare implications. Namely, as long as firms' collusive inclination in their market behaviour stays unaffected, it marginally enhances welfare to encourage independent product development beyond firms' private incentives. On the contrary, if the status quo happens to be near the parity between firms' collusive and non-collusive incentives, then an incremental alteration in R&D policy — either to encourage or to discourage the jointness of the RJV — can entail a discontinuously massive impact on welfare.

References

Abreu, D.J. (1986), \External Equilibria of Oligopolistic Supergames", Journal of Economic Theory, 39, 191-225.

Abreu, D.J. (1988), \On the Theory of In¯nitely Repeated Games with Discounting", Econometrica, 56, 383-96.

Brodley, J.F. (1990), \Antitrust Law and Innovation Cooperation", Journal of Economic Perspectives, 4, 97-112.

Cabral, L.M.B. (1996), \R&D Alliances as Non-Cooperative Supergames", CEPR Discussion Paper No. 1439.

Chang, M.H. (1991), \The E®ects of Product Di®erentiation on Collusive Pricing", International Journal of Industrial Organization, 9, 453-69.

Chang, M.H. (1992), \Intertemporal Product Choice and Its E®ects on Collusive Firm Behavior", International Economic Review, 33, 773-93.

d'Aspremont, C. and A. Jacquemin (1988), \Cooperative and Noncooperative R&D in Duopoly with Spillovers", American Economic Review, 78, 1133-7.

d'Aspremont, C. and A. Jacquemin (1990), \Cooperative and Noncooperative R&D in Duopoly with Spillovers: Erratum", American Economic Review, 80, 641-2.

Deneckere, R. (1983), \Duopoly Supergames with Product Di®erentiation", Economics Letters, 11, 37-42.

Dixit, A.K. (1979), \A Model of Duopoly Suggesting a Theory of Entry Barriers", Bell Journal of Economics, 10, 20-32.

EC Commission (1990), Competition Law in the European Communities, Volume I, Rules Applicable to Undertakings, Brussels-Luxembourg, EC Commission.

Friedman, J.W. and J.-F. Thisse (1993), \Partial Collusion Fosters Minimum Product Di®erentiation", RAND Journal of Economics, 24, 631-45.

Goto, A. and R. Wakasugi (1988), \Technology Policy", in Komiya, R., M. Okuno and K. Suzumura (eds.), Industrial Policy of Japan, New York, Academic Press.

Grossman, G. and C. Shapiro (1986), \Research Joint Ventures: An Antitrust Analysis", Journal of Law, Economics and Organization, 2, 315-37.

Häckner, J. (1994), \Collusive Pricing in Markets for Vertically Di®erentiated Products", International Journal of Industrial Organization, 12, 155-77.

Häckner, J. (1995), \Endogenous Product Design in an In¯nitely Repeated Game", International Journal of Industrial Organization, 13, 277-99.

Häckner, J. (1996), \Optimal Symmetric Punishments in a Bertrand Di®erentiated Product Duopoly", International Journal of Industrial Organization, 14, 611-30.

Jorde, T.M. and D.J. Teece (1990), \Innovation and Cooperation: Implications for Competition and Antitrust", Journal of Economic Perspectives, 4, 75-96.

Kamien, M., E. Muller and I. Zang (1992), \Cooperative Joint Ventures and R&D Cartels", American Economic Review, 82, 1293-1306.

Katz, M.L. (1986), \An Analysis of Cooperative Research and Development", RAND Journal of Economics, 17, 527-43.

Katz M.L. and J.A. Ordover (1990), \R&D Cooperation and Competition", Brookings Papers on Economic Activity, 0 (Special issue), 137-91.

Lambertini, L. (1997), \Prisoners' Dilemma in Duopoly (Super)games", Journal of Economic Theory, 77, 181-91.

Lambson, V.E. (1987), \Optimal Penal Codes in Price-Setting Supergames with Capacity Constraints", Review of Economic Studies, 54, 385-97.

Martin, S. (1995), \R&D Joint Ventures and Tacit Product Market Collusion", European Journal of Political Economy, 11, 733-41.

Ross, T.W. (1992), \Cartel Stability and Product Di®erentiation", International Journal of Industrial Organization, 10, 1-13.

Rothschild, R. (1992), \On the Sustainability of Collusion in Di®erentiated Duopolies", Economics Letters, 40, 33-7.

Shapiro, C. and R. Willig (1990), \On the Antitrust Treatment of Production Joint Ventures", Journal of Economic Perspectives, 4, 113-30.

Singh, N. and X. Vives (1984), \Price and Quantity Competition in a Di®erentiated Duopoly", RAND Journal of Economics, 15, 546-54.

Suzumura, K. (1992), \Cooperative and Noncooperative R&D in an Oligopoly with Spillovers", American Economic Review, 82, 1307-20.

Tao, Z. and C. Wu (1997), \On the Organization of Cooperative Research and Development", International Journal of Industrial Organization, 15, 573-96.