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TO PROMOTE R&D COOPERATION: A STRATEGIC TRADE POLICY?

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ABSTRACT

When American and European policy-makers justify their adjustment of the antitrust law in favor of research and development (R&D) cooperation among firms, they mention among other reasons their desire to provide domestic firms with an additional tool to strengthen their competitiveness. The idea is that domestic firms would achieve innovation faster and cheaper through R&D cooperation and afterward would better face foreign rival competitive pressure and gain larger market shares. The question that arises then is: Does the promotion of R&D cooperation allow to reach such a goal?

This research uses the strategic trade policy approach which developed in the 80s to analyze the efficiency of R&D cooperation as an industrial-cum-trade policy tool. The decision problem of the government concerned with stimulating domestic firms' competitiveness in presence of a foreign competitive pressure is examined in a partial equilibrium three-stage game. The objective is to determine the optimal degree, from a domestic point of view, of collaboration among domestic firms.

Before firms act, the domestic government defines the extent to which domestic antitrust law allows cooperation in R&D and market collaboration after joint R&D efforts. Three alternative policies are available: to forbid any joint activity, to allow only R&D cooperation, to allow R&D cooperation and the extension of the joint efforts to production and sales. Then, given the implemented policy, the domestic firms invest in R&D in order to improve their production process and become more productive. Finally, foreign and domestic firms produce and compete for sale. The cases of Cournot and Bertrand competition (i.e., two games) are investigated and compared.

The subgame perfect equilibrium analysis of these two games show that the optimal strategy for the government consists in tailoring its R&D cooperation policy according to the industry characteristics. In particular, the analysis points out that in its policy decision the government should take into account the intensity of market competition and the industry trade structure. For example, under price competition, the common wisdom policy, "to allow R&D cooperation, but to forbid market collaboration" is not optimal. The trade structure (approximated by the proportion of domestic demand in the world demand in the model) matters in the policy efficiency assessment because it determines the magnitude of the domestic welfare loss induced by collusion among domestic firms. This work confirms thus a key result of the strategic trade policy literature: the dependence of the optimal policy on the type of competition prevailing on the market.

In addition, this analysis reveals that the influence of a foreign competitive pressure on profit-maximizing levels of R&D investment and on the emergence of collusive behaviors varies according to the nature of market competition. Moreover, it also draws attention to the need to assess the probability and the effects of market collusion after R&D cooperation from a global point of view, taking into consideration the existence of foreign competition and market imperfections. Finally, this study indicates that to promote R&D cooperation is not a panacea; indeed there exist in both games a parameter range for which none of the three alternatives leads to R&D investment by domestic firms.

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Section 1: Introduction

For the last fifteen years, the United States of America (USA) and the European Union (EU) have been debating about the desirability of promoting R&D cooperation among firms. The background of this discussion was the existing antitrust law which considers as illegal any inter-firm collaboration likely to affect competition in a welfare-worsening way. The adjustment of the competition law toward more flexibility has been advocated by several economic and law experts. During the 80s, at least three significant achievements have come out of this debate: first, the National Cooperative Research Act (NRCA) was passed in the USA in 1984; second, the European Research Cooperative Agency (Eurêka) was created in 1985 by the joint initiative of European governments and industrialists; third, the EU voted a bloc exemption for R&D cooperation in 1987.[1]

This modification of antitrust law aimed at favoring a flexible treatment of R&D cooperation agreements was based on a thorough analysis of the private and public costs and benefits of R&D cooperation. Among the other arguments used to justify such departure from a strict application of the antitrust law were the hopes and beliefs that R&D cooperation could help firms to restore and/or increase their competitiveness and enable them to better face foreign competitive pressure. The idea was that R&D cooperation is likely to lead to faster and cheaper innovations thanks to the internalization of technological spillovers, the R&D costs and risks sharing, the synergies of assets and skills, and the enhanced diffusion of innovation.

However, no formal analysis -to my knowledge- has attempted to evaluate the efficiency of promoting R&D cooperation and of allowing joint exploitation of cooperative R&D outcomes taking into account foreign competitive pressure. The present research offers an efficiency assessment of this

[1] The National Cooperative Research Act (NRCA) passed in the USA in 1984 explicitly specifies the legal treatment of R&D cooperation agreements according to a rule of reason and offers a possibility of registration for R&D cooperative agreements after which damages are reduced from treble to single. (See the 1990 Summer issue of the Journal of Economic Perspective for an interesting forum of experts on the state of American antitrust law vis-a-vis R&D cooperation.) The objective of the European Research Cooperative Agency (Eurêka) created in 1985 by the joint initiative of European governments and industrialists is to promote cooperative R&D projects that should lead to new, finalized, and marketable products and systems. The bloc exemption for R&D cooperation voted in 1987 by the EU confirms the European stand, namely that the legality of R&D cooperation agreements is assessed using a rule of reason (as expressed in the 1968 Notice on R&D cooperation) and extends the EU tolerance to joint exploitation of collectively achieved R&D outcomes under certain circumstances. (For more details, see Jacquemin (1988).)

antitrust-cum-trade policy aimed at encouraging R&D cooperation using an open economy framework,.

In order to tackle this industrial policy problem, I follow the strategic trade policy approach that developed in the 80s after the works of Brander and Spencer.[2] As it is standard in this literature stream, I analyze the policy issue in a partial equilibrium framework using a sequential game. A three-stage game is built in which the government implements first a policy, then the domestic firms choose an R&D investment strategy, and finally the domestic and foreign firms compete for sale in the market. The cases of Cournot competition and Bertrand competition are both examined and then compared.

Although the model uses specific functional forms and is solved under particular assumptions, the equilibrium outcomes confirm one of the main conclusions of the strategic trade policy theory: the efficiency of a policy -in this case, an antitrust-cum-trade policy- depends on the type of competition prevailing on the market.[3] This central result -namely,the dependence of the optimal policy on trade and market features- is expected to be preserved if certain restrictive assumptions (homogeneous good, a unique world market, symmetric domestic firms, non-strategic role of the foreign agents at the R&D and policy stages) are relaxed. However, at the same time, the use of less restrictive assumptions is likely to lead to less contrasted outcomes.

The game results also point out to interesting facts relevant for antitrust and/or policy authorities. First, the structure of trade (as approximated by the proportion of domestic demand in the world demand) matters to assess the desirability of allowing market collaboration after R&D cooperation. Indeed, it determines the magnitude of the welfare loss due to collusion that is to be borne by domestic consumers. Second, the influence of foreign competition on R&D investment at equilibrium varies according to the nature of market competition. Third, the link between R&D cooperation and market collusion is examined and is revealed to be dependent on the nature of competition and on the intensity of foreign competitive pressure. Fourth, it is observed that there exist in both games and under all policy alternatives parameter ranges for which no R&D investment occurs. This highlights the fact that to promote R&D cooperation is not a panacea.

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[2] In the strategic trade policy approach, government's policy choices are viewed as interventions meant to alter the economic environment in which domestic firms act. The objective is to enable firms to select actions or strategies that they could not have credibly chosen without intervention on the one hand, and that generates a rent transfer from foreign firms to domestic firms on the other hand. In other words, by a strategic trade policy, the government tries to modify domestic firms' incentives so that their decisions lead to increased domestic welfare. See, for example, Spencer and Brander (1983).

[3] See the survey by Dixit (1987)

The present research suggests thus that in order to maximize domestic social welfare policy-makers should tailor their R&D cooperation policy according to industry characteristics, especially the nature of market competition and the kind of trade structure. A rule of reason treatment seems thus to be the most suitable policy. The explicit specification of the factors considered to be favoring the extension of the collaboration after cooperative research might be welcomed by entrepreneurs and by lawyers as a means to reduce uncertainty ant the costs of investigating cases.

Besides working in an open economy framework and incorporating foreign competitive pressure, this research supplements existing contributions in the R&D cooperation literature by introducing explicitly asymmetry among firms.[4] Although this asymmetry is modelled naively, it is a first step toward handling less symmetric situations which characterize several industries. It is also an attempt toward enquiring about the behavior diversity caused by firm heterogeneity and about the consequences of this diversity on the efficiency of R&D policy. The effect of this asymmetry is particularly visible at the market stage through changing the incentives that domestic firms have to collude -a change which has on turn a repercussion on the motivations to cooperate in R&D. This seems to suggest that an explicit modelling of the transition between R&D cooperation and market collusion be undertaken -no such exercise being known to me. The result of this investigation would also contribute to the evaluation of R&D cooperation policy. Indeed European R&D policy-makers based some of their R&D cooperation programs on the hypothesis that the nature of the cooperative relationship has a tendency to move away from an R&D focus towards market behavior considerations.

In the rest of the paper, the model is described in Section 2. Then the analysis of the Cournot and Bertrand competition games is performed respectively in Section 3 and Section 4. Finally, the outcomes of both games are compared and concluding remarks are made in Section 5.

Section 2: The Model

In this section, the model used to examine the optimal R&D cooperation policy under quantity

[4] In existing models, it is often assumed that all firms cooperate (whether in an all-industry association or not); in addition, symmetry among firms is frequently used to solve the equilibrium. Among interesting attempts involving less symmetry are Katz (1986) which investigates the conditions under which one R&D cooperative association coexists at equilibrium with individually acting firms, and Bhattacharya et al (1990, 199?) which examine the mechanisms under which firms differing in initial knowledge agree to cooperate in R&D.

competition and under price competition is described. The difference between the two types of competition lies in the nature of the sale action, the strategic variable at the market stage referred to as z. This strategic choice consists in selecting either an output level in the case of Cournot competition, or a price level in the case of Bertrand competition. In either case, the three firms' sales actions will induce an equilibrium quantity for each firm.

One single tradeable good is produced by two countries, a foreign country and a home country. The world demand for that good is assumed to be linear in quantities. The inverse demand function is written as $p = a-bY$, where p is the good price and Y is the world quantity demanded of the good. It is assumed that $Y \leq (a/b)$ (i.e., $p \geq 0$). The home country's demand corresponds to a fraction α of the world demand and the foreign country's demand to a fraction $(1-\alpha)$.

The good is produced by one foreign firm, with index f, and by 2 symmetric domestic firms, with indices $i = 1,2$. The output produced by a domestic firm with index i is denoted by y_i and the foreign-produced output by y_f. All firms sell in the world market (i.e., they sell in their own country as well as abroad). It is assumed that selling abroad induces no transaction costs; therefore, the allocation of a firm output between its national and international market follows no rule.[5] In equilibrium, $Y = y_1+y_2+y_f$.

The cost structures of the domestic firms have two parts: production costs characterized by constant returns to scale and R&D investment costs featuring decreasing returns to scale. Investment in R&D generates a new process of production featuring lower marginal production costs. This reduction in marginal costs is assumed to be proportional to R&D investment, and the marginal costs is constrained to remain non-negative when R&D investment would lead to negative marginal costs given the proportionality rule. Hence, total production costs, C_i, depend on the initial marginal costs c_i, on the output level y_i, and on the R&D investment level x_i. If $x_i<c_i$, then $C_i(y_i,x_i) = (c_i-x_i)y_i$, otherwise, $C_i(y_i,x_i) = 0$.[6] Domestic firms are assumed to initially have identical marginal costs $c_1 = c_2 = c$ where $o < c < a$.

5 When the domestic demand exceeds the production of the domestic firms (i.e., $y_1+y_2 < \alpha Y$), the trade balance shows net imports by the home country. Such a balance implies that even if domestic firms have exported part or all of their output, the quantity of imports from the foreign firm exceeds the quantity of home country exports. Similarly, in the opposite case (i.e., $y_1+y_2 > \alpha Y$), the trade balance shows net export by the home country.

6 This cost function ensures that production costs never become negative. It implies that R&D investment beyond c_i is not optimal since it increases total costs but does not reduce the marginal production costs further.

The cost of investing x_i unit of R&D is written as $(x_i)^2/2$. The decreasing returns to scale in R&D investment represent the increasing difficulty of obtaining larger and larger cost reductions. It is assumed that patents are granted for process improvements. Innovative firms holding a patent are protected from imitation and can reap the returns of their innovation. If two firms innovate simultaneously, they both get patents for their own innovation.

Given these cost structures and aggregate output Y, profits for domestic firm i selling y_i after having invested x_i are given by: $\Pi_i = (a-bY)y_i - (c-x_i)y_i - x_i^2/2$.[7]

The foreign firm is not modeled as a strategic player in the R&D game. Its cost structure is summarized by a function showing constant return to scale with respect to output: $C_f(y_f) = ey_f$ where $0 < e < a$. Given aggregate output Y, the profits of the foreign firm selling y_f are given by: $\Pi_f = (a-bY)y_f - ey_f$.[8]

The intensity of the foreign competitive pressure faced by the domestic firms is measured by the differential between the marginal production costs of the domestic and the foreign firms. It is assumed that a cost differential exists in favor of the foreign firm if the domestic firms do not invest in R&D: $c > e$.[9]

Cooperation in R&D, if allowed, takes the form of a Research Joint Venture (RJV) where the research is performed in one research center only, with all the RJV members having access to the outcome of their joint R&D investment (i.e., the same reduction in production costs) and sharing the costs of that joint investment equally among themselves.[10] This specific RJV organization would

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[7] This Π_i profit function is the normalized form of a more general profit function: $\Pi_i' = (r-sY')\, y_i' - t(u-x_i')y_i' - v(x_i')^2/2$. The profit function used in the text is derived from Π_i' by performing a sequence of substitutions using the following relationship definitions: $(x_i)^2=v(x_i')^2$, $(y_i)^2=t(y_i')^2/v$, $(y_f)^2=t(y_f')^2/v$, $(c)^2=(u)^2/v$, $(a)^2=v(r/t)^2$, $(b)^2=(sv/t^2)^2$. In so doing, two parameters can be eliminated with no loss of generality. Consequently, the meaning of parameters and variables is richer than it appears.

[8] Similarly as for Π_i, Π_f is the normalized form of a more general profit function: $\Pi_f' = (r-sY')\, y_f' - wy_f$. The foreign firm profit function used in the text is derived from Π_f' by performing the same sequence of substitutions as described in the previous footnote. In addition, w^2 is substituted by $(te)^2/v$.

[9] The opposite assumption, $c<e$, leaves the computations under quantity competition unchanged; but results must be reinterpreted to fit the situation in which domestic firms are more competitive than the foreign firm. Under price competition, this opposite assumption would modify calculations considerably. It would also mean that the foreign firm represents no serious competitive threat, which is of a lesser interest. In order to focus on interesting cases that are comparable across price and quantity models, $c > e$ is assumed in the rest of the analysis.

[10] Kamien et al. (1992) study the degree of R&D outcome sharing in a RJV and its effect on the incentive to invest in cooperative R&D. They show that the highest investment levels are observed when each member firm gains access to all the R&D output of the RJV. Since the present model also uses this rule of R&D output sharing, it is expected that other R&D

seem reasonable when the R&D technology at stake is unique, linear and not additive; such an R&D technology assumption is simple and provides a bench-mark for a least beneficial joint venture.[11] Given these internal organization rules, R&D cooperation generates the following positive effects: absence of wasteful duplication, R&D output sharing, and cost sharing.[12]

If firms are allowed to jointly market their output after having cooperated in R&D (i.e., they are allowed to form a Joint Venture (JV)), they choose the sales strategy that maximizes their joint profits and share the production equally among them.

The description of the world economy is completed. This model is now supplemented by the addition of a fourth agent: the government of the home country. The government of the home country wishes to fine-tune its antitrust treatment of R&D cooperation as a tool for technology policy. Its objective is to maximize domestic social welfare, defined as the sum of the country's consumer surplus and the profits of the domestic firms: $W = \alpha CS_W+\Pi_1+\Pi_2$, where α is the percentage of the world demand that corresponds to the domestic demand, and where CS_W is the consumer surplus at the world level. Three policy options are available to the government: (i) "No R&D Cooperation and No Market Collusion", denoted by NN, (ii) "R&D Cooperation but No Market Collusion", denoted by CN, and (iii) "R&D Cooperation and Joint Marketing", denoted by CC.

The antitrust choice of the government determines the strategies available to the firms and the resulting payoffs. Under NN, each domestic firm maximizes its profits independently; under CN, the domestic firms maximize the RJV profits at the R&D stage and then their individual profits at the market stage; under CC, the domestic firms maximize the JV profit at both stages. The foreign firm always maximizes its profits individually.[13]

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output sharing rules would lead to lower levels of equilibrium R&D investment.

[11] The possibility of incorporating spillovers in the model is deliberately left aside. The role of spillovers in R&D cooperation has been studied in various contributions; e.g., Katz (1986), and d'Aspremont and Jacquemin (1988). Their conclusions convey usually a similar idea: the higher the spillover, the higher the incentive to be a member of a cooperative agreement. As the present model parallels that of d'Aspremont and Jacquemin (1988), it is expected that incorporating spillovers in the model will have a positive effect on cooperative R&D investment at equilibrium.

[12] The existence of spillovers, the R&D technology at stake and the internal organization of the cooperation will influence the extent of resource savings and efficiency gains that can be achieved through R&D cooperation, but are unlikely to lead to completely different conclusions.

[13] The notation for domestic social welfare will often be: $W_{NN}[x_1,x_2]$ under NN when x_1 and x_2 are invested respectively by firm 1 and firm 2; $W_{CN}[x_{RJV}]$ under CN when x_{RJV} is invested by the RJV; and $W_{CC}[x_{JV}]$ when x_{JV} is invested by the JV under CC.

This modelling framework allows me to analyze two games, one in which quantity competition prevails at the market stage and one in which price competition prevails, both games involving the 4 same players: one domestic government, two domestic firms, and one foreign firm. The government's action is an antitrust-cum-technology policy g; the set of policy actions is G={NN,CN,CC}. The domestic firms' actions consist of an R&D investment level x and a sales action z for the domestic firms; the set of R&D actions is X = [0,c] and the set of sales actions is Z (where Z = Q = [0,a/b] under quantity competition and Z = P = [0,a] under price competition). The foreign firm's action is a sales action z; the set of sale actions is Z as defined for the domestic firms. In each game, at stage 1, the domestic government announces its technology policy. At stage 2, the domestic firms observe the policy announcement and choose their R&D strategies. At stage 3, the three firms observe the R&D strategies and choose their sales strategies. To solve both games, we use the concept of subgame perfect Nash equilibrium (henceforth, referred to as SPE).

The present model is specific. Its principal restrictions are the absence of product differentiation,[14] the assumption of cost symmetry for the firms that may cooperate,[15] the non-strategic role of the foreign firm at the R&D stage,[16] and the presence of a unique world market instead of the existence of geographic differences between the domestic and the foreign markets.[17] The model's specificity will serve my interests if the derived conclusions are so diverse that little generalization can be expected from working with a less specific model. If this actually happens, this work would confirm what other researches on strategic trade policies have pointed out: trade policy

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[14] The homogeneity of the good reduces the robustness of certain aspects of the Bertrand competition analysis because the harshness of price competition results in drastic outcomes. By incorporating product differentiation, one could avoid these drastic results, and should arrive at additional conclusions establishing relationships between the product differentiation intensity and the type of behaviors observed at equilibrium.

[15] The cost symmetry of the cooperating firms simplifies the modelling of the R&D cooperation and/or collusion. Notice that if transfers are allowed and feasible, no loss of generality occurs by assuming firm symmetry. When such transfer cannot take place -because they are not allowed or not credible- the organization of R&D cooperation in the presence of asymmetry becomes a difficult question. The resulting complexity and unstability of the R&D cooperation may endanger and/or limit the efficiency of a policy allowing for R&D cooperation. A possible remedy to such a situation, i.e., a means to restore the incentive to cooperate in R&D, would be to allow the member firms to use a joint marketing strategy which would make ex-post compensatory transfers feasible.

[16] The assumption that the foreign firm is not an active strategic player at the R&D stage limits the interpretation of the results to a situation in which the actions of the domestic firms do not generate an R&D reaction on the part of the foreign firm. This might be plausible when the domestic firms are small in the market (i.e., if their productivity is low compared to that of the foreign firm) or when the foreign country is known to have a general policy which makes an aggressive R&D response unlikely.

[17] The uniqueness and uniformity of a goods market at the world level is not uncommon in the trade literature, but it limits the applicability of the conclusions derived from the analysis. To introduce segmented markets, and so to allow more elaborate R&D cooperation and joint marketing strategies, might enrich the picture and suggest more precisely the impact of international trade on R&D cooperation strategies. If markets are segmented, the domestic firms will have a greater cost advantage domestically than elsewhere. Greater levels of R&D may be needed to induce larger exports, and there may be a greater impact on domestic consumer surplus from actions at the market stage.

recommendations depend on the nature of competition between firms. In addition, the conclusions will draw attention to the impact of other factors, such as the trade structure, which might be less likely to vary with the nature of competition.

The next two sections present the analysis: first, under quantity competition, and second under price competition.

Section 3: Analysis of the Cournot Competition Game

When Cournot competition prevails, each firm i, i=1,2,f, chooses for its action a quantity $y_i \in Q = [0,(a/b)]$, at the sales stage. In this section, the SPE in pure R&D and sales strategies (with interior solution) is computed for each policy option.[18] Then the SPE interior solutions are examined in detail: the equilibrium levels of output, R&D investment and domestic social welfare of the three policy regimes are compared to identify the optimal policy and the comparative statics of the equilibrium results are studied.

3.1. Policy NN: No R&D Cooperation and No Market Collusion

Under NN, the SPE in pure strategies in which domestic firms act symmetrically and invest in R&D is computed backward.

At the output stage, the foreign and domestic firms maximize their individual profits with respect to their output. The representative domestic firm's problem is to maximize profits with respect to y_i, taking x_1, x_2, and its rivals' output strategies as given. This is: maximize $\Pi_i = (a-bY)y_i - (c-x_i)y_i - (x_i)^2/2$ w.r.t. $y_i \in Q$. The foreign firm's problem is to maximize profits with respect to y_f, taking x_1, x_2, and its rivals' output strategies as given. I.e., maximize $\Pi_f = (a-bY)y_f - ey_f$ w.r.t. $y_f \in Q$. A system of three reactions functions in y_f^{NN}, y_1^{NN}, y_2^{NN} is derived from the first order conditions and then is easily solved: $y_i^{NN}(x_1,x_2) = (a+e-2c+3x_i-x_j)/4b$, for $i=1,2,i\neq j$, $y_f^{NN}(x_1,x_2) = (a+2c-3e-x_i-x_j)/4b$.[19] The equilibrium in the good market obtains when demand equals supply, and the equilibrium price

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[18] The investigation is restricted to cases with concave profit functions, where the domestic firms act symmetrically at both stages, investing the same positive amount in R&D. There exists a non-nul set of parameters for which such situation exists under each policy. See Results 3.1.,3.2., and 3.3.

[19] The second order conditions are always satisfied and the condition for local stability as described in Suzumura (1989) is also always satisfied because the Hessian matrix $H = [\delta^2 \Pi/(\delta y_k \delta y_l)]$, k,l=1,2,f, is negative definite.

on the good market is: $p^{NN}(x_1,x_2) = (a+e+2c-x_1-x_2)/4$.

At the R&D stage, each domestic firm chooses the R&D level that maximizes its profits. The representative domestic firm's problem is to maximize profits with respect to x_i. This is: maximize $\Pi_i^{NN} = (a-bY^{NN})y_i^{NN} - (c-x_i)y_i^{NN} - (x_i)^2/2 = (a+e-2c+3x_i-x_j)^2/16b - (x_i)^2/2$ w.r.t. $x_i \in X$. Assuming a symmetric solution (i.e., $x_1 = x_2$) and concave profit functions (i.e., $b > (9/8)$), the solutions of the system of the two reaction functions are:[20] $\forall$ i=1,2, $x_{i,NN} = 3(a+e-2c)/[2(ab-3)]$. These are the solution to the domestic firms' R&D investment problems when interior solutions only are considered. The domestic social welfare level is given by:

$$W_{NN}[x_{1,NN}, x_{2,NN}] = \frac{\alpha}{2b}\left[\frac{2b(3a-e-2c)-3(a-e)}{2(4b-3)}\right]^2 + \left[\frac{(a+e-2c)^2\ (8b-9)}{4(4b-3)^2}\right]$$

Result 3.1. summarizes these results for the relevant parameter range Σ^{NN}.[21]

Result 3.1.

Under NN, provided that $(a,b,c,e) \in \Sigma^{NN}$, there exists a unique pure strategy SPE with an interior solution in which the domestic firms invest the same positive amount in R&D:

$$[y_1^*, y_2^*, y_f^*; x_1^*, x_2^*; NN] =$$

$$\left[\frac{a+e-2c}{4b-3}, \frac{a+e-2c}{4b-3}, \frac{2b(a+2c-3e)-3(a-e)}{2b(4b-3)}; \frac{3(a+e-2c)}{8b-6}, \frac{3(a+e-2c)}{2(4b-3)}; NN\right]$$

Before I continue on to stage 1, I must solve the quantity game cases for CN and CC. I turn to the case CN next.

3.2. Policy CN: R&D Cooperation but No Market Collusion

Again the model is solved in reverse order, starting with stage 3, the market stage, and

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[20] The condition for local stability as described by Suzumura (1989) is always satisfied because the Hessian matrix H = $[\delta^2 \Pi^{NN} /(\delta x_k \delta x_l)]$, k,l=1,2, is negative definite.

[21] The parameter range for which an equilibrium with both domestic firms investing the same positive amount under CN exists is defined by $\Sigma^{NN} = \{ (a,b,c,e) \in \mathbb{R}_+^4$ such that $b > (3/2)$, $(a+e-2c) > 0$, and $8bc-3(a+e) > 0\}$, where the first inequality ensures that both firms have an incentive to invest symmetrically, and where the second and third inequalities ensure an interior solution at the R&D stage, i.e, an R&D equilibrium investment that is positive (second condition) and smaller than c (third condition). The first inequality also implies that the profit function is concave in R&D since concavity requires that $b > (9/8)$.

continuing with stage 2, the R&D stage. The first stage, the government policy stage, will be solved only after each policy subgame has been solved.

The output stage under CN is exactly the same as that under NN. Indeed the fact that a unique amount of R&D investment is chosen jointly by the two firms with its outcome benefiting both firms and that the investment cost is shared does not modify the output game because the R&D investment is a parameter at the output stage.[22]

At the R&D stage, the domestic firms, via the RJV, choose the R&D level that maximizes their joint profits. The problem of the RJV is to maximize the joint profits of the RJV member firms with respect to x: maximize $\Pi^{CN} = (a\text{-}bY^{CN})(y_1^{CN}+y_2^{CN}) - (c\text{-}x)(y_1^{CN}+y_2^{CN}) - x^2/2 = (a+e\text{-}2c+2x)^2/8b - (x)^2/2$ w.r.t. $x \in X$. Assuming concave profit functions (i.e., b>1) and considering interior solution only, the solution to the RJV's R&D investment problem is: $x_{RJV,CN} = (a+e\text{-}2c)/[2(b\text{-}1)]$
At equilibrium, the domestic social welfare amounts to:

$$W_{CN}[x_{RJV,CN}] = \frac{\alpha}{2b}\left[\frac{b(3a-e-2c)-2(a-e)}{4(b-1)}\right]^2 + \left[\frac{(a+d-2c)^2}{8(b-1)}\right]$$

Result 3.2. summarizes these results for the relevant parameter range Σ^{CN}.[23]

<u>Result 3.2.</u>

Under CN, provided that $(a,b,c,e) \in \Sigma^{CN}$, there exists a unique pure strategy SPE with an interior solution in which the domestic firms invest the same positive amount in R&D:

$$[y_1^*, y_2^*, y_f^*; x_{RJV}^*; CN] =$$
$$\left[\frac{a+e-2c}{4(b-1)}, \frac{a+e-2c}{4(b-1)}, \frac{b(a+2c-3e)-2(a-e)}{4b(b-1)}; \frac{a+e-2c}{2(b-1)}; CN\right]$$

Before I continue on to stage 1, I must also solve the quantity game in case of a permissive antitrust enforcement, CC. I turn to the CC case next.

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[22] The only difference in the statement of the results is that the R&D investment parameter is now the same, x, for both domestic firms as they form a R&D joint venture. These results are: $y_i^{CN}(x) = (a+e\text{-}2c+2x)/4b$, for i=1,2; $y_f^{CN}(x) = (a+2c\text{-}3e\text{-}2x)/4b$; $p^{CN}(x) = (a+e+2c\text{-}2x)/4$.

[23] The parameter range for which an equilibrium with both domestic firms investing the same positive amount under CN exists is defined by $\Sigma^{CN} = \{(a,b,c,e) \in \mathbb{R}_+^4$ such that $b > 1$, $(a+e\text{-}2c) > 0$, and $2bc\text{-}(a+e) > 0\}$. These three inequalities (in their present order) have the same role as the three inequalities in Σ^{NN}, respectively.

3.3. Policy CC: R&D Cooperation and Market Collusion

Under CC, output and R&D investment decisions are made jointly. The two domestic firms gathered in a Joint Venture choose the R&D and the output levels that maximize their joint profit. As previously, I solve the model backward.

At the output stage, the firms choose the output level, y_{JV}, that maximizes their joint profits, and share that output between themselves, i.e., $y_1 = y_2 = y_{JV}/2$. The JV's problem is to maximize the RJV profits with respect to y_{JV} taking x_{JV} and the foreign firm's strategy as given. This is: maximize $\Pi_{JV} = (a\text{-}bY)y_{JV} - (c\text{-}x)y_{JV} - (x)^2/2$ w.r.t. $y_{JV} \in Q$. The foreign firm's problem is the same as before: maximize $\Pi_f = (a\text{-}bY)y_f - ey_f$ w.r.t. $y_f \in Q$. The solution of this system of two reactions functions in y_f^{CC}, y^{CC}, is easily solved:[24] $y_{JV}^{CC}(x) = (a+e-2c+2x)/3b$, and $y_1^{CC}(x) = y_2^{CC}(x) = (y_{JV}^{CC}(x))/2$; $y_f^{CC}(x) = (a+c-2e-2x)/3b$. The equilibrium in the good market obtains when demand equals supply, and the equilibrium price on the good market is thus: $p^{CC}(x) = (a+e+c-x)/3$.

At the R&D stage, the domestic firms, via the JV, choose the R&D level, x, that maximizes their joint profit. The problem of the JV is to maximize the joint profits of its member firms with respect to x: maximize $\Pi_{JV}^{CC} = (a\text{-}bY^{CC})y_{JV}^{CC} - (c\text{-}x)y_{JV}^{CC} - x^2/2 = (a+e-2c+2x)^2/9b - (x)^2/2$ w.r.t. $x \in X$. Assuming that the SOC holds (i.e., $b>(8/9)$), the solution to the JV's R&D investment problem is: $x_{JV,CC} = 4\,(a+e-2c)/\,(9b-8)$. The domestic social welfare under CC is:

$$W_{CC}[x_{JV,CC}] = \frac{\alpha}{2b}\left[\frac{3b(2a-e-c)-4(a-e)}{(9b-8)}\right]^2 + \left[\frac{(a+e-2c)^2}{(9b-8)}\right]$$

Result 3.3. summarizes these results for the relevant parameter range Σ^{CC}.[25]

Result 3.3.

Under CC, provided that $(a,b,c,e) \in \Sigma^{CC}$, there exists a unique pure strategy SPE with interior solution in which both domestic firms invest the same positive amount in R&D:

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[24] The second order conditions are always satisfied and the condition for local stability as described by Suzumura (1989) is also always satisfied because the Hessian matrix $H = [\delta^2 \Pi/(\delta y_k \delta y_l)]$, k,l=RJV,f, is negative definite.

[25] The parameter range for which an equilibrium with both domestic firms investing the same positive amount under CN exists is defined by $\Sigma^{CC} = \{(a,b,c,e) \in \mathbb{R}_+^4$ such that $b > (8/9)$, $(a+e-2c) > 0$, and $9bc-4(a+e) > 0\}$. These three inequalities (in their present order) have the same role as the three inequalities in Σ^{NN}, respectively.

$$[y_{JV}^{*}, y_f^{*}; x_{JV}^{*}; CC] =$$

$$\left[\frac{3(a+e-2c)}{9b-8}, \frac{3b(a+c-2e)-4(a-e)}{b(9b-8)}; \frac{4(a+e-2c)}{9b-8}; CC\right]$$

After solving stages 2 and 3 for all three policies in the quantity model, I solve stage 1, namely, the government policy choice.

3.4 Cournot Competition Game Equilibrium

Given that domestic firms are assumed to behave symmetrically and invest in R&D under each antitrust-cum-technology policy,[26] the entire quantity game equilibrium can be found by solving the first stage, namely the government decision stage. At that stage, the government compares the R&D and production outcomes arising under each policy and selects the policy which generates the highest level of domestic social welfare. The conclusions of the government's inquiry are summarized in the following two propositions.

Proposition 3.1.

Under Cournot competition, assuming that domestic firms invest symmetrically in R&D at equilibrium under each policy alternative (i.e., a+e-2c > 0 and b ≥ (3/2)):

a) Cost reductions at equilibrium are always ranked as follows: $x_{RJV,CN} > x_{JV,CC} > x_{i,NN}$;

b) Total investment in R&D at equilibrium always compare as follows: $x_{NN} > x_{RJV,CN} > x_{JV,CC}$, where under NN, x_{NN} is defined as $(x_{1,NN} + x_{2,NN})$;

c) Total domestic output at equilibrium, denoted by y^g, always rank as follows: $y_{CN} > y_{NN} > y_{CC}$;

d) Domestic firm profits at equilibrium compare as follows: if (3/2) ≤ b ≤ 5.27, $\Pi_{i,CN} > \Pi_{i,CC} > \Pi_{i,NN}$, and if 5.27 < b, $\Pi_{i,CN} > \Pi_{i,NN} > \Pi_{i,CC}$;

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[26] To derive the parameter conditions that lead to this restriction in analysis is easily done by finding out, through firm profit comparison, when both firms earn more by investing a same positive amount than by not investing. The relevant parameter condition can be summarized as follows: If b ≥ (3/2), domestic firms that behave symmetrically maximize their profits by investing positive amount in R&D at equilibrium under each policy. (For a proof, see Rutsaert (1994).) This condition indicates that the market cannot support both domestic firms investing very large amounts. This happens when the market is large (b being an inverse index of the size of the market demand) as R&D investment increases more than proportionately with market size. The reason lies in the pecuniary externality connected to R&D investment.

It is worth noticing that if b < (3/2), symmetric positive R&D investment by both domestic firms is not an SPE under NN. Indeed, for b < (3/2), there exist pure strategy SPEs in which only one domestic firm invests a positive amount as well as mixed strategy SPEs in which firms invest and do not invest, both with positive probability. (For more details, see Rutsaert (1994).)

e) Domestic social welfare at equilibrium under the three policy options are ranked as follows: (i) always, $W_{CN} > W_{NN}$ and $W_{CN} > W_{CC}$; (ii) the comparison between W_{NN} and W_{CC} depends on the values of the parameters, and $b > 5.27$ is a sufficient condition for $W_{NN} > W_{CC}$.

Proof: Trivial, by algebra.

Proposition 3.2.

In the case of Cournot competition, provided that domestic firms invest the same positive amount at equilibrium (i.e., $(a,b,c,e) \in \Sigma^{NN}$ which is a subset of Σ^{CN} and Σ^{CC}), there exists a unique SPE (with interior solution) for the policy-game:

$$[y_1^*, y_2^*, y_f^*; x_{RJV}^*; CN] = \left[\frac{a+e-2c}{4(b-1)}, \frac{a+e-2c}{4(b-1)}, \frac{b(a+2c-3e)-2(a-e)}{4b(b-1)}; \frac{a+e-2c}{2(b-1)}; CN\right]$$

Proof: This results from Proposition 3.1.e.

The results stated in Proposition 3.1. allow to compare the three policies pair by pair and to distinguish the specific effects of each policy.

Comparing the NN and CN policies leads to the modelling support of the commonly held point of view that, given that market collusion is prohibited, allowing R&D cooperation is socially preferable to forbidding it. The reasons for higher social welfare under CN in my model coincide with the traditional reasons used in favor of R&D cooperation: first, firms access a more efficient technology with cooperation (i.e., achieve a higher cost reduction) due to a more efficient allocation of resources without wasteful duplication; second, domestic firms produce more under CN than under NN as a consequence of a lower marginal cost after R&D investment under CN; third, domestic firms' profits are higher under CN than under NN because the gains from the increase in output and the decrease in marginal cost due R&D cooperation outweigh the losses from the price reduction and the R&D investment costs.

The comparison between the outcomes of CN and CC highlights the consequences of joint marketing in this model: higher cost reductions, outputs, and profits are reached under CN. That is, it is not profitable for the two domestic firms to collude after R&D cooperation.[27] The lower profits obtained through collusion is due to the combination of two factors. First, joint marketing leads to an internalization of the output externality which exists between the competing domestic firms. This internalization causes firms to reduce output in the hope that the resulting price increase would, from a profit viewpoint, more than compensate for the output reduction. Second, following from this, the foreign firm infers that its rivals will have a lower output and reacts by increasing its own output, thereby causing the price to increase by less than expected from the output reduction. This confirms the role played by the foreign firm in the profitability of a market collusion strategy. The low profitability of market collusion relative to individual marketing leads to a lower equilibrium level of cooperative investment under CC because of the concavity of the profit function with respect to cost reductions.

However, one expects that the domestic firms would rationally anticipate that collusion is less profitable than individual marketing under CC. Therefore, it is reasonable to follow Salant et al. (1983)'s suggestion to endogenize the collusion decision so that only profitable collusion take place. With this suggestion, the game is slightly modified by the addition of an intermediate stage between the R&D and the market stages. In that added stage, the domestic firms decide whether or not to collude for sales in the market. In my example, this modified game leads to the outcome that, under CC, joint marketing never takes place even though it is allowed. Hence, the equilibrium levels of R&D investment, output, profits and welfare are those which arise under CN.

The comparison between NN and CC is done assuming that collusion takes place under CC (i.e., not taking into account the fact that firms are expected not to collude). This comparison indicates the mixed effect of going from a strict to a permissive enforcement of the antitrust law. The effects of R&D cooperation are visible in comparing equilibrium investment levels. The effects of collusion are visible in comparing the equilibrium domestic output levels. The combination of these effects at the R&D and market stages leads to an ambiguous ranking of equilibrium profit levels.[28]

The above discussion can be summarized as follows: for the quantity model, allowing R&D

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[27] A similar outcome is pointed out by Salant et al. (1983). Subsequent contributions show that the incentives to collude vary a lot according to the structure and the assumptions of the model under consideration.

[28] If b is small, then profits are higher under CC than under NN; otherwise, profits are higher under NN than under CC. The reason behind this conditional ranking requires considering the three elements comprised in the b parameter. When b is low, the demand size coefficient is large, the R&D cost coefficient is small, and the production cost coefficient is large. Hence, profits are higher under CC because the reduction in output induced by collusive marketing as well as the higher productivity resulting from R&D cooperation allow domestic firms to save on production costs.

cooperation is superior to preventing it, and prohibiting market collusion after R&D cooperation is unnecessary, but it does not prevent any welfare-improving collusion from taking place. Consequently, the highest domestic social welfare is achieved under flexible enforcement of antitrust law. Hence, at the first stage of the quantity game, the domestic government selects the CN policy because it maximizes domestic social welfare.

To study the comparative statics of the stage-2 SPE outcomes under all three policies with respect to cost efficiency and demand parameters reveals that in an SPE, for any g, and hence specifically for g = CN, the domestic levels of R&D investment, output, and profits decrease with the productivity gap between the foreign and domestic firms and increase with the market demand size. The negative influence of the productivity gap -as defined by (2c-e)- on the equilibrium levels of R&D investment arise from two factors: the decreasing returns to scale for R&D investment and the dependence of the R&D investment return on the firm's own initial production costs. As regards the former, the cost of a large investment may more than offset the gain it generates through reduced production costs. As regards the latter, the higher the initial cost, the lower the revenue. The features of the world demand play a role as well: the larger the demand (i.e., high values for a and/or low values for b), the larger the cost reduction and the output. Indeed, a large demand means that, for a given price, a high level of output is sold and a high level of profits is achieved. Consequently, the larger is the demand, the more valuable is any productivity improvement since a larger volume of production would benefit from the improvement.[29]

Comparative statics also shows that the higher the proportion of domestic demand in world demand, α, the stronger the repercussions of collusion on domestic social welfare. Indeed, when α is high, a large percentage of consumers are domestic. As the domestic government seeks to maximize the sum of domestic consumer surplus and domestic producer profits, it is more vigilant about anti-competitive behavior when the number of domestic consumers affected by this behavior is high. At the limit, if there is no domestic consumption (i.e., the net exports equal domestic production), the government cares only about the profits made by the domestic firms and allows them to act without

[29] In addition to influencing the equilibrium levels of investment, output and profits, a (also referred to as an index of the consumer valuation) determines the existence of domestic production given initial productivity levels. This is reflected in the relevant condition: a+e-2c > 0, where (e-2c) is always negative by assumption on e and c. When a is small, it may happen that the foreign firm is so competitive relative to the domestic firms that it is not profitable for the domestic firms to produce. In such a case, only a different -maybe more interventionist- industrial policy may adequately modify the environment to make production profitable; the state of domestic production in previous periods will determine which industrial policy is appropriate.

policy constraints.[30]

The subgame perfect equilibrium analysis of the model showed that the common wisdom policy (i.e., that generally accepted and observed, CN) is found to be optimal under quantity competition. In the next section, I analyze the case of Bertrand competition. The comparison of the two analyses, that of the game with quantity competition and that of the game with price competition, is expected to highlight how the efficiency of R&D policy is modified by the type of sales strategy existing at the market stage. This identification would enable me to suggest qualified policy recommendations and draw attention on the specific role of certain R&D and/or market elements.

Section 4: The Analysis of the Bertrand Competition Game

It should be noted at the outset, that the simultaneous price setting game in the final stage is analyzed for a market producing a homogeneous good under constant returns to scale. In such games, it is well known that asymmetric equilibria lead to corner solutions in which some firms make no sales. Consequently, under some conditions, firms will avoid R&D because of the strength of expected competition. This type of result can occur with product differentiation as well, but is highlighted, and more likely to occur, for homogeneous goods. For simplicity reason, I examined the homogeneous goods case, keeping in mind the likely emergence of drastic outcomes to be viewed as illustrative of possible extremes among diverse equilibrium situations.

The prevalence of price competition at the market stage makes a complete analysis of the game on the one hand lengthy and tedious and on the other hand difficult. Indeed the precise handling of price competition requires that the cases of drastic and non-drastic innovations be distinguished.[31]

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[30] In this quantity model, for the parameters I investigate, it is never profitable for the firms to collude. For a detailed proof, see Rutsaert (1994). Therefore, there is no need to examine the possible tradeoff between higher domestic profits and lower domestic consumer surplus due to collusion as a function of α. CN is the optimal policy whatever the proportion of domestic demand in the world demand.

[31] The standard definition of a drastic innovation is slightly modified to take into account the possibility that firms might have different initial marginal production costs: an innovation that reduces the innovator's marginal cost from its initial level, c, via an investment, x, is **non-drastic** if the monopoly price corresponding to (c-x), $p^m(c-x)$, is larger than the minimum of the initial marginal costs of its rivals, and is **drastic** if that monopoly price $p^m(c-x)$ is smaller than, or equal to, the minimum of the marginal costs of its rivals, say e. Another way to characterize a drastic innovation can be derived from solving the profit-maximization problem of that firm as if it were a monopolist: maximize $\Pi^i=(a-by_i)y_i - (c-x)y_i - (x)^2/2$ w.r.t. $y_i \geq 0$ given that $c \geq x \geq c-e$, $y_f = 0$, and $y_{j\neq i} = 0$. The monopoly price corresponding to the unique interior solution, $y^m = (a-c+x)/2b$, is $p^m(c-x) = a-by^m = (a+c-x)/2$. The above definition can therefore be equivalently formulated as: an innovation is drastic (resp. non-drastic) if $x \geq a+c-2e$ (resp. $x < a+c-2e$).

And this on turn renders the computations of the mixed-strategy SPEs complex if R&D investment is considered to be a continuous choice variable. As the principal conclusions are similar whether R&D investment is a discrete or continuous choice variable and whether the innovation is drastic or not,[32] I restrict the present analysis to the case where R&D investment is a discrete choice variable and generates a non-drastic innovation (as indicated by "nd" subscript). This should enable me to go rapidly to the essential: to elaborate the basic reasoning needed to solve the game and to identify the main features of the game equilibrium. Any striking difference or interesting point emerging in other cases will be mentioned in footnotes whenever it will be deemed desirable to do so.

Before beginning the analysis, I first make four assumptions that will be used to find the SPEs.

(A.1.) $\forall$ i,j $\in$ {1,2,f}, i$\neq$j, if $p_i = p_j$ and $MC_i < MC_j$, then $y_j = 0$, and if $p_i = p_j$ and $MC_i = MC_j$, then $y_i = y_j$, where MC_i denotes the constant marginal production costs of firm i. (For simplicity, MC_i will be called marginal costs.)

(A.2.) Each domestic firm has a choice of three levels of R&D investment: (i) no investment: x = 0; (ii) a small investment: x = m; (iii) a large investment: x = h. A small (respectively large) investment is such that the new constant marginal costs is higher (respectively lower) than that of the foreign firm: c-m $\geq$ e (respectively c-h < e).

(A.3.) The market parameters, including h being sufficiently large, are such that the profits of a domestic firm investing a high amount are positive as long as its domestic rival does not invest as much.

(A.4.) The Bertrand competition sets the output price according to the following rules. Let i,j,k $\in$ {1,2,f}: (i) If the two most productive firms have the same marginal cost after the R&D stage, the price equals that marginal cost and the demand is shared between them; (ii) If the two most productive firms have different marginal costs after the R&D stage, then the price will equal the marginal costs of the next to the most productive firm and only the most productive firm serves the demand.

4.1. Policy NN: No R&D Cooperation and No Market Collusion

Under the NN policy, domestic firms choose individually their R&D strategy, and then all firms choose their own price strategy. This NN subgame is solved backward.

At the output stage, given the individual investment decisions of both domestic firms, x_1 and

[32] This observation is based on a thorough analysis developed for, and available in, Rutsaert (1994).

x_2, the three firms compete in price for sales. Knowing the Bertrand competition pricing rules, each firm chooses its price strategy in such a way that its profits are maximized given its marginal cost. The price strategy of the domestic firms is given by: $\forall$ i,j, i≠j, $p_i(x_1,x_2) = e$ if $x_i>x_j$ and $c-x_i<e$, and $p_i(x_1,x_2) = c-x_i<e$ otherwise. The price strategy of the foreign firm is given by: $p_f(x_1,x_2) = \min\{(c-x_1),(c-x_2)\}$ if $c-x_1\geq e$ and $c-x_2\geq e$, and $p_f(x_1,x_2) = e$ otherwise. I denote a triplet of price strategy $\{p_1(x_1,x_2),p_2(x_1,x_2),p_f(x_1,x_2)\}$ by $p(x_1,x_2)$. At the output stage, the equilibrium price is: $p^*(x_1,x_2) = \min\{p_1(x_1,x_2),p_2(x_1,x_2),p_f(x_1,x_2)\}$.

At the R&D stage, given the equilibrium price that arises during the output stage, the domestic firms choose a profit-maximizing R&D strategy.

Define the R&D mixed strategy of the first domestic firm as $\sigma = \{\sigma_0,\sigma_m,\sigma_h\}$ where σ_0 is the probability that firm 1 will not invest, σ_m is the probability that firm 1 will invest a low amount, and σ_h is the probability that firm 1 will invest a high amount. Analogously, define the mixed strategy of the second domestic firm as $\tau=\{\tau_0,\tau_m,\tau_h\}$.

Investing a small amount is a dominated strategy. Indeed, regardless of the amount invested by the domestic rival, the profits of a domestic firm investing a small amount are negative (since this firm will always remain less productive than the foreign firm) and smaller than the profits of not investing. At equilibrium $\sigma_m = 0$ and $\tau_m = 0$.

Since $\sigma_m = 0$ and $\tau_m = 0$, I denote hereafter σ_h by $(1-\sigma_0)$ and τ_h by $(1-\tau_0)$. The normal form of the game after the dominated pure strategy is removed is given in Table 1.

Table 1. Normal Form of the Game

firm1\firm2	0	h
0	0,0	$0,\Pi_2[p(0,h);h,0]>0$
h	$\Pi_1[p(h,0);h,0]>0,0$	$\Pi_1[p(h,h);h,0]<0$, $\Pi_2[p(h,h);h,0]<0$

(i) Pure-Strategy SPEs

It is easy to see that there exists two symmetric SPEs in pure strategies in which only one firm invests: [0,h] and [h,0]. Since h generates a non-drastic innovation, the price will equal e, the profits of the investing firm will equal $\Pi_{i,nd}[\text{invest}] = [(a-e)/b]\,(e-c+h) - (h^2/2)$, the other firms will earn nothing, and the domestic social welfare will equal $W_{nd}[h,0] = \alpha CS_W + \Pi_{i,nd}[\text{invest}] = [\alpha(a-e)^2/(2b)] + \{[(a-e)/b]\ (e-c+h) - (h^2/2)\}$.

(ii) The Non-Degenerate Mixed-Strategy SPE

If firm 1 chooses a non-degenerate mixed strategy at the equilibrium, it must be the case that given the mixed strategy of its rival, the firm is indifferent between investing 0 or h. That is, given τ_0, $E\Pi_1[0;\tau_0] = E\Pi_1[h;\tau_0]$ where $E\Pi[r;\rho]$ is the expected profits of a firm choosing a pure strategy in R&D, r, given its rival's mixed strategy in R&D, ρ. Because a firm earns zero profits by not investing, this equality reduces to: $0 = \tau_0\ \Pi_1[p(h,0);h,0] + (1-\tau_0)\ \Pi_1[p(h,h);h,h]$. Since $\Pi_1[p(h,h);h,h] < 0$, τ_0 must be positive in order for this equality to hold. The value of τ_0 for which firm 1 is indifferent between investing and not investing is the solution of the τ_0-equation that this equality represents: $\tau^* = -\Pi_1[p(h,h);h,h] / \{\Pi_1[p(h,0);h,0] - \Pi_1[p(h,h);h,h]\}$.[33] A similar reasoning holds for firm 2. The same sequence of computations leads to the value of σ_0 for which firm 2 is indifferent between investing and not investing: $\sigma^* = -\Pi_2[p(h,h);h,h] / \{\Pi_2[p(h,0);h,0] - \Pi_2[p(h,h);h,h]\}$.[34] Since the two domestic firms are symmetric, $\sigma^*=\tau^*$.

Then it is easy to prove that $[\sigma^*,\tau^*]$ is the unique Nash equilibrium in non-degenerate strategies in R&D for the NN subgame.[35] The value of σ_{nd}^* and τ_{nd}^* is computed by substituting the profits by their values in σ^* and τ^*:

$$\sigma^*_{nd} = \tau^*_{nd} = \frac{-(-h^2/2)}{\left[\frac{(a-e)}{b}(e-c+h) - \frac{h^2}{2}\right] - \left[\frac{-h^2}{2}\right]} = \frac{bh^2}{2(a-e)(e-c+h)}$$

At the $[\sigma^*, \tau^*]$ equilibrium, the expected domestic social welfare, denoted by EW, reduces to

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[33] Notice that $0 < \tau^* < 1$ since $\Pi_1[p;h,h] = (-h^2/2) < 0$ and since $-\Pi_1[p(h,h);h,h] < \{\Pi_1[p(h,0);h,0] - \Pi_1[p(h,h);h,h]\}$.

[34] Notice that $0 < \sigma^* < 1$.

[35] A sketch of a proof is given:
Existence: Using $\sigma^* = \tau^*$, i,j=1,2, i≠j, if firm i decides not to invest with probability σ^* and decides to invest h with probability $(1-\sigma^*)$, then firm j will be indifferent between investing and not investing. In particular, it may choose not to invest with probability σ^*. Similarly for firm j. Therefore $[\sigma^*,\tau^*]$ is a Nash equilibrium in mixed-strategies in R&D.
Uniqueness: If firm 1 chooses not to invest with probability σ_0' such that $0 < \sigma_0' < \sigma^*$, then the pure strategy "not to invest" will be a profitable deviation from the mixed strategy τ^* for firm 2. Indeed, given σ_0', firm 2 will earn more by not investing than by randomizing between 0 and h (i.e., $E\Pi_2[0;\sigma_0'] > E\Pi_2[h;\sigma_0']$). Similarly, if firm 1 chooses not to invest with probability σ_0' such that $0 < \sigma^* < \sigma_0'$, then the pure strategy "to invest h" will be a profitable deviation for firm 2. Indeed, given σ_0', firm 2 will earn more by investing h than by randomizing between 0 and h (i.e., $E\Pi_2[0;\sigma_0'] < E\Pi_2[h;\sigma_0']$). Exactly the same reasoning holds when firm 2 chooses to invests with a probability $\tau_0' \neq \tau^*$. Therefore, $[\sigma^*,\tau^*]$ is the unique mixed-strategy Nash equilibrium.

the expected domestic consumer surplus because the domestic firms earn zero expected profits. $EW_{nd} = \alpha E(CS_W) = (\alpha b/2)\ E(Y_{nd}^2)$, where E(.) refers to the expectation operator. That is, $EW_{nd} = (\alpha b/2)\ E(Y_{nd}^2) = (\alpha b/2)\ \{\ (\sigma_{nd}^*)^2\ [(a-c)/b]^2 + 2\ \sigma_{nd}^*\ (1-\sigma_{nd}^*)\ [(a-e)/b]^2 + (1-\sigma_{nd}^*)^2\ [(a-c+h)/b]^2\ \}$. After the substitution of σ_{nd}^* by its value in EW_{nd}, the expression can be rewritten as:

$$EW_{nd} = \frac{(\alpha b/2)\ [b^2h^4(a-c)^2 + 2(bh^2)[2(a-e)(e-c+h)-bh^2](a-e)^2]}{\left[2b(a-e)(e-c+h)\right]^2} + \frac{(\alpha b/2)\ [2(a-e)(e-c+h)-bh^2]^2[a-c+h]^2}{\left[2b(a-e)(e-c+h)\right]^2}$$

The comparative statics of the solution shows that the probability that a domestic firm invests increases with the size of the market demand and decreases with foreign productivity. The reason behind the positive effect of the market size is simple: when the market demand is large (i.e., when b is small) the quantity demanded at a given price is large and this makes the revenues from investing a fixed amount large. To explain the effect of foreign competition, it must be remembered that, in the case of non-drastic innovation, the equilibrium price is lower than the profit-maximizing price corresponding to the reduced marginal costs. Hence, a higher foreign productivity means even lower price and greater quantity. Then, since marginal revenues is less than marginal costs (by definition of profit-maximizing price), this lowers profits.[36]

iii) Conclusions

These results are summarized in the following result.[37,38]

Result 4.1.

Under the NN policy, in the case where R&D investment is a discrete choice variable and generates a non-drastic innovation, there exist two symmetric SPEs in pure strategies in R&D, [e,c,e;h,0;NN] and [c,e,e;0,h;NN], and a unique SPE in mixed strategies in R&D,

[36] It is possible to compare the probability that a domestic firm invests h when h generates a drastic innovation (σ_d^*) with that when h generates a non-drastic innovation (σ_{nd}^*) due to a lower e. If the innovation is drastic, the domestic firm will have a higher probability of investing h than if foreign competitiveness causes the innovation to be non-drastic, $\sigma_{nd}^* > \sigma_d^*$. The reason is that for a single firm at the output stage (given any level of R&D costs), a drastic innovation generates higher profits than a non-drastic innovation.

[37] These conclusions are very similar to the conclusions derived in the cases where the the R&D investment is a continuous choice variable and/or when the innovation is drastic. In all cases, under NN, there exist two symmetric SPEs in pure R&D strategies in which only one domestic firm invests and there exists at least one SPE in R&D mixed strategies in which firms invest with a positive probability and do not invest with a positive probability.

[38] The SPE of the NN policy is denoted by: $[p_1^*,p_2^*,p_f^*;x_1^*,x_2^*;NN]$.

$[p_1*,p_2*,p_f*;\sigma_{nd}*,\sigma_{nd}*;NN]$ where $\sigma_{nd}*=bh^2/[2(a-e)(e-c+h)]$ is the probability that a domestic firm does not invest.

Under NN, these SPEs in pure and mixed R&D strategies lead to different situations in terms of final domestic productivity and pricing. At least one domestic firm always invests in the pure-strategy SPE equilibria, but this is not always the case for the mixed-strategy SPE. In the latter case, the home country faces the possibility that no investment will take place or that investment will be duplicated. Consequently, the expected cost reduction is higher when domestic firms invest with certainty (i.e., in a pure-strategy SPE).[39] In terms of pricing, monopoly pricing (constrained by a price not greater than e) is always observed in a pure-strategy SPE. In a mixed-strategy SPE, a competitive price emerges only when both domestic firms invest.[40] Therefore, the outcomes of a mixed-strategy SPE will be socially preferred by the domestic government only if the expected benefits of competition offset the costs of both the absence and duplication of investments.

Game theory alone does not indicate which type of equilibrium is likely to provide predictions that are more realistic for application. Accordingly, in comparing policies, I will consider separately the cases of pure- and mixed-strategy SPE, and my conclusions will depend on whether the SPE is in pure or mixed strategies.

4.2. Policy CN: R&D Cooperation But No Market Collusion

Under the CN policy, domestic firms cooperate in R&D; then, at the output stage, the three firms choose their price strategies individually. This CN subgame is solved backward, supposing that the CN policy is such that if firms wish to invest in R&D, it is compulsory that the investment be done in an RJV.

At the output stage, given the investment decision of the RJV, x_{RJV}, the three firms compete in price for sales. Knowing the Bertrand competition pricing rules, the price strategy of the domestic firms is given by: $\forall$ i=1,2: $p_i(x_{RJV}) = c-x_{RJV}$, and the price strategy of the foreign firm is given by:

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[39] In my specific case of a discrete choice variable, this result is easy to derive because only two levels of cost reduction can be observed at equilibrium: 0 or h. In the pure strategy equilibrium, h is invested with probability one whereas in the mixed strategy equilibrium, h is invested with probability $[1-(\sigma_{nd}*)^2] < 1$, because $\sigma_{nd}*$ is shown to be smaller than one. Therefore, the expected cost reduction is h in the former equilibrium and $([1-(\sigma_{nd}*)^2]\ h)$ in the latter equilibrium.

[40] Competitive pricing means here that the equilibrium price equals the seller's marginal production costs. Notice that if there is no investment so that only the foreign firm sells, it uses its competitive advantage to price above its marginal costs, and when only one domestic firm sells, its uses its monopolistic position to set the price above its marginal costs.

$p_f(x_{RJV})$ = $c\text{-}x_{RJV}$ if $c\text{-}x_{RJV} \geq e$ and $p_f(x_{RJV})$ = e otherwise. I denote the triplet of price strategies $\{p_1(x_{RJV}),p_2(x_{RJV}),p_f(x_{RJV})\}$ by $p(x_{RJV})$. At the output stage, the equilibrium price is $p^*(x_{RJV})$ = min $\{p_1(x_{RJV}),p_2(x_{RJV}),p_f(x_{RJV})\}$.

At the R&D stage, given the equilibrium price that arises during the output stage, domestic firms choose an R&D strategy that maximizes their profits. It is easy to see that the RJV member firms will earn at most zero profit. This happens when the RJV does not invest.[41] Thus there is a unique SPE in which the RJV does not invest and where the foreign firm serves the entire demand at a price that equals the marginal costs of its rivals: [c,c,c;0;CN]. The domestic social welfare amounts to $W_0 = [\alpha(a\text{-}c)^2]/(2b)$.

Hence, I find that if forced to use an RJV for any R&D, firms under CN will not invest in R&D. Note however that policies of the form of CN are generally in the form of permitting joint R&D, not making it compulsory. Suppose a decision making stage to the game were to be added, between the policy and the R&D stages, in which firms could decide whether or not to form an RJV. It is transparent that, under CN, they would not form an RJV. Without an RJV, they would perform as in NN above.

The analysis of the CN subgame leads thus to the results as summarized in the next result.[42,43]

<u>Result 4.2.</u>

Under CN, [c,c,c;0;CN] is the unique SPE if the domestic firms are forced to cooperate in order to invest and cannot collude on the market. If R&D cooperation is not compulsory under CN, the domestic firms will prefer to choose their R&D strategies individually. In such a case, the equilibria are the same as those arising under NN.

That no investment takes place in an RJV where the member firms compete in price against

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[41] If the RJV invests, whether the new marginal costs of its member firms are higher or lower than e, price competition will set the output stage price at the level of their new marginal costs and will prevent the member firms from covering their R&D costs.

[42] These conclusions are similar to the conclusions derived in the cases where the the R&D investment is a continuous choice variable and/or when the innovation is drastic. In all cases, when the implementation of the CN policy forces firms to cooperate for any R&D investment, there exists a unique SPE in pure R&D strategies in which both domestic firm do not invest. When R&D cooperation is not compulsory under CN, then the SPEs that arise are the same as those that occur under NN.

[43] The SPE of the CN policy is denoted by: $[p_1^*,p_2^*,p_f^*;x_{RJV}^*;CN]$.

each other to provide an homogeneous good at the market stage has already been pointed out earlier.[44] The causes are known: price competition and perfect substitutability of goods. There are Bertrand model assumptions that would modify the set-up and restore the incentive to cooperate in R&D under CN. For example, to add à la Kreps and Scheinkman a production capacity stage to the game prior to the price setting stage is likely to restore incentive to cooperate in R&D under some circumstances.[45] Another way of altering the equilibrium is by introducing product differentiation. There is always a level of sufficient product differentiation which would render joint R&D profitable since when domestic firms sell their own output in totally separate markets, joint R&D is clearly optimal.

4.3. Policy CC: R&D Cooperation and Market Collusion

Under the CC policy, domestic firms may cooperate in R&D and collude against the foreign firm in the market for sales after R&D cooperation. This CC subgame is solved backward.

At the output stage, the JV member firms sell jointly their output and choose the price strategy maximizing their joint profits. Given the JV investment decisions, x_{JV}, the JV and the foreign firm compete in price for sales. Aware of the Bertrand competition pricing rules, the JV sets its price strategy: $p_{JV}(x_{JV}) = e$ if $c-x_{JV}<e$, and $p_{JV}(x_{JV}) = c-x_{JV}$ otherwise. The price strategy of the foreign firm is given by: $p_f(x_{JV}) = c-x_{JV}$ if $c-x_{JV}\geq e$ and $p_f(x_{JV}) = e$ otherwise. I denote the pair of price strategies $\{p_{JV}(x_{JV}),p_f(x_{JV})\}$ by $p(x_{JV})$. At the output stage, the equilibrium price is $p^*(x_{JV}) = \min\{p_{JV}(x_{JV}),p_f(x_{JV})\}$.

At the R&D stage, given the equilibrium price that arises during the output stage, the colluding domestic firms choose an R&D strategy that maximizes the JV profits. Define the R&D mixed strategy of the JV as $\sigma = \{\sigma_0,\sigma_m,\sigma_h\}$ where σ_0 is the probability that the JV does not invest, σ_m is the probability that the JV invests a low amount, and σ_h is the probability that the JV invests a high amount.

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[44] See, for example, Katz (1986).

[45] Indeed, Kreps and Scheinkman (1983) show that, under certain circumstances, the Cournot outcome is equivalent to the outcome of a capacity-constrained price game. Using their contribution, the result of the previous chapter (namely that domestic firms find it profitable to cooperate in R&D under CN if quantity competition prevails) suggests that the existence of capacity constraints might restore (if some conditions are satisfied) the incentive to cooperate in R&D for firms competing in price in order to sell an homogeneous good.

Then it is easy to show that under CC σ_h=1 is the unique pure strategy SPE. Indeed, to invest a small amount and not to invest are dominated strategies because the JV earns higher profits by investing h. Hence, $\sigma_h = 1$ is a dominant strategy, and is the equilibrium strategy. Since h generates a non-drastic innovation, the price equals e, the constant marginal costs of the foreign firm. Each domestic firm produces and sells (a-e)/2, earning half of the JV profits $\Pi_{JV,nd}[e,e;h] = [(a-e)/b] (e-c+h) -(h^2/2)$. The foreign firm does not produce and earns nothing. The domestic social welfare is given by: $W_{nd}[h] = \alpha CS_W + \Pi_{JV,nd}[e,e;h] = [\alpha(a-e)^2/(2b)] + \{[(a-e)/b] (e-c+h) - (h^2/2)\}$.

The conclusions of the analysis of the CC subgame are gathered in the next result.[46,47]

Result 4.3.

Under CC, [e,e;h;CC] is the unique SPE in pure R&D strategies.

4.4. The Price Competition Game Equilibrium

It is reasonable to assume that under CN the domestic government allows R&D cooperation without forcing the domestic firms to cooperate in order to invest. Firms are known to choose individually their R&D strategy in such a case. Therefore, the effective choice of the government is either to prohibit any type of collaboration or to allow firms to cooperate in R&D and collude in the market in order to sell the output of the RJV.

The consequences of the CC policy are well defined and unique, but those of the NN policy depend on which type of SPE -in pure, or in mixed, R&D strategies- arises. I must thus consider the two cases separately when comparing with the outcomes of the CC policy. This may suggest which policy should be chosen taking into account the absence of a criterion for the emergence of pure versus mixed strategy SPEs. Consequently, I derive two propositions.[48]

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[46] These conclusions are similar to the conclusions derived in the cases where the the R&D investment is a continuous choice variable and/or when the innovation is drastic. In all cases, under the CC policy, there exists a unique SPE in pure R&D strategies in which the RJV invests in R&D and serves alone the entire demand.

[47] The SPE of the CC policy is denoted by: $[p_{JV}*,p_f*;x_{JV}*;CC]$.

[48] The analysis of the price competition game in the case of a continuous R&D choice variable allows in addition to draw conclusions about the comparative statics of the SPEs with respect to the market size and the foreign productivity. In particular, it can be shown that equilibrium levels of R&D investment observed in pure strategy SPEs increase with the size of the market and with the productivity of the foreign firm. Moreover this analysis also shows that there exist parameter values for which the three policies lead to identical results: no investment will take place. (See Rutsaert (1994) for details).

Proposition 4.1.

If an SPE in pure R&D strategies arises under NN, then the policies NN and CC generate the same gain in productivity for the home country and the same domestic social welfare.

Proof: Trivial, by comparison. $W_{nd}[h,0] = W_{nd}[0,h] = W_{nd}[h]$.

Proposition 4.2.

When an SPE in mixed R&D strategy arises under NN, then

$$b > \left[\frac{\alpha(e-c+h)(2a-c+h-e) - 2(a-e)(e-c+h)}{h^2}\right],$$

$$\text{or identically} \quad \alpha < \left[\frac{2(a-e)(e-c+h) + bh^2}{(e+h-c)(2a-c+h-e)}\right]$$

is a sufficient condition for the CC policy to be socially preferable to the NN policy.

Proof: see Appendix.

If an SPE in pure strategies arises under NN, it is shown that NN and CC would lead to identical domestic social welfare results. Only further assumptions or model extensions may help overcome this identical result and make the government's decision more realistic by taking into account additional factors.[49]

If an equilibrium in mixed strategy is to emerge under NN, then the NN and CC policies will lead to different results. Under NN, the risk that no investment takes place and the risk that the investment expenditure is duplicated exist. However, domestic consumers will benefit from a competitive price with positive probability. Under CC, none of those risks or advantages exist. On the one hand, the JV always invests and the R&D outcome and costs are shared. On the other hand, the joint marketing strategy of the JV never leads to a competitive price. The sufficient condition

[49] For example, the goverment decision might incorporate dynamic considerations. It might consider the number of domestic firms active in the domestic industry as an important factor for future competition. If such dynamic considerations play a role, then NN and CC might be distinguished in the case of pure strategy SPEs. Indeed, what differentiates the two policies is the number of firms remaining active at the output stage. Under NN, only one domestic firm stays in the market whereas under CC both domestic firms remain active in the market. The government may link its decision on considerations about how easy it is to catch up with an innovator and enter the market again after having fallen behind in terms of productivity, and how difficult it is to deter collusion habits among duopolists. Another solution might come from introducing transaction costs, such as for setting up an JV under CC and for correlating behaviors under NN (so that effectively only one domestic firm invests). Then, it would be a comparison of the transaction costs that would determine the goverment decision.

under which CC is socially preferable to NN highlights the two factors which make the gains to domestic consumers large under competitive pricing.[50] They are the proportion of the domestic consumption in the world demand and the size of the market demand: the lower the proportion of domestic demand and/or the lower the market size, the more likely it is that CC is socially preferable. The primary factor of note is that mixed strategy NN foregoes all domestic profits (in expected value terms). So, for example, if there were no domestic consumption, there would be no welfare benefit from R&D in NN, whereas there would be benefits in CC. Even when all consumption is domestic, the possibility of lower prices does not offset the losses of profits and of potential consumer surplus in case of no domestic R&D investment, over a wide range of parameters.[51]

Since the government's choice between NN and CC is dependent on the nature of equilibrium under NN and on the parameter values, only incomplete guidelines can be suggested to help the domestic government's policy decision at stage 1. In a homogeneous goods market where price competition prevails and where foreign competitive pressure prevents domestic firms from producing profitably, the government should employ a qualified technology policy for handling R&D cooperation. This qualified policy would allow cooperation in R&D followed by joint marketing when the domestic demand is small compared to the world demand, or when the size of the market is small.[52]

Section 5: Comparison of the Cournot and Bertrand Games and Concluding Remarks

The decision problem of a government which wishes to promote R&D cooperation as a technology-cum-trade policy when foreign competitive pressure challenges domestic firms was examined. The homogeneous product Cournot and Bertrand games that were investigated represent

[50] These factors are also identified in the sufficient condititon under which CC is optimal in the case of a drastic innovation when the R&D investment is a discrete choice variable. In addition, there exist parameter values under which NN is socially preferable to CC in the case of a drastic innovation. When the R&D investment is a continuous choice variable, then no clear analytical result such as the above conditions is forthcoming. However, the value of α is still acting in the same direction: the lower its value, the more likely CC is preferred to NN. See Rutsaert (1994) for details.

[51] The parameter space restrictions and knowledge of some parameters for which mixed strategy NN is socially preferred to CC inhibits generalization. But the mixed strategy case does highlight the factors of importance. Fear of rival's investment may inhibit R&D, and domestic competition reduces profits earned on foreign sales.

[52] A rule of reason approach could be used to implement this type of qualified policy. It might be legal for domestic firms to cooperate in R&D, and market jointly the outcome of their R&D if it could be shown that they compete in price against competitive foreign competitors in a homogeneous goods market featuring a low total demand (that would not support several competitors) and/or if there is low domestic consumption. The trade policy implications, e.g., retaliation in either R&D or alternative trade policies, is beyond the scope of this theoretical inquiry.

polar extremes of degrees of competitiveness within non-cooperative games. Although real markets are typically characterized by heterogeneous products, looking at these two cases allowed a first step in the study of the effects of R&D cooperation policy, namely the identification of some of their extremes outcomes. The arising of striking differences between the results of the two games reflects some of these extremes, while the emergence of similarities draw attention to some stable facts.

The first difference between these games lies in the efficiency of the policy "to allow R&D cooperation while prohibiting market collusion" : optimal when quantity competition prevails, and sub-optimal when price competition prevails. Hence, depending on the type of market competition, the optimal policy clearly differs. The second difference relates to the profitability of joint marketing after R&D cooperation. Given the scope of my analysis of this model, it is never profitable to collude in the case of quantity competition and it is always profitable to collude in the case of price competition. Beyond its categorical tone, this observation draws attention to the fact that the decision between flexible and permissive enforcement of antitrust law should not be limited to an analysis of the effect of market behaviors. The third difference is found by comparing the influence of foreign competitive pressure on the equilibrium level of R&D investment in the case of pure strategy SPEs.[53] The equilibrium R&D investment level increases with foreign productivity in the Bertrand game and decreases with it in the Cournot game.[54]

The first similarity between the quantity and price models is the positive role of the size of market. Indeed, its influence on revenues accruing after a production process improvement is qualitatively the same whether firms compete in price or in quantity: the larger the demand at a given price, the larger the revenues at that price, everything else being constant, and thus the incentive to invest larger amounts in R&D at equilibrium. The second resemblance is the inability of any of the three R&D policies to create an incentive to invest in R&D under certain circumstances. This suggests that to promote R&D cooperation (whatever the extent of collaboration) is not panacea, and that then other policies would be more effective. The cause of the absence of investment should help determine

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[53] The SPEs in mixed strategies being not fully studied in both quantity and price competition games, the difference in the influence of foreign competitive pressure cannot be analyzed.

[54] This might be explained as follows. In the former game, only the most productive firm produces, and it serves the entire demand alone. In the case of non-drastic innovation (the pertinent case), if a domestic firm becomes the most productive one after investing in R&D, it serves the entire demand by quoting the foreign's firm marginal costs as an equilibrium price. Hence, the innovative firm has a higher marginal incentive to invest when these costs are low because it sells more at this lower price. In the Cournot game, the domestic firms do not face such a constraint since they can sell even if they are not as profitable as the foreign firm. Also, they do not enjoy the same incentive since less productive firms remain active in the market. For given initial domestic costs, a higher foreign productivity indicates a larger productivity gap and lower sales on which to recover R&D costs. The investment necessary to reduce a large gap in a profitable way is made less profitable by the decreasing returns to scale of R&D investment.

which alternative R&D policy should be chosen.

This comparison of the equilibrium outcomes of the two games shows that the optimal policy decision depends on the type of competition prevailing in the product market and on the characteristics of this market. Such a conclusion corroborates a key contribution of the strategic trade policy literature: the intensity and the nature of market competition affect the efficiency of a government policy aimed at modifying domestic firms' decision environment so as to induce actions (by these firms) that reap foreign firms' rents.

Moreover, this open economy analysis allows to highlight the role of foreign competitive pressure and of trade structure (as represented by the proportion of domestic demand in the world demand). The influence of foreign competition on the profit-maximizing level of R&D investment and on the profitability of collusive sales behavior by domestic firms appears, in both cases, to vary with the nature of competition in the product market. Also the trade structure is shown to be a criterion in selecting the optimal policy because it determines the magnitude of domestic welfare loss generated by non-competitive sales behavior by domestic firms.

It is expected that the core of this research -namely, the dependence of the policy's efficiency on the nature of competition and the industry features- will be preserved if certain restrictive assumptions are relaxed. However to investigate the policy choice at stake in this work under less restrictive assumptions is likely to highlight new elements of interest to explain facts observed in reality. For example, the explicit modelling of product differentiation might permit to derive a differentiation threshold which would specify the minimum degree of product heterogeneity required in order for the flexible antitrust policy to become optimal. Another line of inquiry would consist in observing how incorporating market segmentation affects the pattern of incentives to invest cooperatively in R&D and to collude after R&D cooperation.[55] The release of the assumption concerning the non-strategic behavior of the foreign firm and government seems to be a desirable modification the outcome of which is hard to predict.

[55] Also it might happen that joint marketing after R&D cooperation could be used by the domestic firms not so much to modify their domestic position, but to better penetrate the foreign market. See, for example, in Chiang and Masson (1988).) Policy-makers would have to identify carefully the objective of the joint marketing, and to keep their policy flexible enough so that the joint marketing strategies would minimize negative consequences for domestic consumers.

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Appendix

Proof of Proposition 4.2.

By definition EW = $(\sigma_{nd}*)^2\ W_{nd}[0,0] + \sigma_{nd}*\ (1-\sigma_{nd}*)\ W_{nd}[0,h] + \sigma_{nd}*\ (1-\sigma_{nd}*)\ W_{nd}[h,0] + (1-\sigma_{nd}*)^2\ W_{nd}[h,h]$, where $\sigma_{nd}*$ is the probability that a domestic firm does not invest at equilibrium.
Therefore in order to show that EW < $W_{nd}[h]$, it would be enough to show that the four following inequalities hold: $W_{nd}[0,0] \leq W_{nd}[h]$, $W_{nd}[h,0] \leq W_{nd}[h]$, $W_{nd}[0,h] \leq W_{nd}[h]$, and $W_{nd}[h,h] \leq W_{nd}[h]$. I show that the first three inequalities always hold and I derive as a sufficient condition the condition that makes the last inequality hold.
First, I observe that $W_{nd}[0,0] \leq W_{nd}[h]$ since $\Pi_{1,nd}[c,c,c;0,0] = 0 < \Pi_{1,nd}[e,e;h]$ and since $CS_W[p=c] < CS_W[p=e]$. Second, I observe that $W_{nd}[h,0] = W_{nd}[0,h] = W_{nd}[h]$. Third, I derive two conditions under which $W_{nd}[h,h] < W_{nd}[h]$. Since $W_{nd}[h,h] - W_{nd}[h] = [\alpha\ \{(e+h-c)(2a-c+h-e)\}\ /2b^2] - [(a-e)\ (e-c+h)/b] - [h^2/2]$, $W_{nd}[h,h] < W_{nd}[h]$ if one of the two following conditions are satisfied:

$$b > \left[\frac{\alpha(e-c+h)(2a-c+h-e) - 2(a-e)(e-c+h)}{h^2}\right]$$

$$\text{or identically } \alpha < \left[\frac{2(a-e)(e-c+h)+bh^2}{(e+h-c)(2a-c+h-e)}\right]$$

Therefore, this condition is also a sufficient condition for EW < $W_{nd}[h]$.