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INNOVATIVE STRATEGIC GROUPS IN
MULTINATIONAL INDUSTRIES *

By

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1. Introduction

The importance of technological change for the growth and sustainability of economic welfare is well known. In the last fifteen years analytical oriented research resulted in significant progress towards a better understanding of the micro-economic forces that contribute to shaping firms' innovative activities (Kamien and Schwartz (1982), Scherer (1984)). The clarification and testing of the Schumpeterian hypotheses on firm size and market structure received considerable attention. In recent years the game theoretic analysis has served to enrich the analytical understanding (see e.g. Reinganum (1984) and Shapiro (1985)) of the effects of technological rivalry on the pace of the research and development race, while the incentives created by patent and licensing possibilities and the possible impact of the pre- and post-innovation market structure scenario has been explored as well. Imitation and diffusion activities and the link of innovative activities with the strategic positioning of firms likewise received attention (Brander and Spencer (1983)). And a beginning has been made with the investigation of normative and positive issues related to government's policies towards technological change (Spencer and Brander (1983), Spence (1984)).

The innovative activities of firms located in a small and open economy, such as Belgium, raise some specific issues which, despite the

progress of recent research, do not appear to have been explored in detail. The majority of industries in the Belgian economy are characterized by the presence of multinational firms, which may and typically will compete with domestic firms, that have no (or less) direct investments in other national markets. Firms operating with changing technologies and/or customer and input markets pursue even within the same industry a variety of successful strategies. Clusters of firms that follow a similar technology or marketing strategy ¹ are so called strategic groups. Mobility barriers (Caves and Porter (1977)) may limit the easy and quick switch from one group to another and firms can continue to earn (normal or above normal) profits within each strategic group.

It appears reasonable to adopt the working hypothesis that innovative strategy differences are likely to exist between domestic and multinational companies, if only because the latter face and shape different internalized technology and input markets. Technological rivalry within a multinational company, for example, has intrinsic features of a cooperative venture with a maximum extent of spin offs within the firm and the realisation of economies of scale and scope. Domestic firms may be on a different footing, if only in these dimensions. On an analytical level the question emerges whether asymmetries between multinational and domestic companies may result in quite different innovative strategies that coexist in an industry. In addition it remains to be investigated on both a conceptual and empirical level, in what strategy dimensions the strategic groups differ and if indeed clusters of multinational and domestic firms pursue diverse avenues related to success.

A venture into the asymmetries in innovative strategies in multinational industries should at the very least provide some answers to the issues raised above. This paper reports on an attempt to meet this chal-

lenge. A relatively simple game theoretic scenario with firms deciding on research and development and production and asymmetries in the multi-market involvement is rationalized and analysed to understand the possibilities for different strategies to coexist in an industry. It will be shown that multinational and domestic firms may well pursue different research and development strategies given various scenarios of conduct. Moreover, data resulting from a survey of "high tech" companies were analysed to search for differences in the innovative strategies and in scores of perceived and realised success or failure. Systematic differences across domestic and multinational firms were sought for. Although the usual data and methodological caveats apply, the empirical findings are consistent with differences in strategic positioning by both groups of firms that all are significantly related to success.

The next paragraph details a formal scenario to analyze strategic differences in multinational industries. Inferences are detailed in a consequent section after which the empirical results and conclusions are presented.

2. Multinational industries

Multinational and domestic firms that pursue different successful strategies may be viewed as belonging to different strategic groups of the industry. Viewing strategies in a decision theoretic spirit, i.e. as the solution to long-run profit maximisation, clearly has limitations for explaining the existence of such strategy clusters. Asymmetries in objectives or the heterogeneity of research and development or production technologies (for example, reflected in durable firm specific assets) as well as differences in input or output markets, typically will

involve diverse strategies. But one of the essential characteristics of strategic groups is precisely that corporate strategies differ, not only significantly, but also persistently in a stable fashion (e.g. Newman (1978)). Given that different strategies at least in the short-run involve different levels of profitability, it is not clear why a strategic group configuration would be persistent, since one would expect firms simply to switch to the successful one. In the long run the differences would evaporate since firms would focus on a (more) unique set of successful actions that render a normal return. Mobility barriers related for example to entry and exit costs (Caves and Porter (1977)) have been introduced to explain why strategic groups persist.

Instead of focusing on the above decision theoretic view, it appears natural to view strategies in a game theoretic framework. It is well known that rival firms may be in an asymmetric stable Nash equilibrium, regardless of the presence or not of mobility barriers. A stable asymmetric game theoretic equilibrium say in innovative actions that yields normal or above normal profits to the participating firms, involves by definition different successful strategies that coexist in a stable fashion.

Multinational and domestic firms choosing innovative activities will be viewed as taking into account the interactions of these strategies since they operate in the same industry and are rivals in any given national market. Multinational companies operate plants and/or distribution facilities in different (national) markets. Domestic firms only have production facilities in one country. Both types of firms may or may not export.

The essence of the multinational firm is, however, that it is optimally tuned to benefit from economies of scale and scope in both R&D and market supply. Multinational firms supply commodities which, with very little alteration, can be sold in different national markets. The results of R&D can be embodied in the multinational companies' products which are sold in a variety of markets. The externalities (spin offs) of R&D in one, say home, market on the supply in other markets are internalized in the multinational company. This internalisation can be viewed as a response to adverse selection and moral hazard problems that accompany asymmetries in information connected with licensing agreements (Caves (1984), p. 204-207). Multinational companies may in these circumstances prefer not to license the innovation to rival (domestic) firms because of strategic reasons ².

A simple scenario can be set up to highlight and analyze the innovative strategies of multinational and domestic firms. Consider an industry with two markets. Consumer preferences may, but need not, be different across markets. Serving both markets from one market involves a "transaction cost" related say to transportation and or distribution (incl. marketing). There are two firms, one of which is a multinational that operates with "low" transaction costs t^m . The other, domestic firm, has "high" transaction costs t^d . Even if the markets are identical in demand conditions and if both firms produce perfect substitutes intra-industry trade will occur in a Nash equilibrium (Brander (1981), Neven and Philips (1985)) provided t^d is not too high compared with t^m . The transaction cost advantage is posited to be sufficiently important so that only the multinational serves both markets and the domestic firm is limited to the first market. The "membership game" in which the firms achieve the initial cost advantage is not looked at. Both firms can be thought of as having been involved in some uncertain innovative race, in

which the winner becomes the multinational firm and the loser or imitator is nevertheless able to capture part of the market ³. The multinational firm and the domestic firm operate in a duopoly in market one and the former has a monopoly in the market two.

The intention is not to develop a theory, but rather to illustrate underlying economic tendencies, hence it is useful to employ simple functional specifications. Firm demand is supposed to be linear and production cost constant. R&D expenditures are supposed to be product oriented and to shift the intercept of the firm's linear demand curves. This specification has the advantage that the game can also be interpreted (*mutatis mutandi*) as a cost reducing game (see Katz (1985)).⁴

The multinational firm's inverse demand curve in market one is $p_1^m = \alpha_1^m(x) - u - \beta v$, with $\alpha_1^m(x)$ the intercept. The price p_1^m is a function of the "stock of knowledge" x available in the firm and of the output u and v of respectively the multinational and domestic firm. The domestic firm faces $p^d = \alpha^d(y) - v - \beta u$, with y the stock of knowledge available in this firm. Both companies produce substitutes but products may nevertheless be differentiated (given that $0 \leq \beta \leq 1$).⁵ For $\beta = 0$ products are differentiated to the extent that firms have a monopoly in segments of market one. In its home market the demand curve for the multinational is $p_2^m = \alpha_2^m(x) - \delta w$, with w the production of this firm in market two. Note that the multinational is transferring "costlessly" its stock of knowledge to both markets. Diminishing returns are assumed, i.e. $d^2\alpha_1^m/dx^2 < 0$, $d^2\alpha_2^m/dx^2 < 0$ and $d^2\alpha^d/dy^2 < 0$.

Unit production costs are constant for both firms, and equal to c_1^m and c_2^m for the operations of the multinational in market one and two

respectively and c^d for the domestic firm. The cost c_1^m equals $c_2^m + t^m$ with t^m the transaction cost.

R&D expenditures are r and s for the multinational and domestic firm respectively. There are possibly spin offs from one company to the other. The stock of knowledge in the multinational is $x = r + \phi_d^m s$ and for the domestic firm it is $y = s + \phi_m^d r$. The spin-off parameters are constants related for example to technology and are bounded, i.e. $0 \leq \phi_d^m \leq 1$ and $0 \leq \phi_m^d \leq 1$.⁶ In summary

	Market 1	Market 2
Multinational firm	Output u	w
	R&D exp r	
	Knowledge $x = r + \phi_d^m s$	$0 \leq \phi_d^m \leq 1$
	Demand $p_1^m = \alpha_1^m(x) - u - \beta.v$	$p_2^m = \alpha_2^m(x) - \delta.w$
	Unit costs $c_1^m = c_2^m + t^m$	c_2^m
Domestic firm	Output v
	R&D exp s	
	Knowledge $y = s + \phi_m^d r, 0 \leq \phi_m^d \leq 1$	
	Demand $p^d = \alpha^d(y) - v - \beta.u$	
	Unit costs c^d	

Table 1 : The multinational firm industry setting

Equilibrium in the described multinational industries can be characterized using different solution concepts. Both noncooperative and cooperative conduct will be explored.

3. Strategic R&D in multinational industries.

Firms are deciding on levels of R&D expenditures that will result in product (or process) improvements or novelties, realizing that output decisions will be made contingent on the outcome of the innovative activities. A two stage game is considered, with the R&D game played in the first stage and the output game in the second one, given that the outcome of the first play is known ⁷. The game is solved through backward induction i.e. a feedback equilibrium concept (subgame perfect equilibrium) (Basar and Olsder (1982)) is used. The intention is to characterise circumstances in which innovative strategic groups with multinational and domestic firms arise.

3.1. Noncooperative equilibria.

The major focus is on a Nash equilibrium, some comments on a Stackelberg scenario will also be given before moving to the cooperative situation. The value of the multinational and domestic firm at the beginning of the second stage is respectively

$$\pi^m = u(\alpha_1^m - c_1^m - u - \beta v) + w(\alpha_2^m - c_2^m - \delta w) \quad (1)$$

and

$$\pi^d = v(\alpha^d - c^d - v - \beta u) \quad (2)$$

The Nash equilibrium of the output game played in this last period is

$$u^*, v^*, w^*, \text{ with } \pi^m(u^*, v^*, w^*) = \max_{u, w} \pi^m(u, v^*, w) \text{ and}$$

$$\pi^d(u^*, v^*) = \max_v \pi^d(u^*, v). \text{ It is easily verified that}$$

$$u^* = \frac{2 m_1^m - \beta m^d}{4 - \beta^2}, \quad v^* = \frac{2 m^d - \beta m_1^m}{4 - \beta^2}, \quad w^* = \frac{m_2^m}{2\delta} \quad (3)$$

with $m_1^m \equiv \alpha_1^m(x) - c_1^m$,

$$m^d \equiv \alpha^d(y) - c^d, \quad (4)$$

$$m_2^m \equiv \alpha_2^m(x) - c_2^m.$$

Asymmetric demand-cost-margins m_1^m , m^d , m_2^m do not prevent the existence of a Nash equilibrium with positive outputs and profits, provided $(\beta/2) < m_1^m/m^d < 2/\beta$.

The R&D investment decision is taken in the first stage of the game, with both the multinational and domestic firm realizing that the innovative strategies chosen are irreversible and that the outcome as reflected in the magnitude of the firm's demand curve will be observed before the output game. Firms have perfect foresight as to the equilibrium of this second stage game. The objective functions of resp. the multinational and the domestic firm are ⁸

$$V^m = \pi^m(u^*(r,s), v^*(r,s), w^*(r,s), r, s) - r \quad (5)$$

and

$$V^d = \pi^d(u^*(r,s), v^*(r,s), r, s) - s \quad (6)$$

with $u^*(r,s)$, $v^*(r,s)$ and $w^*(r,s)$ defined through (3) and the knowledge levels $x = r + \theta_d^m s$ and $y = s + \theta_m^d r$. Given the Nash property of the outputs levels it is clear that $0 = \partial V^m / \partial u^* = \partial V^m / \partial w^* = \partial V^d / \partial v^*$.

The first stage of the subgame perfect equilibrium is the Nash equilibrium r^* , s^* such that $V^m(r^*, s^*) = \max_r V^m(r, s^*)$ and $V^d(r^*, s^*) = \max_s V^d(r^*, s)$. The equilibrium r^*, s^* solves therefore both ⁹

$$\frac{\partial V^m}{\partial r} = 0 = \frac{\partial \pi^m}{\partial v^*} \cdot \frac{\partial v^*}{\partial r} + \left[\frac{\partial \pi^m}{\partial r} - 1 \right] \quad (7)$$

and

with $m_1^m \equiv \alpha_1^m(x) - c_1^m$,

$$m^d \equiv \alpha^d(y) - c^d, \quad (4)$$

$$m_2^m \equiv \alpha_2^m(x) - c_2^m.$$

Asymmetric demand-cost-margins m_1^m , m^d , m_2^m do not prevent the existence of a Nash equilibrium with positive outputs and profits, provided $(\beta/2) < m_1^m/m^d < 2/\beta$.

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with $u^*(r,s)$, $v^*(r,s)$ and $w^*(r,s)$ defined through (3) and the knowledge levels $x = r + \theta_d^m s$ and $y = s + \theta_m^d r$. Given the Nash property of the outputs levels it is clear that $0 = \partial V^m / \partial u^* = \partial V^m / \partial w^* = \partial V^d / \partial v^*$.

The first stage of the subgame perfect equilibrium is the Nash equilibrium r^* , s^* such that $V^m(r^*, s^*) = \max_r V^m(r, s^*)$ and $V^d(r^*, s^*) = \max_s V^d(r^*, s)$. The equilibrium r^*, s^* solves therefore both ^a

$$\frac{\partial V^m}{\partial r} = 0 = \frac{\partial \pi^m}{\partial v^*} \cdot \frac{\partial v^*}{\partial r} + \left[\frac{\partial \pi^m}{\partial r} - 1 \right] \quad (7)$$

and

$$\frac{\partial V^d}{\partial s} = 0 = \frac{\partial \pi^d}{\partial u^*} \cdot \frac{\partial u^*}{\partial s} + \left[\frac{\partial \pi^d}{\partial s} - 1 \right] \quad (8)$$

as well as (3). Although the reaction curves in r and s need not necessarily be downward sloping the subsequent discussion will only focus on this case ¹⁰. In addition it is assumed that the second-order optimality conditions are satisfied and that own effects of R&D on marginal profit dominate cross effects, i.e.:

$$\partial^2 V^m / \partial r^2 < \partial^2 V^m / \partial r \partial s \text{ and } \partial^2 V^d / \partial s^2 < \partial^2 V^d / \partial s \partial r \text{ }^{11}.$$

To understand the feedback Nash equilibrium, note that each firm takes into account the direct consequences on the profits, represented by the expression between brackets, as well as the strategic effects of R&D decisions. If the firms were to decide on r , s and output simultaneously instead of sequentially, i.e. if they were to decide on open loop strategies, the strategic terms would be ignored. The sign of the feedback effects is dependent on the spillovers since

$$\frac{\partial V^*}{\partial r} = (2 \theta_m^d \cdot d\alpha^d / dy - \beta \cdot d\alpha_1^m / dx) / (4 - \beta^2) \quad (9)$$

and

$$\frac{\partial u^*}{\partial s} = (2 \theta_d^m \cdot d\alpha_1^m / dx - \beta \cdot d\alpha^d / dy) / (4 - \beta^2) \quad (10)$$

while

$$v \cdot \frac{\partial \pi^m}{\partial v} = u \cdot \frac{\partial \pi^d}{\partial u} = -\beta u v \leq 0 \quad (11)$$

For zero spill overs an increase in R&D results in a decrease in the rivals output and hence in an increase in profitability. Hence the feedback equilibrium levels are larger than the open loop decisions that ignore these strategic positioning (Brander and Spencer (1983)). For posi-

tive between firm spill overs (e.g. $\theta_m^d = \theta_d^m = 1$) this need not hold¹², since a larger R&D effort may result in an increase in rival's output and a negative impact on own profits¹³.

Of central concern here is whether the asymmetries between the multinational and domestic firm, for example with respect to the demand cost margin and spin offs are accompanied with different innovative strategies. A feedback Nash equilibrium with r^* different from s^* may be interpreted as both firms belonging to a different strategic group. To extract some possible basic tendencies let

$$\begin{aligned}\alpha_1^m &\equiv l_1^m + x^\mu, & l_1^m &\geq 0 \\ \alpha_2^m &= l_2^m + x^\mu, & l_2^m &\geq 0 \\ \alpha^d &= l^d + y^\mu, & l^d &\geq 0\end{aligned}\tag{12}$$

with $\mu < 1$ to reflect diminishing returns towards increasing knowledge levels. Both firms are equally productive in transferring a given stock of knowledge into additional demand¹⁴. Using the mean value theorem (see Appendix 1 and 2) it can be verified that as long as the described scenario and functional specifications apply, while R&D is a strategic substitute¹⁵, the multinational company's equilibrium strategy may be "more" or "less" innovative than the domestic company's. The multinational's equilibrium expenditures r^* will be greater (smaller) than the domestic firm's investments s^* if and only if ψ^N is positive (negative), with

$$\begin{aligned}\psi^N &= m_1^m [k_1(4-\beta^2\theta_d^m) + 2\beta(1-\theta_m^d)] + m_2^m k_1((4-\beta^2)^2/4\delta) \\ &\quad - m^d [2 k_1 \beta(1-\theta_d^m) + (4-\beta^2\theta_m^d)]\end{aligned}\tag{13}$$

$$k_1 = [(1+\theta_d^m)/(1+\theta_m^d)]^{\mu-1}\tag{14}$$

and the margins evaluated at symmetric R&D levels.

The multinational firm will be part of a more innovative strategic group, to capitalize on the spin offs in both markets and the lower transaction costs in a broad set of circumstances. Indeed, $\psi^N > 0$ and $r^* > s^*$ if the spill-overs between companies are identical ($\emptyset_m^d = \emptyset_d^m = \emptyset \geq 0$) and $m_1^m \geq m^d$. The demand-cost margins are to be evaluated at symmetric R&D levels, hence in view of (12)

$$\begin{aligned} m_1^m - m^d &= (l_1^m - c_1^m) - (l^d - c^d) \\ &= (l_1^m - t^m) + (c^d - c_2^m) - l^d \end{aligned} \quad (15)$$

since $c_1^m = c_2^m + t^m$. When both firms are equally efficient in their home markets ($c^d = c_2^m$), the multinational will be more innovative if it is positioned in a sufficiently important market segment compared with the domestic firm. The large original market (l_1^m) is more than compensating the transaction cost of serving the foreign market ($l_1^m - t^m > l^d$). These tendencies are reinforced if the multinational firm has a cost advantage (say because of its size) in the production ($c^d - c_2^m > 0$). In the described scenarios one may observe domestic firms "focusing" on "niches" in the market with relatively modest innovative activities compared to multinational firms that within the same industry are positioned in large market segments. With R&D focusing on new products ($l_1^m = l^d = 0$) the multinational is in the present context less likely to be positioned in the more innovative strategic group, unless it has a significant cost advantage ($c^d - c_1^m > 0$).

The between firm spin offs help to determine the asymmetries in innovative effort, since

$$\frac{\partial \psi^N}{\partial \theta_d^m} = k_1 \beta (2m^d - \beta m_1^m) > 0 \quad \text{for } (m_1^m/m^d) < 2/\beta \quad (16)$$

and

$$\frac{\partial \psi^N}{\partial \theta_m^d} = \beta (\beta m^d - 2m_1^m) < 0 \quad \text{for } \frac{\beta}{2} < (m_1^m/m^d) \quad (17)$$

Provided that the multinational demand cost margins differ from the domestic ones within the bounds indicated ¹⁶, it is more likely that the multinational firm will be in the more innovative strategic group as the spin offs towards (from) the domestic firms decrease (increase). One of the inferences that can be drawn is that a higher cost domestic firm may well be part of a more innovative cluster which is in equilibrium with less innovative multinational firms, in particular if the spin offs from the multinational company are important and the externalities towards this firm are low. For this to happen it is necessary that the domestic firm has a sufficiently large market segment to begin with, i.e. say before the product improvement R&D venture. To verify this let $\theta_m^d = 1$, $\theta_d^m = 0$ and $((4-\beta^2)^2/48)) \approx 1$. It is easily verified that

$$\begin{aligned} \psi^N/k_1 &= 4(l_1^m - c_1^m) + (l_2^m - c_2^m) - 5\beta(l^d - c^d) \\ &\quad - m^d((4-\beta^2)/k_1 - 3\beta) \end{aligned} \quad (18)$$

with $k_1 = 2^{1-\mu}$. Only for l^d sufficiently large ($\beta > 0$ and μ sufficiently close to one) it is possible that $\psi^N < 0$ and $s^* > r^*$.

To obtain some insights as to the sensitivity of the inferences to the equilibrium concept, a Stackelberg feedback equilibrium can be analyzed (see Appendix 3, A.3.1.). The multinational firm, for example, may be leading in both the output and R&D game with the domestic firm deciding on its best response given the decisions of the other firm. As long

as R&D is a strategic substitute among the firms ($ds/dr < 0$) and the spill over between firms are not too large, the multinational firm is likely to be positioned in a more innovative strategic group even in circumstances where in a Nash equilibrium this firm would focus on less innovative policies than the domestic firm.¹⁷ These circumstances and $m^m \geq m^d$ are also sufficient for the multinational to spend more on R&D than the domestic firm, for any value of β , $0 < \beta < 1$.

3.2. Cooperative equilibria.

Both the multinational and domestic firm may realize that industry profitability (in market one) can be improved upon by cooperation. The question emerges what impact cooperation may have on the observed strategic clusters and on the extent of the R&D efforts of the firms and the industry. Two scenarios seem to be of interest: a joint venture in R&D but competition (Nash) in the output game and cooperation in both R&D and production.

With a joint venture in R&D and Nash in the last stage, the multinational and domestic firms continue to produce Nash output levels u^* , v^* and w^* as defined by (3), given the knowledge resulting from the cooperative R&D game. In the first stage r and s are chosen with perfect foresight as to these output levels and with the objective of maximizing industry profits $V = V^m + V^d$, with V^m and V^d defined by (5) and (6). The resulting cooperative R&D decisions r^* and s^* solve therefore:

$$\frac{\partial V}{\partial r} = 0 = \frac{\partial \pi^m}{\partial v^*} \cdot \frac{\partial v^*}{\partial r} + \frac{\partial \pi^d}{\partial u^*} \cdot \frac{\partial u^*}{\partial r} + \left[\frac{\partial \pi^m}{\partial r} + \frac{\partial \pi^d}{\partial r} - 1 \right] \quad (19)$$

$$\frac{\partial V}{\partial s} = 0 = \frac{\partial \pi^m}{\partial v^*} \cdot \frac{\partial v^*}{\partial s} + \frac{\partial \pi^d}{\partial u^*} \cdot \frac{\partial u^*}{\partial s} + \left[\frac{\partial \pi^m}{\partial s} + \frac{\partial \pi^d}{\partial s} - 1 \right] \quad (20)$$

as well as (3). The direct consequences of R&D on industry profits are again represented by the expression between square brackets. Open loop cooperative R&D strategies are obtained by equating these terms to zero. The indirect or strategic effects of R&D are represented by the other terms; the joint venture incorporates the strategic impact on both the profits of the multinational and the domestic firm. The equation for

$\partial v^*/\partial r$ and $\partial u^*/\partial s$ were defined earlier ((7) and (8)). It is easily verified that

$$\frac{\partial u^*}{\partial r} = (2 \cdot d\alpha_1^m/dx - \beta \cdot \theta_m^d \cdot d\alpha^d/dy) / (4 - \beta^2) \quad (21)$$

and

$$\frac{\partial v^*}{\partial s} = (2 \cdot d\alpha^d/dy - \beta \cdot \theta_d^m \cdot d\alpha_1^m/dx) / (4 - \beta^2) \quad (22)$$

while the impact of output changes on the other firm's profits is still negative (see (11)). Given the functional specifications for the dependence of demand on knowledge, the total strategic effect is negative for $m_1^m \geq m^d$ ¹⁸. Given that the multinational demand cost margin is not smaller than the domestic firm's margin, the total strategic (feedback) R&D effort ($r^* + s^*$) will be smaller than the open loop efforts in joint R&D venture and Nash output scenario. This holds regardless of the spin offs between the companies and is the reverse of the inferences drawn with Nash R&D behavior (and small spin offs)¹⁹.

In the joint venture on strategic R&D the multinational firms will spend more (less) on innovative strategies as ψ^c is positive (negative) with

$$\begin{aligned} \psi^c = m_1^m [k_1(4+\beta)(1-\theta_d^m) + 2(1+\beta)(1-\theta_m^d)] + ((4-\beta^2)^2/4\delta)k_1 m_2^m(1-\theta_d^m) \\ - m^d [k_1 2(1+\beta)(1-\theta_d^m) + (4+\beta)(1-\theta_m^d)] \end{aligned} \quad (23)$$

and k_1 defined by (14).

Provided that $m_1^m \geq m^d$ the domestic firm will contribute less to R&D if $[(1+\theta_d^m)/(1+\theta_m^d)]^{\mu-1} (1-\theta_d^m) \geq (1-\theta_m^d)$. Equal but less than perfect spill overs are sufficient for the multinational firm to spend more because of the perfect spin offs within the firm. With perfect between firm spin offs ($\theta_d^m = \theta_m^d = 1$) there exists a symmetric solution in the joint venture.

A comparison of the joint venture R&D efforts r^* , s^* with the Nash levels r^* , s^* is possible, noting that the necessary condition (19) and (20) of the joint venture can be rewritten as:

$$\frac{\partial V}{\partial r} = 0 = \left[\frac{\partial \pi^m}{\partial v^*} \cdot \frac{\partial v^*}{\partial r} + \frac{\partial \pi^m}{\partial r} - 1 \right] + \frac{\partial \pi^d}{\partial u^*} \cdot \frac{\partial u^*}{\partial r} + \frac{\partial \pi^d}{\partial r} \quad (24)$$

and

$$\frac{\partial V}{\partial s} = 0 = \left[\frac{\partial \pi^d}{\partial u^*} \cdot \frac{\partial u^*}{\partial s} + \frac{\partial \pi^d}{\partial s} - 1 \right] + \frac{\partial \pi^m}{\partial v^*} \cdot \frac{\partial v^*}{\partial s} + \frac{\partial \pi^m}{\partial s} \quad (25)$$

The Nash equilibrium is defined by looking at the impact of R&D on own profits, given the Nash strategy of the other firm. Formally r^* and s^* solves the expressions between square brackets (cfr. (7) and (8)). The

joint venture on R&D also incorporates the effects of R&D on the other firms. For example for the R&D efforts of the multinational:

$$\frac{\partial \pi^d}{\partial u^*} \cdot \frac{\partial u^*}{\partial r} + \frac{\partial \pi^d}{\partial r} = - \frac{v^*}{(4-\beta^2)} (2 \cdot d\alpha^m/dx - \beta \cdot \theta_m^d \cdot d\alpha^d/dy) + v^* d\alpha^d/dy \theta_m^d$$

For positive spin offs from the multinational to the domestic firm, the joint venture takes into account the negative effect of an increase in r on domestic firm profits because of the increase in the multinational firm's output as well as the positive effect on the domestic firm's demand because of the spin off. One would expect this positive effect to dominate if θ_m^d is close or equal to one in which case the multinational would spend more on R&D in the joint venture than in a Nash scenario. Of course a countervailing tendency would result from spin offs from the domestic firm. In fact $r^* > r^\circ$ follows if indeed $\theta_m^d = 1$ and $\theta_d^m = 0$. These and other inferences are summarized in Table 2 (see Appendix 3, A.3.2.). They all can be rationalized along similar lines.

$\theta_m^d = \theta_d^m = 0$	$r^* + s^* > r^\circ + s^\circ$
$\theta_m^d = \theta_d^m = 1$	$r^* + s^* < r^\circ + s^\circ$
$\theta_m^d = 0 \quad \theta_d^m = 1$	$r^* > r^\circ \quad s^* < s^\circ$
$\theta_m^d = 1 \quad \theta_d^m = 0$	$r^* < r^\circ \quad s^* > s^\circ$

Table 2: Comparison of Nash R&D strategies r^* and s^* with strategies r° and s° resulting from R&D joint venture and Nash output behavior.
The multinational company (m) spends r , the domestic firm (d) s . θ_i^j indicates between firm spin offs.

The findings confirm that spill overs are an important determinant of R&D strategies. With low externalities between firms, Nash strategies

result in highly innovative industries. With important spin offs joint ventures in R&D may well result in more R&D ²⁰.

Finally it may be argued that a joint venture in R&D perhaps renders Nash behavior in output less likely. A complete cooperative setting in both R&D and output with both the multinational and domestic firm producing in market one, result in output levels :

$$\bar{u} = \frac{m_1^m - \beta m^d}{2(1-\beta^2)} \quad \bar{v} = \frac{m^d - \beta m_1^m}{2(1-\beta^2)} \quad (26)$$

for $0 \leq \beta < 1$, and

$$\bar{u} = \bar{v} = \frac{m_1^m + m^d}{8} \quad \text{with } m_1^m = m^d \quad (27)$$

for $\beta = 1$, $\theta_d^m = \theta_m^d = 1$, $\alpha_1^m = \alpha^d$ and $x=y$. The output of the multinational in the home market stays $m_2^m/28$. In the first stage R&D levels are chosen to maximize industry profits $\bar{V}$, taking into account the optimal output levels. The optimal R&D values solve

$$\frac{\partial \bar{V}}{\partial r} = \frac{\partial \pi^m}{\partial r} + \frac{\partial \pi^d}{\partial r} - 1 = 0 \quad (28)$$

and

$$\frac{\partial \bar{V}}{\partial s} = \frac{\partial \pi^m}{\partial s} + \frac{\partial \pi^d}{\partial s} - 1 = 0 \quad (29)$$

evaluated at $\bar{u}$, $\bar{v}$ and $m_2^m/28$. The open loop and feedback strategies are the same since the problem is reduced to a decision theoretic structure. The spin offs are an essential determinant of the possible asymmetries in R&D investment as Table 3 illustrates.²¹

$0 \leq \beta < 1$		$0 < \beta < 1$		
		$\frac{m_1^m +}{m^d} \leq a$	$a < \frac{m_1^m +}{m^d} < b$	$\frac{m_1^m +}{m^d} \geq b$
$\theta_m^d = \theta_d^m = 0$	$\bar{r} \leq (\geq) \bar{s}$ as $[(m_1^m - m^d)^* + m_2^m(1-\beta)/\delta] \leq (\geq) 0$	$r^* > \bar{r}$ $s^* < \bar{s}$	$r^* + s^* < \bar{r} + \bar{s}$	$r^* < \bar{r}$ $s^* > \bar{s}$
$\theta_m^d = \theta_d^m = 1$	$\bar{r} = \bar{s}$		$r^* + s^* < \bar{r} + \bar{s}$	
$\theta_m^d = 0, \theta_d^m = 1$	$\bar{r} < \bar{s}$	Ambiguous	$r^* + s^* < \bar{r} + \bar{s}$	Ambiguous
$\theta_m^d = 1, \theta_d^m = 0$	$\bar{r} > \bar{s}$	Ambiguous	$r^* + s^* < \bar{r} + \bar{s}$	Ambiguous

with * evaluated at symmetric R&D levels

+ evaluated at $\bar{r}$ and $\bar{s}$

$$a = \beta(8+\beta^2)/(4+5\beta^2) \quad \text{and} \quad b = (4+5\beta^2)/\beta(8+\beta^2)$$

Table 3 : Results on cooperative R&D expenditures $\bar{r}$ and $\bar{s}$. Comparison is with strategies r^* and s^* resulting from R&D joint venture and Nash output behavior. θ_i^j indicates between firm spin offs. For $\beta=0$ clearly $r^*=\bar{r}$ and $s^*=\bar{s}$. For homogeneous products ($\beta=1$, $\theta_d^m=\theta_m^d=1$, $\alpha_1^m=\alpha^d=\alpha$, $x=y$) R&D expenditures are symmetric : $\bar{r}=\bar{s}$, and $r^*+s^*<\bar{r}+\bar{s}$.

The complete cooperation results in a less innovative industry than would apply with only a joint venture in R&D that seeks open loop strategies. The reason is that the overall cooperation restricts its industry output to the monopoly level, while the joint venture seeks in the open loop fashion, simultaneously with its R&D strategies, a larger Nash output and hence more R&D ²². The strategic R&D levels with a joint venture on R&D, however, are typically lower than the open loop values. If output levels are chosen in a Nash way after knowledge levels are observed, the joint R&D venture also has an incentive to restrict R&D. The question is whether this negative incentive is sufficient to result in strategic R&D levels below the complete cooperation levels. It can be verified, that the strategic considerations of the R&D joint venture are apparently important enough in the present framework to result in lower industry R&D if competition in output prevails than if cooperative output levels are chosen ($r^* + s^* < \bar{r} + \bar{s}$) in a wide set of circumstances (see Table 3).

4. Innovative strategic groups: some first empirical results.

The analyzed game theoretic scenarios clearly point to the possible existence of innovative strategic groups in multinational industries. Empiricism does suggest asymmetries between the innovative efforts of domestic and multinational firms as reflected, say in their reported R&D expenditures (Hirschey (1981)). An empirical test of the obtained inferences needs to go beyond simple measures of innovative input and of resulting economic performance. The innovative inputs and performance of a multinational's subsidiary may be a weak indicator of the overall company's strategy and performance. A company's innovative strategy, moreover, can hardly be summarized in one single input variable, nor can it be viewed in isolation from the production and marketing strategies.

The empirical exploration consequently focused on a multivariate measurement of strategy and performance on the basis of survey data, obtained from companies operating in eleven multinational industries ²³. Only companies that operate at least one R&D and production unit in Belgium in the selected (high-tech) industries were contacted. Of the 222 companies which were found to be actively engaged in development and marketing of new products and processes, 140 completed the questionnaires. The survey contained 66 questions on the strategy of the companies ²⁴. Strategies could be typified by answering queries about:

- the nature of the marketed products (16 questions);
- the nature of the market in which the firms operate (20 questions);
- the adopted technology and production characteristics (11 questions);
- the specific features of the R&D and marketing processes within the company (19 questions).

In addition, a set of 9 questions asked for the performance in terms of success and failure obtained from the development and introduction of new products and the contribution to the overall performance of the company.

The survey data thus provided subjective assessments of both strategy and performance. The limitations of this approach are clear. It was possible, however, to grasp to some extent the innovative strategies of the multinational companies not only in terms of the local subsidiary company itself, but also in view of the overall firm positioning in technology and product markets. The performance evaluations also are sufficiently broad to encompass their impact in the multimarket environment.

4.1. Measuring innovative strategies and performance

A principal component analysis was applied to the survey results to deal with the multidimensional character of strategy and to identify strategic factors from the information available. The results were derived from the 66 questions dealing with strategy as discussed above supplemented with three questions asking for a subjective evaluation by the company managers of the state of development of the technology and the market. The analysis led to ten interpretable strategy dimensions, which together accounted for 60 % of all variance and are given in Table 4.

. TECHNOLOGY ORIENTED STRATEGIES

PRIN1 : Emphasis on innovation

High technology products, new products, first of their kind, leader in the technology race, R&D is main strategy

PRIN2 : Scope of innovation

New products fit into the existing products assortment, new products can use the same production unit, marketing and distribution channels, ...

. MARKET DEVELOPMENT STRATEGIES

PRIN3 : Intensive marketing towards existing large markets
Strongly market and marketing-oriented, market push innovations, markets are large, high (potential) sales.

PRIN4 : Market driven specialisation (niche-strategy)
Very little competition on the output market, products are of high quality without being technically complex, emphasis on marketing instruments to develop new markets.

PRIN5 : New penetration of existing markets
New marketing and distribution channels, large potential of customers to be tapped.

. SPECIFIC STRATEGIES COUPLED WITH STABILIZING TECHNOLOGIES OR MARKETS

PRIN6 : Technological race in competitive markets
Technology push innovations, innovations aimed at undercutting the market price, highly competitive setting.

PRIN7 : Image building product differentiation of high cost products
High unit cost, high risk products, highly competitive, small output market, offensively differentiating through image building, emphasis on marketing rather than on R&D.

PRIN8 : Reputation based supply of efficient equipment goods
Stable technology, low growth, marketing instruments focuses on building and maintaining reputation of being highly qualitative, unique, efficient, cost saving.

PRIN9 : Market squeezing
Offensive marketing strategy oriented towards segments of the market not already fully exploited, products offered have no comparative advantage.

PRIN10: R&D- led product differentiation of low cost products
R&D aiming at differentiating technologically low risk products.

Table 4: Identification of 10 principal strategy components. The distinguishing features (responses to survey questions) are given below the tables of the strategy dimension.

Two performance measures were derived from a principal component analysis applied to the set of questions dealing with the objective and subjective evaluation of success of the company's introduction of new products. The components account for 56 per cent of total variance and are summarized in Table 5 ²⁵.

SUC: Degree of success

Global evaluation of the company's performance, contribution of new products to profit performance, evaluation with respect to competitive location of the company, evaluation with respect to initial targets set out by the company, contribution of new products to sales revenue, per cent of new products that have been successfully developed and commercialized.

FAIL: Incidence of product innovations failures

Percentage of new products whose development was not commercialized, percentage of new products for which commercialization failed.

Table 5: Performance components.

4.2. Differences between domestic and multinational companies.

In order to examine the existence of systematic differences between multinational and domestic companies, the standard hypothesis is tested whether these companies belong to the same population with respect to the different performance and innovative strategy factors ²⁶.

Statistically significant differences show up for five of the ten strategy components, see Table 6.

	DOM	MNC	
PRIN1	-0.367	0.559	*
PRIN2	-0.200	0.447	
PRIN3	-0.276	0.301	*
PRIN4	0.276	-0.293	*
PRIN5	0.126	-0.108	
PRIN6	0.383	-0.227	*
PRIN7	-0.004	0.078	
PRIN8	-0.237	0.060	
PRIN9	-0.092	0.015	
PRIN10	0.250	-0.193	*
N	63	61	

Table 6: Average scores of strategy components for domestic (DOM) and multinational (MNC) companies. * Indicates significantly different mean values for a 10 % confidence level. N is the sample size.

A marked difference is found for the strategy dimensions: PRIN1, PRIN3, PRIN4, PRIN6 and PRIN10. (The first factor PRIN1, takes account of 15 per cent of all variance of the survey results.) These findings imply that multinationals are more innovation-oriented than Belgian domestic companies (PRIN1) and tend to develop their products more for large markets (PRIN3). Domestic firms, on the other hand, score significantly high with respect to market niche strategies (PRIN4) and product differentiation (PRIN10). The necessity of R&D, as a weapon to stay competitive vis-à-vis rivals appears also more typical for domestic companies than for multinational companies (PRIN6).

With respect to the performance components, no statistically significant difference is found (using a 10 per cent significance criterion) between domestic and multinational companies. Repeating the same test, but controlling for different industries, only a significant difference is found in the telematics industry, where multinational companies seem to fail less than domestic companies. The difference is not matched with a similar difference for the success indicator.

The different strategy dimensions of multinational and domestic firms appear to be accompanied with similar perceived performance. To understand the coexistence of different strategies, it is useful to relate the strategy and performance indicators. From regressing strategy dimensions on the company's performance, it is interesting to find coefficients significantly different from zero for the strategy dimensions PRIN1 - PRIN4, together with PRIN10.

Except for PRIN2 these strategy dimensions are also the ones which are found to differ significantly for domestic and foreign controlled

	SUC		FAIL	
	(1)	(2)	(3)	(4)
INTERC	0.057 (0.287)	-0.054 (0.287)	0.091 (0.205)	0.134 (0.209)
PRIN1	0.193 ** (0.055)	0.127 ** (0.062)	0.123 ** (0.039)	0.149 ** (0.045)
PRIN2	0.139 ** (0.062)	0.144 ** (0.061)	-0.037 (0.044)	-0.039 (0.044)
PRIN3	0.233 ** (0.084)	0.234 ** (0.087)	0.034 (0.060)	0.030 (0.063)
PRIN4	0.171 * (0.088)	0.179 ** (0.087)	-0.033 (0.063)	-0.035 (0.063)
PRIN5	-0.006 (0.101)	-0.003 (0.100)	-0.031 (0.073)	-0.032 (0.073)
PRIN6	0.068 (0.094)	0.066 (0.096)	-0.008 (0.067)	-0.011 (0.070)
PRIN7	-0.166 (0.106)	-0.192 * (0.111)	0.045 (0.076)	0.050 (0.080)
PRIN8	-0.122 (0.114)	-0.093 (0.112)	0.079 (0.081)	0.072 (0.081)
PRIN9	0.060 (0.128)	0.067 (0.126)	0.002 (0.092)	-0.001 (0.092)
PRIN10	0.441 ** (0.122)	0.477 ** (0.122)	-0.007 (0.087)	-0.019 (0.089)
MIEL	0.868 ** (0.417)	0.927 ** (0.411)	-0.147 (0.297)	-0.173 (0.299)
BIOT	0.470 (0.564)	0.797 (0.575)	1.386 ** (0.403)	1.267 ** (0.419)
NEWM	-1.049 ** (0.352)	-1.067 ** (0.346)	0.110 (0.251)	0.119 (0.252)
TELE	-0.211 (0.468)	0.120 (0.511)	0.050 (0.334)	0.159 (0.372)
BURO	-0.053 (0.513)	-0.173 (0.460)	0.229 (0.366)	0.037 (0.335)
ROBO	-0.001 (0.451)	-0.154 (0.449)	-0.078 (0.322)	-0.019 (0.327)
AERO	0.301 ** (0.147)	1.214 ** (0.577)	0.011 (0.105)	0.035 (0.420)
NEWR	-0.907 * (0.504)	-0.875 * (0.497)	-0.490 (0.359)	-0.508 (0.362)
MEDI	0.113 (0.541)	0.311 (0.560)	-0.844 ** (0.386)	-0.895 ** (0.408)
AGRO	-0.600 (0.506)	-0.571 (0.498)	0.543 (0.361)	0.534 (0.363)
ENGI	0.322 (0.454)	0.328 (0.453)	-0.755 ** (0.324)	-0.790 ** (0.330)
PRIN13		0.011 (0.032)		0.001 (0.023)
PRIN14		0.072 ** (0.033)		-0.028 (0.024)
R ²	0.498	0.527	0.351	0.362
F	3.97 (21,106)	3.97 (23,106)	2.16 (21,106)	2.02 (23,106)

Table 7 : Regression results from the strategy-performance relationship. Standard errors in parentheses, ** = significant at the 5 % level, * significant at the 10 % level (see footnote 19 for a description of the sectoral dummies).

firms. The possible extra effects of combining the basic innovation strategy of the company with one of these market development strategies can be captured by the interaction variables $PRIN13 = PRIN1*PRIN3$ and $PRIN14 = PRIN1*PRIN4$. The results in Table 7 suggest that the adoption of a focused strategy and innovation has a net effect on performance, which, given the magnitude of the point estimates, would render this combination as a viable alternative to large market developers investing in innovation. Without being too speculative, it seems reasonable to assume that technological spill overs from R&D intensive companies are important behind this effect.

With respect to industry differences, the coefficients of the industry dummies suggest that micro-electronics and aeronautics are (significantly) more related to success, whereas new materials and resources would lead to less successful innovations.

Applying the same econometric structure for failure, the explanatory power decreases considerably. Failure of innovations is a process that needs to be distinguished from successful innovations. The observation that the more the company invests in innovations, the more failures occur, is straightforwardly related to the uncertain nature of the R&D process. Similarly biotechnology would seem to belong to the more riskful, while medical equipment and engineering industries would seem to belong to the class of less riskful industries.

The empirical findings appear to clearly support the proposition that multinational and domestic firms belong to different strategic groups within the investigated high-tech industries. The multinational firms focus on more aggressive innovative strategies that accompany the development of large markets, while domestic firms tend to focus more on

small market niches and product differentiation and less emphasis on innovation. The different strategic positions appear to be significantly related to objective and subjective measures of performance and in that sense can be interpreted as rational choices. The strategic differences are in line with asymmetric game theoretic equilibria analyzed in earlier sections.

5. Conclusions.

The existence of innovative strategic groups was explored in a game theoretic framework and documented from survey data analysis. In multinational industries, domestic firms compete with multinational companies in some but not all (output) market segments. The multinational firm supplies several different (national) markets. Its technological base is reflected in the products or services that it moves with relatively small transaction costs across markets. Domestic firms, on the other hand, face higher transaction costs and because of this, may serve a more limited market spectrum.

The sketched asymmetries of multinational industries appear to be sufficient to result in a broad set of circumstances in stable asymmetric innovative strategies of the multinational and domestic firms. Following Brander and Spencer (1983), R&D investments were viewed as having a strategic dimension, because of their ability to influence the product rivalry game. Spin offs of R&D to the knowledge base of rival firms appear to be a significant determinant of innovative strategies. In situations where the between firm spin offs are identical, the multinational company was found to adopt a more innovative strategy than the domestic firm if it is positioned in a sufficiently important market segment. This tendency would result in a Nash feedback (subgame perfect) equili-

brium if R&D are strategic substitutes (in the Bulow et. al. (1985) terminology) and certain functional specifications apply. The asymmetric strategic differences are reinforced if the multinational firm is producing with a cost advantage and if the spin offs from the multinational R&D are low while those resulting from the domestic firm R&D are important. The same strategic differences between multinational and domestic firms may apply, possibly reinforced, in situations with the former firm leading or both firms cooperatively deciding on R&D.

In a feedback Nash equilibrium (with unimportant spin offs), the strategic dimension of R&D results in more industry R&D than would result with open loop strategies and the firms committing simultaneously to both R&D and output. This feature, however, may not hold with the firms cooperating on R&D. Complete cooperation on both R&D and output may also result in more industry R&D than with a joint venture limited to R&D.

Survey data from companies operating in eleven high-tech multinational industries were explored to search for differences in innovative strategies and performance. The survey approach obviously incorporates certain subjective assessments but did allow to infer the multidimensional nature of strategies that related to R&D, production and marketing activities. The empirical analysis would seem to support the hypothesis that multinational and domestic firms indeed do belong to different strategic groups within the investigated high-tech industries. The multinational companies appear to focus on more innovative strategies that accompany the development of large markets, while domestic firms tend to be positioned in small market niches and/or emphasize product differentiation. The different strategies are all related significantly to success.

Appendix 1

All of the statements involving a comparison of equilibria can be verified with the aid of the mean value theorem (see Brander and Spencer (1983)). For the reader's convenience the essential points are repeated here. Let r^* , s^* and r° , s° denote two possible R&D equilibria and let $\Delta r = r^* - r^\circ$, $\Delta s = s^* - s^\circ$, and

$$\Delta V_r^m = V_r^m(r^*, s^*) - V_r^m(r^\circ, s^\circ) \quad (1')$$

$$\Delta V_s^d = V_s^d(r^*, s^*) - V_s^d(r^\circ, s^\circ) \quad (3')$$

with V^m and V^d objective functions defined by (5) and (6) in the text and the subscripts denoting partial differentiation. (The equations are easily adapted for the investigation of the cooperative equilibria). According to the mean value theorem there exists a point $\Delta V_r^m = V_{rr}^m \Delta r + V_{rs}^m \Delta s$ and $\Delta V_s^d = V_{sr}^d \Delta r + V_{ss}^d \Delta s$ where the cross partial derivatives are evaluated at some point "between" (r^*, s^*) and (r°, s°) .

Cramer's rule yields

$$\Delta r = (\Delta V_r^m V_{ss}^d - \Delta V_s^d V_{rs}^m) / D \quad (4')$$

$$\Delta s = (\Delta V_s^d V_{rr}^m - \Delta V_r^m V_{sr}^d) / D \quad (5')$$

$$\Delta r + \Delta s = (\Delta V_r^m (V_{ss}^d - V_{sr}^d) + \Delta V_s^d (V_{rr}^m - V_{rs}^m)) / D \quad (6')$$

with $D = (V_{rr}^m V_{ss}^d - V_{rs}^m V_{sr}^d) > 0$ (because of assumed stability. $V_{rs}^m < 0$ and $V_{sr}^d < 0$ for r and s strategic substitutes, $V_{rr}^m < 0$, $V_{ss}^d < 0$ for the second order optimality condition, and $V_{ss}^d < V_{sr}^d$, $V_{rr}^m < V_{rs}^m$ assumed.

Appendix 2

To compare the magnitudes of r and s in a given equilibrium, it is supposed that at a symmetric equilibrium $V_s^d(r^*, s^*) = 0$ holds. (Say that the reaction curve ds/dr crosses the bisecting line at that point. Existence is assumed, hence the strategic substitute property needs to hold in a sufficiently wide range of r and s values). By definition $V_s^d(r^*, s^*) = 0$ and $V_s^d(r^*, s^*) = 0$. Also $V_r^m(r^*, s^*) = 0$ and only $V_r^m(r^*, s^*)$ needs to be evaluated, which can be done using $V_s^d(r^*, s^*) = 0$. For a feedback Nash equilibrium the partial derivatives are:

$$V_r^m = \partial V^m / \partial r = \frac{2u^*}{(4-\beta^2)} [2 \, d\alpha^m/dx - \beta \cdot \theta_m^d \cdot d\alpha^d/dy] \\ + w^* \, d\alpha_2^m/dx - 1 = 0,$$

$$V_s^d = \partial V^d / \partial s = \frac{2v^*}{(4-\beta^2)} [2 \, d\alpha^d/dy - \beta \cdot \theta_d^m \cdot d\alpha_1^m/dx] - 1 = 0,$$

$x^* = r^* + \theta_d^m s^*$, $y^* = s^* + \theta_m^d r^*$, and u^* , v^* , w^* defined by (3).

The ψ^N expressions of the text follow after some manipulation, using the specified functional forms of α_1^m , α^d and α_2^m . The stated claims follow easily from checking (4') and (6'). A similar reasoning can be applied for the other equilibrium concepts.

Appendix 3

A.3.1. Stackelberg leadership in output and R&D.

The Stackelberg game with the multinational firm leading results in the second stage the following output levels

$$u = \frac{2m_1^m - \beta m^d}{2(2-\beta^2)}, \quad v = \frac{(4-\beta^2)m^d - 2\beta m_1^m}{4(2-\beta^2)}, \quad w = \frac{m_2^m}{2\delta} \quad (7')$$

with $(\beta/2) < m_1^m/m^d < (4-\beta^2)/2\beta$. The domestic firm is also follower with respect to R&D and solves in the first stage

$$\max_s V^d = \pi^d(u(r,s), v(r,s), r, s) - s$$

taking r as given and noting (7'). The reaction function $s = s(r)$ of this firm is implicitly defined by:

$$\partial V^d / \partial s = \frac{v}{2(2-\beta^2)} [(4-\beta^2) \cdot d\alpha^d/dy - 2\beta \cdot \partial_d^m d\alpha_1^m/dx] - 1 = 0 \quad (8')$$

The multinational takes this best response function as given and solves

$\max_r V^m = \pi^m(u(r,s), v(r,s), r) - r$ again noting (7'). The Stackelberg equilibrium solves therefore (7'), (8') and

$$\begin{aligned} \partial V^m / \partial r = 0 = & \frac{(4-\beta^2)u}{4(2-\beta^2)} [(2 d\alpha_1^m/dx - \beta \cdot \partial_m^d \cdot d\alpha^d/dy) + \\ & + (2 \cdot \partial_d^m d\alpha_1^m/dx - \beta \cdot d\alpha^d/dy) ds/dr] \\ & + (w \partial_d^m d\alpha_2^m/dx) \cdot ds/dr + w d\alpha_2^m/dx - 1 \end{aligned} \quad (9')$$

A.3.2. Cooperation in R&D, Nash in output.

The Nash output levels of stage two are defined by (3). The cooperative feedback R&D levels r^* , s^* , solve

$$V_r = \partial V / \partial r = \frac{2}{(4-\beta^2)} [u (2.d\alpha_1^m/dx - \beta.d\alpha^d/dy \cdot \emptyset_m^d) + v (2. \emptyset_m^d d\alpha^d/dy - \beta.d\alpha_1^m/dx)] + w d\alpha_2^m/dx - 1 \quad (10')$$

and

$$V_s = \partial V / \partial s = \frac{2}{(4-\beta^2)} [u (2.\emptyset_d^m.d\alpha_1^m/dx - \beta.d\alpha^d/dy) + v (2.d\alpha^d/dy - \beta.\emptyset_d^m.d\alpha_1^m/dx)] + w.\emptyset_d^m.d\alpha_2^m/dx - 1 = 0 \quad (11')$$

Substitution from (10') and (11') in the Nash expressions (7) and (8) with the specified functional forms yields

$$V_r^m(r^*, s^*) = \frac{2v}{(4-\beta^2)} (\beta k_1^o - 2\emptyset_m^d) \quad (12')$$

and

$$V_s^d(r^*, s^*) = - \frac{2}{3} [u(2k_1^o \emptyset_d^m - \beta) + w k_1^o \emptyset_d^m] \quad (13')$$

with $k_1^o = [(r^* + \emptyset_d^m s^*) / (s^* + \emptyset_m^d r^*)]^{u-1}$. For $\emptyset_m^d = \emptyset_d^m = 1$ a symmetric solution is optimal and applying the methodology outlined above to (12') and (13') provides the results of Table 2 in the text.

A.3.3. Cooperation in output and R&D

Cooperation in the output stage , results in output levels defined by (27) and (28). In the first stage $\bar{V} = V^m + V^d$ is maximized taking these output levels into account. The optimal values result from

$$\partial \bar{V} / \partial r = 0 = \bar{u} \cdot d\alpha_1^m / dx + \bar{v} \cdot \theta_m^d d\alpha^d / dy + w \cdot d\alpha_2^m / dx - 1 \quad (14')$$

and

$$\partial \bar{V} / \partial s = 0 = \bar{u} \cdot \theta_d^m d\alpha_1^m / dx + \bar{v} \cdot d\alpha^d / dy + w \cdot \theta_d^m \cdot d\alpha_2^m / dx - 1 \quad (15')$$

Substitution from (14') and (15') into the R&D cooperation-Nash output expressions (10') and (11') provides

$$\begin{aligned} \text{sign } V_r(\bar{r}, \bar{s}) = & - \text{sign } \{\beta^2\} \cdot \{ [m_1^m [(4+5\beta^2) \cdot \bar{k}_1 - \beta \cdot \theta_m^d \cdot (8+\beta^2)] \\ & - m^d [(4+5\beta^2) \cdot \theta_m^d - (8+\beta^2) \cdot \beta \cdot \bar{k}_1]] \} \end{aligned} \quad (16')$$

and

$$\begin{aligned} \text{sign } V_s(\bar{r}, \bar{s}) = & - \text{sign } \{\beta^2\} \cdot \{ [m_1^m [(4+5\beta^2) \cdot \bar{k}_1 \cdot \theta_d^m - \beta \cdot (8+\beta^2)] \\ & - m^d [\beta \cdot (8+\beta^2) \cdot \bar{k}_1 \cdot \theta_d^m - (4+5\beta^2)]] \} \end{aligned} \quad (17')$$

with $\bar{k}_1 = [(\bar{r} + \theta_d^m \bar{s}) / (\bar{s} + \theta_m^d \bar{r})]^{\mu-1}$. The results of Table 3 can now be verified using the mean value theorem methodology.

Notes

- 1 Or a strategy along some other dimension, related for example to market or firm organisation.
- 2 It may be difficult to monitor the licensee's output because of asymmetry in information and/or imitation possibilities. Then fixed fee licensing is appropriate and will not always be privately or socially optimal (see Katz and Shapiro (1985)). See also Kamien and Tauman (1984).
- 3 Hence the envisaged race is not of the "winner-take-all" variety (cfr. Stewart (1983)).
- 4 Given that $\beta = 1$ in the demand specification and that the intercepts $\alpha_1^m = \alpha^d = \alpha$ independent of x and y . The marginal costs would depend on x and y , i.e. $c_1^m = c_1^m(x)$, $c^d = c^d(y)$ and $c_2^m = c_2^m(x)$.
- 5 The demand functions that accompany the inverse demand specifications given in the text, are for $\beta < 1$:

$$u = (\alpha_1^m - \beta\alpha^d - p_1^m + \beta p^d)/(1-\beta)(1+\beta) \quad \text{and}$$

$$v = (\alpha^d - \beta\alpha_1^m - p^d + \beta p_1^m)/(1-\beta)(1+\beta)$$

It is assumed throughout the paper that asymmetries allow both firms to have a positive demand.
 For $\beta = 1$ and perfect between firm spin offs, $\alpha_1^m = \alpha^d = \alpha$ and $x = y$, products of both firms are perfect substitutes with common price $p_1^m = p^d = \alpha - (u+v)$.
 More general linear specifications can be analyzed.
- 6 See Van Cayseele (1986) for spin offs and the timing of innovations.
- 7 See J.A. Brander and B.J. Spencer (1983), for results in a one market symmetric firm case.
- 8 Discounting is ignored to simplify computations without loss of significance.
- 9 Fulfillment of the second order conditions as well as stability and uniqueness will be assumed.
- 10 This is the situation with R&D being a strategic substitute in the terminology of Bulow et. al. (1985). The slope of the reaction curves are $dr/ds = -V_{rs}^m/V_{rr}^m$ and $ds/dr = -V_{sr}^d/V_{ss}^d$ with subscripts denoting partial differentiation. Strategic substitutes (complements) refer to $V_{rs}^m < 0$, $V_{sr}^d < 0$ ($V_{rs}^m > 0$, $V_{sr}^d > 0$). It can be verified that the cross partial derivatives may, but are not necessarily negative sloping.
- 11 This last condition implies reaction function stability. See also Brander and Spencer (1983).
- 12 The statements can be verified with the methods described in Appendix 1.

- 13 Note that an increase in R&D of one firm increases the marginal profitability of an output change in both firms, if spill overs are positive and only of the firm itself if spill overs are zero. With zero spill overs the effect of increased R&D is to push the (downward) sloping reaction curves outward and output increases for the firm changing R&D (decreases for the other). With positive spill overs both reaction curves change with a change in R&D and the net effect appears unclear in general.
- 14 Differences in this regard can easily be incorporated, as long as the μ parameter stays common, without relevant consequences for the main inferences.
- 15 See footnote 7.
- 16 The bounds are for symmetric levels of R&D, hence they can easily be interpreted from equation (15). The restrictions need in any case to be satisfied at the Nash equilibrium.
- 17 It can be verified that the leading multinational firm will spend more on R&D than the domestic firm if and only if ψ^s is positive, with

$$\begin{aligned}\psi^s = & \psi^N + m_1^m [k_1 \cdot (12 - 4\beta^2 - 3\beta^2 \cdot \theta_d^m) + 2\beta \cdot (3 - \beta^2) \cdot (1 - \theta_m^d)] \\ & - m^d [k_1 \cdot 2\beta \cdot (3 - \beta^2) \cdot (1 - \theta_d^m) + (12 - 8\beta^2 + \beta^4) - \beta^2 \cdot (3 - \beta^2) \cdot \theta_d^m] \\ & + m_2^m \cdot k_1 \cdot [16(2 - \beta^2)^2 - (4 - \beta^2)^2] / \delta \\ & + 2(4 - \beta^2)(2 - \beta^2) \cdot u \cdot [(2 \cdot k_1 \cdot \theta_d^m - \beta) ds/dr] \\ & + [4(2 - \beta^2) / \delta] \cdot m_2^m \cdot k_1 \cdot \theta_d^m \cdot ds/dr\end{aligned}$$

and u defined by equation (7') of the Appendix and k_1 defined by equation (14) in the text.

- 18 Given (12)

$$\text{sign} \left[\frac{\partial \pi^m}{\partial v^*} \cdot \frac{\partial v^*}{\partial r} + \frac{\partial \pi^d}{\partial u^*} \cdot \frac{\partial u^*}{\partial r} \right] =$$

$$\text{sign} [m^d (4\beta \cdot \theta_m^d - (4 + \beta^2) k_1^*) - m_1^m [(4 + \beta^2) \cdot \theta_m^d - 4\beta \cdot k_1^*)]$$

and

$$\text{sign} \left[\frac{\partial \pi^m}{\partial v^*} \cdot \frac{\partial v^*}{\partial s} + \frac{\partial \pi^d}{\partial u^*} \cdot \frac{\partial u^*}{\partial s} \right] =$$

$$\text{sign} [m_1^m (4\beta \cdot \theta_d^m k_1^* - (4 + \beta^2)) - m^d ((4 + \beta^2) \cdot \theta_d^m k_1^* - 4\beta)]$$

$$\text{with } k_1^* = [(r^* + \theta_d^m \cdot s^*) / (s^* + \theta_m^d \cdot r^*)]^{\mu-1} > 0$$

- 19 Cfr. the discussion following equation (11) above. The result is dependent on the assumption

$$V_{ss} - V_{rs} < 0 \quad \text{and} \quad V_{rr} - V_{sr} < 0$$

(see Brander and Spencer (1983) or the Appendix 1).

- 20 For similar results in symmetric games, see Reinganum (1981) and Katz (1985).
- 21 The R&D investment of the multinational technology r is greater (smaller) than the domestic effort s in the cooperative venture, if and only if ψ^j is positive (negative), with

$$\begin{aligned} \psi^j = & m_1^m \cdot [\bar{k} \cdot (1 - \theta_d^m) + \beta \cdot (1 - \theta_m^d)] \\ & - m^d \cdot [\beta \cdot \bar{k} \cdot (1 - \theta_d^m) + (1 - \theta_m^d)] + m_2 (1 - \beta^2) \cdot \bar{k} \cdot (1 - \theta_d^m) / \delta \end{aligned}$$

with $\bar{k}$ evaluated at a symmetric solution. The first column of Table 3 can now be verified.

- 22 The proof rests on a comparison of (26) and (27) evaluated at $\bar{u} = \bar{v}$ and w^* , with the expression between square brackets in (19) and (20) evaluated at u^* and v^* and w^* . To verify that the Nash output is larger than the cooperative levels for equal knowledge levels employ the restriction on the margins implied by positive output. Application of the mean value methodology yields the claim in the text.
- 23 The survey centered on the development of products, based on three rapidly evolving technologies:
- micro electronics: MIEL
 - bio-technology: BIOT
 - new materials: NEWM
- and the processing of these products in the following application industries:
- Telematics: TELE
 - Burotics: BURO
 - Robotics: ROBO
 - Aeronautics: AERO
 - New energy resources: NEWR
 - Medical technology: MEDI
 - Agro-industries: AGRO
 - Engineering: ENGI
- 24 The authors would like to thank Prof. P. Vanden Abeele and I. Christiaens for kindly providing the survey data. The survey was inspired by the work of Cooper (1983).
- 25 No eigenvalues higher than one were obtained for factors beyond the first two ones.
- 26 The results where they are considered as a separate class will be reported elsewhere.

References

- Basar, T. and G.J. Olsder, 1982, Dynamic noncooperative game theory, London, Academic Press.
- Brander, J.A., 1981, Intra-industry trade in identical commodities, *Journal of International Economics*, 11, 1-14.
- Brander J.A. and B.J. Spencer, 1983, Strategic commitment with R&D: the symmetric case, *Bell Journal of Economics*, 14, 225-235.
- Bulow, J.I., J.D. Geanakoplos and P.D. Klemperer, 1985, Multimarket oligopoly, strategic substitutes and complements, *Journal of Political Economy*, 93, 488-511.
- Caves, R. and M. Porter, 1977, From entry barriers to mobility barriers: conjectural decisions and contrived deterrence to new competition, *Quarterly Journal of Economics*, 37, 247-261.
- Caves, R.E., 1984, Multinational enterprise and economic analysis, Cambridge, Cambridge University Press.
- Cooper, R.G., 1983, The impact of new product strategies, *Industrial Marketing Management*, 12, 243-256.
- Hirschey, M. 1981, R&D intensity and multinational involvement, *Economic Letters*, 7, 87-93.
- Kamien, M.I. and N.L. Schwartz, 1982, Market structure and innovation, Cambridge, Cambridge University Press.
- Kamien, M.I. and Y. Tauman, 1984, The Private Value of a Patent : A Game Theoretic Analysis, *Journal of Economics*, Suppl. 4, 99-118.
- Katz, M.L. and C. Shapiro, 1985, On the licensing of innovation, *The Rand Journal of Economics*, 16, 504-520.
- Katz, M.L., 1985, An analysis of cooperative research and development, Working paper Department of Economics, Princeton, Princeton University.
- Neven, D. and L. Philips, 1985, Discriminating oligopolists and common market, *The Journal of Industrial Economics*, 34, 133-150.
- Newman, H.M., 1978, Strategic groups and the structure performance relationship, *The Review of Economics and Statistics*, 60, 417-427.
- Reinganum, J.F., 1981, Dynamic games of innovation, *Journal of Economic Theory*, 25, 21-41.
- Reinganum, J.F., 1984, Practical implications of game theoretic models of R&D, *American Economic Review*, 74, 61-66.
- Scherer, F.M., 1984, Innovation and growth. Schumpeterian perspectives, Cambridge, M.I.T. Press.
- Shapiro, C., 1985, Patent licensing and R&D rivalry, *American Economic Review*, 75, 25-30.

Spencer, B.J. and J.A. Brander, 1983, International R&D rivalry and industrial strategy, *Review of Economic Studies*, 50, 707-722.

Stewart, M.B., 1983, Non cooperative oligopoly and preemptive innovation without winner-take-all, *Quarterly Journal of Economics*, 48, 681-694.

Van Cayseele, P., 1986, Spillovers and the cost of multiproject R&D, *Managerial and Decision Economics*, to appear.