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R&D-Competition between Vertical Corporate Networks: Structure, Efficiency and R&D-Spillovers

by

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Abstract

The strategical role of R&D-spillovers within vertical corporate networks (intia-group R&D-spillovers) are neglected in the innovation theory of Industrial Organization. Against this background we formalize in a two-industry model the effects of R&D-compedtions between two exclusive vertical corporate networks on market structures, technological opportunities and the development time of new products. It can be shown that highe* efficiency of organizing corporate networks increases the group size and raises the level of supplier's innovative activities. We found that intra-group R&D-spillovers stimulate the competition between upstream-firms and increase the probability of the core downstream-firms t:) win the R&D-competition. This can explain the observed differences of firm's technolog cal opportunities on the upstream-market. Finally we discuss the importance of vniversity-bt sed R&D-spillovers to improve the capacities of the network members to absorb imra-gr >up R&D-spillovers.

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1. Introduction

Lead time is a very important factor in the innovation process (Cusumano and Vobeoka 1992; Clark 1989). In order to be the first to innovate a new (intermediate) product, tl ere is intensive R&D-competition not only between independent firms but rather between inr ovation groups (Imai 1989; Suzuki 1993; Turnbull et al. 1992). These so called corporate networks are based on the level of manufacturer-supplier relationships and strategically led by core firms. The consequences of these forms of R&D-competition between vertical strategic networks and the importance of R&D-spillovers within corporate networks on the structure and efficieny of innovative activities have been neglected in the theory of industrial organization

The aim of the paper is to formalize the effects of R&D-competition between two vertical corporate networks on market structures, technological opportunities, effic ency of firm's innovative activities and on the introduction time of new products. We extend t te model of the R&D-race, described by Lee and Wilde (1980), to a two-industry model. In this model R&D-activities, earmarked to lead to an earlier expected introduction time of a given innovation, are distributed across manufacturer and supplier firms within vertical corporate networks. We investigate the relationships between the size of the networks and the level of transactions costs. Core downstream-firms have incencitives to restrict the size of their corp irate networks, depending on the level of transaction costs.

In order to be able to analyse the different effects of R&D-competition two characters of vertical networks will be compared. The first innovation group only exists because of costumer-specific R&D-investments on the supplier side. The connection.; between the independent members are functional specific and loose. The members of the second innova ion group form a strategic network led by a core manufacturer. The strategy of the core manufacturer is characterized by the fact that these firm conducts supplier-specific R&D md transfer the generated technological informations to the suppliers of their network without direct compensation. The manufacturer profits from its innovative efforts by reducing the time of the development of a new product and increasing their probability to be the first in the R&D-competition.

The strategic transfer of important technological informations are profit maximizing only under certain circumstances. Especially if complementary informations spill over from the core manufacturers to the supplier•market, the creating of information networks are profit enhancing for the core firms. The inter-industry information transfer within the networks also reduces the costs of transaction between the core manufacturers and their suppliers, resulting in an increase of the number of network-members. This last effect also forces the supplier's

R&D-efforts and increases the probability that the informing manufacturer will be the one to make the innovation.

To use the complementary informations of the core firm, it is necessary for the suppliers to have the capacity to absorb the external informations to take full advantage of the knowledge generated by the core firm. It will be shown that the R&D-spillovers created by universities improve the supplier's absorptive capacity. Hence core manufacturers have incentives to open their corporate networks for non-profit organizations to encourage the realization of economies of scale in R&D.

The paper is proceeds as follows. In chapter 2 we describe the role of corporate networks in the innovation process. We distinguish special types of vertical corporate networks. This is been done in the intention, to ciearify the relations between vertical corporate networks, transaction costs and different forms of R&D-spillovers. In chapter 3 we formalize the effects of the R&D-competition between two corporate networks on the size of the networks, market structure and on the innovative activities of upstream-firms. In chapter 4 we include intra-group R&D-spillovers, which are strategically generated from the core downstream-firms. We analyse the effects of this strategy on the technological opportunities, efficiency of firm's innovative activities and on the introduction time of new products. Chapter describes the importance of university-based R&D-spillovers for corporate networks.

2. Vertical corporate networks, transaction costs and the role of R&D-spillovers

Corporate networks are for-profit organizations which „due to the intensity of their interaction, constitute a subset of one (or several) markers)'[1] (Thorelli 1986, S.38). Thus corporate networks are hybrid organizational governance forms laying in a continuum between the extrem points of hierarchy and market.

In our paper we focus on *vertical corporate networks* which base on the relationships between manufacturers and suppliers to develop and produce a custom-tailored good. Suzuki (1993) pointed out that to a large extent the essence of corporate networks lays in the cooperation between manufacturers and suppliers in the R&D-process and in the improvement of the quality of custom-tailored products. This view is supported by many studies in different manufacturing industries in the fields of automotive, aircraft, biotechnolgy, electronical machinery- and telecommunication (Clark and Fujimoto 1991; Imai 1989; Sydow 1992). Because lead time is an important factor of innovation success, the essence of a corporate network is not only to improve product quality but also to reduce the time firms require „to introduce a new product from concept generation to pilot production (Cusumano and Nobeoka 1992, S.271).

Vertical corporate networks can have various organizational forms and structures (Geri tch 1995; Robertson and Langlois 1995). The distinctions of the networks base on the *tightnes.* of the relationships between the members, the hierarchical control and strategic leadership of c ire firms within the networks and the exclusive character of networks. Important for all organizational forms of corporate networks is that they involve cooperative as well as competitive behaviors of members. On the one side there may be cooperative behavior among manufacturers and suppliers. On the other side, the suppliers within an corporate network may compete in developing and producing intermediate goods for their customers.

For our purpose we distinguish vertical corporate networks of three types:

- An *exclusive corporate network* is given when a manufacturer on a downstream-market forms an innovation group with a small number of suppliers to develop and produce custom-tailered goods. The linkages between the members are tighter than if firms offer standardized goods (Thorelli 1986).

- A *strategic corporate network* is an exclusive innovation group which is strategically led by a core firm. Jarillo (1988, S.32) defines strategic networks as „long term, purposeful arrangements among distinct but related for-profit organizations that allows those firms in them to gain or sustain competitive advantage vis-a'-vis their competitors outside the network". Hence core firms have the ability to influence directly the actions of the other group members. In our case manufacturers cooperate with their suppliers, communicate intensively and share important R&D-informations to reduce the development time of new products. Core firms create R&D-spillovers to gain competitive advantage over their competitors outside the network. Additional core manufacturers influence the dynamics and structure of connected upstream-markets as well as the R&D-behavior of suppliers.

- An *open network* is characterized by a strategic corporate network which is not exclusive for suppliers and manufacturers but are also open to non-profit organizations like universities and research centers. Opening a network to universities is a certain strategic action of core firms. Klevorick et al. (1995) show in their empirical study that R&D-spillovers from universities play an important role for firm's capacities to absorb technological knowledge. Thus core firms have incentives to internalize university based R&D-spillovers within their group to improve the absorptive capacity of their members. This give all firms within a network a competitive advantage compared to firms outside the innovation group. An additional effect is that the number of suppliers within a corporate network may also increase if universities are involved.

It is often argued that network organizations other than core firms „co-determine the formation of strategies within the network“ and that „the structuration of a corporate network does not simply result from straightforward rational and intentional action of management“ (Sydow and Windeler 1993, S.194). In line with the innovation theory of industrial organization, we assume that the strategic choice of core firms and implicitly the costs of organizing and managing the different transactions within a network defines the boundaries and dynamics of corporate networks. In the case of vertical corporate networks the core firms have the ability to choose, manage and to change the size of their networks (Benassi 1993; Sydow and Windeler 1993). Thorelli (1986) shows that the linkages between the members of corporate, networks are complex, relatively stable, but also allow new entries as well as exits of firms. Hence network structures are moderately dynamic. The dynamic allows core firms to charge the size or boundaries of their networks.

2.1 Vertical corporate networks and the role of transaction costs

The neoclassical theory of industrial organization mainly looks on the superior efficiencies of firms based on advantages in production costs and technological opportunities as well as on economies of scales (Tirole 1988). In this view an internalization of different functions within a firm will be prefered as long as subadditivities of costs exist. X-inefficiences (Leibenstein 1966) within a firm increase the costs and raise incentives to use markets for transactions. The same is true for the internalization of R&D. So long as firms are superior in technological and financial opportunities they will undertake R&D inhouse.

Contrary to this view, Williamson (1975, 1989) pointed out that the main focus of firms is the minimization of transaction costs, which the neoclassical theory approach has neglected for a long time. Hence whether a set of transactions ought to be executed across markets, within different forms of corporate networks or within firms depends on the relative efficiency of each governance structure. ‚Jf the net benefit of forming or joining a group exceeds that of implementing transactions within the firm or through the market, the firm has the incentive to form or to join a group“ (Goto 1982, S.61). Additional to this view we believe that not only the decisions of forming or joining a network but also the size and type of corporate networks are determined through the levels of transaction costs carried by core firms. We assume that the structurations of networks based only on rational actions of core firms and leave out the consideration of social and psychological factors.

Even when transactions within a corporate network are always more efficient than transactions through the internal organization of the firm or through the market, core firms have to choose the optimal size (scope) of the group what is equal to choosing the optimal number of members (suppliers). We think that the transaction costs of forming, adjusting, coordinating, controlling and specifying R&D-projects within corporate networks are increasing in the size of the network. That implies an U-shaped transaction-cost-function for a corpoiate network.

In choosing the optimal organizational form of transactions, core firms have io make a two-stage decision: At first firms have to decide whether they transact through the market, within the firm or within corporate networks, depending on the relative efficiency of e ich governance type. This can be described as the *organization-setting-stage.* Second core firms decide contingent on the choosen organizational form - in our case a corporate netv ork - the most efficient size of their organizational form. Hence they set the capacity of the corporate networks *(capacity-setting-stage).*

2.2 Vertical corporate networks and the role of R&D-spillovers

It is common to the state in the innovation theory that R&D-spillovers limit the appropriability of innovative rewards (Spence 1984). Shares of generated R&D-informations of individual firms may be used by other firms without purchasing the right to do so. Therefore R&D-spillovers are (positive or negative) external effects, which have to be distinguished from information transfers, for which firms can charge market prices or licensing fees. For example, if manufacturers contract out the R&D-activities, the information transfer bases on formal R&D-contracts with compensation schedules. As a result R&D-spillovers raise incentives to perform R&D-cooperations between firms to fully internalize these external effects (DeBondt andVeugelers 1991).

We want to extend the spillover-concept of the Industrial Organization theory to information transfers between organizations within a vertical corporate network. The innovation theory of Industrial Organization pays attention only of intra-industry R&D-spillovers or interindustry R&D-spillovers between independent markets. The focus of our paper lays in *intra-group* R&D-spillovers between downstream-firms (manufacturers) as the sender of informations and upstream-firms (suppliers) as the receiver and user of the transfered informatk ns. Further we investigate R&D-spillovers from universities and their impacts on the structure and efficiency of vertical corporate networks.

2.2.1 Intra-group R&D-spillovers between manufacturers and suppliers

Numerous field studies have shown that firms in vertical related markets contribute to the R&D-eflorts of their suppliers or customers without direct compensation (Dyer and Ch chi 1993; Imai 1989; Shaw 1985; VanderWerf 1991). They strategically create R&D-spillovcrs even if a market for informations does not exist. The incentives for this spillover strategics are various. Firms may improve the technological opportunities of suppliers (customers) to stimulate their innovative efforts (Harhoff 1993; Peters 1995). Further R&D-spillovers may be easier to realize with lower costs than a money-based exchange (Schrader 1993).

The reasons for generating R&D-spillovers may come from the appropriation of indiiect returns. New informations can decrease the production costs of the acquiring firms, improve the quality of their new products or reduce the development ¡time of new products and processes. Further, if not the quantity but rather the quality of informations are under control of core firms, R&D-spillovers reduce the level of own transaction costs, lead to a larger size of corporate networks and to new entries on supplier markets. These effects cause an expansion of manufacturer profits. The incentives for information sharing are increasi ig, if the new technological knowledge can easily be transfered as well as used within the corporate networks only. This means that the extent of R&D-spillovers between competing ver deal corporate networks must be low or there must be a large time-lag between sending and receiving the R&D-informations.

2.2.2 R&D-spillovers between corporate networks and universities

Additional to the transfer of technological knowledge core firms can open tleir network to include R&D-spillovers from non-profit organizations like universities. They have incentives to promote the information transfer among the (actual and potential) members of their corporate networks, because such spillover-informations can improve the technological opportunities of their suppliers. Empirical studies show that innovative firms take advantage if they have possibilities to acquire R&D-spillovers from universities (Grabow et al. 1995; Henderson 1994; Jaffe 1989). Closed linkages to university research have positive impacts on the generation, adaption and implementation of innovation. Tight relationships to universities are one factor to explain the relatively high R&D-intensitics of innovative firms (Feldman 1994; Becker 1994; Pfirrmann 1991).

Because of the described importance of university based R&D-spillovers core firms have incentives to open their corporate networks for R&D-spillovers from universit es. We assume that this type of R&D-spillovers improves the strategic capacity of core firms. This irr plies taat core firms play a role as an organizer of the information transfer from universitites to tl eir suppliers. They want to improve the technological opportunities and absorptive ppssibilitie.' of the suppliers in the network.

3. Modelling the effects of the R&D-competition between corporate netwoi ks

The following two-industry-model bases on the R&D-race, developed from Lcury (1)79) and Lee and Wilde (1980). On the factor demand side we consider a duoptfistic industry, consisting of two downstream-firms *i,j* that produce a homogeneous good ant earn i current profit π_0. Both firms compete to be first to introduce a new technology, what makes the older technology obsolet. Also we assume that the production of the new good on the downstream-market requires a new intermediate good, that have to be developed under uncertainty on an upstream-market. Hence there is a stochastic relationship between R&D-investments of suppliers and the introduction time of new intermediates. This implies that *the time of discovery of a new intermediate good determines the introduction time of the innovation on the downstrearn-market.*

For simplification we assume that the considered inter-industry R&D-process can be divided into different stages. At first both downstream-firms specify and evaluate the design, styling and specific technical properties of the new good on the downstream- *and* ups .ream-market[1]. On the basis of the customer-specific requirements refering to the new interme Jiate good, the suppliers have to solve the technological problems including prototyping a id tooling. To concentrate our analysis of the R&D-race between upstream-firms we assume that both downstream-firms have completed this *design-stage* at the same time. The fixer R&D-costs of downstream-firms *Y* reflect their R&D-activities on this stage. In the following we neglect tiis design-stage and look only on the next *two* stages.

On the first stage downstream-firms select - independent of the actions of their competitors - the number of suppliers. Choosing the number of suppliers is equal to choosing the size of the inter-industry R&D-project and implicitly the scope of the corporate networks or innovation groups. We can define this action of downstream-firms as a *strategic* setting of *intra-group R&D-capacity.* On the second stage the upstream-firms compete with the firms *within* their innovation-group and with the firms of *other* networks to be first to make the discovery. After the realization of the innovation on the upstream-market the new good will be introduced on

[1] It is important to note that the innovations of both customers are effectively the same, regardless of their design and styling. This implies that consumers have no differences in preferences between the innovations. This will be true also for the technological properties of the new intermediate good. Hence w i can define these good as a *custom-tailored product* (often called as *black box* product).

the downstream-market without delay[2]. We make this assumption to point out the importance of the innovative activities of suppliers for their customers.

In the basis model we want to analyse the R&D-competition between two corporate networks, in which the relationships of manufacturers and suppliers are only loose. Manufacturers are not involved in the R&D-activities of their suppliers. There is no R&D-ccoperation and information sharing between the members. In this context we have to make some important assumptions:

1) We do not focus on the circumstances on which downstream-firms decite to do R&D inhouse or to make market-lengths transactions in R&D to firms on the up ,tream-market. In our model downstream-firms have no incentives to undertake the R&D-project inhouse because suppliers are superior to the internal sourcing of downstream-firm . This is often the case for complex intermediates that require transaction-specific investmc its (Nishiguchi 1994). But contracting with suppliers as well as organizing the inter-industr / R&D-projcct is associated with high transaction costs, which can not be neglected. Transaction co.'ts increase with the scope of the network, measured through the number of sup diets.

2) Each manufacturer i and j will form an *exclusive* innovation group wi h n^i and n^J upstream-firms (the index i denotes firms which are members of the group of the downstream-firm i and otherwise), whereas n^i (n^j) will be determine! through the strategic action of downstream-firms. The total number of upstream-firms s $N = n^i + n^J$. This assumption implicates that group-independent upstream-firms can no. exist and the upstream-market structure can be endogenously determined through decisions of the core downstream-films.

3) The investments of downstream-firms in external R&D-Iabs are envisaged to be made with diminishing returns that are reflected in the quadratic form of the tram action-costs in coordinating an innovation group: $(d/2)n^2$ with $n = n^i$ or n^j. The parameter a is inversely related to downstream-firms's efficiency of organizing the inter-industry R&D-project. High values of d implicate low organisational efficiency or - for given size of the innovation group - high transaction costs and vice versa.

4) Upstream-firms will have to pay entry costs, if they want to participate in the corporate network. These entry costs can be reflected through the level and charactt r of their fixed R&D-costs X. The level of fixed R&D-costs describes the necessary genet c technological

[2] In many industries, at this stage the whole R&D-process is not completed. The winning supplier have to develope the new intermediate in cooperation with their customers further on in more detail. But incurring this additional stage in our model will not change our results.

opportunities and requirements for upstream-firms to be choosen as a developer. But even if the levels of fixed R&D-costs are the same for all upstream-firms, the character of fixed R&D-costs can be different. This implicates *customer- or group-specifity* of former R&D-investments. For example, suppliers of equal technological opportunities may have to adjust their R&D-activities with same costs to different customers.

5) The upstream-firms within a group - but also the innovation groups itself - play a non-cooperative R&D-game. Because downstream-firms apply the single-sourcing strategy[3], only the winning upstream-firm will take a positive project value $V^u = \pi^u / r$, with r denoting an exogenously given discount rate and π^u the constant rewards of innovation. The winner-take-all assumption is also valid for the downstream-market: $V^D = \pi^D / r$. This implies that after innovation we have two temporary monopoly situations in the up- and downstream-market. A quantity competition between the two corporate networks does not appear. Further we state that the rewards of innovation for upstream- and downstream-firms are fixed before playing the R&D-game and the sane in both groups: $\pi^{Ui} = \pi^{Uj}, \pi^{Di} = \pi^{Dj}$.

6) The time of discovery of each upstream-firm is uncertain and distributed according to $P(T \leq t) = 1 - e^{-ht}$, with the hazard rate h as the constant probability of making a discovery during $[t; t + dt]$. In the basic model h is only a function of the R&D-investments of individual upstream-firms x with the following properties: $h_x(x) > 0$, $h_{xx}(x) < 0$, $h(0) = 0$, $h_x(+\infty) = 0$ and $h_x(0) = +\infty$ (Tirole, 1989, S.394). In the model with strategic genera'ed R&D-spillovers the hazard rates include also the R&D-investments y of the manufacturers: $h = h(x,y)$. The properties of h with regard to x or y are the same.

7) We assume symmetry between the upstream-firms within the two networks, i. e. the hazard rates of the upstream-firms in group *i,j* are equal. This implicates that the probability for the downstream-firm *i,j* to win the inter-industry R&D-competition is $n^i h^i$ and $n^j h^j$.

8) For all models we assume negligible *intra-industry* R&D-spillovers on the upstream- and downstream-market. In the case of inter-industry R&D-spillovers, which are strategic generated through the two downstream-firms, this condition implicate that only *intra-group* R&D-spillovers exist.

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[3] For example, it is common in the automotive industries that downstream-firms, which are core in their corporate network, let compete their suppliers independently to be first to discover new intermediate products (Asanuma 1985; Clark and Fujimoto 1991). Especially the Japanese automakers announce a R&D-race between the suppliers within their *keiretsus.* In recent years it is also common in most European countries that automakers choose the *single sourcing strategy.* Dyer and Ouchy (1993) pointed out that single sour ring strategies are superior, when large cost savings in production and organization can be realized.

10) Only if the weighted value of innovation exceeds the value of the current monopoly profit downstream-firms will undertake a R&D-project (profit incentive). Thus for the downstream-firms, starting a R&D project is optimal if and only if

$$A = (n/N)\, \pi^D - \pi_0 > 0.$$

Because of the R&D-competition between the two innovation groups, the realization of π^D depends on the success of the upstream-firms, which are *members* of their group. The proportion of own members *(n)* and the number of all upstream-firms $(N = n^i + n^j)$ captures the situation of competition between the two networks.

3.7 *Equilibrium level of R&D on the upstream-market*

The sequential Nash equilibrium is *subgame perfect* and computed through backward induction. The profit function of a representative upstream-firm, which is a member of the innovation group of downstream-firm *i*, is given by[4]

$$\underset{x^i}{Max}\; ED^{Ui} = \int_0^{\infty} e^{-(r+h^i+a^i+n^j h^j)t}\,(h^i V^U - x^i)\,dt \qquad (1)$$

$$= \frac{h^i V^U - x^i}{h^i + a^i + n^j h^j + r},\ \text{with } x^i > 0,\ a^i = (n^i - 1)h^i,\ i \neq j.$$

The degree of rivalry *within* the corporate network is described through the parameter *a*. $n^j h^j$ denotes the degree of rivalry *outside* the network. Each upstream-firm maximizes its profit with regard to own R&D-investments given the R&D-investments by the other firms. The first-order condition of profit maximization is:

$$[(a^i + n^j h^j + r)(h^i_x V^U - 1) - h^i + h^i_x x^i] = 0. \qquad (2)$$

We focus our analysis only on the symmetric Nash-equilibrium. Substituting (2) into the profit function (1) yields after some transformations (subscripts are neglected)

$$V^U - 1/h_x - x > 0. \qquad (3)$$

It is easy to verify that in equilibrium expression (3) must be non-negative. In the reverse case, no upstream-firm will be active in the R&D-game, because it will earn only negative profits. Denote $x(n)$ as the R&D-investment of upstream-firms which realize equation (2) for a given

[4] We look only at the situations of upstream-firms, which are members of the innovation group *i*. But the conditions are the same for firms in innovation group).

size of the innovation group. Because $h_{xx} < 0$, the second-order condition are always satisfied. For the symmetric case it can be shown (see Lee and Wilde 1980) that a unique and stable equilibrium requires

$$S = h_{xx}\left((N-1)h + r)V^U + x\right) + h_x(N-1)\left(h_x V^U - 1\right) < 0. \tag{3'}$$

At first we want to derive comparative statics of $\tilde{x}(n)$ with respect to the degree of rivalry *within* (a) and *outside* the groups (nh). Because of expression (3) it can be shown that

$$\left.\frac{dx}{da}\right|_{x=\hat{x}} = \left.\frac{dx}{dnh}\right|_{x=\hat{x}} = -\frac{h_x V^U - 1}{h_{xx}\left((N-1)h + r)V^U + x\right)} > 0. \tag{4}$$

The effect of increasing rivalry is the same whether the scope of the own or of the competing innovation group increases. *For upstream-firms there is no difference being a member of a large or a small industrial network.* If we want to derive the impact of increasing rivalry on the upstream-market in full industry equilibrium we have to consider both effects in (4). After total derivation of the necessary condition (2) we get

$$\left.\frac{dx}{dN}\right|_{x=\hat{x}} = -\frac{h_x V^U - 1}{S} > 0, \text{ with } S<0. \tag{5}$$

It is important to note that (5) can only hold if suppliers have *no possibility to switch* between the two innovation groups. Thus an increase in the number of upstream-firms within the groups does not lead to an equal decrease in the number of upstream-firms outside the groups. Because of (4), if switching of suppliers were allowed, there would be no rivalry effect.

3.2 Equilibrium level of group-size on the downstream-market

On the first stage of the R&D-project the scope of the innovation group is choosen with perfect foresight of the R&D-investment decisions given on the second stage. After integration, the profit function of downstream-firm i is given by:

$$\underset{n^i}{Max}\ E\Pi^D = \frac{\pi_0 + n^i h^i V^D - d^i n^{i2}/2}{n^i h^i + n^j h^j + r} - Y^i, \text{ with } i \neq j. \tag{6}$$

We restrict or analysis only to *interior* solutions. We want to exclude corner solutions from our analysis, in which the zero-profit condition on the upstream-market is achieved (the value of expression (3) is zero). In this case downstream-firms can not choose the profit maximizing number of suppliers.[5] Here we can show that core downstream-firms build up strategic entry barriers on the upstream-market, restricting the market entry of new suppliers. The first-order condition is

$$\frac{\partial E\Pi^D}{\partial n}+\frac{\partial E\Pi^D}{\partial \hat{x}^i}\frac{d\hat{x}^i}{dn}+\frac{\partial E\Pi^D}{\partial \hat{x}^j}\frac{d\hat{x}^j}{dn}=0,\text{ with } n = n^i. \tag{7}$$

We can decompose equation (7) into three effects. The first term on the left l and side is the *direct* or *cost effect* of choosing the scope of the corporate network. In our rr odel this effect can be expressed in the symmetric case as

$$\frac{\partial E\Pi^D}{\partial n}=\frac{h^2V^D(N-n)+hA-dn(h(2N-n)/2+r)}{(Nh+r)^2} \tag{8}$$

It is easy to show that the numerator of the direct effect (8) decreases in hi; her levels o: d what implicates decreasing organizational efficiency.

The other two terms in (7) describe the *indirect or strategic effects* of the nurr ber of choosen suppliers on the R&D-quantities of *own* and *competitor´s* upstream-firms. Tl e effect of the R&D-efforts of own suppliers on the expected profit of the core firm is positive, because the R&D-investments of members increase the probability of the downstream-firm to win the R&D-race. In the opposite case, increasing R&D-investments of competitor´s suppliers reduce the probability of success and therefore expected profits. The *total* strategic effect - the sum of the second and third term of (7) - is always positive:

$$\frac{\partial E\Pi^D}{\partial \hat{x}}\frac{d\hat{x}}{dn}=h_x N(A+dn^2/2)/\left(Nh+r\right)^2\frac{d\hat{x}}{dn}>0, \tag{9}$$

with $\quad \frac{d\hat{x}}{dn}=\frac{d\hat{x}}{dN}>0.$

The numerator in (9) must be positive, because the parameter A is always positive. Otherwise downstream-firms have no incentive to develop new products. Further in expression (5) we have seen that increasing the number of suppliers within a group stimulates the rivalry between *all* firms on the upstream-market. Therefore - in the view of the downstream-firms - the positive effects of increasing rivalry within a group are always larger than the negative effects

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[5] Corner solutions exist if $\hat{n}<n^*$ and $\hat{N}<N^*$, with $\hat{n}$ ($\hat{N}$) denoting the number of suppliers within a network if condition (3) is zero and n^i (N^*) denoting the number of suppliers within a network which solves the necessary condition (7).

outside the group and the strategic effects are positive. For the further analysis let A' and n' denote the equilibrium values which solve (2) and (7).

Now we look on the necessary condition (7) in more detail. This allows us to describe he interdependencies of lead time, transaction costs and size of corporate network< We can st ite the following propositions:

a) 'If downstream*firms do ignore the transaction costs of organizing interindustry R&)-projccts, they have always incentives to enlarge the size of their innovatit n group, what increases their probability to win the R&D-competition[6]. Setting d in (7) eq lai to zero, the direct effect (8) and the strategic effect (9) are always positive. This impl es, that in this case core firms will look *only at the time of developmentfor new product and therefore overinvest in external R&D-capacity.*

b) Neglecting transaction costs is optimal only if the organizing and controllii g of corporate networks is perfectly efficient. In all other cases if the size of corporate net vorks is above n^*, the transaction costs will increase in larger extent than the gain of reducing the development time of new products. Thus, in a) we have the situation that the *(expected) speed ofdevelopment is toofast.* But for high transaction costs, it is rationa for core firns to restrict the size of their corporate networks and to slow down the exoected time of discovery, which *increases* their expected profits.

Looking at the dependence of network's sizes and the transaction costs form: lly we have to clear out the condition that interior solutions exist. It can be shown that lowei organizational efficiencies have two opposite effects on the necessary condition (7). On tl e one side an increase in d reduces the value of the *direct* effect (8). For a given level of tht total strategic effect, this can be offset by a *decrease* in the number of members (for proof, sec appendix). On the other side lower efficiency leads to an increase in the numerator of (9) and enlarges the positive value of the total *strategic* effect. For a given direct effect, this can ie offset by an *increase* in the size of the corporate network. Hence the whole effect of d on the size of the network seems to be ambigeous. *But the impact of organizational efficiency on the direct cost-effect must always be stronger than on the strategic effect.* Only this co idition ensures that downstream-firms are strategically active in choosing the size of their groups. If the condition does not hold, the value of the negative direct effect, given the level of organizational efficiency d, is always smaller than the values of the positive strategic effects. No interior solution (7) can exist. Therefore we state that even if the strategic effects were

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[6] The boundaries of the corporate networks will be determined only through the zero-profii condition on the upstream-market (3).

increasing in d and declining in n, higher organizational efficiency leads to i larger size of innovation groups (note that the effect of increasing rivalry ($ds / \partial N$) is indepe idem of d).

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c) In chapter 2 we have pointed out, that core firms can minimize the expected transact·on costs for a given project value or maximize their expected profits. But in the case of ci st-minimization they will neglect the positive total strategic effect (9), which leads to a smaller size of corporate networks and to a lower speed of innovation time. Additionally, ft r a given number of corporate networks, the concentration on the upstream-market vill increase.

4. Strategic generated intra-group R&D-spillovers between manufacturers and suppliers

In the following we extend the basis model to allow downstream-firms to be active on the intermediate-specific R&D-stage. They strategically generate R&D-spillovers o improve the technological opportunities of their suppliers and to fasten the time of product cevelopmem on the upstream-market. But before we analyse the effects of this information strategy form; lly, we have to specifiy the different *natures* of R.&D-spillovers, which are an integral part of the problem-solving process on the upstream-market (see also Katsoulacos and I Iph 1995, ·fon Hippel 1994).

If manufacturers choose the *quantity of information,* we assume that al firms decide simultaneously on the R&D-efforts. The informations flow piece-by-piece from the downstream- to the upstream-firms within the R&D-race on the upstream-market, but the manufacturers can not control the level of usefulness of the transfend knowledge. Manufacturers have only the possibility to anticipate the effects of their own F.&D-efforts on the R&D-decisions of the information acquiring suppliers. Further upstream firms have no insight in the conception of the R&D-project managed by manufacturers, and vice versa.

Contrary to the control of the quantity of informations, the manufacturers car. decide on the *quality* (level of usefulness) of the created knowledge spillovers. This implies that downstream-firms act as first movers and choose their intermediate-specific R&D-efforts before the R&D-racc on the upstream-market begins, which has impacts on the research design of supplier's R&D-process. They can decide which problem-solving R&D-informations arc necessary for the R&D-process of the suppliers and which are not. For example, manufacturers provide their suppliers with informations belonging to the design and conception of the new intermediates or with informations about problems at the surface with other intermediates (Clark and Fujimoto 1989, 1992). But additional to the different time-dependence of R&D-spillovers, we believe that the sharing of quality (rather than the quantity of informations) reduce the level of transaction costs. Spillovers improve the coordination of the R&D-project because upstream-firms have earlier insight in the conceptions of the project and may better adjust their R&D-activities to the needs of their customers. Cost intensive transactions like design-changings, quality controls, etc. can be minimized.

4.1 The impact of quantity-based R&D-spillovers

Downstream-firm i maximizes its profit with respect to own R&D, given the R&D-quantities of upstream-firms and downstream-firm j. In consideration of (6), the first-order condition of profit maximization with respect to own R&D-investments y is given through

$$\left[n^i h^i\left(n^j h^j V^D + B + y^i\right) - (n^i h^i + n^j h^j + r)\right] / (Nh+r)^2 = 0, \tag{10}$$

with $B = V^D r - \pi_0 + dn^{i2}/2 < 0$. Remember that we have excluded intra-industry R&D-spillovers on the downstream- and the upstream-market. Only group-members can use the transfered informations. Further on, the necessary condition for profit-maximizing on the *upstream-market* is given through equation (2) with $h=h(x,y)$. We assume unique and stable equilibria on both markets, which can easy be verified. On stage two of the inter-industry project - with perfect foresight of the R&D-quantities - downstream-firms maximize their profits with respect to the number of *own* suppliers. Let in the symmetric Nash-equilibrium x^{**}, y^{**} and n^{**} denote the firm's choices of R&D-quantities and number of suppliers, which solve equations (2), (6) and (10) simultaneously.

In consideration of (10) we get in the symmetric case the slopes of the *reaction functions* on the downstream-market

$$\frac{dy}{dx} = R^D = -\frac{nh_{yx}\left[hV^D n + B + y\right] - h_x}{nh_{yy}\left[hV^D n + B + y\right]} \tag{11.a}$$

and for the upstream-market in consideration of (2)

$$\frac{dx}{dy} = R^U = -\frac{h_{xy}\left((N-1)h + r)V^U + x\right) - h_y}{h_{xx}\left((N-1)h + r)V^U + x\right)}. \tag{11.b}$$

We see that the slopes of the reaction functions R^D and R^U are always negative for $h_{xy} \leq 0$ and that they become positive for $h_{xy} > 0$ and $h_{xy}h - h_x h_y \geq 0$. For $h_{xy} > 0$ and $h_{xy}h - h_x h_y < 0$ the signs of the slopes are ambigeous. Like the results of Beath et al. (1989)

lor inlra-market R&D-competition, also in the case of strategic generating F&D-soillovers, any outcome is possible. The R&D-activities of knowledge spillovers generating dounstream-firms and their spillovers acquiring upstream-firms *may* be strategic substituí es or strategic complements.

Il R&D-spillovers are *strategic substitutes* to supplier's R&D-investments, the invohement of the core downstream-firms displace a costless fraction of the R&D-activities of their own suppliers. In the case of *perfect* (non-perfect) substitutes, the core firms have, to bear *ail* (a fraction of) R&D-costs itself. For all values of $y^* < x^*$ the equilibrium value of the ht zard rate will decline (Harhoff 1993). Core downstream-firms have no incentive to create knowledge spillovers.

The incentives for contributions of core downstream-firms for the R&D-aciivities of their suppliers will be stronger if the slopes of the reaction functions are both positive- and the R&D-efforts of down- and upstream-firms are strategic complements. Downstream-firms will decide to transfer important technological informations to their suppliers only if this s.rategy reduces their time for developing the new intermediate product and increases their possibilities of innovation. For a given size of the corporate network this will always be he case if the individual hazard rates of suppliers increase: *if* < *h*~.

It is important to note that the case of strategic complements can not be a necessary condition for core firms to create knowledge-spillovers. Core firms are rational actors and look rather tor the improvement of their own probability than of supplier's individual probab lity to win the R&D-race. This implicates that in equilibrium the hazard rate of the whole network must be growing: $nh^{**} < n$ 'h~. Therefore in equilibrium, a decrease in individual hazard rates can be more than offset through an large increase in the size of corporate networks and vice versa. But the incentives to create knowledge spillovers are always larger for strategic complements than for strategic substitutes.

Sufficient condition for strategic intra-group R&D-spillovers

For an involvement of downstream-firms in supplier's R&D-activities the condition of increasing *group-hazard rates* is only necessary but not sufficient. Because downstream-firms have to involve the R&D-costs for creating the spillover strategy, the *sufficient* condition requires the following inequality

$$E\,\pi^D(x\sim, y\sim, n") > E\,\pi^D(x > `). \qquad (12.a)$$

In equilibrium expected profits have to increase. After some transformations of the downstream-firm's profit function with and without R&D-spillovers we can express (12.a) as

$$\frac{\Delta nhV^{D} - \Delta i - y}{\Delta Nh} > E\Pi^{D}(x^{*}, n^{*}), \qquad (12.b)$$

with $\Delta nh + n^{*}h^{*} = n^{**}h^{**}, \Delta Nh + N^{*}h^{*} = N^{**}h^{**}, \Delta i + dn^{*2}/2 = dn^{**2}/2$, $\Delta nh > 0$, and $\Delta Nh > 0$.

At first we want to look at the relationship between the size of the corporate network and the number of firms on the whole upstream-market: *n/N*. *For a given N, a larger group-size n will make the knowledge creating strategy more likely.* Because of the stochastic relationship between R&D-investments and development time, the probability of the spillover creating downstream-firm to be the winner of the R&D-race is larger, the more independent R&D-labs (suppliers) can use the R&D-informations (Peters 1995). Further, less competition of the downstream-market (*n/N* → *1*) gives incentives to strategic generation of R&D-spillovers. In the extreme case of only one network (*N=n*), the number of members has a clearly positive effect on the realization of core firm's spillover strategy.

Furthermore the existence of intra-group R&D-spillovers is more likely, when R&D-spillovers are strategic complements and therefore stimulate the R&D-activities of upstream-firms. The individual hazard rates of group members increase, given the number of suppliers. Hereby the technological opportunities of suppliers as well as the productivity of manufacturer's informations play a crucial role. To illustrate this, we assume a special functional form of the hazard rate as an innovation production:

$$h(x, y) = x^{\alpha} y^{\beta}. \qquad (13)$$

The paramaters α and β define the efficiency and productivity of the different R&D-investments with respect to the probability of suppliers to win the race. If manufacturer's R&D-efforts are of low efficiency (α→0), the impact of the innovation production is only small, which makes the spillover strategy unlikely. In this situation the incurred R&D-costs *y* may be larger than the gain of the growing probability to win the race. Shorter development times of new products may not be privately desirable. The same is true for the efficiency of supplier's R&D-efforts being low (β→0), which implicates also low technological opportunities of the suppliers. As an important result we get that *the incentives to create knowledge spillovers increase with high technological opportunities of the suppliers and with large productivity of the transfered informations.*

The R&D-spillover strategy does not only effect the individual hazard rate but also the size of the corporate networks.[7] The change of the group size has two opposite effects. On the one side an increase in n enlarges the competitive effects on the upstrearn-market and leads to higher individual R&D-investments of suppliers. The expected time of sufficient product development for the spillover generating downstream-firms decreases. On the other side, an increase in the number of members also enlarges the transaction costs involved. Only if the net effect is positive and sufficiently high, core firms will be active in the R&D for their suppliers and the size of their corporate networks increases. In the opposite case of high transaction costs (low organizational efficiency) and therefore negative values of the ne benefit manufacturers will either not be active in R&D for their suppliers or they reduce the size of their network. But the case of reducing the group size will only occur if

- R&D-investments of suppliers and manufacturers are strategic complements,
- the productivity of both R&D-investments are high, and/or
- the rivalry effect on the upstream-market (dx/dn) is sufficiently low.

Intra-group R&D-spillovers and profit situations of suppliers

In chapter 3.1 we have shown (expression (3)) that in equilibrium the expected profit of upstream-firms must be non-negative and can be expressed through:

$$£11 = {}^{u}V^{U} - 1/h_{x} - X > 0, \quad with\ h = h(x \backslash n\sim) \ or\ h = h(x\sim, y^{*}, n^{**}).$$

The profit situation of upstream-firms depends on the marginal effect of ovn R&D with respect to suppliers and manufacturers R&D-investments as well as on the size of the corporate network.

R&D-spillover strategies of core manufacturers have three different effects on upstream-firm's profits. First, because R&D-activities of down- and upstream-firms are strategic complements (see 11.a and U.b), R&D-spillovers increase the equilibrium levels of individual R&D-investments of upstream-firms and also their probability to be the first to make an innovation. The marginal effects of own R&D on the hazard rates increase with the use of external informations $(h^{\wedge} > 0)$, which leads to higher expected profits. Second, R&D-spillovers also stimulate the R&D-efforts of the R&D-acquiring firms. For a given reward of innovation V^{v} and a given size of the corporate network, the expected profits of suppliers decrease

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[7] A complete analysis of the R&D-spillover effects on the equilibrium value of the network size n'' is relatively complex. We get no distinct signs for the total derivative on n''. This implies that the size of corporate networks may decrease or increase with intra-group R&D-spillovers.

(k_{xx} 0). The whole effect is positive, only if $|ft_{xt}| < h$„ . Third, if R&D-spillovers increase the size of corporate networks, they stimulate the rivalry on the upstream-market. Suppliers individual R&D-costs *(dx/dn>0)* and the total amount of competitor's R&D-costs *(d(N-I)x/dn>0)* increase. Lee and Wilde (1980, S. 433) show that the rivalry-effect is negative. New entries on the supplier market, which implicate increasing sizes of networks, decrease expected profits (JEFI ^{U} *I dn* < 0). Even if $|\hat{i}_x J < h$^ , expected profits of suppliers may decline in the strategy of information sharing and in the size of network's growing to a large extent.

This give us the result *that an involvement of manufacturers in supplier's R&D is only under certain circumstances profit-enhancing for the R&D-acquiring suppliers.* Information transfers may not be desirable for upstream-firms, but always for downstream-fi-ms.

4.2 The impact of quality-based R&D-spillovers

In the last chapter we described, in which situations manufacturers and suppliers simultaneously decide on their level on R&D-investments. When downstream-firms choose the quality of informations, they have the probability to respond to the R&D-decisions of their suppliers. Thus we have a *three-stage game.* On the first stage manufacturer; decide on the size of their corporate networks with perfect foresight of the R&D-decisions. On the second stage they choose the optimal level of R&D-investments, which anticipates the R&D-activities of their suppliers. On the third stage the suppliers compete in an R&D-racc to be first to discover the new intermediate good, setting their optimal level of R&D-efforts.

Because the first and third stage were previously explained in chapter *32,* we want to concentrate our analysis on the second stage. The first order condition with respect to *y* can be expressed through

$$\frac{dE\pi^D}{dy} = \frac{dEK^D}{dy} + \frac{dEU^D}{dx^\wedge}\frac{dx^\wedge}{dy} + \frac{dEH^D}{dd}\frac{dd}{dy} \stackrel{!}{=} 0 \qquad (14)$$

(+) (+)

The first term is the *direct* effect given in equation (10). The second term describes the *strategic* effect of manufacturer's R&D-investments on the ex-post R&D-activities of suppliers. The reason is that manufacturer's R&D-decisions change the R&D-behavior of the member-firms. Because of positive sloped reaction functions (11.a and 11.b) and the positive impact of supplier's R&D-investments on manufacturer's probability to make the innovation (9), this strategic effect is positiv. The third term gives us the *quality-effect* of the R&D-spillovers on expected profits, which also has a positive sign. For example, if downstream-firms can control the quality of the transfered informations they can improve the technolog cal properties of the prototypes, what reduces the costs of testing the prototypes. The whole process of trial and error will be shorter. The number of transactions and the transaction costs will decline. For a given size of a corporate network, lower levels of transaction costs (higher organizational efficiency) yield higher profits for the manufacturer.

This give us the following propositions: *Contrary to theformer model of quantity-based R&D-spillovers, the equilibrium level of manufacturer's R&D-investment will be higher. Furthermore the decline in transaction costs always results in a larger size of the corporate networks.* Because Ai in (12.b) is negative, manufacturers have an incentive to increase the size of their networks.

4.3 Discussion and extensions

Our formal analysis based on a simple two-industry modell with restrictive assumptions. The first simplification was, that only the winning upstream- and downstream-firm can earn positive profits. In the situations that the looser of the R&D-race get a fraction of customer's demand, Stewart (1983) and Delbono and Denicolo (1989) have shown that under ce lain conditions the positive effect of increasing rivalry between competing upstream-firms on innovative activities will reversed. In these situations, core downstream-firms have *higher* incentives to restrict the size of their innovation groups and to build up strategic entry oarriers on the upstream-markets.

Further, we have restrict our analysis only of two industries (one downstream- and one upstream-market). Inter-industry R&D-projects, which are coordinated through core downstream-firms, involve often more than one upstream-market (see Langlois and Robertson 1995). Like in the automotive industry, the intermediates for new automobiles are produced in different upstream-markets (electronics, rubberies, etc.). Our results will strengthen in these situations. The role of transaction costs in innovation groups seems to be more important (and higher) in inter-industry R&D-projects with many vertical related markets than with only one upstream-market. This can be verified through several case studies (see for example Cusumano and Nobeoka 1992). The efficiency of organizing large inter-industry R&D-projects are decreasing in the number of upstream-markets and in the number of members on these upstream-markets. We believe, that for given organizational efficiency and given number of downstream-firms the more upstream-markets are involved in the R&D-projects the less suppliers on these markets can be members of a corporate network.

Further on, if vertical corporate networks exists - for given organizational efficiency and gi/cn number of upstream-markets - lower concentrations on downstream-markets yields also lower concentration on upstream-markets. In this context we think that our model can explain a part of the regional differences in scope of corporate networks. Dyer and Ouchi (1993) pointed out that European or American automakers do not involve transaction costs in their decisions about profit maximizing, but the Japanese automakers do so. Therefore in Europe and the U.S.A, an automaker has a direct relationship to more than 1000 partsmakers. In Japan, one automaker only has direct relationship to 200-300 suppliers (see also MRI 1987; Turnbull et al. 1992). These differences are remarkable because European and American automakers have higher shares of vertical integration in the upstream-markets than the japanes automakers.

An important assumption of our analysis was the neglection of inter-group and intra-industry R&D-spillovers. Imai (1989) pointed out, that especially in Japan the extent of R&D-spillovers among *vertical keiretsu* are high and technologies diffuse rapidly and reciprocally among them. Suzumura (1993, S.586) found in his empirical analysis of the Japanese electrical machinery industry „positive R&D spillovers, stemming from the R&D activities of other keiretsu groups.“ But he can not observe significant effects of R&D-spillovers from upstream-firms of other corporate networks to a core downstream-firm.

Incuring inter-group R&D-spillovers have important implications for our model. On the one side R&D-spillovers among the innovation groups stimulate the R&D-inc mtives of the receiver of the informations which rises the probability to win the R&D-race. But on the other side the incentives for downstream-firms to generate R&D-spillovers strategic ally decline in the extent of inter-group R&D-spillovers because suppliers and the downstream-firm of the competing corporate networks can use these informations costless. This reduce; rival's expected time of development and increases their expected profits. A reciprccally barter of informations among competing groups are unlikely in our model. If only one R&D-project exits and only the winner can earn a positive profits, receivers of the informati ms may get an advantage if they behave opportunistic.

5. R&D-spillovers between corporate networks and universities

Finally we want to analyse the effects of R&D-spillovers from universitites on the efficiency and performance of corporate networks. University-based R&D-spillovers improve the *strategic capacity* of the core firms on the downstream market, because they can transfer these important R&D-informations to their suppliers in the corporate network to fasten the development time of the intermediate good. In our model core firms arrange and manage the contacts to the universities. They have to choose, which universities have the abilities and capacitities to generate and/or deliver the relevant R&D-informations in a given time period.

Core firms will only be motivated to cooperate with universities, if the importance of the acquired informations for their own R&D-activitites is sufficiently high. The benefit-cost-relation in acquiring the informations must therefore be positive. In this case it is reasonable that the core firms have to carry the costs of the R&D-informations required from the universities. Additional to this function as financiers, core firms also play the role of the organizer of the information transfer. They pass the important R&D-inform; tions 'rom the universitites to their suppliers which can adapt and use the university-based R&D-spillovers without restrictions and financial compensation.

The university-based R&D-spillovers improve the technological opportunities and he absorptive capacities for the suppliers in vertical corporate networks. The effects of ¡his improvements are various. First, the knowledge transfer leads to an increase in the producti' ity of supplier's and manufacturer's R&D-efforts (a and p), which determine the hazard rate.[1] of the suppliers as shown in (13). This implicates, that a and p are functions o' the university based R&D-informations *u: a^a(u)* and psp(w), with 3a(u)/9u>0 and 3/?(u)/ehr :■0. Therefore the probability of the suppliers to develop the required intermediate gooi is positively influenced by the informations transfered. For given costs of R&D, the time of product development will be reduced.

Second, for given R&D-productivities, the transfered informations can reduce the fixed costs of suppliers *X*. A part of the fixed costs will be covered by the transfered informations. This will also motivate new firms to enter corporate networks, because the entry costs on the upstream-market decrease. This lowers the level of the market concentration, which stimulates the R&D-efforts of upstream-firms and increases the probability of core firms tc win the R&D-competition. But this strategy may only be profit-enhancing, if corner solutions exist. In the case of interior solutions, there is no incentive to stimulate new entries in the up stream-market.

Third, university-based R&D-informations can improve the absorptive capacity of suppliers. In the former model we implicitly assumed that all R&D-informations will be revealed. This means that the manufacturers have the possibility to set the extent of R&D-spiUovers (5) at the maximum value (6=1). The extent of R&D-spillovers depends on the absorptive capacity (Cohen and Levinthal 1989). For lower capacities (8<1) only a fraction of the R&D-spillovers, which are generated by the suppliers, can internalizes by the suppliers. But in these cases the universities can support the suppliers w'ith R&D-informations which increase their capabilities to absorb more R&D-informations of their manufacturers.

Regarding to the absorptive capacity of the single supplier, university-based R&D-informations can also have quality aspects. Thereby the process of the information transfer and the adaption of the R&D-spillovers by the suppliers can be improved *(synergetic* information effects). This leads to lower transaction costs within the corporate network. Further the expected profits of the manufacturers as well as the size of the corporate network will increase.

6. Conclusion

In our paper we focus on the effects of a R&D-competition between two exclusive vertical corporate networks (innovation groups) on upstream-market structures, technological opportunities, efficiency of firm's innovative activitites and the time of introduction of new products. In this context we analyse the relationships between the size of corporate networks and the level of transaction costs.

We have shown that core firms have incentivites to transfer R&D-related informations to their suppliers in the network. R&D-spillovers, which are given as strategic complements from the manufactures in corporate networks, stimulate the R&D-process and the competion between the suppliers, reduce the time of development of intermediate goods and increase the probability for the manufactures to win the race. Intra-group spillovers may also reduce the costs of transactions between core manufactures and their suppliers. Additional we have pointed out that strategical intra-group spillovers can change the structure of the whole supplier market as well as the technological opportunities of the network members. This can explain the observed differences of technological opportunities within a given supplier-market. Finally we have discussed the importance of university-based R&D-spillovers according to out formal model. They improve the absorbtive capacities of the network members on the upstream-market. These motivate core firms to open their network for universities.

Appendix

In the symmetry case, the direct effect can be explained through:

$$\frac{\partial E\Pi^D}{dn} = D = \frac{h^2V^D(N-n)+hE-rdn}{(Nh+r)^2} \quad \text{with } E = A - nd(2N-n)/2. \qquad \text{(A.1)}$$

D has the opposite sign of the value of the strategic effect: $D<0$. Without further proof, it can be shown that $\partial E\Pi^D / dn$ is declining in d. Differentiation of (A.1) with respect to n, we get:

$$\frac{\partial^2 E\Pi^D}{dn^2} = \frac{(hdE/dn-rd)(Nh+r)-2h(h^2V^D(N-n)+hE-rdn)}{(Nh+r)^3}, \qquad \text{(A.2)}$$

with $\partial E/\partial n = -dN$ for AN-An.

Because of the condition (A.1), for $D=0$ the second term of the numerator of (A.2) may be neglected. The sign of the second derivation on profits with respect to group size (A.2) is negative. This is also true for the case of $D<0$ (positive strategic effects). We can transform (A.2) to

$$\frac{\partial^2 E\Pi^D}{dn^2} = -\frac{G+dh(N-n)(Nh+2r)+dr^2}{(Nh+r)^3} \qquad \text{(A.3)}$$

with $G = 2h^2(N-n)(hV^D - dn/2) > 0$.

Because of the positive profit expectations of manufacturers (6), G has a positive sign. The numerator of (A.3) must be negative. Therefore lower organizational efficiency (*d* declines) can be compensated with an decrease in the size of the corporate network (*n* increase).

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