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Evidence from the Microelectronics Industry

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ABSTRACT

The primary goal of this paper is to improve our understanding of the complex relationship between the positioning of companies in alliance networks and their innovative performance. In particular, we expect that a firm's innovative performance depends partly on its position in specific network settings (block membership or non-block membership), with additional effects caused by the technology positioning strategies firms pursue in terms of technological specialization in alliance blocks. Alliance groups derive their competitive advantage from their superior and particular technologies, which they develop and exploit together in the alliance blocks.

Incorporating this moderating effect of the degree of technological specialization in alliance blocks (exploitation or exploration) seems to give more insight in the contextual issues in this stream of literature.

Keywords: strategic technology alliances, alliance block membership strategy, microelectronics industry, innovative performance, technology strategies

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INTRODUCTION

The rapid increase in the number of newly established strategic alliances has led to the emergence of dense international strategic alliance networks (Chung et al.2000; Gomes-Casseres, 1996; Gulati, 1998). Over the past decades firms have gradually become more and more embedded in these dense inter-firm networks. Some of the most successful firms have recognized that particular network positions allow them to reap the full benefits from inter- firm alliances. In the academic literature several authors have begun to study the effectiveness of network positions by examining the effects of relational and structural embeddedness on company performance (see e.g., Hagedoorn and Duysters, 2002; Rowley et al., 2000). In this paper we are interested in the effects of strong forms of embeddedness on innovative performance of firms. This is a debated issue, because in spite of a growing body of theoretical contributions, the empirical literature has been rather inconclusive about the performance effects of cohesive sub-group membership, which is the strongest form of social embeddedness. Furthermore, we will aim to improve our current understanding of how contextual factors like a firm's technology strategy, can moderate the effect of network positioning and innovative performance.

Recent literature on strategic alliances has made significant progress in advancing our current understanding of inter-alliance dynamics, i.e. how social factors, social relations and competitive tension between alliances affects the intent of creating, building and sustaining collaborative advantage through alliance formation (e.g Gulati, 1995, 1998; Walker, Kogut and Shan, 1997, Chung, Singh and Lee, 2000). This so-called endogenous dynamic refers to with whom specifically alliances are formed (Gulati et al, 1999) as firms have several suitable partners at their disposal. In this context, alliance formation is based on building preferential relationships that are characterized by trust, stability and rich exchange of information between partners (Powell, 1990; Gulati, Gargiulo, 1999). Most of these theoretical contributions on network evolution assert that network formation proceeds through the formation of new relationships, building on the experience with existing ties. This stream of research thus focused on the role of the social structural context as an important driving factor in the alliance formation process (e.g. Gulati, 1995; Walker, Kogut and Shan, 1997; Chung, Singh, Lee, 2000). This social structural context refers to the fact that firms are embedded in a network of relations and have access to several qualified and resource complementary partners, which influences the decision with whom to tie up.

Specifically, the social network perspective we adopt, addresses this social structural context driving the alliance formation process. It explains the collaborative behaviour of actors in terms of their position in networks of relationships (Gulati, 1998). The perspective posits that actors are embedded in a network of social relationships. Embeddedness refers to the structure of a network of social relations that can affect the firm’s economic action, outcomes and behaviour and that of its partners. Thus, embeddeness influences the firms’ tying behaviour, because it enables preferential relations to emerge from the direct and indirect contacts firms have built up in previous partnerships. By investing in those relations through the replication of their existing ties, firms build up social capital (Burt, 1992). Social capital captures the shared values, norms and trust between alliance partners and is thus by its very nature dependent on history (Chung, Sing and Lee, 2000). Social capital drives the network to self-organize, self-transform and self-reinforce, as social capital forms the basis upon which the actors establish future social relations (Gulati, 1998). In this way, the network becomes a growing repository of information on the availability, reputation, competencies and reliability of prospective partners (Gulati, 1995; Powell et al., 1996). This process typically leads to the formation of densely connected blocks of collaborative relationships consisting of firms that are all mutually connected through multiple alliances. The emergence of such alliance block[i] is generally considered as the emergence of one of the strongest forms of social embeddedness of companies. We define alliance blocks as cohesive subgroups in a social network which are characterized by a very dense networks of ties within the subgroup as compared to the relatively sparse networks of ties outside the subgroup" (Wasserman and Faust, 1994: 267). Thus, the main characteristic of an alliance block or a cohesive subgroup in a social network is that the relationships among its members are more important and more numerous than the relationships between members and non-members (Fershtman, 1997). Alliance blocks, are generally characterized by a multitude of relatively strong ties (Nohria and Garcia-Pont, 1991; Vanhaverbeke and Noorderhaven, 2001). Alliance block members seem to maintain and replicate strong and multiple ties within their group. The effect of block membership on the innovative performance of companies can therefore be seen in the light of the current debate on the advantages and disadvantages of social embeddedness. In this debate on the role of social embeddedness (e.g., Rowley et al., 2000; Gargiulo and Benassi, 2000) the basic arguments stem from Burt's (1992) structural hole argument versus Coleman's (1988) closure argument. Burt (1992) suggests that firms embedded in sparsely connected networks will enjoy brokerage advantages based on access to non-redundant information (see also Rowley et al., 2000). Hence, strategic opportunities increase as firms form bridges between densely connected, i.e. redundant, parts of the network to other non-redundant, parts of the network (Burt, 1992; Walker et al., 1997). Such strategies enable these firms to access knowledge that is expected to have a higher yield than generated through redundant ties.

Alternatively, Coleman (1988) argues that being part of a dense and apparently somewhat redundant network - like in an alliance block - is advantageous since it involves trust and cooperation among its members. As argued alliance blocks constitute the strongest form of embeddedness and are therefore a particular case-in-point. Increased cooperation in such alliance blocks consisting of trusting partners is then expected to generate high spill-over effects among network participants that also increase the performance of their joint activities.

In examining the relation between network positions in dense or sparse networks and changing technological environments, some authors argue that strong and well-embedded ties between partners are particularly effective under conditions of relative stability, whereas weak ties between somewhat distant companies are particularly geared towards dynamic industry environments (e.g., Rowley et al., 2000; Uzzi, 1997; Walker et al., 1997). Others (e.g., Hagedoorn and Duysters, 2002) found that under conditions of technological and market turbulence a learning strategy employing many, seemingly redundant, alliances might be more effective to increase firm performance than a strict maximizing strategy that is geared towards bridging structural holes by means of distant inter-firm ties.

Despite several interesting theoretical contributions, the literature is still rather inconclusive about the performance effects of network positioning and more in particular on the effects of very strong forms of embeddedness such as block membership and technology strategies on company performance. Empirically, the effectiveness of an alliance block membership strategy in relation to innovative performance has remained largely unexplored. In order to contribute to the network theory on the relationship between embeddedness and innovative performance we choose to study one of the strongest form of embeddedness, alliance blocks, and their effect on innovative performance. We expect that the use of alliance blocks provides much more clear-cut results than the study of weaker forms of embeddedness.

In this paper we will suggest a number of hypotheses, derived from our current understanding of some basic relationships between alliance block membership and innovative performance. Our main argument is that the effect of network positioning of companies on their innovative performance depends on both their position in one of two basic network settings (block membership or non-block membership) and on the technology strategy they follow that is either exploitation or exploration. Incorporating the moderating effect of the degree of technological specialization in alliance blocks seems to be a major step into discovering the contextual issues that prevents previous research from drawing clear-cut and generalizable conclusions.

1. HYPOTHESES

Network Position and Innovative Performance

Firms frequently select partners based on prior experience. Partnering is therefore often influenced by the network of prior ties (Gulati and Gargiulo, 1999) and depends on the embedded social relations that a firm is already engaged in (Granovetter, 1985; Gulati, 1998). This repeated tie effect can create strong cohesive ties through frequent interaction. These strong ties are solid and reciprocal relationships that create a basis of trust and intimacy between partners (Granovetter, 1973; Brass et al., 1998).

When firms invest a substantial amount of time and energy in order to establish these strong relationships, changing partners in the short run is not very likely, as it involves substantial switching costs and it increases the risk that other existing relationships with its partners will also dissolve (Chung et al., 2000). As a consequence, firms prefer to engage in local search and replicate their existing ties rather than search for new ones (Gulati, 1995, 1998; Walker et al., 1997). In the context of innovative activities, firms use these local search strategies to initiate new joint R&D projects that share common technological characteristics with those of their prior partners (Stuart and Podolny, 1996). This local search process requires some pre-alliance technological overlap (Lane and Lubatkin, 1998; Mowery et al., 1996) or similarity in R&D activities (Rosenkopf and Nerkar, 2001) in order for firms to assimilate and understand the technology that firms can access through their ties (Duysters and Lemmens, 2003). Similarity thus encourages interaction, which can be seen as the main cause of attraction. This process is referred to as ‘interaction breeds similarity’ and ‘similarity breeds attraction’ (Brass et al., 1998). In this context of local search and similarity, firms maintain and replicate strong and multiple ties, which lead to the formation of densely connected alliance groups. Thus, the more alliance block members will replicate their existing ties within their group, the higher the density of their in-group ties, which will result in a higher the level of embeddedness within the group (Gomes-Casseres, 1996; see Knoke and Kuklinski, 1982 for a more general social network perspective).

Since trust is an important basis for knowledge sharing and joint learning (Brass et al., 1998; Nooteboom, 2002), firms use their strong and trustworthy relationships in the alliances within groups of collaborating companies (alliance blocks) to take advantage of knowledge spillovers to improve their innovative performance (Vanhaverbeke and Noorderhaven, 2001). Then, as these block members focus on technologies that are fairly similar, local search contributes to their incremental innovations, which further increases the block members' competence in their technological domain and expertise (Rosenkopf and Nerkar, 2001).

On the other hand, firms that follow an individual innovation strategy outside of alliance blocks cannot take advantage of network externalities and knowledge spillovers that multiple, embedded ties provide for alliance block members. These non-block members lack this densely connected web of ties that constitutes a learning environment founded on trust-based governance, which is required for technological learning (Gomes-Casseres, 2001; Vanhaverbeke and Noorderhaven, 2001).

In other words, given the cohesion and familiarity of group-members based on their multiple, embedded ties in alliance blocks, companies with joint innovative activities that share knowledge within these alliance blocks are expected to generate higher innovative performance than firms that follow an individual innovation strategy outside alliance blocks. Hence:

H1: *Members of alliance blocks have a higher innovative performance than non-alliance block firms.*

We expect that the benefits of alliance block membership are not distributed in a uniform way over time. Joining an alliance block provides the strongest benefits for the company immediately after it becomes a member of the block. The new environment and the abundance of new (indirect) ties increase the likelihood that the firm discovers and exploits new opportunities. Over time, the benefits of being a block member will level off as over time as firms may start to suffer from relational ‘over-embeddedness’ (Uzzi, 1997), caused by relational inertia and the increasingly redundant similarity of firms within alliance blocks. Hence, we expect a negative relationship between the duration of a firm's membership in an alliance block and its innovative performance. The positive effect of an alliance block membership strategy based on the replication of preferential relations can also turn into a paralyzing effect as firms become locked-in in their own closed social system (Duysters and Lemmens, 2003). Relational inertia occurs when block members are constrained in their partner choice when linking up with firms of another alliance block or ‘outsiders’ in general (Gomes-Casseres, 1996). Over time, they may experience implicit social pressure from their partners to replicate their ties within the alliance block (Duysters and Lemmens, 2003) in order to prevent knowledge leakage outside of the alliance block. An implicit expectation of loyalty to other block members can prevent block members from allying with firms from competing alliance blocks (Gulati et al., 2000) as this can result in conflicting interests among its partners (Nohria and Garcia-Pont, 1991). Hence, certain potential partners outside of an alliance block are not available when they have ties to ‘outside’ competitors of block members. In this way, competing alliance blocks can foreclose further partnering opportunities from non-block members (Gomes-Casseres, 1996). As a consequence, potential partners outside alliance blocks are simply excluded from partner selection and, based on their initial choices, firms can become locked-in their own alliance blocks. This phenomenon of strategic gridlock (Gomes-Casseres, 1996) forces blocks members to engage in local search for partners within their own alliance block, which can make them both relationally inert and over-embedded.

The repeated tie effect in alliance blocks can also lead to an increasing similarity in technology profiles and can eventually result in technological over-embeddedness. In that context, the block members’ post-alliance technological profiles converge and they will increasingly become more similar. In the long run this will decrease potential learning effects among alliance partners (Mowery et al., 1996; Duysters and Lemmens, 2003) as too much focus on developing competences through local search can lead firms to develop core rigidities (Leonard-Barton, 1995) and can cause firms to fall into competency traps (Levitt and March, 1988). This rigidity among block members will increase the likelihood that they become cognitively locked-in (Uzzi, 1997; Gargiulo and Benassi, 2000). The cognitive lock-in effects isolate block members from firms outside of the alliance block, as it filters the information and new perspectives that reach block members. In this state of rigidity, collective blindness, and technological over-embeddedness (Uzzi, 1997), alliance block members suffer from decreasing opportunities for learning and innovation (Duysters and Lemmens, 2003).

As a consequence, firms in alliance blocks tend to gradually become more restrained in taking advantage of new technological opportunities and resource niches. Therefore, in terms of learning we expect that, over time, both relational and technological over-embeddedness lead to decreasing opportunities for learning and innovation. Therefore, we hypothesize:

H2: There is a negative relationship between the duration of a company's alliance block membership and its innovative performance.

Technology strategies of alliance block members and innovative performance

Alliance groups are basically technology-driven. Technology collaboration through direct ties in alliance blocks may have some advantages regarding their technology development. Firms in alliance blocks focus on similar, incremental innovations in their local search strategies. In this way, block members exploit their existing capabilities by linking up with firms in their own alliance block with similar technological profiles to improve their innovative performance. It provides access to complementary knowledge and skills to speed up the innovation process and enables firms to transfer knowledge and replenish their knowledge bases (Mowery et al. 1996; Kogut 1988). In this way, firms can internalize the competencies of partners to create next-generation competencies (Hamel 1991; Sakakabira 2002). The newly created knowledge becomes available to all firms involved. R&D investments made by partner block members have spillover effects in the sense that other block members receive more new knowledge in return than in a stand-alone strategy outside of a block (Vanhaverbeke, Gilsing, Beerkens and Duysters, 200?).

This benefit is especially relevant in case these firms follow a strategy of technological specialization. Technological specialization goes hand in hand with following an exploitation strategy instead of an exploration strategy. Exploitation focuses on existing core technologies and further improving and deepening them to attain competitive advantage; exploration on the opposite reflects the broadening of the knowledge base. Alliance groups derive their competitive advantage from their superior and particular technologies, which they develop and exploit together in the alliance blocks. This results in technological standard battles among alliance groups and independent firms (Gomes-Casseres 1996; Das and Teng 2002). Since firms within those alliance blocks complement and build on each other's specific technologies, we expect that these alliance block members can reach critical mass in terms of economies of scale and scope through their technological specialization in groups. Differences in performance among competing alliance groups can be due to the nature of the technological knowledge they possess and their ability to exploit that knowledge (Steensma and Corley 2000) over time.

Therefore it seems that companies, which have a higher technological specialization, will be more innovative when they stay in a block for a longer time period, than firms that are less specialized. Then as long as the basis for partner attractiveness and ties within blocks does not change, the technological regime does not shift. This leads to a situation in which highly specialized alliance blocks thrive, whereas firms that follow an exploration strategy and are positioned outside of a block are less effective. Non-block companies will have a hard time to individually coordinate and connect these incremental innovations (Chesbrough and Teece, 1996) as they follow individual innovation strategies outside of alliance blocks.

These companies 'waste' a substantial amount of resources on individual projects under conditions where joint, incremental innovations are more effective.

H3: The longer the period of block membership in combination with a high degree of technological specialization of the block member, the higher the innovative performance of block-members compared to non-alliance block members

DATA, VARIABLES AND METHOD

Sample

Our analysis refers to a group of major companies in the international microelectronics industry on which we have information regarding their partnering behavior during the period 1980-1997. The information on R&D and technology-driven alliances was obtained from the MERIT-CATI database (see Duysters and Hagedoorn (1993) for a description). The total number of strategic alliances in the sample is 2,864 concerning 69 firms. Our data on R&D expenditures and revenues are available only from 1988 to 1997 and hence this defines the period we analyze. Due to taking lags our estimation period is 1989 to 1997.

We focus on the microelectronics sector and its network of strategic alliances for a number of reasons. The industry has been technology-driven throughout its history, which indicates that technological positioning strategies and technology based competition are keys to survival (Podolny and Stuart, 1995). In the microelectronics industry, one finds a large number of strategic technology alliances that play an important role in the competitive strategies of companies (see amongst others, Duysters and Hagedoorn, 1998; Gomes-Casseres, 1996; Hagedoorn, 1993; Park et al., 2002).

Furthermore, the microelectronics industry is a strategically important sector. It can be considered as the driving force of technological change in virtually all sectors of the information technology industry. It is of strategic importance, not only in terms of market size but also because its outputs are vital components in a wide range of other products. Finally, the industry has a high propensity to patent, especially in the period of our study. This allows us to track the innovative performance of the companies in our sample by means of their patenting activity.

METHOD

The dependent variable is a count variable and takes only nonnegative integer values - i.e. the number of patents a firm successfully filed for in a particular year. In our analyses we have used a conditional fixed effects negative binomial model. Though the fixed effects model is less efficient than the random effects model, the fixed effects model generates consistent estimates even when unobserved and observed firm-variables are correlated. Another advantage of the negative binomial model is that it can account for count data that are overdispersed.[ii] For this reason, we prefer the negative binomial to a Poisson estimator. (Hausman, Hall, & Griliches, 1984).

Variables and measures

The dependent variable *innovative performance* is measured by the number of US patents successfully applied for by firms in the period 1983-1997. Patents are allocated to the year the patent was applied for rather than the year it was granted to the firm, because the innovation has materialized when the company files for a patent rather than when it is granted. Despite some shortcomings, this indicator is generally considered as being the most appropriate measure of innovative performance at the company level (Acs and Audretsch, 1989; Ahuja and Katila, 2001; Hagedoorn and Duysters, 2002), especially in a single-industry high-tech sector study. Limiting the study to a single industrial sector minimizes problems related to other factors affecting patent propensity as these factors are likely to be stable within one industry (Griliches, 1990; Ahuja and Katila, 2001).[iii] The microelectronics industry has shown a very high propensity to patent in the period of our study and therefore patents seem to be a valid way to measure innovative performance.

Before we start the description of the explanatory variables we note that these are lagged one year in the empirical specifications. The independent variable *alliance block membership* indicates whether firms are part of a specific alliance block or not. Alliance blocks are densely connected subsets of actors in a network (Knoke and Kuklinski, 1982). We operationalize alliance block membership by investigating line connectivity within the group to line connectivity with firms outside the group. Line connectivity of a pair of alliance partners refers to the minimum number of lines to be removed to make sure no path exists anymore between them. Line connectivity thus indicates the extent to which a pair of alliance partners remains connected by some path, even when alliances are deleted from the alliance network.

We use ‘lambda sets’ to compare in-group ties to out-group ties; In other words, we compare the number of alliances with partners outside the group and the number of alliances within the group (Wasserman and Faust, 1994). In short, Lambda sets (Borgatti et al.,1990) represent a measure of cohesiveness in subgroups based on the number of alliances that should be removed in order disconnect two firms in the alliance network. It is therefore a measure of connectivity. A cohesive subset is likely to be difficult to disconnect when specific relationships are removed. Relatively strong blocks are characterized by a dense set of multiple connections by its partners. The removal of specific relationships in this case does not have a large impact on the overall connectiveness of partners in the block. Borgatti, Everett and Shirey (1990) define a Lambda set as “The set of nodes Ns, is a lambda set if any pair of nodes in the lambda set has larger line connectivity than any pair of nodes consisting of one node from within the lambda set and a second node from outside the lambda set”

The higher the clustering level, the higher the line connectivity will be between all pairs of alliance partners (and therefore the higher the strength of ties within alliance blocks). This implies that the higher the line connectivity, the more the density of the ties with an alliance block increases. As a result, the hierarchical clustering level at which the lambda sets is constructed measures the level of embeddedness (to which we refer as "lambda level").

To construct the '*block membership'-dummy variable,* we chose a cut-off point in the lambda levels, which was available for all periods: the hierarchical clustering level 4.

Lambda sets were also defined at a clustering level of 2. Defined in this way, lambda sets are larger and less cohesive than lambda sets at clustering level 4. Hence we chose level 4 because we found that the group emerging at level 4 was more densely tied than the group at level 2[iv]. Firms that form lambda sets at that clustering level got a value of 1 for the block membership variable and 0 otherwise.

In order to estimate the relation between innovativeness and the number of years a company is member of an alliance block, we created a variable measuring the duration of block membership. In this variable we count the years in which a company is unbrokenly present in an alliance block: *years in block*. In our dataset this implies that a company can be engaged in an alliance block for a maximum of 16 years as our data on alliance formation start early on. To avoid left-censoring problems, lambda sets were computed for the period prior to the observation period up to 1970. We start counting the *years in block* in 1981.

The variable for *technological specialization* is derived by dividing the number of patents applied for in fifteen main semiconductor patent classes by the total amount of patents applied for per company per period. We expect that companies with a higher number of patent applications in microelectronics as compared to their overall patent applications (higher specialization in microelectronics), will be more innovative than firms that are less specialized in microelectronics.

To test our hypotheses regarding the moderating role of technological specialization on the effect of duration of block membership and innovative performance, we introduce an *interaction term.* This allows us to measure the combined effect of the years a firm is pursuing an alliance *block membership* strategy and the nature of its technology strategy it is pursuing. It measures whether the performance effect of block membership is contingent on the level of technological specialization. We expect that a higher level of technological specialization positively moderates the innovative effectiveness of a certain network positioning strategy in terms of block membership or non-block membership.

We also introduced a number of control variables. First, we control for size of the firm in terms of the natural logarithm of annual revenues.[v] As we study technology partnerships, we also control for *R&D intensity*: the ratio of microelectronics-related R&D expenditures to revenues. We expect a positive effect of R&D intensity on patent activity, as these research efforts will (at least partly) be transformed into patents. This relationship, however, might not be linear as patenting rate may decrease gradually with an increase in R&D expenditure (Hagedoorn and Duysters, 2002[vi]).

Finally, we included two types of dummy variables. The first one indicates in which economic area the company is headquartered (Ohmae, 1985): a company can be headquartered in North America, Asia or Europe - the default is North-America. Firms from a different economic block may differ in their propensity to patent. Year dummy variables were included to capture changes over time in the propensity of companies to patent their innovations – 1989 is the default.

RESULTS

Table 1 describes the variables. Table 2 shows the descriptive statistics for all variables.

[INSERT TABLE 1 ABOUT HERE]

[INSERT TABLE 2 ABOUT HERE]

Table 3 represents the results for the random effects negative binomial model explaining the effect of different independent variables on the innovative performance (number of patents) of the companies. To avoid multicollinearity between block membership and years in block, we did not combine the variables in one regression (Table 3, model 1 and 2).

The first hypothesis (H1) states that alliance block members are more innovative than non-block members. The estimate shows that block membership is indeed positively and significantly related to innovative performance. Companies in alliance blocks have on average 11% (= exp (0.1148, $p < 0.1$) more patents than firms that are not a member of alliance blocks (see table 3, model 1).

To test hypothesis 2 we estimated the effect of the duration of block membership on innovative performance. The independent variable is the number of years a company is a block member, instead of block membership as such. According to hypothesis 2, we expect that there is a negative relation between years of block membership and innovative performance. Model 2 in Table 3 indicates that the impact on the innovativeness of the firm is negative and statistically significant (-0.0230, $p < 0.05$). Therefore, we cannot reject hypothesis 2.

[INSERT TABLE 3 ABOUT HERE]

We also hypothesized that a high level of technological specialization in combination with a longer duration of block membership would be beneficial for the innovative performance of alliance block member (H3). The results for hypothesis 3 are shown in Model 2. In this model, the potential interaction between technological specialization and block based embeddedness is introduced as an interaction term.

In model 2, the coefficient for specialization is negative and highly significant (-0.5862, p<0.01). In contrast, the interaction with duration has a positive and significant effect (0.1364, p<0.01). This result indicates that long term membership of an alliance block pays off in case of pursuing a technology specialization, i.e. technology exploitation strategy.

These results imply that we find support for hypothesis 3: long term membership of alliance blocks pays off when technological specialization is high. Figure 1 illustrates the combined effect of block membership duration (number of years a firm is member of a block) and its technological specialization. Point A represents a situation where non-specialized (or technological diversified firms) have been member of a block for a long period; let us say 10 to 15 years. Firms with a highly diversified patent portfolio do not benefit from long term membership of a particular alliance block. Point B reflects a situation in which a firm is highly specialized in a particular type of technology but stays only a year or a few years in a block. This situation is, according to our results, also detrimental for the firm. In contrast, highly specialized firms that stay for a long time in a particular alliance block seem to profit enormously of that membership (see point C in Figure 1). In sum, companies with a broad technology portfolio do not profit from block membership and the effect aggravates the longer a firm stays member of that block. Highly specialized firms should avoid short term stays in an alliance block but they can increase their innovative performance considerably when they stay for a long time in a block with the same partners.

As far as the control variables are concerned, there are a few interesting results. The R&D intensity variable shows a negative sign in both models. We expected a positive sign as companies with higher investment intensity in R&D should be more innovative – all else equal. The negative effect find its roots in the inclusion of some start-ups that are outliers because they invest heavily in R&D and do not have yet commercial products on the market.

The sign of the coefficient of the 'size'-variable, expressed as the natural logarithm of annual revenues, is positive and significant as expected in both models. Since this variable is expressed as a natural logarithm its coefficient can be considered as elasticity. The fact that coefficient is much smaller than one indicates that smaller companies in microelectronics innovate proportionally more than their large counterparts. Finally, companies from Europe demonstrate significantly higher levels of innovative performance than their US-based and Asian competitors.

DISCUSSION AND CONCLUSION

This paper aims to improve our understanding of the effect of alliance block membership on innovative performance. Since the academic literature has been rather inconclusive about the performance effects of multiple collaborative agreements in general and of alliance block membership in particular, this study intends to contribute both in a theoretical as well as in an empirical way to the innovation performance effects of firms in alliance networks (e.g Rowley et al. 2000; Gargiulo et al.; 2000).Since alliance block membership can be seen as the strongest form of social embeddeness, the effect of block membership on the innovative performance of companies can therefore be considered in the light of the current debate on the advantages and disadvantages of social embeddedness (e.g. Burt, 1992; Coleman, 1988; Rowley et al, 2000).

Furthermore, we were particularly interested in the moderating effect of the duration of block membership and the technology strategy they pursued in terms of either exploitation or exploration on innovative performance. Incorporating this moderating effect of the degree of technological specialization in alliance blocks (exploitation or exploration) provides a more detailed insight in the contextual issues in this literature stream on network positioning and innovative performance.

If we first make abstraction from the possible moderating effect of technological specialization, our findings indicate that a block membership strategy does indeed positively influence the innovative performance of companies. Members of cohesive subgroups develop well embedded network ties, characterized by solid, reciprocal and trustworthy relationships (Granovetter, 1973).

We expected a negative relationship between the number of years that a company is continuously present in an alliance block and its innovative performance; this hypothesis was confirmed. Firms in alliance blocks tend to gradually become more restrained in taking advantage of new technological opportunities and resource niches due to being over-embedded in the network.

However, this picture changes when we consider the role of technological specialization in the technology positioning strategies of companies. The latter positively affects the relation between the network position in alliance blocks and the innovative performance. The impact of the duration of block membership is contingent on the level of their technological specialization in the network. Our results indicate that long term membership of an alliance block pays off in case of pursuing a technology specialization, i.e. technology exploitation strategy. Long term membership of alliance blocks pays off when technological specialization is high, but becomes a liability when the level of technological specialization is low. This could be explained by the fact that firms in alliance blocks focus on similar, incremental innovations in their local search strategies. In this way, they exploit their existing capabilities by linking up with firms in their own alliance block with similar technological profiles to improve their innovative performance: they can speed up the innovation process and replenish their knowledge bases. Since firms within those alliance blocks complement and build on each other’s specific technologies, we expect that these alliance block members can reach critical mass in terms of economies of scale and scope through their technological specialization in groups. Therefore it seems that companies, which have a higher level of technological specialization, will be more innovative when they stay in an alliance block for a longer time period, than firms that are less specialized. This leads to a situation in which highly specialized alliance blocks thrive, whereas firms that are not embedded in an alliance block are less innovative. Non-block companies will have a hard time to individually coordinate and connect these incremental innovations and ‘waste’ a substantial amount of resources on individual projects under conditions where joint, incremental innovations are more effective.

To our knowledge, this paper is a first attempt to empirically link this intermediate level of alliance network characteristics (block membership vs. non-block membership) and to the innovative performance of companies. Hopefully, our paper stimulates further research that could incorporate more diverse network positioning strategies and contingency variables - than technological specialization alone- on innovative performance. We think of differentiating between several roles that non-block members can occupy in a network, like peripheral players or brokers that overarch occupying structural holes (Burt, 1992; Walker et al., 1997; Rowley et al., 2000, Baum et al., 2003). Companies occupying the latter role can access new information that opens up opportunities for them to explore alternative technological options and new technological environments (Hagedoorn and Duysters, 2002; Rowley et al., 2000). Brokers might be more innovative than peripheral players positioned in loosely coupled inter-firm networks. Also, including broker positions in future research could provide a more complete understanding of whether the virtues of block membership would weigh up against the possible innovative advantages of a broker position.

This study is limited to only one industrial sector, which enables us to systematically explore the basic questions related to network strategy and innovative performance without the disturbances one could encounter in a multi-industry design.

However, future research might provide further insight into this crucial relationship through more in-depth empirical research that covers other (high-tech) industries and more contingencies. This paper can be seen as a starting point for future research aiming to improve our understanding of the complex relationship between the positioning of companies in alliance networks and their innovative performance.

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• **Table 1: Description of the variables**

Variable name	Variable description	
Innovative performance variable	Count of the number of US patents successfully filed for in year t. Average over a three year period (period 1983-2000)	dependent
Block membership	A dummy variable indicating whether firm is member of a normalized lambda set with a cutoff-point set at the hierarchical clustering level 4	
Duration (Years in block)	Number of years a company is unbrokenly present in an alliance block	
Specialization	The number of patents applied for in fifteen main semiconductor patent classes divided by the total amount of patents applied for per company per three year period.	
Technological capital	Count of the number patents that a firm filed for during the a period three years prior to the year of observation	
Firm size (ln revenues)	Natural logarithm of the total sales of the firm in t-1 (x 1000 Euro). Average over a three year period	
R&D-intensity	Ratio of R&D expenditures over revenues. Average over a three year period.	
Year	Dummy variable indicating a particular period (1989-1991 to 1995-1997)	
Europe	Dummy variable set to one if the firm is headquartered in Europe	
Asia	Dummy variable set to one if the firm is headquartered in Asia	
Periods	Dummy variables indicating three year periods from 1990-1992 to 1995-1997	

- **Table 2: Descriptive statistics and pair wise correlations**

~	*Mean*	*s.d.*	*Min*	*Max*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*
1. Innovative performance	164.79	340.583	0	3006	1															
2. Block membership	0.49	0.500	0	1	0.3894	1														
3. Years in block	1.04	2.610	0	15	0.4102	0.7186	1													
4. R&D intensity	0.15	0.563	0.0008	9.789	-0.1241	0.1348	0.2570	1												
5. Specialization	0.39	0.309	0	1	-0.2094	-0.0090	0.0746	0.2823	1											
6. Size (ln sales)	15.36	2.069	6.7475	18.937	0.6293	0.2831	0.2789	-0.3374	-0.4943	1										
7. Europe	0.26	0.439	0	1	-0.1193	-0.0187	0.0720	-0.0763	-0.1593	0.0703	1									
8. Asia	0.24	0.424	0	1	0.2582	-0.0653	-0.1867	-0.1710	-0.1766	0.3189	-0.1972	1								
9. Year 90	0.091	0.288	0	1	-0.0671	-0.0187	-0.0547	-0.0030	-0.0700	0.0449	-0.0078	0.0190	1							
10. Year 91	0.091	0.288	0	1	-0.0907	0.0162	-0.0563	0.0459	0.0074	-0.0180	0.0047	-0.0152	-0.1235	1						
11. Year 92	0.091	0.288	0	1	-0.0706	0.1296	0.0177	-0.0045	-0.0329	-0.0063	0.0158	-0.0022	-0.1184	-0.1323	1					
12. Year 93	0.091	0.288	0	1	-0.0904	0.0606	-0.0022	0.0387	0.0132	-0.0524	0.0206	-0.0074	-0.1333	-0.1489	-0.1428	1				
13. Year 94	0.091	0.288	0	1	-0.0043	0.0131	0.0323	-0.0249	-0.0342	-0.0047	-0.0431	-0.0274	-0.1285	-0.1435	-0.1376	-0.1549	1			
14. Year 95	0.091	0.288	0	1	0.0536	-0.0387	0.0521	-0.0211	-0.0181	-0.0005	-0.0058	-0.0274	-0.1285	-0.1435	-0.1376	-0.1549	-0.1493	1		
15. Year 96	0.091	0.288	0	1	0.1076	-0.1041	0.0452	-0.0111	0.0867	0.0049	0.0101	-0.0088	-0.1210	-0.1351	-0.1296	-0.1459	-0.1405	-0.1405	1	
16. Year 97	0.091	0.288	0	1	0.1817	-0.0638	-0.0039	0.0040	0.0929	0.0113	0.0047	-0.0152	-0.1235	-0.1379	-0.1323	-0.1489	-0.1435	-0.1435	-0.1351	1

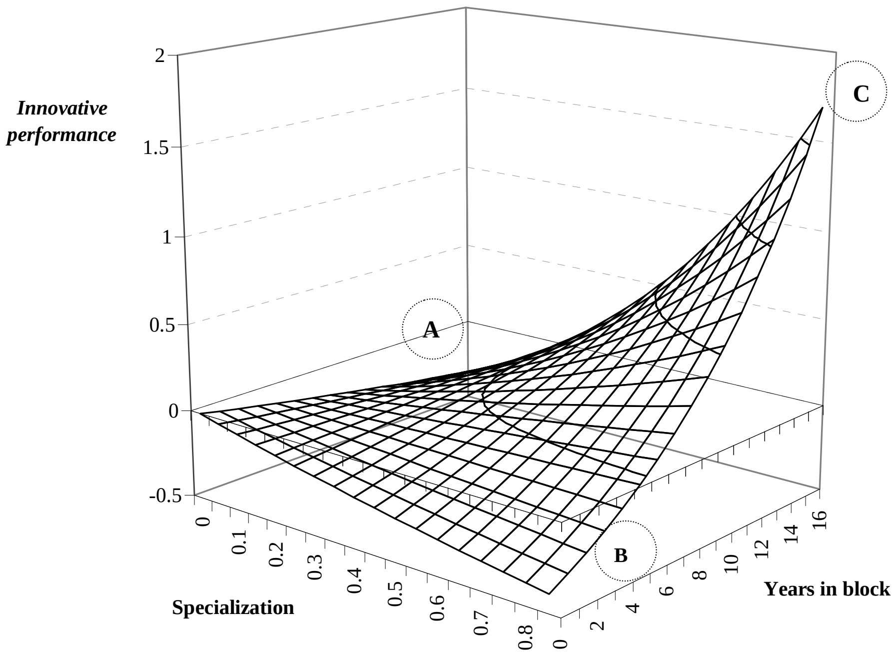
- **Table 3 Random effects estimates explaining the innovative performance of firms**
-

Variable	*H1(model 1)*	*H2&H3 (model 2)*
Block membership	0.1148* (0.0716)	
Years in block		-0.0230** (0.0095)
(Specialization)*(Duration)		0.1364*** (0.0357)
Specialization	-0.5848* (0.3231)	-0.5862*** (0.2257)
R&D intensity	-0.3488 (0.4557)	-03612 (0.4627)
Size (logarithm of revenues)	0.2865*** (0.0646)	0.4039*** (0.0477)
Europe[vii]	*2.6886*** (1.109)*	*4.1408**** (1.4746)*
Asia	0.4551 (0.3019)	0.4022* (0.2493)
Year 90	0.0687 (0.1422)	0.0188 (0.1094)
Year 91	-0.0007 (0.1468)	-0.1095 (0.1128)
Year 92	-0.0097 (0.1513)	-0.1521 (0.1130)
Year 93	0.0014 (0.1531)	-0.1306 (0.1129)
Year 94	0.0014 (0.1544)	0.0242 (0.1122)
Year 95	0.2795* (0.1531)	0.0716 (0.1123)
Year 96	0.4201*** (0.1541)	0.1682 (0.1146)
Year 97	0.4989*** (0.1576)	0.2405** (0.1151)
Constant	-2.492** (1.0606)	-4.2879*** (0.7642)
Wald chi sq.	350.46***	510.01***
Number of observations	229	330
Number of firms	39	47

- Notes:
- *Significant at the 10 % level, **Significant at the 5 % level, ***Significant at the 1 % level;
- Numbers in parentheses are standard errors.

+ Likelihood-ratio test of alpha=0

Figure 1: The combined effect of technological specialization and number of years in an alliance block



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- **ENDNOTES**

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[i] Nohria and Garcia-Pont (1991, p. 106) define a strategic block as "...a set of firms that are connected more densely to each other than to other firms in the industry". The existence of strategic blocks of firms was already anticipated by Harrigan (1985) who described them as constellations of firms. Empirical analysis of strategic blocks in different industries can be found in Nohria and Garcia-Pont (1991), Gomes-Casseres (1996) and Vanhaverbeke and Noorderhaven (2001).
The concept of alliance blocks is also related to the small worlds concept indicating that the inter-organizational network is characterized by clique-like groups of firms. The density within the groups is high and low between the groups (Baum et al, 2003; Schilling and Phelps, 2004; Watts, 1999).

[ii] In the Negative Binomial model, the variance of the dependent variable is larger than the mean, in contrast to the Poisson model, where the variance equals the mean.

[iii] Also, as indicated by Hagedoorn and Cloodt (2003), in high-tech sectors, such as microelectronics, patent counts are equally well-suited for the measurement of innovative performance as other indicators such as patent citations and new product announcements.

[iv] We also used a cut-off point of 2 to test for the robustness of the empirical results. The results were found to be very similar to the ones using cut-off point 4.

[v] We have chosen revenues as an indicator for firm size instead of the more frequently applied employment indicator to account for the effects of quasi-integration. Japanese companies often have fewer employees than their US and European competitors on account of the Japanese lean production methods and sophisticated customer supplier networks (Duysters and Hagedoorn, 1995).

[vi] 'R&D-expenditures' would be an interesting control variable but it correlated in a very strong way (0.90) with annual sales. To avoid multicollinearity problems we chose to introduce R&D-intensity as a control variable.

[vii] USA is the default.