THE ECONOMICS OF COOPERATION AMONG HIGH-TECH FIRMS - TRENDS AND PATTERNS IN STRATEGIC TECHNOLOGY PARTNERING SINCE THE EARLY SEVENTIES

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Abstract
This paper analyses some basic trends and patterns in inter-firm strategic technology partnering in high-tech sectors such as information technology sectors, the biotechnology industry and new materials during the past two and a half decades. The paper concentrates on technology cooperation for which a combined innovative activity or an interchange of technology is at least part of the agreement. The strategic character of this group of alliances is given by looking only at those inter-firm agreements which are aimed at improving the long term perspective of the product market combinations of at least one of the companies involved.

The description of growth patterns in strategic technology partnering for each of the three high-tech sectors reveals that, despite some sectoral particularities, this phenomenon has become increasingly popular during the eighties and the early nineties. Basic categories of partnerships can be identified in terms of contractual or equity arrangements each with different organizational, contractual and financial properties. Joint ventures, once the most prominent form of inter-partnering, have, to a very large degree, been replaced by a wide variety of contractual agreements. In particular in high-tech sectors inter-firm partnering is dominated by these somewhat more informal modes of partnering. This development suggests that partnering in so-called high-tech sectors demands organizational flexibility with the actual mode fitted to the organizational needs of the project in which the partners are involved.

International patterns of partnering in these high-tech sectors are discussed for the Triad (USA, Europe, Japan) in terms of changes in the distribution of domestic and cross-border alliances. The increase of alliances has led to a larger number of international partnerships. However, in relative terms these international partnerships have not been able to keep pace with the increase of domestic alliances or alliances in the same economic region. An explanation for this somewhat stagnant pattern can be found in the additional level of complexity that companies face in international alliances.
1. Introduction

This paper analyses some basic trends and patterns in inter-firm strategic technology partnering during the past two and a half decades. The paper concentrates on "technology" cooperation as we discuss only those modes of cooperation and agreements for which a combined innovative activity or an interchange of technology is at least part of the agreement, although the agreement itself will very often pertain to many other subjects of corporate behaviour. The "strategic" character of this group of alliances is given by looking only at those inter-firm agreements which are aimed at improving the long term perspective of the product market combinations of at least one of the companies involved. These strategic technology partnerships differ from other partnerships such as cost-economizing agreements which we think are more associated with the control of either standard transaction costs or operating costs of companies. Partnerships based on the standard transaction cost argument are largely related to economizing on the costs of information transfer from separate market partners through a lasting partnership which enables both partners to communicate more intensely, for instance in co-makership relations. When the control of operating costs is central to an agreement firms outsource part of their production for instance to economize on the costs of under-utilization and below minimum scale efficiency of capital goods. In general these modes of cooperation are excluded from the present analysis. Furthermore, we will study in particular high-tech sectors such as information technology sectors, the biotechnology industry and new materials.

The first section discusses some of the major factors that could explain this intriguing topic of firm behaviour. Basic motives mentioned in that context are related to both technological and market opportunities. This is followed by a description of growth patterns in strategic technology partnering for each of the three high-tech sectors since 1970. In general these patterns reveal that, despite some sectoral particularities, this phenomenon has become increasingly popular during the eighties and the early nineties. In that context it is important to stress that strategic technology partnering comes in many appearances. Basic categories of partnerships can be identified in terms of contractual or equity arrangements each with different organizational, contractual and financial properties. Therefore, one section in this paper is devoted to a brief discussion of the above mentioned properties of these basic categories of modes of cooperation. In that section we will also pay some attention to the analysis of possible changes in the historical distribution of different categories of partnerships. Finally, international patterns of partnering in these high-tech sectors are discussed for the Triad (USA,
Europe, Japan) in terms of changes in the distribution of domestic and cross-border alliances.

In general this contribution is of an empirical nature. The empirical material provided in this paper is generated through the MERIT-CATI data bank, see the Appendix.

2. Some General Factors Explaining Strategic Technology Partnering

Table 1 provides a categorization of factors frequently mentioned in the literature to explain inter-firm strategic technology partnering. These factors range from the complexity of scientific development going beyond the capabilities of even the largest firms to the scanning of international markets for new products in the context of jointly followed pre-empting strategies.1 In other words, they encompass all the stages of the innovation process in high-tech industries, from shared basic research to joint market entry with new products.

<table>
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<tr>
<th>Table 1: Factors explaining strategic technology partnering</th>
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<tr>
<td><strong>Basic and applied R&amp;D and other innovative activities:</strong></td>
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<tr>
<td>- Increased complexity and inter-sectoral nature of new technologies and scientific disciplines.</td>
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<td>- Monitoring the evolution of scientific knowledge and complementary technology.</td>
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<td>- Sharing of uncertainty and costs in R&amp;D.</td>
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<td>- Competitive pressures to shorten product life cycles and reduce the period between invention and market introduction.</td>
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<tr>
<td><strong>Market access and search for opportunities:</strong></td>
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<tr>
<td>- Monitoring of markets and other environmental changes and opportunities.</td>
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<td>- Internationalization, globalization and entry into foreign markets.</td>
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<td>- Search for new products and expansion of product range.</td>
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The first group of factors are those related to the joint undertaking of and further advancement of research and the diffusion of some basic scientific and/or technological knowledge amongst participating companies. Some of this is clearly related to concrete research activities, be it basic or applied research, other factors are associated with some general endeavour at the technological or scientific frontier of particular fields of

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1 The literature focusing on the rationale for the growth of this partnering behaviour is more extensively discussed in Contractor and Lorange (1988), Mowery (1988), Mytelka (1991) and Hagedoorn (1993).
technology, i.e. sharing the state-of-the-art. Other relevant factors are the increased complexity and inter-sectoral nature of new technologies and the cross-fertilization of scientific disciplines and fields of technology. Here it is the growing interrelationship between for instance sub-fields of chemistry, physics, and electronics; computer science and process technologies; materials science, electronics, and chemistry that build the necessity for close collaboration between companies. As even many very large and diversified firms still lack some competence in a number of scientific and technological fields, cooperation creates the necessary complementary technology and scientific inputs enabling these companies to capitalize on economies of scope through joint efforts. In the same domain we find the necessity for companies to monitor the evolution of technologies in order to assess technological synergies and relevant complementarities of technologies. Here also, the central explanation is that no company will have an all-embracing competence in every field of technology and therefore a concrete evaluation of possible synergies might at some stage of a particular technological trajectory warrant a joint undertaking with another company. A number of more specific factors are related to the need to reduce and share the uncertainty which is inherent to performing R&D as well as sharing of costs of R&D. Other factors are more closely related to concrete innovative projects in a joint activity of two or more companies in order to reduce the total period of the product-life-cycle and the contraction of the period between invention and market introduction.

Another set of factors explaining why firms cooperate through strategic technology partnering deals with opportunities for market entry through a joint monitoring of environmental changes in combination with developing new products or processes. At an international level combining some activities of two (geographically) separated firms for particular markets favours internationalization and globalization of companies that lack the economic control, competence or experience to follow such a strategic move independently. Finally, inter-firm agreements are mentioned in the literature for their ability to create new markets and products, to provide market-entry and to expand the product range of both partners.

In the following we will report some findings from previous research on partnering during the eighties (Hagedoorn and Schakenraad, 1990 and Hagedoorn, 1993). These studies reveal that two major factors probably explain a substantial part of the growth of the number of strategic technology alliances. Technological complementarity and reduction of the innovation period are of particular importance in high-tech sectors. Market entry and production-related factors appear to be disproportionately more relevant in technologically less advanced sectors. Technological complementarity as a major factor explaining the growth of strategic technology partnering appears to be very
important in a number of sectors, such as biotechnology, new materials and some sub-fields of information technology. In other words, technological complementarity of firms is a major force behind strategic partnering in the three high-tech fields discussed in this paper. In biotechnology the explanation can be found in the complementarity between relatively small specialized biotechnology firms and large chemical and pharmaceutical companies. The generic character of new materials, which often entails a combination of different technological and engineering disciplines, generates clear possibilities for a number of uses of these new materials for which technological competence that goes beyond plain development work appears necessary. In that context users and producers of new materials have a clear need for technological complementarity. In a sense the same holds for sub-fields of information technology such as industrial automation and software where technological complementarity appears to be the major motive as well. In industrial automation manufacturers of such systems are in a clear need of cooperation with users from different sectors of industry, as well as with companies that are competent with regard to different aspects of information technology. In the software sector technological complementarity is in particular necessary for the development of complex and dedicated software for a large number of applications in all spheres of automation.

Market access and restructuring is of considerable relevance in mature sectors of industry and in some high-tech sectors such as telecommunications, computers and microelectronics. For telecommunications this is quite understandable if we recognize that the international telecom market has until recently been characterized by many national monopolies and domestic oligopolistic markets. Even for the largest companies market access to particular foreign markets was only possible through alliances with national producers. In recent years this sector is witnessing a process of restructuring due to excess capacity, deregulation, increased speed of technological development and fierce competition in which strategic alliances play their role. These latter arguments also apply to fields such as computers and microelectronics. On the other hand market-related factors still have little significance in biotechnology, which is understandable because technological development so far has generated few products that could cause a major shift towards new markets or a restructuring of existing markets.

Finally, it is worth mentioning that although the lack of financial resources and the high costs of R&D projects are frequently mentioned to explain the possible growth of strategic technology alliances, the overall relevance of these factors appears rather small. Actually only in biotechnology and telecommunications these factors are found to have played a significant role in creating strategic technology partnering behaviour. In biotechnology the lack of financial resources plays a role as the research of many small
firms has gradually entered the phase of developing new products. The necessary capital is frequently obtained through alliances with larger companies. For telecommunications the development costs of new digital switching systems and other equipment frequently exceed the sum of US$ 1 bn. That level of investment forces even the largest companies to seriously think about alliances and occasionally enter into a partnership.

3. Growth Patterns In Strategic Technology Partnerships

Having some understanding of factors that explain a number of the basic motives for firms to engage in these alliances, it seems interesting to pay some attention to the actual growth pattern of partnerships in high-tech sectors. Figure 1 shows the growth pattern of the newly established strategic technology alliances for the period 1970-1993 in information technologies, biotechnology and new materials, as registered in our databank. In the field of information technology related alliances we see a strong growth pattern of annually made partnerships during the past two and a half decade. However, most of this growth took place during the eighties and early nineties. During the first half of the seventies strategic alliances were almost non-existent even in a major field of partnering such as information technologies. From 1976 to 1980 the number of newly made partnerships rose from just over ten alliances made in 1976 to over 60 new alliances created in 1980. In 1985 this number had risen to about 180. Since then we see a further annual increase to over 200 alliances made each year during the second half of the eighties and the first half of the nineties.

In biotechnology and new materials the growth pattern is somewhat different. In biotechnology the number of alliances was extremely small during the seventies, which is not that surprising if we realize that the technology itself was almost non-existent. With the growing importance of biotechnology as a field of research and development we also see a growth in the number of alliances, which rises from just over 10 partnerships established in 1977 to over 60 made in 1980. Strategic technology partnering in biotechnology reached its peak with nearly 140 strategic technology partnerships created in 1985. Since then the number of newly made alliances dropped during the second half of the eighties. This decrease in the number of new alliances coincided with some industry restructuring activities during that period such as some important take-overs of new biotech firms, bankruptcies of others and fewer venture capital resources that combined probably explain a decrease in the number of industry participants and fewer
Figure 1: Growth of newly established strategic technology alliances in information technologies, biotechnology and new materials, 1970-1993

Source: MERIT-CATI.
partnering opportunities. However, during the most recent years we again see an increase of alliances from a record low of nearly 40 in 1991 to nearly 140 partnerships created in 1993.

Strategic technology partnering in new materials appears to follow a somewhat similar pattern as in biotechnology, only somewhat more "flattened". We see a gradual increase to nearly 80 alliances made in 1986, after which the number of newly made partnerships declined to about 25 in 1990 with a new growth to over 60 new alliances made during 1993.

In other words, since the early seventies strategic technology partnering in high-tech sectors demonstrates, despite some irregularities, an overall growth pattern in the number of newly made alliances. The second half of the eighties marks a period of some stagnation but in recent years we again witness a growth in the number of newly made partnerships.

4. Modes of Strategic Technology Partnering

So far we have discussed strategic technology alliances in general terms. However, it has to be stressed that strategic partnering takes place in a wide variety of organizational modes. In order to arrange the understanding of these different forms of inter-firm cooperation a number of taxonomies have been introduced. Auster (1987) has differentiated "international corporate linkages" into technology transfers and exchanges, R&D arrangements and joint ventures. Chesnais (1988) presented a taxonomy of types of inter-company agreements which are, amongst other things, set against government involvement, technological characteristics, capital requirements and industry structures. Somewhat different categorizations are found in Harrigan (1985), Casson (1987), Contractor and Lorange (1988) and Hagedoorn (1990). Some of these authors introduced a categorization based on the degree of ownership and control, others proposed a classification of different types of cooperative agreements leading from more extensive to intensive forms of cooperation between companies. In the following we distinguish between a group of relatively strong modes of interorganizational governance through equity arrangements such as joint ventures, research corporations and minority investment, and another group of so-called contractual arrangements such as joint development agreements, R&D pacts and R&D contracts. In several contributions it is argued that these different modes of cooperation have a distinctive impact on the
character of technology sharing, the organizational context and the possible economic consequences for participating companies.²

Joint ventures are probably the oldest and most well-known mode of inter-firm partnering. We refer to joint ventures as the combinations of the economic interests of at least two separate companies in a "distinct" firm: profits and losses are usually shared according to equity investment. In the context of strategic technology partnering we consider as joint ventures those "firms" that have shared R&D as a specific company objective besides production, marketing, sales, etc. Research corporations are a sub-category of joint ventures with distinctive research programmes of which the main purpose is to supply R&D to the parent companies. Joint ventures, in particular those with an impact on joint R&D, have, according to many observers,³ become more popular in the past decades. From the brief description of joint ventures and research corporations it is obvious that the creation of a new firm with usually two parents creates a relatively high degree of organizational interdependence. In terms of Williamson's (1975, 1985) "markets and hierarchies" this comes close to hierarchical structures with parent companies sharing control over their joint venture. Different company strategies such as entry into new markets, repositioning and expansion in existing markets and exit strategies in declining markets are reflected in these joint ventures.⁴

Despite the "popularity" of R&D-related joint ventures the economic and organizational stability of the joint venture mode as such appears questionable. Some experts estimate that about half of all joint ventures fall short of expectations or are discontinued within a couple of years. Major reasons for these failures are found in different views of participating companies on strategy and the lack of agreement in advance on how to run the joint venture. Kogut's (1988) research shows that over 45% of a sample of about 150 joint ventures were terminated within 5 years, with instability rates for international joint ventures peaking after 5 and 6 years. Berg et al. (1982) found that about 40% of 50 joint ventures in the U.S. chemicals industry in the period 1924-1969 was terminated within 5 years. Porter (1987) discusses a small sample of acquisitions, joint ventures in new fields and start-ups indicating that about 50% of the joint ventures are divested by one of the partners within a few years. However, others doubt whether there is hard evidence that the failure rate of international joint ventures exceeds the normal corporate failure rate for single-company ventures.⁵

³ See e.g. Berg and Friedman (1978), Hladik (1985) and OECD (1986).
⁴ See Berg and Hoekman (1988) and Harrigan (1988).
⁵ See for example Contractor and Lorange (1988).
Problems in maintaining joint ventures are generally thought to derive from the risks of sharing proprietary know-how, the desire for control by individual partners, coordination of different time-horizons, disagreement on design specifications, government policies and the effects of minimum efficient scale in R&D which can make decentralisation of R&D both costly and difficult to control by partners. Potential disadvantages mentioned from a more general welfare economics point of view are reduction of actual and/or potential competition, and the possibility of foreclosure of particular markets.7

Some minority equity investments, in particular if combined with other forms of technology cooperation, can be seen as a form of cooperation between companies which in the long run could affect the technological performance of at least one partner. Previous research (Hagedoorn and Schakenraad, 1990) suggests that minority investments, combined with research contracts, reached a peak in their contribution to inter-firm cooperation during the second half of the seventies and even then they were mainly concentrated in biotechnology. In our opinion it is, however, doubtful whether the appropriation of the technological achievements of another company are effected this way. Due to limited participation, the access to exclusive rights or decision making will frequently remain small. If a smaller "high tech" company is of any interest to a larger company, the more favourable alternatives are probably either majority sharing (integration), joint ventures, technology exchange agreements or a package deal consisting of a combination of several modes of inter-firm technology cooperation.

During the past decades a number of non-equity or contractual forms of strategic technology cooperation, in particular joint R&D agreements, have become an alternative to joint ventures. We understand these contractual arrangements to cover technology and R&D sharing by two or more companies through undertakings which establish research projects or joint development agreements with shared resources. Hence these agreements suggest a relatively strong commitment of companies and solid inter-organizational interdependence during the joint project, although the interdependence is smaller than is the case with joint ventures. This category of cooperation covers a wide variety of legal and organizational arrangements. In particular large companies seem to apply many of these agreements to explore possible benefits of cooperation before entering into further reaching agreements such as joint ventures (see Hagedoorn and Schakenraad, 1989).

Research contracts are examples of non-equity alliances that regulate R&D cooperation in which one partner, usually a large company, contracts another company,

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7 See also OECD (1986).
frequently a small one, to perform particular research projects. For the contract initiating party advantages can be found in the possibility to focus on particular areas of research with substantial cost-saving compared to full fledged in-house research facilities. Disadvantages for those companies are related to the lack of in-house expertise to assess the value of contract-research and the dissociation of development expertise from manufacturing expertise.\textsuperscript{8} For the other contractor benefits are found in terms of substantial R&D funding and cooperation with experienced partners. There are also considerable disadvantages such as low profit margins from licensing technology and the transitory nature of these contractual relationships and their revenues.

An interesting question in this context is whether sectors differ with respect to either equity or contractual arrangements. According to Harrigan (1985), rapidly changing technological development in sectors of industry induces the formation of somewhat informal forms of cooperation such as non-equity agreements, with growing maturity of industries joint ventures, as more formal modes of cooperation, become the more appropriate form of collaboration. In a similar vein Harrigan (1988) states that non-equity agreements are more suited for industrial sectors characterized by an uncertain environment, whereas joint ventures offer better opportunities for partnering companies in stable sectoral environments. Osborn and Baughn's (1990) survey of the literature suggests that technological stability of industrial sectors is a crucial factor explaining different patterns for equity and non-equity partnerships. In sectors with low degrees of R&D intensity one will witness a certain dominance of joint ventures, whereas R&D intensive sectors will demand more organizational flexibility leading to a general preference for contractual agreements. Yu and Tang (1992) demonstrate that stable sectoral environments with oligopolistic structures seem to favour joint venture formation, uncertain environments, with large number of companies, high risks and high investment intensity, will lead to a larger number of non-equity agreements. Recent research by Hagedoorn and Nanula (1994) also suggests that the level of technological sophistication of sectors of industry affects the distribution of equity and contractual modes of strategic technology partnering. These findings demonstrate that high-tech sectors will be characterized by a disproportionate share of contractual agreements, whereas in medium and low-tech industries one finds a relatively large number of joint ventures.

Figure 2 shows the gradual decrease of the relative importance of equity-sharing alliances compared to contractual arrangements for the combined high-tech sectors that we discuss in this paper. During the 1970s, when there were only a small number of

\textsuperscript{8} See also Oblozas and Macdonald, (1988) and Teece, (1987).
Figure 2: Share of contractual and equity modes of strategic technology partnerships, core technologies, 1970-1993

Source: MERIT-CAT.
Figure 3: Share of contractual and equity modes of strategic technology partnerships in information technologies, biotechnology and new materials, 1970-1993

Source: MERIT-CATI.
alliances, approximately 75% of the newly made alliances were of the joint venture type. Since the 1980s the share of contractual arrangements has increased from about 40% during most of the eighties to approximately 75% in the early nineties. In other words, with the growth of the number of strategic technology alliances over the past decades their organizational characteristics in terms of administrative control, ownership, and contractual relationship have changed substantially.

Figures 3 indicates some sectoral differences. As information technology is by far the largest of these sectors in terms of the number of alliances, it is no surprise that the proportion of equity to contractual agreements is quite similar to the trend for the combined core technologies. In biotechnology the majority of strategic alliances made during the past two decades has been of a contractual nature. Strategic technology partnerships for developing new materials have a relatively high participation by companies from somewhat more mature sectors such as chemicals, steel and mechanical engineering. As mentioned above joint ventures tend to be favoured as a mode of cooperation in more mature industrial sectors. This could explain why the share of equity alliances remained relatively high during the second half of the seventies and the early half of the eighties when the other high-tech fields already witnessed a change towards contractual agreements. Also during most of the years since 1985 the share of contractual agreements in new materials has remained somewhat smaller than in information technologies and biotechnology.

However, it is clear that the overall growth of strategic technology alliances since the late seventies has in particular taken place through a wide variety of contractual agreements. Joint ventures are still important but in the early nineties about three quarter of the newly made alliances are of a non-equity nature.

5. International Patterns in Strategic Technology Alliances

A number of contributions from both the management literature,9 and industrial and international economics,10 stress the role that strategic technology partnering plays in the internationalization strategies of companies. If one accepts that the economy at large is becoming more internationalized one could expect a growth in international strategic technology alliances as well. In this section we will see to what extent strategic technology partnerships in high-tech industries have become more internationalized. As

before we will pay attention to alliances made between companies from the Triad. Ohmae (1985, 1990) emphasizes the dominant role that companies from the USA, Japan, and Europe play in these international strategic technology partnerships. This is confirmed in findings by Freeman and Hagedoorn (1994) who report that over 90% of the strategic alliances made during the eighties were made between companies from the Triad. For high-tech fields such as those discussed in this paper this share of Triad partnerships even goes up to about 95%.

In order to more or less equalize the regional content of alliances and to somewhat control for size differences between individual European countries, the USA, Japan and Europe (the EU and EFTA) will each be considered as one region. Only alliances between these blocks are accepted as international alliances, intra-European alliances are seen as regional alliances.

If we look at the international pattern for partnering in high-tech sectors during the past two and a half decades as pictured in figure 4 we notice a number of major characteristics and changes in the international distribution. During the seventies, when there were so few alliances at all, nearly 65% of them were of a domestic nature. Both intra-European and intra-US partnerships took a share of roughly between 25% and 30%. With the increasing number of partnerships made during the first half of the eighties the share of international or inter-regional alliances increases to nearly 45%. However, during the second half of the eighties the share of international partnerships is decreasing again to less than 40%. An important feature of that period is the expanding share of alliances in which US firms are involved. During the second half of the eighties over 60% of the strategic technology alliances involve US partners. If we look at the first four years of the nineties we see that the share of domestic or regional alliances is nearly 58% and the share of international alliances is going up again. However, all these changes seem marginal if compared to the major changes in terms of the involvement of US firms. Our figures for the most recent period indicate that 44% of all strategic technology alliances made in these high-tech industries in the Triad are built between US firms. In total over 80% of partnerships made in the most recent period involve at least one US firm. Another striking feature is that the share of intra-European alliances has dropped from nearly 30% during the seventies to over 20% during the eighties to only a share of about 10% during the early nineties.

Although some differences are found for each of the three high-tech sectors studied in this paper, the main patterns are also found at a more disaggregated level. In information technologies (figure 5) the share of international alliances stays at about 40% during most sub-periods since the seventies. The share of intra-US partnerships increases from about 20% during the early seventies via nearly 25% and 32% to nearly 47% during
Figure 4: International distribution of newly established strategic technology alliances in core technologies, 1970-1993

Source: MERIT-CATI
the early nineties. Total US involvement decreases from less than 60% to over 80% in the most recent years. The state of the European information technology industry seems reflected in the share of intra-European alliances that has recently dropped from 20 to over 25% for most of the period to less than 10% in the nineties, whereas the share of European involvement in international alliances has remained at a level of about 20%.

Partnerships in biotechnology (figure 6) do demonstrate a gradual increase in the share of international alliances from less than 30% in the seventies and over 35% in the early eighties to nearly 40% and about 47% in late eighties and early nineties. The percentage of intra-US alliances initially decreased from about 44% to 34% in the second half of the eighties after which this share increased again to 41% in recent years. Total US involvement stayed at a level of about 70% since the seventies but in recent years this increased to 85% of all alliances made in the Triad. This surely seems to indicate the strong position taken by the US biotech industry and its technological infrastructure. In that context we can also point at the strong growth in the share of US-European alliances paralleled by a decrease of intra-European alliances. Nearly 36% of all biotech alliances made during the early nineties are made between US and European firms. This number reflects the many examples of large European chemical, agro-chemical and pharmaceutical firms that engage in alliances with smaller R&D intensive US biotech firms.

Finally, in new materials (figure 7) the share of international alliances appears to follow a somewhat irregular pattern from 33% in the first period up to 47% during the early eighties, down to 36% and back up to 45% in the early nineties. The share of intra-US alliances went up from a remarkably low share of around 15% to 20% in the second half of the eighties to 35% in recent years. Total US involvement went up from less than 40% to nearly 50% and over 70% in the period 1990-1993. European chemical companies have played an important role in new material technology and together with their overall strength this could indicate why the share of European involvement in new materials was still strong in terms of its share in partnerships made during the seventies and early eighties. Since then the share of European partnerships has dropped considerably but compared to the other high-tech fields this decrease is somewhat less dramatic.\footnote{The sudden drop in the share of intra-Japanese strategic technology partnerships in new materials made during the first couple of years of the nineties cannot be explained.}
Figure 5: International distribution of newly established strategic technology alliances in information technologies, 1970-1993

1970-1979
- Japan-USA: 16.7%
- Europe-USA: 20.2%
- Europe-Japan: 5.3%
- USA: 21.1%
- Japan: 9.6%

1980-1984
- Japan-USA: 16.5%
- Europe-USA: 22.3%
- Europe-Japan: 7.9%
- USA: 24.8%
- Japan: 7.2%

1985-1989
- Japan-USA: 10.8%
- Europe-USA: 22.5%
- Europe-Japan: 5.2%
- USA: 32.0%
- Japan: 4.2%

1990-1993
- Japan-USA: 15.1%
- Europe-USA: 20.1%
- Europe-Japan: 5.4%
- USA: 48.7%

Source: MERIT-CATL
Figure 6: International distribution of newly established strategic technology alliances in biotechnology, 1970-1993

Source: MERIT-CATI.
Figure 7: International distribution of newly established strategic technology alliances in new materials, 1970-1993

1970-1979
- Japan-USA 9.3%
- Europe-USA 11.6%
- Europe-Japan 11.6%
- Europe 39.5%
- USA 18.3%
- Japan 11.6%

1980-1984
- Japan-USA 13.6%
- Europe-USA 20.4%
- Europe-Japan 13.6%
- Europe 27.2%
- USA 14.6%
- Japan 10.7%

1985-1989
- Japan-USA 13.4%
- Europe-USA 14.9%
- Europe-Japan 7.6%
- Europe 15.6%
- USA 19.5%
- Japan 29.0%

1990-1993
- Japan-USA 10.8%
- Europe-USA 26.6%
- Europe-Japan 8.6%
- Europe 17.3%
- USA 34.5%
- Japan 2.2%

Source: MERIT-CATI.
All in all, these figures suggest two major patterns:

- internationalization is an important aspect of strategic partnering behaviour in high-tech industries but its importance should not be overstated, most strategic technology alliances are still made between companies from the same country or the same international region

- US companies become increasingly important as the major "source" of strategic technology partnering.

6. Conclusions

Complexity is a major characteristic of the world of international business and corporate strategy and apparently inter-firm strategic technology partnering is no exception to this "rule". The complexity surrounding these strategic alliances can be described in a number of dimensions in terms of technology, product markets, geographic markets, alternatives regarding the mode of cooperation and the domestic or cross-border background of "parent" companies. The current speed of scientific and technological development, the effective complementarity of once separated fields of science and technology, the need for companies to increase learning economies and the required shortening of the period between invention and market introduction describe much of the technology dimension of this complexity. Market-related aspects of complexity can be found in cooperation for new product markets, joint entry in geographically "new" markets or attempts to subdue the forces of increased (international) competition. Also the sheer growth in the number of different modes of partnering ranging from quasi hierarchical forms such as joint ventures to a wide variety of contractual arrangements, each with their own strategic, organizational and control-related implications, expresses the level of complexity that one has to expect for this phenomenon. Finally, international alliances with partners from different countries or different continents are probably more complex to manage than domestic partnerships as linguistic and cultural differences, distance of control and a large number of other factors have to be considered.

The complexity involving strategic technology alliances apparently did not have a negative effect on the growth in the number of strategic technology alliances. On the contrary, the dimensions of complexity discussed in this paper can be seen as a major driving force behind the remarkable increase of partnerships made since the seventies. Although strategic technology partnerships, in particular in the form of joint ventures,
can be traced back to the early years of the twentieth century, the period of growth in
terms of large numbers of partnerships, paralleled by a wider sectoral dispersion, did not
start until the late seventies and early eighties. After a short period of diminishing growth
rates towards the end of the eighties, the strong increase of new alliances made during
the early nineties suggests that this phenomenon is not as transient as some, including the
present author, until recently appeared to assume.

The pattern of growth in both the number of partnerships and the set of alternative
modes of governance of these technology alliances have been frequently mentioned as a
striking feature of this phenomenon. Joint ventures, once the most prominent form of
inter-firm partnering, have, to a very large degree, been replaced by a wide variety of
contractual agreements. In particular in high-tech sectors inter-firm partnering is
dominated by these somewhat more informal modes of partnering. This development
suggests that partnering in so-called high-tech sectors demands organizational flexibility
with the actual mode fitted to the organizational needs of the project in which the
partners are involved.

Organizational complexity returns if one considers international strategic technology
partnerships. As demonstrated in the above the increase of alliances has also led to a
larger number of international partnerships. However, in relative terms these
international partnerships have not been able to keep pace with the increase of domestic
alliances or alliances in the same economic region. An explanation for this somewhat
stagnant pattern can be found in the additional level of complexity that companies face in
international alliances. Given all the different dimensions of complexity that companies
already face with domestic technology partnerships an international partnership creates
additional problems. Therefore, international alliances are not necessarily the first option
for companies, in particular so if this involves strategic control over technology.
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Appendix  The Cooperative Agreements and Technology Indicators (CATI) Information System

The CATI data bank is a relational database which contains separate data files that can be linked to each other and provide (dis)aggregate and combined information from several files. So far information on about 7,000 strategic technology alliances has been collected for the period 1980-1993. Systematic collection of inter-firm alliances started in 1987. Many sources from earlier years are consulted to establish a retrospective view. In order to collect interfirm alliances various sources are consulted: newspaper and journal articles, books dealing with the subject, and in particular specialized journals which report on business events. Company annual reports, the Financial Times Industrial Companies Yearbooks and Dun & Bradstreet's 'Who Owns Whom' provide information about dissolved equity ventures and investments, as well as ventures that were not registered when surveying alliances.

This method of information gathering which one can refer to as "literature-based alliance counting" has its drawbacks and limitations due to the lack of publicity for certain arrangements, low profile of certain groups of companies and fields of technology. Despite these shortcomings, which are largely unsolvable even in a situation of extensive and large-scale data-collection, we have been able to produce a clear picture of the joint efforts of many companies. This enables us to perform empirical research which goes beyond case studies.

The data bank contains information on each agreement and some information on companies participating in these agreements. The first entity is the inter-firm cooperative agreement. We define cooperative agreements as common interests between independent (industrial) partners which are not connected through (majority) ownership. In the CATI database only those inter-firm agreements are being collected, that contain some arrangements for transferring technology or joint research. Joint research pacts and second-sourcing are clear-cut examples. We also collect information on joint ventures in which new technology is received from at least one of the partners, or joint ventures having some R&D program. Mere production or marketing joint ventures are excluded. In other words, our analysis is primarily related to technology cooperation, i.e. those agreements for which a combined innovative activity or an exchange of technology is at least part of the agreement.