

CHOOSING ORGANIZATIONAL MODES OF STRATEGIC TECHNOLOGY PARTNERING: INTERNATIONAL AND SECTORAL DIFFERENCES

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Abstract. This paper focuses on international strategic technology partnerships, and the choice that companies have in terms of the organizational mode, either through complex inter-organizational modes involving equity-sharing, or contractual non-equity alliances. The empirical results show that the choice of particular mode of cooperation varies with the technological characteristics of sectors of industry. Joint ventures are disproportionately represented in relatively mature industries. Contractual alliances dominate strategic technology partnering in so-called high-tech industries.

INTRODUCTION

In this paper, we study international and sectoral determinants of inter-organizational, strategic technology partnering. We define strategic technology partnering as inter-firm cooperation for which a combined innovative technological activity or an exchange of technology is at least part of an agreement [Contractor and Lorange 1988; Hagedoorn 1993]. These strategic technology alliances can be divided in two basic categories. The first concerns inter-organizational modes of technology cooperation that involve equity sharing, in particular joint ventures and jointly owned research corporations. The second category involves contractual alliances that cover a relatively large group of partnerships without equity sharing, such as joint development agreements, joint research pacts, cross licensing, second-sourcing agreements, mutual second-sourcing, and R&D contracts.

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Strategic technology partnerships that involve equity sharing tend to possess a governance structure with a new administrative element while contractual alliances do not. The categorization of strategic alliances into these two major modes is supported by recent research that suggests that these modes are fundamentally different: while contractual alliances display quasi-market characteristics, joint ventures are quasi-hierarchical in nature [Osborn and Baughn 1990]. Along similar lines, Hagedoorn [1993] provides an analysis of motives for different modes of strategic technology partnering in a multi-sectoral setting which suggests that inter-organizational modes of technology cooperation characterized by equity sharing are aimed at both market- and technology-mediated objectives. The multidimensionality of the wider set of objectives indicates that equity arrangements are not merely driven by technology sharing, or exclusively aimed at the creation of innovations. In general, even technology-focused joint ventures have a wide range of company objectives. Also, companies do not establish an undertaking such as a joint venture with all its organizational, financial and managerial complexities for a short period of time, and it is generally intended that a joint venture is operational for a substantial number of years. The actual unstable character of many joint ventures [Harrigan 1988; Kogut 1989; Porter 1987], as expressed in the high failure rate, does not contradict the intended long-term perspective of this mode of cooperation nor the multidimensional objectives. Hagedoorn [1993] also establishes that a disproportionate share of non-equity arrangements or contractual strategic technology alliances are primarily R&D- or innovation-driven. Their focus is one-dimensional and their duration is usually relatively short term from the perspective of the alliance itself, although they can have a long-term effect on participating companies.

The international aspect of this phenomenon is studied by concentrating on cross-national alliances. A substantial part of the existing literature focuses on economic, organizational or strategic properties of strategic alliances in general. In recent years a growing body of literature [Dunning 1993; Hladik 1985, 1988; Mowery 1988; Mytelka 1991; Osborn and Baughn 1990] looks in particular at cross-border strategic alliances and joint ventures. In the present contribution we follow the literature mentioned above in stressing the importance of these international alliances for our understanding of changing patterns of international competition. In that context we differentiate between inter-continental and intra-regional alliances. The relevance of this differentiation of nondomestic alliances is supported by Hagedoorn and Schakenraad [1993] who found that international (inter-regional) alliances between firms from Europe, the USA or Japan are particularly aimed at market entry, whereas alliances focusing on joint R&D are, in general, more intra-regional, i.e., aimed at cooperation between partners from one of the major regions of the Triad. In the following, we look in particular at international partnering of four main groupings: U.S.-European Union (EU) alliances, Japanese-EU alliances, U.S.-Japanese alliances, and nondomestic, intra-EU alliances.

The paper presents a description of general trends and patterns in international strategic technology partnering during the 1980s and the early 1990s, followed by a more specific analysis related to a number of propositions derived from the literature. These propositions concern:

- the effect of the level of technological sophistication of sectors of industry on companies' choice of different modes of partnering;
- the degree to which countries differ as to how their companies concentrate their alliances in particular sectors;
- the extent to which there is a disproportional preference of companies to engage in contractual partnerships regardless of the level of technological sophistication of the country of origin of participants.

Following a discussion of the main results, we close with the conclusions that can be drawn from this contribution and some suggestions for future study.

SECTORAL AND INTERNATIONAL ASPECTS OF CROSS-NATIONAL ALLIANCES: SOME PROPOSITIONS

The literature on joint ventures and inter-firm cooperation in general suggests a number of patterns in the sectoral distribution of international strategic technology alliances. Hladik [1985] and Hagedoorn [1993] found a clear association of the technology-intensity of sectors with the occurrence of R&D joint ventures and strategic technology partnering. According to Harrigan [1985], rapidly changing technological development in sectors of industry induces the formation of somewhat more informal forms of cooperation such as non-equity agreements. As industries become mature, more formal modes of cooperation such as joint ventures become the preferred form of collaboration. In a similar vein, Harrigan [1988] states that non-equity agreements are more suited to industrial sectors characterized by an uncertain environment, whereas joint ventures offer better opportunities for partnering companies in stable sectoral environments. Link and Bauer [1989] found that the higher the research intensity of industries, the greater the proportion of R&D funds spent on cooperative research. Osborn and Baughn's [1990] survey of the literature suggests that technological stability of industrial sectors is a crucial factor in explaining different patterns of equity and non-equity partnerships. R&D intensive sectors demand more organizational flexibility, leading to a general preference for contractual agreements, whereas in sectors with low R&D intensity, where organizational flexibility is less crucial, technology partnering agreements tend to be dominated by joint ventures. Dunning [1993] analyses the preference for contractual modes of 'technology-based cross-border alliances' in international high-technology sectors with companies combining their strategic firm-specific advantages with particular advantages of countries. Auster [1992] demonstrates a preference for technical agreements

over equity agreements in U.S.–Japanese alliances as the technology involved becomes more sophisticated. In light of the findings reviewed here, we submit that the level of technological sophistication of sectors of industry affects the distribution of equity or non-equity modes of strategic technology partnering. Thus:

Proposition 1: A larger proportion of contractual agreements (versus equity agreements) is found as the degree of technological intensity of industries increases.

Apart from patterns in the distribution of modes of cooperation and their inter-sectoral divergence, we also intend to evaluate the degree to which companies from different countries deviate in respect to their sectoral preference for international technology partnerships. The literature on foreign direct investment, trade and technology suggests that firms of different nationalities have dissimilar industrial patterns of specialization, and these are associated with their country-specific characteristics, such as technological advantages, market size and so-called national systems of innovation [Narula 1995]. It is well established that the innovative activities of individual countries are largely dominated by their large, multinational companies [Cantwell 1991; Patel and Pavitt 1991]. As such it is not unlikely that a similar pattern of country specialization will prevail in the propensity of these firms to engage in international strategic technology partnering.

The technological sophistication of countries and their industrial patterns of specialization are to a great extent influenced by the national systems of innovation [Nelson 1993; Lundvall 1992]. Several scholars (see for instance contributions to Freeman and Lundvall [1988]) have suggested that, compared to firms from small countries, firms from larger countries tend to have a larger pool of resources, including their national technological infrastructure, from which to draw on, compared to smaller countries. Furthermore, the domestic markets of companies from smaller countries can constitute a disadvantage in the development of new technologies, especially in sectors which require a relatively high minimum efficient scale [Walsh 1988]. In general, given the high cost of R&D associated with most new technologies, companies from small countries are expected to focus on a just a few niche sectors. The national systems of innovations of small countries generally, though not always, tend to further accentuate this 'specialization' of innovative activities by small country firms. Large countries, and firms from these countries, tend to have greater resources at their disposal, and are inclined to be involved in a wider variety of industrial sectors than smaller countries. This line of reasoning seems particularly relevant for the group of very small countries with absolute size disadvantages.

However, country size is not the only determinant of country patterns in international strategic technology partnering. The relative level of techno-

logical sophistication of countries has also to be taken into account. For instance, although Spain has a market size that is more than twice that of Belgium (1990 GDP \$ 487bn against \$ 192bn), it has a lower level of technological sophistication (company R&D/GDP in 1990 was 0.47% against 1.23% – source: OECD).

What we suggest here is that technologically advanced countries are diversified in terms of their sectoral distribution of technology: the level of technological sophistication of these advanced countries is found across a wide array of industries and technologies. On the other hand, technologically less advanced countries also tend to have limited resources that result in the spreading of their resources in fewer sectors. We submit that if this trend in different patterns of specialization of countries extends to the participation of companies in international strategic technology partnering, then:

Proposition 2: The participation in international strategic technology partnering by companies from technologically advanced countries will be evenly allocated across the overall sectoral distribution of partnerships, whereas the participation of companies from technologically less advanced countries will be specialized in a small number of sectors.

Countries differ with respect to their level of technological sophistication, but increased international competition amongst the leading developed economies has led to a technological convergence of sectors into similar levels of technological development. However, it is important to note that even small differences can be decisive in determining the relative international competitiveness of one country over another. In general, technological convergence implies similarity of technologies, but this does not imply that the competitive advantages of countries will be identical [Archibugi and Pianta 1994; Narula 1995]. The argument being made here is simply that various sectors across countries have internationally comparable levels of technological sophistication. Countries can specialize in particular sectors or technologies, but the level of technological development for each field is comparable for most countries in the industrialized world as their companies have to compete in international markets. Therefore, we postulate that the preference for particular modes of international cooperation will be primarily associated with the technological intensity of sectors and not with the level of technological sophistication of countries at large. Thus:

Proposition 3: The assumed disproportional preference of companies to form contractual agreements in high-tech sectors and joint ventures in other sectors is not intermediated by the level of technological sophistication of countries.

METHOD OF DATA COLLECTION

In order to test the propositions and also to discuss some general patterns in international strategic technology partnering, our empirical research employs the MERIT-Cooperative Agreements and Technology Indicators (CATI) data bank. This relational database, with information on over 13,000 technology cooperation agreements involving some 5000 different parent companies, was established in the late eighties. After a pilot project in 1986–1987, systematic collection of inter-firm technology alliances started in 1988. Many sources from earlier years were consulted, which enables us to take a retrospective view. For all sectors of industry or fields of technology in our data bank, we have information on cooperative agreements from at least as early as 1980 up to 1993. In order to collect information on inter-firm alliances and their parents, we consulted various sources, such as informal reports, newspaper and journal articles, books dealing with the subject, and specialized technical journals which also 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 we might call 'literature-based alliance counting' has its drawbacks and limitations such as inadequacy of certain sources, low profile of certain companies or industries, bias in favour of Anglo-Saxon sources, and underestimation of certain modes of cooperation such as licensing. It also introduces a certain bias in terms of the frequency versus the scale of alliances. Despite these shortcomings, which are largely unsolvable even in a situation of extensive and large-scale data collection, we think 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 or general statements. We avoided some of the weaknesses of the database by focusing on the more reliable parts, such as strategic technology alliances, and by ignoring cost-economizing partnerships and licensing agreements.

The databank contains information on each agreement and some information on companies participating in these agreements. The main entity is the inter-firm cooperative agreement. We define cooperative agreements as common interests between independent (industrial) partners that are not connected through (majority) ownership. The CATI database includes only those inter-firm agreements that contain arrangements for transferring technology or joint R&D. Mere production or marketing agreements are excluded. In other words, our analysis is primarily related to technology cooperation. Our focus is on those forms of cooperation and agreements for which a combined innovative activity or an exchange of technology is at least part of the agreement. Consequently, we exclude partnerships that regulate no more than the sharing

of production facilities, the setting of standards, collusive behaviour in price-setting and raising entry barriers, although all of these may be side effects of inter-firm cooperation as we define it.

We count as an alliance any agreement made between two or more companies at a particular moment. Subsequent agreements between the same partners are considered as individual and separate agreements. However, if a particular agreement consists of several legal forms of cooperation that are parts of the agreement at large, such as a joint venture with a licensing agreement, we consider this as one agreement. If a partnership is extended with a new partner or a new contract is made between two cooperating firms we view this as a new alliance. Frequencies reported in this paper therefore refer to the number of individual partnerships. Although we do have information on the value of a limited number of alliances (such as the amount of investment) we prefer not to utilize this information for two reasons. First, the coverage of this data excludes contractual agreements for which the value of the agreement is not disclosed, and second, a large percentage of technology partnerships involve interchange of knowledge rather than the exchange of funds or capital.

In this paper, we record for each alliance: the number of companies involved, country of origin of each partner, year of establishment of the agreement, field(s) of technology and/or industry and modes of cooperation. The country of origin of a given company refers to the country where a company or its head office is registered. Therefore, international alliances are partnerships between companies registered in different countries. This obviously has certain limitations in the case of international companies, because a number of their partnerships are between their local subsidiaries and local partners. However, many of these 'artificial' international alliances are monitored from the head-office. Furthermore, there is no other choice in the context of large databases than to follow a strict procedure for categorization. Decisions regarding the possible degree of international subsidiary-level monitoring are impossible to make for a population of thousands of agreements and companies. For the categorization of industries and fields of technology according to their degree of technology intensity, we use the standard OECD classification (see also Hagedoorn [1993]).

We make a distinction between cooperative agreements that are expected to be aimed at the strategic, long-term perspective of the companies involved and those agreements that we think are more associated with the control of either transaction costs or operating costs of companies. In case both general motives appear possible, either because it is not feasible to differentiate between the cost or the strategic argument or because partners often have alternating motives as a consequence of the character of the agreement, we have marked such agreements as being of a mixed character. The procedure is described extensively in Hagedoorn [1993] and Hagedoorn and Schakenraad [1990]. In practice, our decision rules imply that joint ventures with R&D,

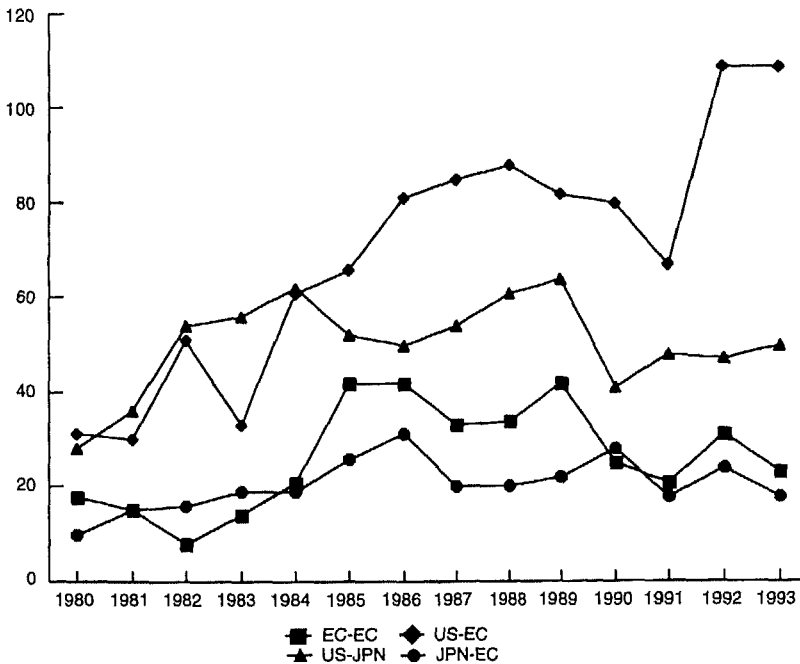
research corporations, joint R&D pacts, customer-supplier agreements combined with licensing, cross-licensing, research contracts with licensing, and (mutual) second-sourcing agreements are taken as strategic alliances. Excluded are standard co-makership contracts, co-production agreements, and single licensing agreements for which the cost-economizing argument is thought to be a major motive. The total number of international strategic technology alliances included in the present analysis is 5063.

SOME GENERAL PATTERNS IN INTERNATIONAL STRATEGIC TECHNOLOGY PARTNERSHIPS

The general growth pattern of newly made international strategic technology partnerships and its distribution for the 1980s and the early 1990s is given in Figure 1. This pattern of the annual growth of strategic technology partnering follows the overall growth pattern of domestic and non-domestic alliances as reported in a large number of studies [Chesnais 1988; Contractor and Lorange 1988; Hagedoorn and Schakenraad 1993; Haklisch 1986; Hergert and Morris 1988; Mowery 1988; Mytelka 1991]. Our data suggest that in general the number of strategic technology partnerships for all international combinations has grown rapidly during the first half of the eighties. However, since the mid-eighties there has been some difference in growth patterns. The growth pattern of newly established alliances between companies from Japan and the EU has more or less stabilised. After a steady increase of newly made nondomestic alliances within the EU during the first half of the eighties, there appears to have been a gradual stagnation in the growth of these intra-regional (non-domestic) alliances within the EU towards the end of the period. To some extent this pattern, though at a higher overall growth level, is also visible for alliances made between firms from the U.S. and Japan. Although there are fluctuations in the growth of international alliances between companies from the U.S. and the EU, the pattern in Figure 1 suggests an overall rise for newly established partnerships throughout the period, after some decrease in the growth of newly made alliances at the end of the eighties. Further study of our data reveals that this increase in U.S.-EU alliances is due to the growth of contractual alliances.

Given our interest in both equity and contractual arrangements, we examine the possible differences in preference for each of these modes of governance. An 'equity-contractual arrangement' ratio expresses the number of joint ventures relative to the number of contractual arrangements for intra-EU (nondomestic) alliances, U.S.-EU alliances, Japan-U.S. alliances, and Japan-EU for the period 1980-1993. We found that most of the international alliances are of a non-equity type. However, there are significant differences between the four groupings. For intra-EU and U.S.-EU partnerships, joint ventures are a small minority of the total number of strategic technology alliances, with ratios of 0.37 for both combinations. The higher ratios for Japan-

FIGURE 1
The Growth of International Strategic Technology Alliances
(Joint Ventures and Contractual Agreements), 1980–1993



U.S. alliances (0.52) and Japan-EU alliances (0.67) indicate that partnerships with Japanese companies are more frequently governed by equity arrangements. As suggested by internalization theory [Buckley and Casson 1976, 1988; Dunning 1993; Rugman 1980] these equity agreements offer a larger degree of control over technology sharing than non-equity partnerships.

MAJOR FINDINGS

Table 1 shows the sectoral distribution of international equity and contractual technology partnerships for U.S.-Japan, U.S.-EU, Japan-EU and intra-EU groupings. As noted earlier, due to the nature of the MERIT-CATI database, which contains information mainly on technology partnering, a majority of the sectors for which data are available in sufficient detail are high-tech sectors. Furthermore, to test the first proposition, we have to take into account that the majority of international strategic agreements in the MERIT-CATI database – about 70 % – are of a non-equity nature (see Table 1). As the literature attests to, high technology sectors tend to have a higher share of contractual agreements than medium- or low-tech sectors. Therefore, it is reasonable to argue that for high-tech sectors we can expect that 30% or less of the strategic

TABLE 1
Sectoral Distribution of International Equity and Contractual Technology Partnerships, USA, Japan, Intra-EU, 1980-1993

	USA-Japan	USA-EU	Japan-EU	EU-EU	Totals
	JV/Total (%)	JV/Total (%)	JV/Total (%)	JV/Total (%)	JV/Total (%)
Biotechnology ***	16.36	17.53	26.67	13.04	17.69
New Materials Technology ***	47.76	52.81	60.87	38.46	52.80
Computers ***	19.64	20.00	45.45	35.71	22.95
Industrial Automation ***	43.24	30.19	20.00	13.64	30.37
Micro-electronics ***	19.23	17.48	20.45	6.82	16.94
Software ***	20.00	21.43	7.69	20.45	20.81
Telecommunications ***	21.95	29.82	30.77	32.61	28.28
Other I.T. ***	20.00	35.29	38.46	33.33	34.62
Automotive **	70.21	35.71	21.43	33.33	50.51
Aviation/Defense ***	12.50	16.67	25.00	23.53	17.83
Chemicals **	71.83	51.95	72.73	61.54	64.65
Consumer Electronics **	45.45	70.00	37.50	20.00	43.59
Food and Beverage *	66.67	45.45	100.00	100.00	63.16
Heavy Electric/Power ***	7.14	27.78	0.00	14.29	16.22
Instrumentation/Med. Technology ***	75.00	8.33	0.00	25.00	32.61
Other *	75.00	20.00	25.00	33.33	30.00

* low level of technology, ** medium level of technology, *** high level of technology
 Classification is based on OECD guidelines (see Hagedoorn [1993]).

technology alliances are joint ventures. For medium- and low-tech industries we assume that more than 30% of the alliances are joint ventures.

In general, the data in Table 1 appear to support the first proposition regarding the association of sectoral technology intensity and the preference for either equity or contractual agreements, as twelve out of sixteen sectors follow the predicted distribution. For high-tech fields such as biotechnology, all information technology sectors (with the exception of 'other I.T.'), the aviation-defense sector, and heavy electrical equipment, we find that the vast majority of partnerships (between 72% and 82%) are of a contractual nature. For twelve of the forty-four international combinations in high-tech sectors, we do not find the expected 70% or more of contractual agreements. However, new materials is the only high technology sector that clearly falsifies the proposition, both across the board and for each of the four individual international combinations. In that sector, the share of equity partnerships is higher than 50%, similar to that expected for medium-tech industries. This similarity is not altogether coincidental. A considerable number of the firms engaged in technology partnering in new materials are in fact from the chemical, steel and engineering industries [Hagedoorn and Schakenraad 1991]. These sectors are characterized by an intermediate level of technological sophistication, and tend to have a higher share of joint ventures. Companies in these industries are engaged in technological development in new materials that frequently replace

existing applications of their 'traditional' products. The preference for joint ventures when engaging in joint technology development in their sectors of origin seems to extend to alliances undertaken in new materials. Instrumentation-medical technology also demonstrates a share of joint ventures above 30% but the deviation is rather small and primarily caused by the extremely high share of U.S.-Japanese joint ventures in that sector.

The three sectors with a medium-technology intensity: automotive, chemicals and consumer electronics, follow the expected distribution. However, there is considerable variation for different international combinations. In chemicals, the vast majority of alliances (about 65%) are joint ventures. In the automotive industry, the general distribution is about fifty-fifty, although this is once again largely due to the large number of U.S.-Japanese joint ventures. In consumer electronics over 40% of the partnerships are equity alliances. Finally, the only low-tech sector in our sample, food and beverages, appears to support the assumption that low-tech sectors have a much higher preference for joint ventures than for contractual agreements.

To test Proposition 2 we define 'participation' in terms of the frequency with which companies from a particular country or international region are found in our data. Following some recent contributions to innovation studies [Freeman and Hagedoorn 1995; OECD 1992; Rothwell and Zegveld 1985; Soete and Verspagen 1991] we distinguish between technologically highly developed countries and the somewhat less advanced countries based on an R&D/GDP ratio either above or below 1%.¹ Greece, Ireland, Luxemburg, and Portugal were not included, given the small number of alliances for these countries. Table 2 gives the distribution of the participation of companies from the U.S., Japan and the EU according to nationality and sectoral breakdown. Table 3 shows differences between countries in terms of their degree of specialization in strategic technology partnerships as measured by the coefficient of variation. A higher coefficient indicates that a country is relatively specialized in a few sectors, while a lower coefficient indicates that a country is more diversified in partnering across a larger number of sectors. We see a clear difference in the technological partnering specialization between the technologically less sophisticated countries (Denmark, Spain and Italy) and the technologically advanced countries (Germany, France, U.K., Belgium, Netherlands, Japan, and U.S.).²

In general, strategic alliances involving companies from less advanced countries are concentrated in just a few sectors, whereas in the case of the technologically advanced countries they are more evenly distributed over a larger number of sectors. For Spain three sectors – telecommunications, aviation and defense, and microelectronics – account for a share of over 75% of all partnerships. In Denmark two sectors – biotechnology and new materials – account for over 90% of the international agreements. For Italy, however, although the coefficient of variation indicates that the pattern is

TABLE 3
Summary of the Patterns of International Specialization in
International Strategic Technology Partnering as Expressed in
Coefficients of Variation

Belgium	1.41	Japan	0.92
Denmark	2.79	Netherlands	0.82
France	0.81	Spain	1.61
Germany	0.77	U.K.	0.95
Italy	0.82	USA	0.80

definitely not specialized (Table 3), the industrial distribution of its technology alliances is clearly different from the distribution of the group of technologically more advanced countries (Table 2). For six out of the seven technologically advanced countries, the distribution of alliances is clearly more evenly distributed over all the sectors. The only exception is Belgium, where three sectors – biotechnology, telecommunications and chemicals – account for over 65% of the agreements.

So far, we have been able to establish some preliminary understanding of the relationship between inter-organizational modes of strategic technology partnering, their sectoral setting, and their international environment in a bivariate context for each of the inter-regional combinations. To take our exploration further, we examine the possible association between each of our three basic variables: modes of cooperation, technological sophistication of countries, and technology intensity of sectors.

We have already demonstrated that international strategic technology partnering in high-tech industries appears to be disproportionately organized through contractual arrangements, whereas other sectors with lower levels of technological sophistication have a higher share of joint venturing. We also found some evidence that the level of technological sophistication of countries influences the strategic technology partnering participation of companies from these countries. We now test whether the association between the mode of international technology partnering and the level of technological sophistication of sectors is influenced by the country-level degree of technological intensity (Proposition 3). We distributed the numbers of 'hits', i.e., the number of times that companies from a particular country were engaged in international strategic technology partnering, according to modes of strategic technology cooperation, high-tech or non-high-tech content of sectors, and two groups of countries of different levels of technological sophistication. The differentiation of sectors into levels of technological sophistication and the separation of equity versus non-equity agreements has been discussed above. We again divided the countries into those having a R&D/GDP ratio greater than 1% as technologically sophisticated, and those lower than 1% as less sophisticated. The distribution of the different degrees of participation in

TABLE 4
Participation in Modes of International Strategic Technology Partnering
by Different Levels of Technology for Sectors and Countries

	High-Tech Countries		Lower-Tech Countries	
	High-Tech Sectors	Other Sectors	High-Tech Sectors	Other Sectors
Equity	1006	459	106	27
Non-equity	3100	427	244	41

strategic technology partnering with respect to modes of cooperation, technological sophistication of sectors and countries is given in Table 4.

A cursory examination of the results in Table 4 tentatively suggests that within each of the two subgroups of high-tech and lower-tech countries the sub-distributions are very similar. For a more accurate assessment of the possible effect of levels of technological sophistication of countries, we use two statistical procedures to investigate whether the association between modes of partnering and technological characteristics of industries is maintained for the two levels of technological sophistication of countries. The first procedure is known as the partial association of variables in a three-dimensional setting. The other procedure is a modified χ^2 test.

Expanding on the standard procedure for calculating cross products in simple 2×2 tables, the partial association can be measured for three variables. The precise statistical procedure can be found in Moser and Kalton [1971]. Here we will follow accepted practice and only reproduce the measurements for the intermediate and final steps in the analysis. The partial cross product for high-tech countries (the left-hand side of Table 4) is -0.03986, the partial cross product for the lower-tech countries (the other part of Table 4) is -0.0128. The two marginal associations, through which the effect of the third variable (country level of technological sophistication) on each of the two variables are calculated, are -0.00176 and -0.00106. These low levels of marginal association indicate that the association between sectors of industry and modes of cooperation holds. The buildup of both partial associations and the combined marginal association can be expressed in their relative contribution to the association of the variables. The contribution to the partial association for high-tech countries is 97.3%, the contribution for low-tech countries is 2.7%. The contribution of the combined marginal associations is 0%. The extremely low value of the contribution of the combined marginal associations indicates that the gross association of sectors of industry and the preference for equity or non-equity partnerships holds across countries of different levels of technological sophistication.

A second procedure, based on a modified χ^2 -test, generates similarly strong results. Our findings of a $\chi^2 = 9.868$ with a significance level of $p < 0.025$ also

indicate that the preference of companies to form contractual agreements in high-tech sectors and a disproportionate number of joint ventures in other sectors is not significantly intermediated by the level of technological sophistication of countries. Further details of this procedure are provided in Appendix 1.

DISCUSSION AND CONCLUSIONS

It has to be stressed that complexity governs the choice of inter-organizational mode of governance taken by an alliance, and thereby influences the strategic implications for the companies involved. This complexity has internal and external effects on firms involved in strategic technology partnering, which can be described in three dimensions.

The first dimension is the organizational complexity that is inherent when two or more firms engage in an alliance. The mode of governance that is undertaken for a given alliance is affected by the trade-off between minimizing intra-organizational complexity and maximizing control over the alliance by each partner. The more complex inter-organizational mode of technology cooperation, such as a joint venture, raises a number of problems of corporate governance. Its quasi-hierarchical nature not only reaches intermediate levels of corporate control, but also introduces dilemmas related to trust, forbearance and opportunism [Parkhe 1993]. Contractual agreements appear to involve lesser intra-organizational complexity because no separate new administrative element is created. However, although contractual agreements in themselves are less complex, companies often engage in several alliances simultaneously with a variety of partners. This introduces an additional level of complexity namely difficulties associated with both the administration of these partnerships and the need to continuously monitor the net benefits accruing from various contractual alliances [Osborn and Baughn 1990].

The second dimension that determines the organizational complexity (and thus the mode of governance) is the fact that these agreements involve technological development. The process of technological development is both complex and uncertain, and although the return on investment may be high, this reflects the degree of uncertainty that companies face. Technologies for which markets are not well defined and which involve high uncertainty are typically those in which strategic alliances are favoured. If it were not for these characteristics, we probably would not have witnessed the growth of strategic technology alliances over the past decade. In other words, the object of this particular group of alliances – the joint development or sharing of new technologies – is already intrinsically a matter of high complexity, compared with other activities such as manufacturing. However, the level of uncertainty and the resulting complexity differ by sector. Technology development is faster, more complex and uncertain in industries that are high-tech, whereas the value of innovations and their potential benefits are uncertain. By contrast,

in mature industries, technology development is relatively slow-paced with incremental changes in technology, and the market and value of the technology are relatively well defined. Technology partnering in high-tech sectors tends to be characterized by a preference for contractual agreements, compared with medium- and low-tech sectors where a disproportionate share of joint ventures is found.

The third dimension is associated with the international context of these alliances, which further exacerbates the already high level of complexity. It is obvious that sharing technology with a partner creates organizational complexity, but this is further increased if the partner is in another country or continent. In terms of control, the agreement has to be monitored from corporate headquarters over long distances or from a local or regional subsidiary. However, even in the latter case, there is often no real reduction in the 'distance of control' but it frequently merely results in the introduction of an additional level of corporate governance. Nonetheless, companies of different national backgrounds are also influenced by their past business experiences as well as by the difficulties of maintaining control over the alliance across borders. Companies that have collaborated on other projects in the past, and are familiar with the business practices and/or regulatory framework in which their partners operate, will perceive less uncertainty in engaging in partnerships that are less complex than with firms with which they have had little experience.

Our results indicate considerable differences between companies of different nationalities in their propensity to engage in strategic technology partnering. These differences do not pertain to differences in preferred modes of governance but more specifically to the sectoral and geographical patterns of the international technology alliances in which companies engage. The participation of companies in strategic technology partnering and the distribution of these alliances over a large number of sectors appear to increase with the increasing levels of technological sophistication of home-countries of these companies. In choosing particular modes of cooperation, the level of technological sophistication of industries plays an important role. In situations of high-tech complexity, in terms of high uncertainties about both the outcomes of the process of technological change as well as the market structural consequences of these changes, the number of alliances are increasing. Under these unstable conditions, when organizational flexibility and speed of information transfer are vital, companies have a disproportionate preference for more informal, contractual and quasi-market oriented agreements. More stable industry structures combined with less dynamic technological changes are paralleled by a relatively higher share of quasi-hierarchical and also more formal modes of cooperation as found in the joint venture mode. In such situations, organizational control over information flows and new technological applications with a long life cycle is more relevant than in the case of

technologies that are quickly outdated, when speed of information processing is more important than organizational control itself.

Given the exploratory character of this contribution a discussion of future research topics is appropriate:

- In order to improve both our theoretical and analytical understanding of international strategic technology partnering, the analysis of this phenomenon has to be further integrated in the understanding of corporate internationalization and other aspects of company behaviour, such as technology strategies [Duysters and Hagedoorn 1995; Harrigan 1985; Nohria and Garcia-Pont 1991]. This implies a multivariate setting in which different modes of cooperation are analyzed against a multi-sectoral background with a range of strategic alternatives open to a variety of firms. In that context, organizational and structural characteristics as well as behavioural properties such as entry and exit strategies and a range of technology strategies may be possible explanatory variables.
- A more thorough comprehension of the effects of strategic technology partnering on company performance appears necessary. Measuring these effects has to be evaluated in terms of economic effect, improved or possibly deteriorated technological capabilities for different partners, and the implications of a range of modes of cooperation [Powell and Brantley 1992]. The application of network analysis and the further development of related theoretical contributions can improve our knowledge of the complexities and the inter-organizational context of a large variety of inter-firm relationships that effect companies engaged in strategic technology partnering [Nohria and Eccles 1992]. Also, further analysis of the scale of alliances might increase our insight into the strategic importance of alliances in a particular network configuration.
- Organizational complexity has been mentioned as one of the characteristics of international strategic technology alliances [Parkhe 1993]. The understanding of the interaction of organizational control over technology flows through these various partnerships, each with different degrees of complexity, and the benefits of a partnering strategy appears essential. This is not only crucial for the practical purposes of the participating companies, but a clearer comprehension of the organizational implications and corresponding levels of complexity of control will also be necessary to improve our academic understanding of strategic technology partnering.

APPENDIX

The null hypothesis to be tested for the assumed similarity of the distribution of contractual and equity alliances in high-tech and low-tech industries in both categories of countries in Table 4 is:

$$H_0 : p_{j1} = p_{j2} = p_j \quad (j = 1,2,3,4).$$

The alternative hypothesis H_1 is that for at least one j it holds that p_{j1} is not equal to p_{j2} . This p_{j1} refers to the percentage of companies in the population of high-tech countries that belongs to the category j . Schematically this can be shown as:

High-tech		Low-tech	
$p_{1/1}$	$p_{2/1}$	$p_{1/2}$	$p_{2/2}$
$p_{3/1}$	$p_{4/1}$	$p_{3/2}$	$p_{4/2}$

It is obvious that:

$$\sum_{j=1}^4 p_{j/i} = 1; \quad i = 1, 2.$$

Because the p_j s are unknown, we will estimate them from the observations. Under the restrictions of the null hypothesis we estimate the p_j s from the pooled data :

$$\hat{p}_j = \frac{n^{j/1} + n^{j/2}}{N}$$

$$N = n_1 + n_2 \text{ and } n_i = n_{1/i} + n_{2/i} + n_{3/i} + n_{4/i}$$

where $n_{j/i}$ refers to the total number of observations in cell j of population i . n_i refers to the total number of observations in population i .

Now we are able to perform a χ^2 -test. The expected number of observations in cell j of population i is:

$$e_{j/i} = n_i \hat{p}_j$$

$$\chi^2 = \sum_{i=1}^2 \sum_{j=1}^4 \frac{(n_{j/i} - e_{j/i})^2}{e_{j/i}}$$

Similar to the statistical procedures we followed with regard to the partial associations our findings of a $\chi^2 = 9.868$ with a significance level of $p < 0.025$ indicate that the preference of companies to form contractual agreements in high-tech sectors and a disproportionate number of joint ventures in other sectors is not significantly intermediated by the level of technological sophistication of countries.

NOTES

1. R&D/GDP ratios for 1990 are: Japan 2.12%, Germany 2.02%, USA 1.98%, France 1.48%, U.K. 1.47%, Belgium 1.23%, Netherlands 1.16%, Denmark 0.85%, Italy 0.76%, Spain 0.47% (Source: OECD).

2. These findings have to be interpreted with some caution, given the small sample size associated with the less technologically sophisticated nations.

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