ELSEVIER

Research Policy 24 (1995) 207–231

research policy

Strategic technology partnering during the 1980s: trends, networks and corporate patterns in non-core technologies*

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(Final version received October 1993)

Abstract

The growth of the number of inter-firm strategic technology alliances during the 1980s has led to considerable attention to this phenomenon in recent years. In this paper an attempt is made to understand not only basic trends in the growth of inter-firm cooperation in sectors such as chemicals, aviation/defence, automotive and heavy electrical equipment, but also to reveal the role played by a large group of cooperating companies. The research is based on a large databank with information on thousands of alliances and their participating companies. Through statistical analysis it is possible to identify the major players within these sectors. The analysis enables us to recognize the major international networks of inter-firm alliances, the changes over time and different positions taken by world leading companies.

1. Introduction

The study of strategic technology partnering is to a large extent concentrated in so-called high-tech industries or core technologies (see Hagedoorn [3,4], Hagedoorn and Schakenraad [5–7], Mowery [9], and Mytelka [10], to name but a few examples). In the present paper I will attempt to contribute to the understanding of strategic technology partnering in a broader industrial setting with an analysis of trends, market structural patterns, and networks of inter-firm agreements in four industrial sectors, i.e. chemicals, aviation and defence, automotive and heavy electrical equipment. Although strategic alliances in these sectors have not been completely neglected they certainly have not been studied to the same degree as the alliances in fields such as information technology and biotechnology. Data from the MERIT – Cooperative Agreements and Technology Indicators (CATI) databank suggest that alliances in chemicals, aviation/defence, automotive and heavy electrical equipment account for about 25% of the strategic alliances made during the 1980s. A much larger share of the strategic alliances, i.e. about 70% of the alliances made during the 1980s, are related to the new core

* This study was partly financed by the Monitor-FAST Program of the EC. The author would like to thank Jos Schakenraad for assistance with the statistical analysis. Helpful comments by two referees are gratefully acknowledged.

0048-7333/95/$09.50
SSDI 0048-7333(94)00763-J

technologies: information technology, biotechnology and new materials. However, these figures also indicate that the four sectors studied in the present contribution appear to be the only other fields for which substantial numbers of inter-firm alliances were found.

Apart from a sectoral restriction I will also limit the analysis to those inter-firm agreements for which the transfer of technology or the creation of new technology through R&D or other innovative efforts are central to the agreement. This eliminates a wide range of exclusively marketing, production or sales agreements. I will confine the analysis to particular modes of partnering such as joint ventures for which common R&D or technology sharing is a major objective, research corporations, joint R&D pacts, and minority holdings coupled with research contracts. The analysis refers to alliances made by companies on a "private" basis, excluding national and international shared-cost programmes, which facilitates the understanding of patterns of "pure" inter-firm technology sharing, i.e. strategic partnering for which the incentive is found within groups of firms themselves. Another important restriction is the definition of strategic alliances as those inter-firm agreements that can reasonably be assumed to affect the long-term product market positioning of at least one partner. Following Hagedoorn and Schakenraad [5], agreements that have a mainly cost-economizing character are excluded from the following analysis.

The four sectors in this study are identified in terms of rather general product groups. Chemicals comprises inter-firm agreements in bulk chemicals and petrochemicals, fertilizers, synthetic materials pharmaceuticals (except those generated by biotechnology); specialty chemicals such as pesticides and photochemicals; industrial gases; toilet preparations, soap and detergents; paints, dyestuffs and pigments. The automotive sector covers alliances aimed at designing new models and developing parts and components, such as engines for cars, trucks, motor cycles, and agricultural equipment. The next field is the aviation/defence sector with alliances in various kind of aircraft, both civil and military; helicopters; aircraft engines; relevant parts and components; missiles; defence electronics systems; space technology (satellites, rockets, space shuttles). Finally, heavy electrical equipment includes nuclear and solar energy, turbines, generators, railway and other electrical equipment.

The core of this article is the empirical analysis of historical patterns of strategic technology partnering and the evolution of inter-firm networks in the four above-mentioned sectors. Most attention is paid to the identification of basic trends in strategic technology alliances, the main "actors" and their networks; if possible, a comparison is made with some of the relevant findings for new core technologies. In order to reconstruct networks of strategic alliances I will apply a multidimensional scaling technique, measure variation in network density and analyze the stability in groups of leading cooperating companies comparing the first half of the 1980s with the second half. The graphical presentation is somewhat space-consuming, but it enables me to identify concrete networks and the changes in the positions taken by the major companies involved.

2. Trends in strategic technology alliances during the 1980s

Hagedoorn and Schakenraad [7] expressed the view that, based on a substantial body of literature and their own empirical findings, one could expect a growth of strategic alliances in many sectors during the 1980s. However, it was also stated that the growth pattern of strategic alliances would gradually stabilize or even shown a declining growth towards the end of the 1980s. This was thought to be due to the experience of companies with organizational problems, opportunistic behaviour of partners, and the limited success of strategic alliances that are not a panacea for many of the problems that companies face. In short, strategic technology alliances do not necessarily lead to win–win situations. With the phenomenon of strategic technology partnering becoming a more regular aspect of corporate behaviour, firms could become somewhat more conscious of the above mentioned problems which could lead to a decline in the growth of newly made agreements. Such a stagnating growth pattern during the eighties was found for a number of sub-fields in information technology and also in new materials and biotechnology (see Hagedoorn and Schakenraad [5–7]). If such a pattern is found for much of the new core technologies or new technological paradigms, it seems interesting to see whether this is also present in the more traditional sectors we study in the present contribution. Therefore, the first research question is:

Whether the number of strategic technology partnering agreements established during the 1980s has increased continuously or, if there is a certain degree of saturation after companies built up some experience with this relatively new mode of inter-firm organisation, does this lead to a decrease in the number of new alliances?

As shown in Fig. 1, the pattern of all newly established strategic technology alliances found in the MERIT–CATI databank demonstrates that the first years of the 1980s are characterized by a somewhat constant increase of new agreements, followed by a sharp rise during the mid 1980s, which is continued by a somewhat slower rate of increase during the final years of the 1980s. If one compares the first half of the decade with the second half it is found that over 60% of all alliances have been made since 1985. In other words, this pattern does not appear to provide any verification of the implicit hypothesis in the above mentioned research question suggesting a flattening of the growth rate in strategic technology partnering.

At the sectoral level, in the four industries analyzed in this contribution there appears a somewhat differentiated pattern. In particular in chemicals and, to a lesser degree, in the automotive industry, one notices a substantial growth of new alliances made during the second half of the 1980s. In the aviation and defence industry there is a rather fluctuating growth pattern with further growth towards the end of the decade. In heavy electrical equipment the general pattern is one of gradual growth with a few ups and downs.

In general, this sectoral pattern does not support the idea that the growth of strategic technology alliances stagnate if companies build up some experience with this phenomenon. An explanation for this could be found in the novelty of strategic technology partnering in these sectors and the relatively small numbers of alliances for these otherwise large sectors. Compared with for instance, many sectors within the information technology industry, sectors such as the automotive, aviation/defence, chemicals and heavy electrical equipment industries are still characterized by relatively small numbers of R&D joint ven-

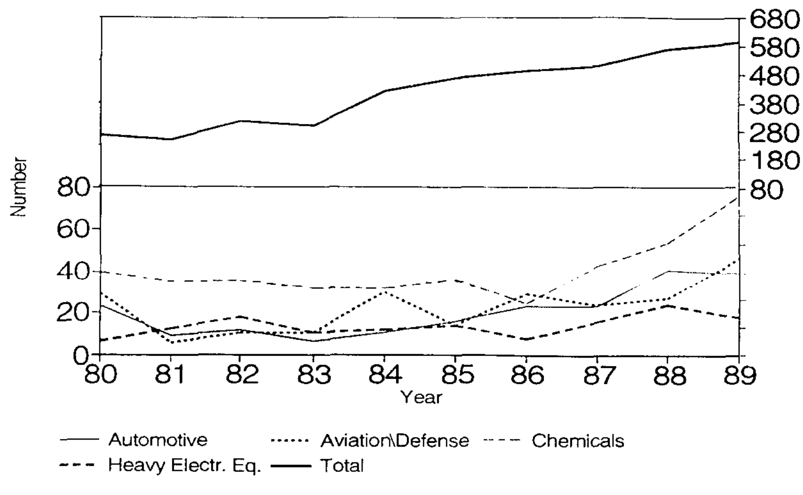

Fig. 1. Growth of newly established strategic technology alliances in chemicals, aviation and defence, automotive, heavy electrical equipment, and overall figures, 1980–1989.

tures and R&D pacts. In these sectors, in particular in the electrical equipment industry and in chemicals, there is a long history of cooperation through cartel-like organizations, excess capacity cutting agreements and licensing. These largely defensive agreements might create an industrial climate where cooperation is part of corporate strategies, but it was not until recently that more offensive technology cooperation oriented agreements were introduced on a somewhat larger scale. Such sectoral differences between fields where a large group of companies built up substantial experience in this phenomenon, as in the information technology industries, and sectors where this phenomenon is less abounding, suggest that corporate experience with strategic technology partnering influences the propensity to engage in such alliances for longer periods. In many of the new core technologies related fields, the growth of strategic technology partnering is tending to stagnate. This probably indicates a somewhat more careful attitude towards strategic technology cooperation once companies have gained some experience in it. The sectors studied in the present paper are still in an early stage of applying these strategic technology partnering agreements, which suggests that the growth pattern found during the second half of the 1980s could follow the same pattern as in new core technologies, but with a time lag of several years.

3. The structure of networks of strategic technology partnering

In the literature it is suggested by several authors, see e.g. Casson [1], Chesnais [2], Hagedoorn and Schakenraad [7] and Mytelka [10], that the increase of strategic alliances has been somewhat asymmetrical in the sense that some large companies have established a substantial number of inter-firm links thereby dominating strategic technology partnering. A discussion of the different theoretical positions taken in that debate does not seem appropriate in the present context. However, a relevant question is whether some companies play a central role in strategic alliances and consequently strategic technology partnerships are unevenly distributed towards "nodal" companies. If that is the case, one can expect the linkages of these firms to have escalated during the second half of the 1980s, which should show up in the analysis of intensified inter-firm partnerships at the sectoral level. In addition to this, one would expect a stable network of major cooperating firms in the sense that the companies with most strategic links during the first half of the 1980s will also take leading positions during the second half of the decade.

Apart from the empirically interesting question as to which companies are actually major collaborators and whether their position changes over time, this topic leads me to two research questions:

does the overall increase of strategic technology linkages of companies during the 1980s demonstrate a denser network of leading companies, and

to what extent is there an association between the order of companies with the most strategic links during the first and the second half of the 1980s, indicating stability in the group of major partnering companies?

Based on these questions one can first formulate the hypothesis that an intensification of strategic technology partnering during the past decade should show up in increased network densities for the sectors studied in this paper. To uncover some aspects of structural centrality of a network, I computed a network density index for each sector. This density index is defined as the ratio of the actual number of links between companies (k) to the possible number of links $1/2n(n-1)$ where n denotes the number of points in the network. For each sector the density for a group of 45 most actively cooperating com-

Table 1
A comparison of sectoral network densities for 1980–1984 and 1985–1989

	1980–84	1985–89
Automotive	0.072	0.094
Aviation/Defence	0.187	0.233
Chemicals	0.121	0.200
Heavy Electrical Equipment	0.089	0.134

panies is calculated; these groups will also be analyzed in more detail through a multi-dimensional scaling technique.

The network densities in all these sectors show a substantial increase comparing the first half of the 1980s with the second half (Table 1). The

Table 2
The top 45 companies with strategic technology links in automotive, aviation/defence, chemicals and heavy electrical equipment, 1980–1984 and 1985–1989

Automotive			
1980–1984		1985–1989	
Renault	21	General Motors Corp.	29
Fiat	20	Mitshubishi	27
Peugeot	18	Fiat	25
Volvo	16	Nissan Motor Co.	25
Mitshubishi	15	Isuzu Motors	24
Toyota Motor Corp.	14	Toyota Motor Corp.	22
Mazda Motor Co.	13	Mazda Motor Corp.	21
Nissan Motor Co.	13	Ford Motor Corp.	18
Ford Motor Co.	12	Renault	16
Honda Motor Co.	12	Chrysler Motor Corp.	15
General Motors Corp.	10	Peugeot	15
Isuzu Motors	10	Volvo	15
DAF Trucks	8	Daimler-Benz	10
Volkswagen	8	Honda Motor Co.	10
Daimler-Benz	7	DAF Trucks	9
American Motors Corp.	6	Volkswagen	9
Chrysler Motor Corp.	6	Allied Signal	8
Navistar Int.	6	Suzuki Co.	8
Suzuki Co.	6	Bosch	7
Bosch	4	Eaton Corp.	7
IRI	4	Fuji Heavy Industries	7
Kia Motors Corp.	4	Gutehoffnungzhütte Aktienverein	7
Saab-Scania	4	Sumitomo	7
Sumitomo	4	Dai-Ichi Kangyo Bank	5
Valmet	4	Olivetti	5
Borg-Warner Corp.	3	Rockwell Int. Corp.	5
Eaton Corp.	3	Tokai	5
Fuyo	3	British Aerospace	4
Lucas Industries	3	Fuyo	4
Nippon Steel Corp.	3	General Electric Co.	4
Van Doorne's Transmissie	3	Klöckner-Homboldt-Deutx	4
Cummins Engine Co.	2	Kia Motors Corp.	4
Fruehauf (K-N Corp.)	2	Masco Industries	4
Fuji Heavy Industries	2	Navistar Int.	4
Klöckner-Homboldt-Deutz	2	Nippon Steel Corp.	4
Komatsu	2	Saab-Scania	4
Masco Industries	2	Thomspon Eamo Wooldridge	4
Porsche	2	United Technologies Corp.	4
Rockwell Int. Corp.	2	Alcan Aluminium	3
Rover	2	Hyundai Corp.	3
Signal Companies	2	Lucas Industries	3
United Stirling	2	Matsushita Elect. Industrial Co.	3
United Technologies Corp.	2	Siemens	3
Valeo	2	Valmet	3
Yamaha Motor Co.	2	Van Doorne's Transmissie	3

exception is the automotive industry, where the network density has "only" increased from 7% to nearly 9.5%. In the aviation/defence industry and the chemical industry, on the other hand, one can even find rather dense networks. During the second half of the 1980s at least 20% of the theoretically possible inter-firm links between groups of leading cooperating firms in these two

Table 2 (continued)

Aviation/defence			
1980–1984		1985–1989	
Messerschmitt-Bölkow-Blohm	54	Daimler-Benz	95
Aérospatiale	31	British Aerospace	52
Daimler-Benz	24	Aérospatiale	48
Dai-Ichi Kangyo Bank	24	IRI	45
Mitsubishi	23	Thomson	38
Hughes Aircraft Co.	22	Fiat	32
Snecma	22	General Motors Corp.	31
British Aerospace	21	Mitsubishi	30
IRI	21	GEC	28
Fokker	20	Siemens	26
Thomson	19	Snecma	26
Fiat	17	United Technologies Corp.	26
McDonnell Douglas Corp.	17	Dai-Ichi Kangyo Bank	23
United Technologies Corp.	17	Fokker	22
Sumitomo	14	General Electric Co.	22
Avions M. Dassault-Breguet Aviation	12	Rolls Royce	21
EFIM	12	Boeing Aerospace Co.	20
Hitachi	12	Instituto Nacional de Industria	20
Rolls Royce	12	Ferranti	18
Société Générale	12	McDonnell Douglas Corp.	18
Ericsson	11	Sumitomo	18
General Electric Co.	11	Cie. Générale d'Électricité	17
Rockwell Int. Corp.	11	EFIM	17
Boeing Aerospace Co.	10	Ishika-Wajima Harima Co.	16
Cie. Générale d'Électricité	10	Matra	16
Fiat	10	Lockheed Corp.	15
GEC	10	Martin-Marietta Corp.	14
Montadel Laden	10	Raytheon Co.	13
Oerlikon Bührle	10	Rockwell Int. Corp.	13
Sener Ingenieria y Sistemas	10	Toshiba Corp.	13
Martin-Marietta Corp.	9	Fiat	12
Matra	9	Hitachi	12
Textron	9	Sener Ingenieria y Sistemas	12
Westland	9	Ericsson	11
Fuji Heavy Industries	8	Oerlikon Bührle	11
Ishika-Wajima Harim Co.	8	Westinghouse	10
Plessey Co.	8	Avions M. Dassault-Breguet Aviation	9
Raytheon	8	General Dynamics Corp.	9
Sonaca	8	Montadel Laden	9
Saab-Scania	7	Philips Gloeilampenfabrieken	9
Instituto Nacional de Industria	6	Int. Tel.& Telegraph Corp.	8
Siemens	6	Matsushita Elect. Industrial Co.	8
Fairchild Industries	5	Société Générale	8
Ford Motor Co.	5	Textron	7
General Dynamics Corp.	5	Sagem	6

fields are actually found. In other words, at this somewhat aggregated level of analysis one does find an overall increase of inter-firm strategic technology partnering reflected in network density indicators for a relatively large group of companies. For new core technologies, such as information technologies and new materials, the network density increase is comparable [6,7].

Turning to the second research question of this section, I refer to Table 2, which lists the 45

Table 2 (continued)

Chemicals			
1980–1984		1985–1989	
Mitsui	27	Mitsubishi	57
Dai-Ichi Kangyo Bank	26	Shell	43
Mitsubishi	25	Mitsui	40
Shell	25	Enimont	38
Sumitomo	25	Sumitomo	38
Dow Chemical Co.	20	Dai-Ichi Kangyo Bank	37
Fuyo	18	Hoechst	36
Hoechst	18	Du Pont de Nemours	35
Solvay & Cie.	17	Solvay & Cie.	34
BASF	16	Dow Chemical Co.	28
Ferruzzi	15	Fuyo	27
DSM	14	Imperial Chemical Industries	26
Imperial Chemical Industries	14	ELF Aquitaine	23
Du Pont de Nemours	13	Akzo	22
Ente Nazionale Idrocarburi	13	Allied-Signal	22
Exxon Corp.	13	BASF	20
Texaco	13	DSM	18
Union Carbide Corp.	13	Exxon Corp.	18
Bayer	12	Saudi Basic Industries Corp.	18
British Petroleum Co.	12	Bayer	17
Industrial Bank of Japan	12	Industrial Bank of Japan	17
Veba	12	Union Carbide Corp.	17
Sanwa	11	British Petroleum Co.	16
Akzo	10	General Electric Co.	18
Petrofina	10	Asahi Chemical Industry Co.	14
Asahi Chemical Industry Co.	9	Veba	14
Phillips Petroleum Co.	9	Neste	12
Saudi Basic Industries Corp.	9	ABB Asea Brown Boveri	11
Celanese Corp.	7	Occidental Petroleum Co.	11
Hercules	7	Sanwa	11
Norsk Hydro	7	Ente Nazionale Idrocarburi	10
Rhöne-Poulenc	7	Texaco	10
Signal Companies	7	Denki Kagutu Kogyo Co.	9
ELF Aquitaine	6	Japan Synthetic Rubber Co.	9
Toyo Soda Corp.	6	Monsanto Co.	9
Cie. Française de Pétrol	5	Petrofina	9
Fujisawa Pharmaceutical	5	Rio Tinto-Zinc Corp.	9
JGC Corp.	5	Atlantic Richfield Co.	8
Monsanto Co.	5	Continental	8
Nissan Motor Co.	5	Hercules	8
Occidental Petroleum Co.	5	Kyowa Hakko Kogyo	8
Pirelli	5	Norsk Hydro	8
Raytheon Co.	5	Toyo Soda Corp.	8
Amoco	5	Olin Corp.	7
WE Grace	5	Amoco	7

companies with most strategic links in each sector during the first and the second half of the 1980s. For each sector it is obvious that many of the leading companies are well represented. The hierarchy of leading cooperating companies does change over time, but the firms found on the list for the first half of the 1980s that are also part of the top 45 during the second half remains re-

Table 2 (continued)

Heavy electrical equipment			
1980–1984		1985–1989	
Hitachi	25	ABB Asea Brown Boveri	51
Toshiba Corp.	21	Siemens	36
Dai-Ichi Kangyo Bank	17	Hitachi	25
Ishika-Wajima Harima Co.	16	Toshiba Corp.	25
Mitsubishi	14	Westinghouse	24
Siemens	13	Mitsui	22
Mitsui	12	Mitsubishi	21
Westinghouse	12	McDermott Int.	17
Bechtel	11	Cie. Générale d'Électricité	16
Int. Tel.& Telegraph Corp.	11	General Electric Co.	16
General Electric Co.	10	Mannesmann	15
McDermott Int.	9	Ishika-Wajima Harima Co.	14
Brown Boveri & Co.	7	Bechtel	13
Northern Engineering Industries	7	Fuyo	13
Sanwa	7	Sulzer	13
Allis-Chalmers Corp.	6	Daimler-Benz	12
Asea	6	Dai-Ichi Kangyo Bank	11
Babcock Int.	6	GEC	11
Ente Nazionale Idrocarburi	6	Framatome	10
Energie & Verfahrungstechnik	6	IRI	9
Fuyo	6	Shell	8
Nobel Industries	6	Thyssen	8
Texaco	6	British International Cable Corp.	7
British International Cable Corp.	5	Chiyoda	7
Cie. Générale d'Électricité	5	Fiat	7
Combustion Engineering	5	Korea Electric Power Corp.	7
Electrobel	5	Rolls Royce	7
Fiat	5	Sanwa	7
GEC	5	Allis-Chalmers Corp.	6
Shell	5	Electrobel	6
Sulzer	5	Int. Tel.& Telegraph Corp.	6
Sumitomo	5	Korea Heavy Industries & Construct.	6
Tractebel	5	Texaco	6
VMF-Stork	5	Tractebel	6
Volvo	5	Babcock Int.	5
AEG	4	Gutehoffnungshütte Aktienverein	5
Atlantic Richfield Co.	4	Société Générale	5
Elektro Sandberg	4	Spie Batignolles	5
Fluidcarbon Int.	4	VMF-Stork	5
Friedrich Flick Industrie	4	Cogema	4
IRI	4	Energie & Verfahrungstechnik	4
Messerschmitt-Bölkow-Blohm	4	Metallgesellschaft	4
Thyssen	4	Nobel Industries	4
Framatome	3	Sumitomo	4
Société Générale	3	Volvo	4

Source: MERIT/CATI.

markably high. For instance, for the automotive sector the percentage of 'stayers' is 73%, for aviation and defence it is 80%, for chemicals it is 73% and for the sector of heavy electrical equipment it is 76%. If Spearman rank correlations are calculated, comparing the rank order during the first half of the 1980s with the second half, one finds relatively high and significant correlations. The rank correlation for leading cooperating firms in the automotive industry is 0.61, for aviation/

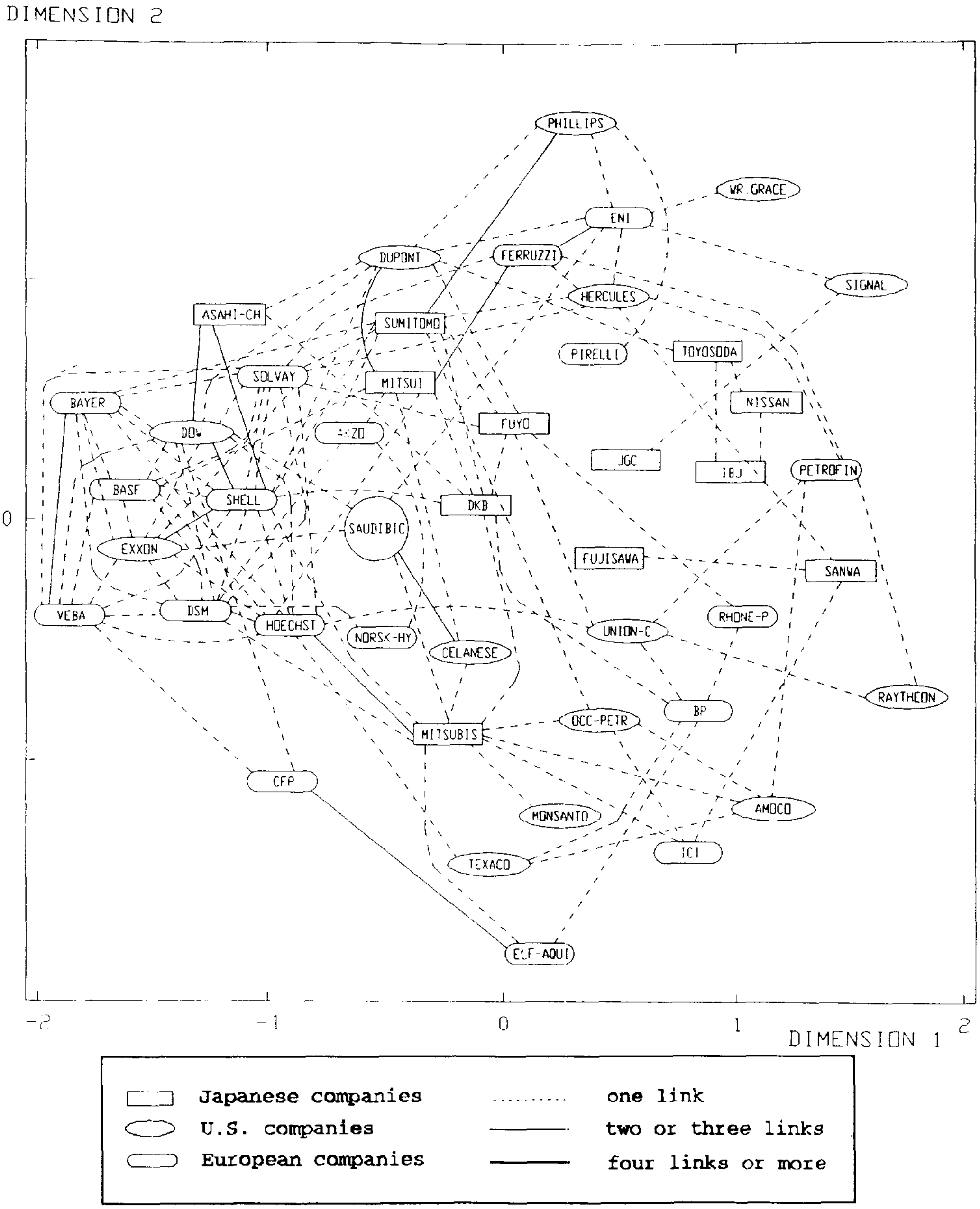

Fig. 2(a). The strategic technology relations among the 45 most intensely cooperating companies in the chemicals sector, 1980–1984.

defence it is 0.46, for chemicals it is 0.57, for heavy electrical equipment it is 0.32. The correlations for all these fields are significant at the 0.01 level, with the exception of heavy electrical equipment where the rank correlation is significant at the 0.05 level. In other words, some companies change position in the rank order, others leave or enter the group of leading cooperating firms, but on the whole networks of leading technology partnering firms in these four sectors appear to be relatively stable configurations.

In order to expand on the analysis presented

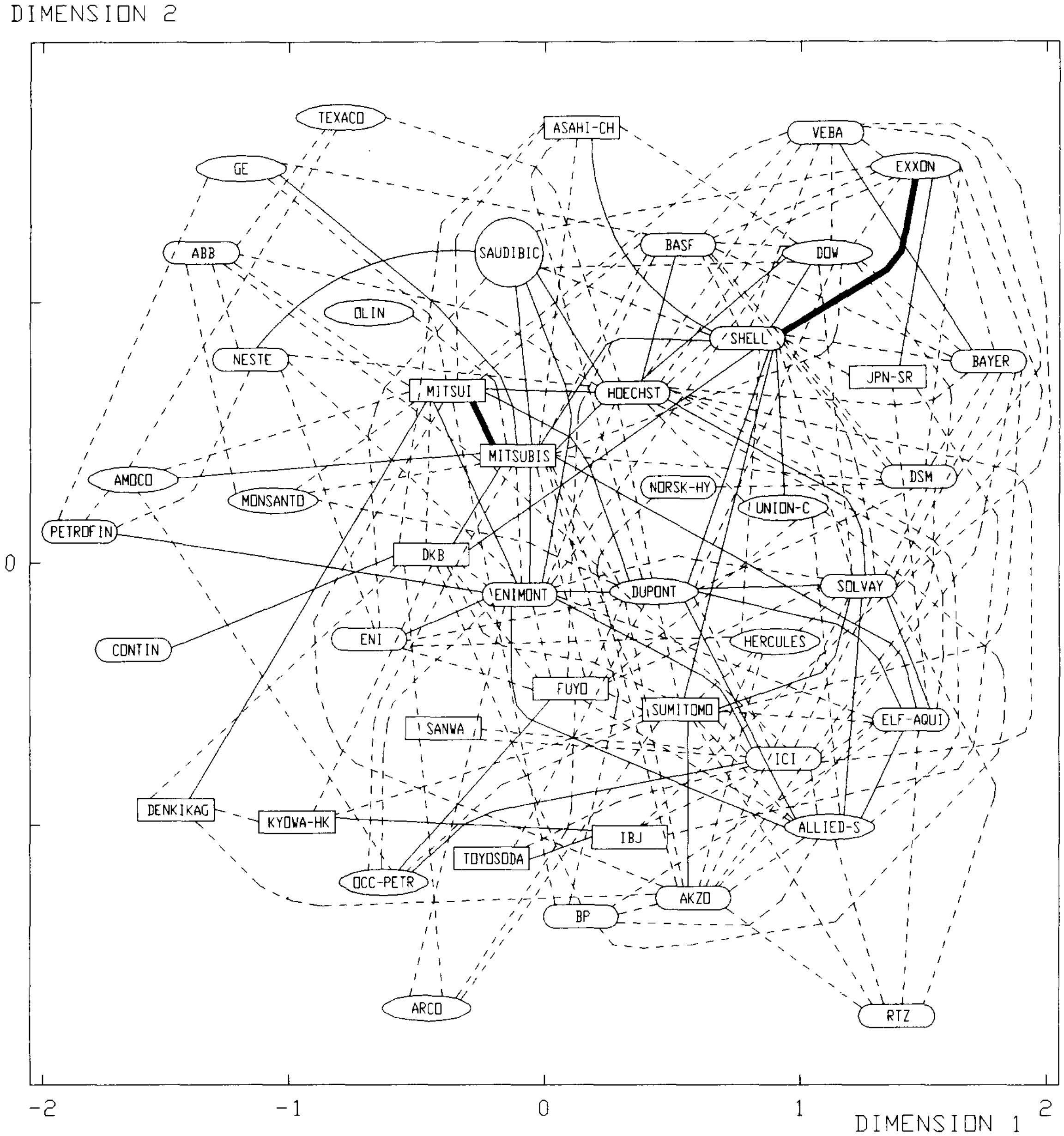

Fig. 2(b). The strategic technology relations among the 45 most intensely cooperating companies in the chemicals sector, 1985–1989. For legend, see Fig. 2(a).

above and to give some further details about increased partnering behaviour by firms, a non-metric multidimensional scaling (MDS) technique is used [8,12]. Such a graphical representation of the sectoral networks of cooperating companies with some simple additional tools can give a concrete overview of network structures that complements network density indicators that underestimate the actual density owing to the neglect of multiple inter-firm linkages. MDS is a data reduction procedure comparable to principal component analysis and other factor-analytical methods. One of the main advantages of MDS is that it can fit an appropriate model in fewer dimensions than factor-analytical methods. This increases the possibility of easy interpretable two-dimensional pictures. MDS offers scaling of similarity data into points lying in an X-dimensional space. The purpose of this method is to provide coordinates for these points in such a way that distances between pairs of points fit as closely as possible to the observed similarities. In order to facilitate interpretation the solution is given in two dimensions, provided that the fit of the model is acceptable. A stress value indicates the goodness-of-fit of the configuration. For all MDS solutions presented in this paper the stress values range from acceptable to good. [1] Since it is technically impossible to picture all firms in each sectoral network, the analysis is restricted to the interrelations of the 45 firms having the most ongoing strategic linkages in a given period. MDS solutions are presented for two time intervals, 1980–1984 and 1985–1989. For the first period I have taken all linkages established in that particular period plus those linkages made before 1980 that, as far I know, were not already discontinued in 1980. For the second period, the years since 1985, the same procedure is followed: all linkages forged in that period plus those linkages from earlier years which were not already terminated before 1985 are taken together. Since the analysis is at the parent company level, alliances of subsidiaries and divisions are assigned to the parent company. Also within each period, the still existing alliances of companies taken over by others or partnerships made by merging companies are assigned to the acquiring or the newly established firm.

To improve the interpretation of the pictures, it is useful to draw lines of different shapes between companies, indicating different degrees of cooperation intensity; for company codes see Appendix B.

3.1. Chemicals

In the 'chemicals' network of the 1980–1984 period American, Japanese, and European corporations are rather randomly distributed without a strong regional clustering (see Fig. 2(a)). Many firms are involved in international clusters. Only a few important ties will be mentioned: Montedison (Ferruzzi) and Hercules created Himont, which was dissolved again in 1987. Phillips Petroleum and Sumitomo worked together on LPE production processes, Ferruzzi and Mitsui on catalysts, Du Pont and Mitsui on fluorochemicals, Bayer and Sumitomo on urethane. Many alliances deal with expensive new process technologies, and therefore also include engineering firms. An example of a large consortium is 'Aethylen Rohrleitungsgesellschaft', in which DSM, Bayer, Veba, BASF, Solvay, Dow, Hoechst, Shell and Exxon participate.

In the second half of the 1980s (see Fig. 2(b)) the many newly created alliances resulted in a much more dense network structure. Again, only a few of the more important developments are mentioned. For instance, Ferruzzi and ENI merged their petrochemical interests to form Enimont. This was followed by a large restructuring and upgrading of chemical and pharmaceutical activities in which a large number of third companies got involved, such as ICI (resulting in a joint

[1] The stress values in the MDS analyses range from acceptable to good, as indicated in the following table.

	1980–1984	1985–1989
Automotive.	0.068	0.075
Aviation/Defence.	0.082	0.096
Chemicals.	0.076	0.113
Heavy Electrical Equipment.	0.039	0.078

venture in PVCs), Du Pont (pharmaceuticals) and Arco (elastomers). Other examples of intensely cooperating companies are Saudi Arabia Basic Industries Corporation (SABIC) which forged links amongst others with Hoechst, Exxon, ENI, Shell, Neste, Dow Chemical and Mitsubishi. General Electric Plastics (GEP) started a joint venture with a Mitsubishi affiliate, Asahi Glass, on polycarbonate sheet and film. Mitsui established ties with Mitsubishi, Denki Kagatu, General Electric, and Monsanto. Another example of multi-firm cooperation is a joint research pact on CFC alternatives, established by Akzo, Allied-Signal, ELF, Du Pont, Solvay, and RTZ.

Detailed analysis of the data not reproduced in this paper suggests that increased cooperation in this sector is caused by a relatively large number of research pacts aimed at innovative research on chemistry and process engineering together with joint restructuring and upgrading op-

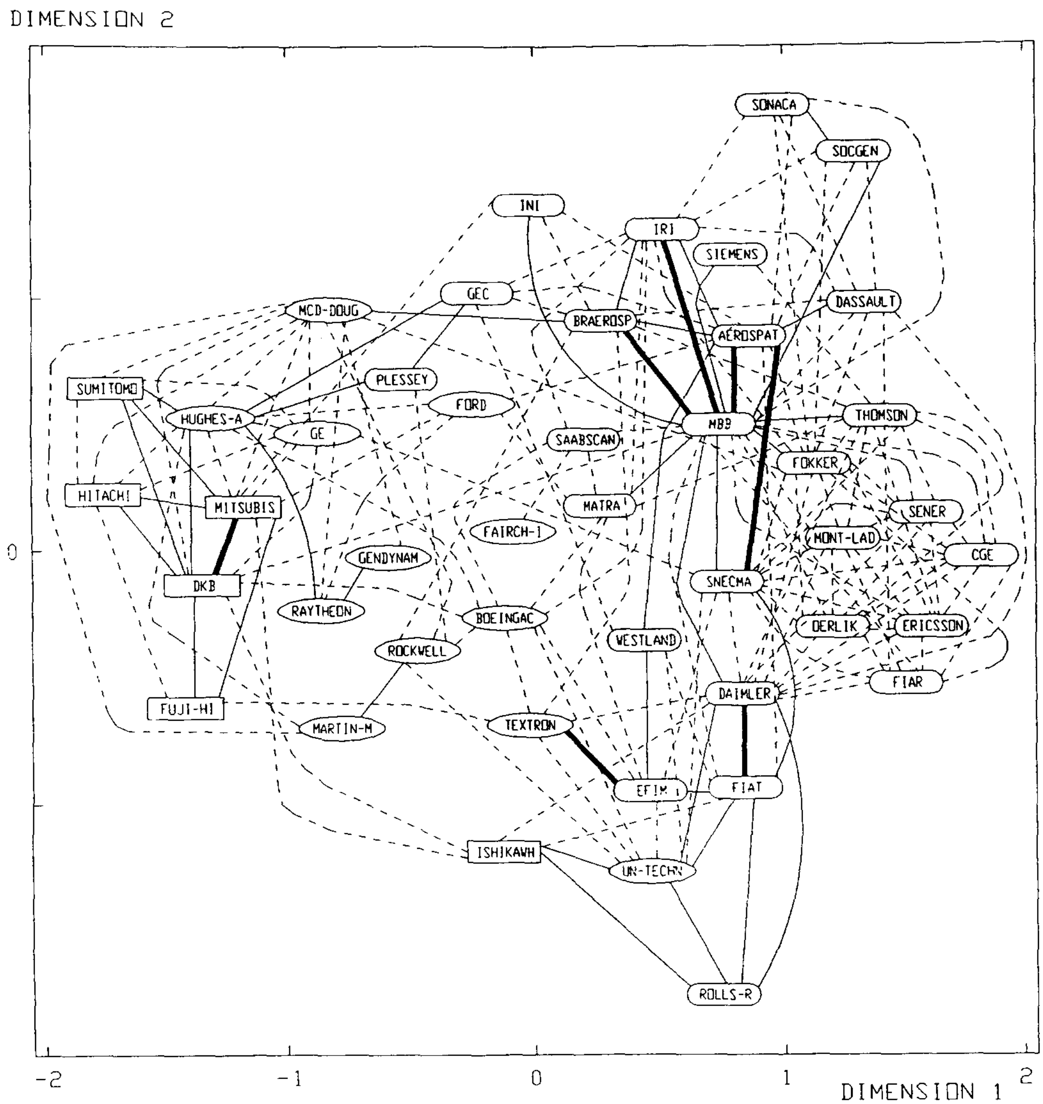

Fig. 3(a). The strategic technology relations among the 45 most intensely cooperating companies in the aerospace/defense sector, 1980–1984. For legend, see Fig. 2(a).

erations involving many new process technologies. This has resulted in a dense network of cooperating firms during the second half of the 1980s in which many firms have a comparable network centrality.

3.2. Aviation / defence

During the first half of the 1980s (see Fig. 3(a)) there are already a large number of cooperating European companies in the aviation and defence sector. Some Japanese corporations can also be found in the top list of intensely cooperating companies (see also Table 2). American companies, which are world leaders in such areas as civil and military aircraft, are present but not in a dominant way (McDonnell Douglas, General Dynamics, Boeing, United Technologies), whilst others such as Lockheed are even missing.

During the first half of the decade there are

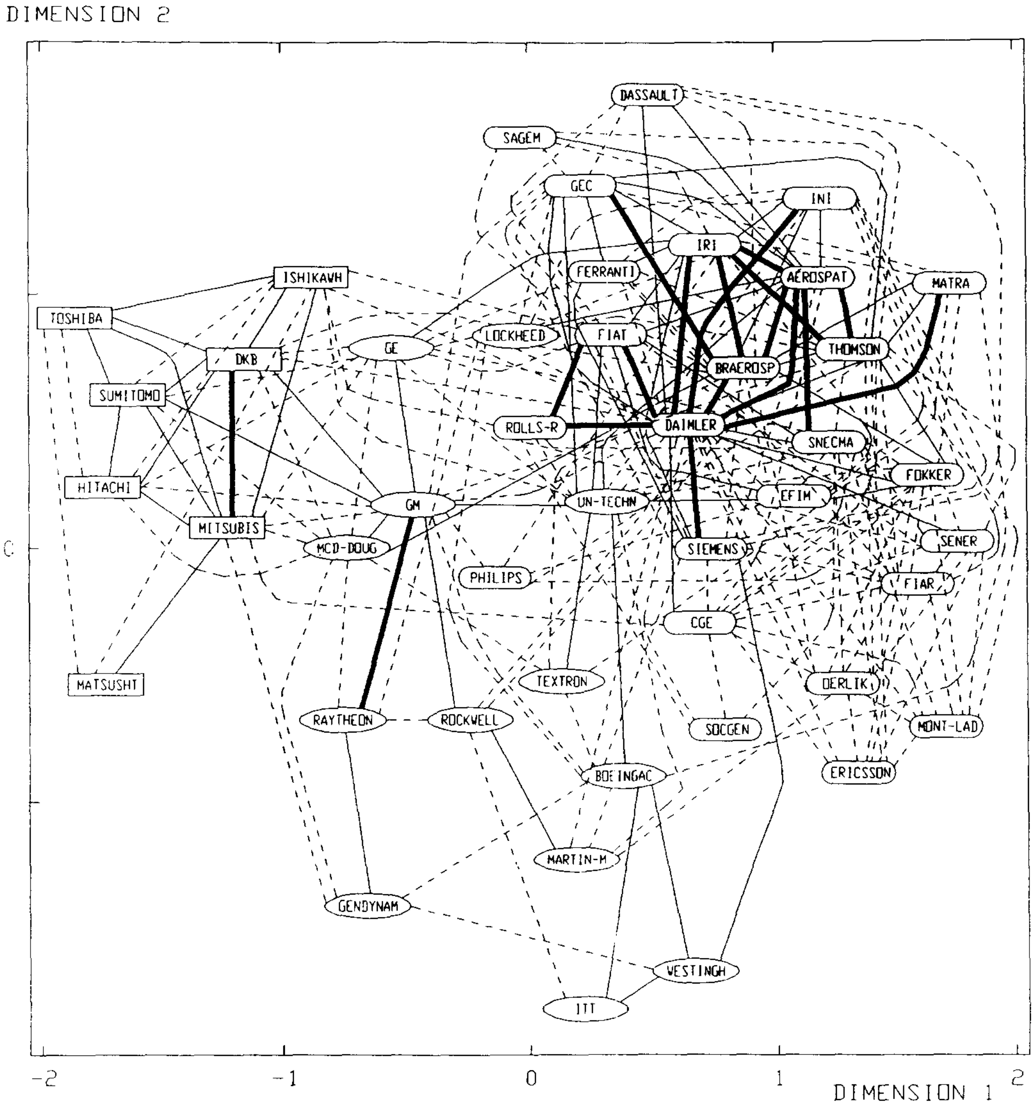

Fig. 3(b). The strategic technology relations among the 45 most intensely cooperating companies in the aerospace/defense sector, 1985–1989. For legend, see Fig. 2(a).

already four important Japanese consortia: Japan Aero Engines, International Aero Engines, Japan Aircraft Development Corporation, and Japan Communications Satellite. These consortia have often linked up with US and European partners (Boeing, Hughes Aircraft, Rolls Royce). Some of them started participating in large, risk-sharing aircraft programmes, such as Boeing's 767 and later on, 7J7 programmes. Important European joint development and manufacturing projects are:

– the ATR aircraft project of Italian Aeritalia

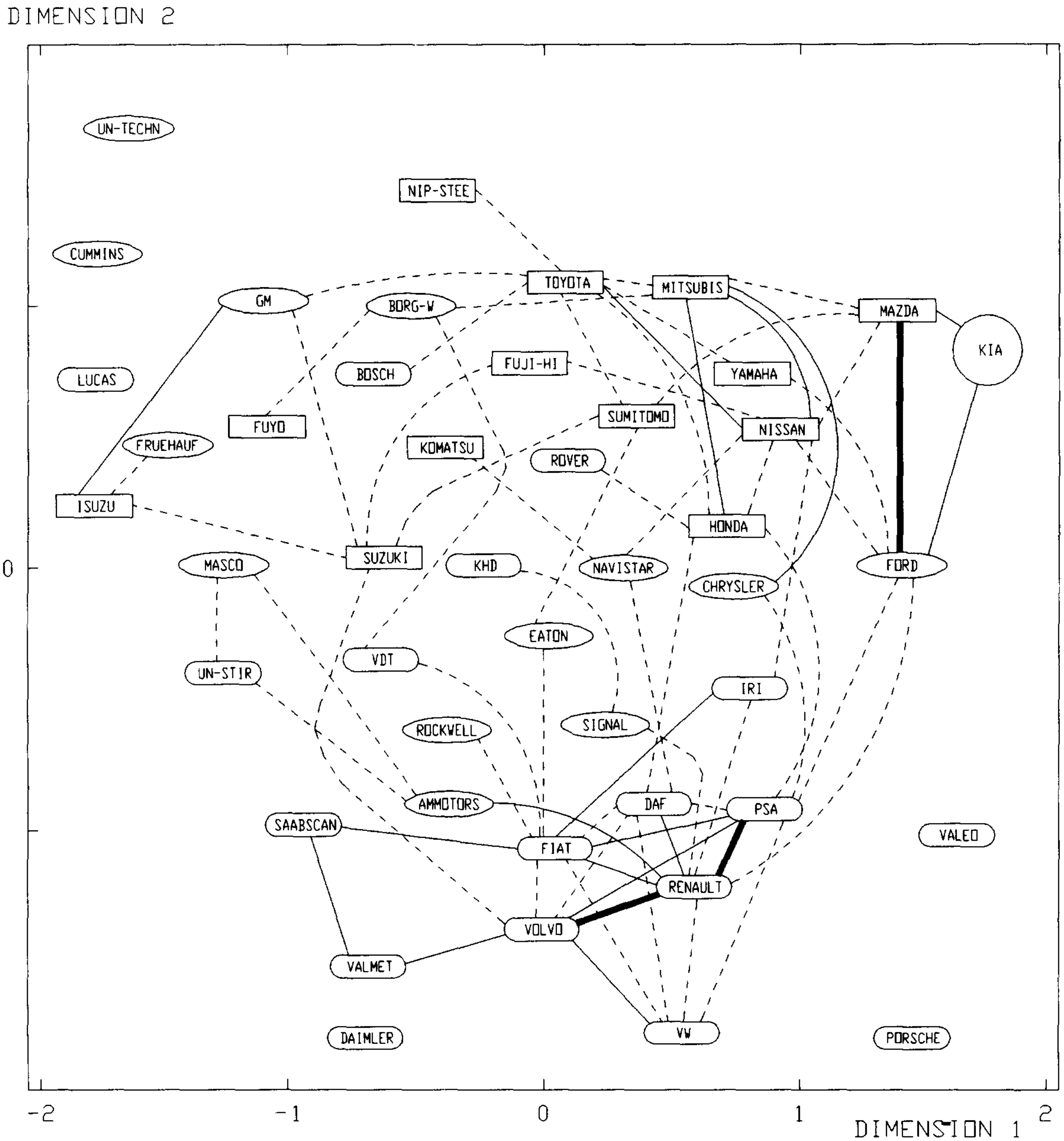

Fig. 4(a). The strategic technology relations among the 45 most intensely cooperating companies in the automotive sector, 1980–1984. For legend, see Fig. 2(a).

(part of the IRI group) and the French firm Aérospatiale;
- European Helicopters Limited of Agusta (EFIM group) and Westland;
- Panavia and Turbo-Union (both to build the Tornado combat aircraft);
- Airbus Industrie (of Aérospatiale, British Aerospace, CASA, and a German consortium headed by MBB);
- Euromissile;
- United Satellites, a joint venture of BT, GEC/Marconi and British Aerospace;

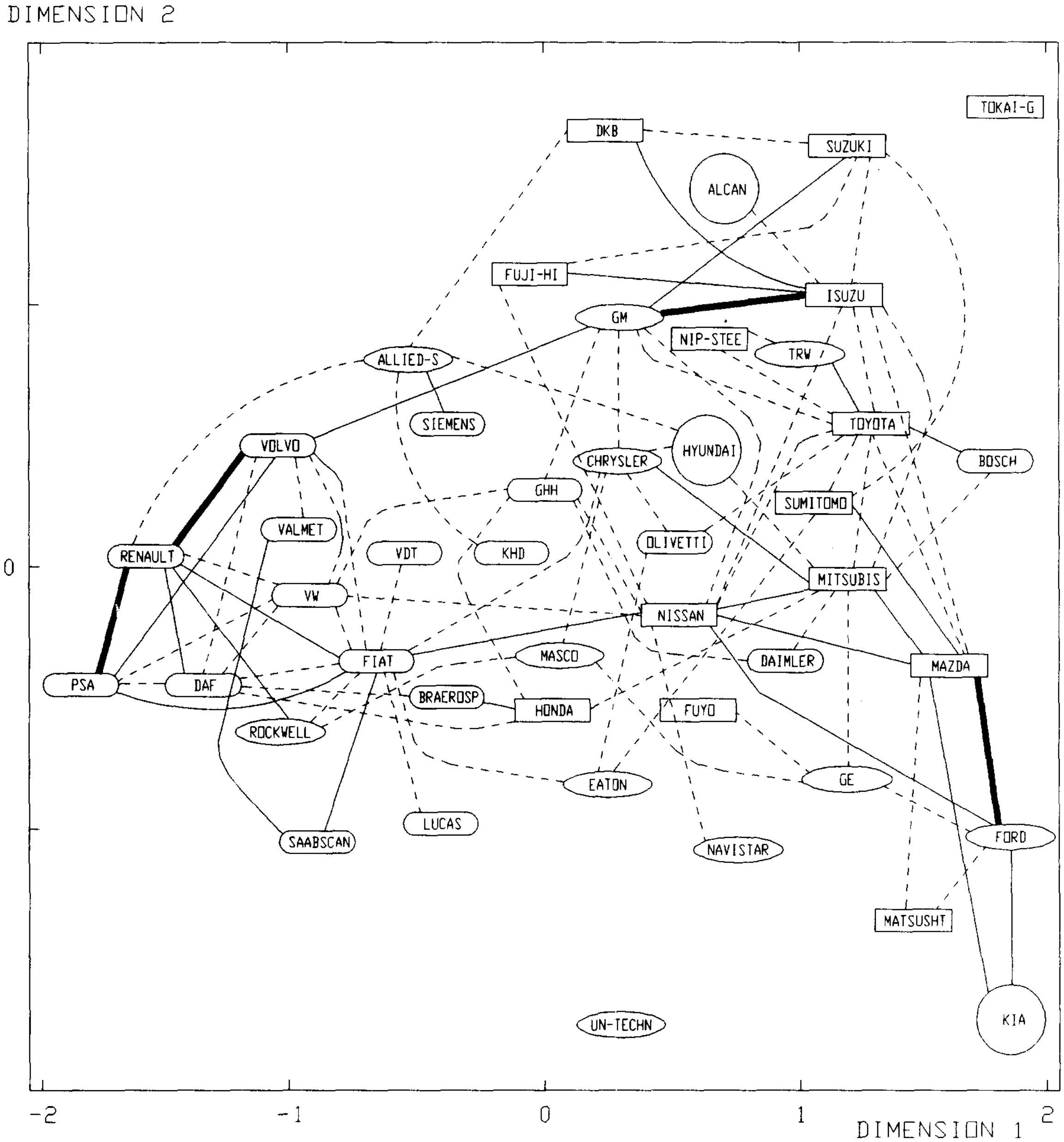

Fig. 4(b). The strategic technology relations among the 45 most intensely cooperating companies in the automotive sector, 1985–1989. For legend, see Fig. 2(a).

– the Lynx and Gazelle helicopter projects of Westland and Aérospatiale.

Furthermore, there are many huge bidding consortia as well as relatively small tie-ups and strategic cross-holdings in the European defence and aerospace industry, in particular in the UK, Belgium, France, and Italy. In Germany Daimler and MBB play a leading role. Examples of US–European alliances are CFM, the aero-engines joint venture of GE and Snecma, and Saab-

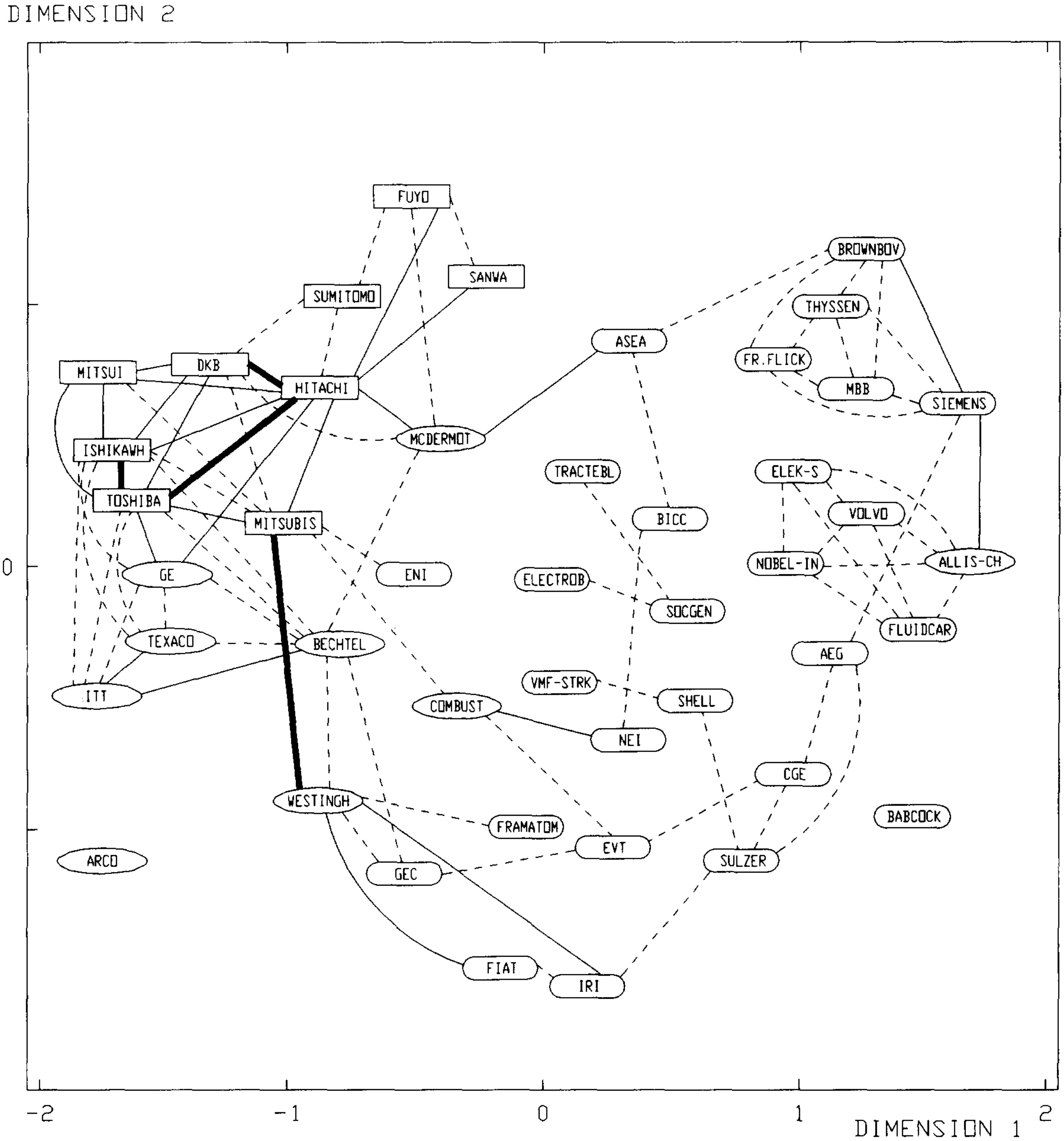

Fig. 5(a). The strategic technology relations among the 45 most intensely cooperating companies in heavy electrics, 1980–1984. For legend, see Fig. 2(a).

Fairchild, which built turboprop aircraft (this joint venture collapsed in 1985). US firms frequently teamed up in order to develop and build missiles, such as the AGM missile family, Raytheon and Hughes Aircraft, Rockwell and Martin-Marietta, and General Dynamics–Raytheon.

In the years 1985–1989 (see Fig. 3(b)) the network has been influenced by important takeovers: GM acquired Hughes Aircraft, Daimler got control over MBB, and United Technologies bought Westland. In this period many new aircraft, aviation, and defence joint projects were

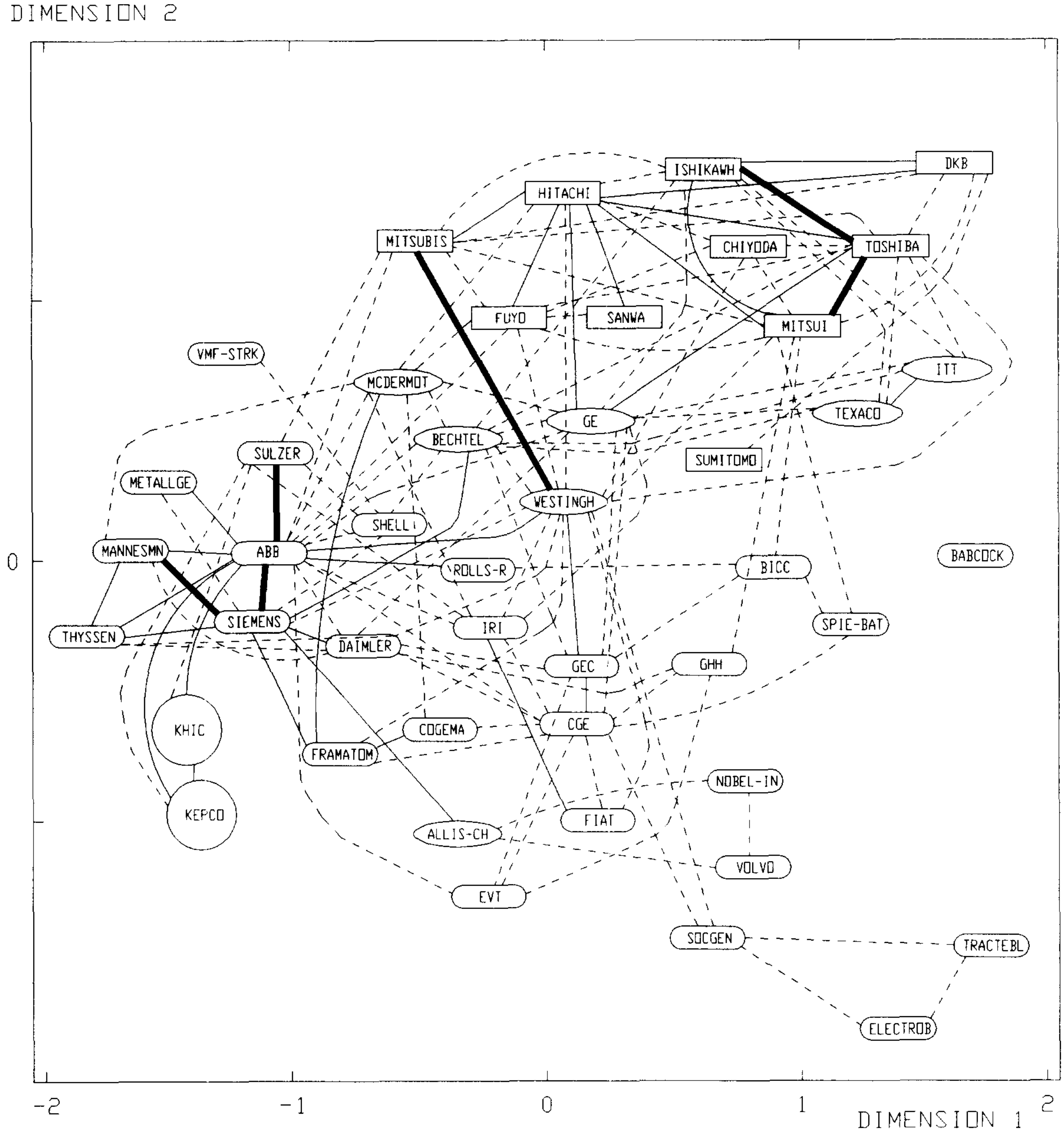

Fig. 5(b). The strategic technology relations among the 45 most intensely cooperating companies in heavy electrics, 1985–1989. For legend, see Fig. 2(a).

started, but often by the same groups or consortia. In Europe particular the number of cross-holdings increased. The increased network density mentioned above is also found in Fig. 3(b) where one can see that European companies have substantially increased their inter-firm linkages.

3.3. Automotive

In the years 1980–1984 the top of the network for the automotive sector covers leading car and truck manufacturers as well as some large suppliers, but it is obvious that strategic technology partnering has not led to a dense network (see Fig. 4(a)). Somewhat denser European and Japanese clusters can be found; the former includes Fiat, PSA, Renault, Volvo, etc. while Mitsubishi, Toyota, Mazda, Nissan, and Honda form the core of the Japanese cluster. An American equivalent is missing as the leading US car producers (GM, Ford, Chrysler, American Motors) take highly divergent positions in the network. American Motors teamed up with Renault, GM with Isuzu, Suzuki, and Toyota, Chrysler set up Diamond-Star Motors with Mitsubishi, while Ford cooperated intensely with Mazda. United Stirling and VDT are small innovative companies which attracted attention from large corporations through partnerships.

In the second half of the 1980s (see Fig. 4(b)) the European cluster still operates, whilst the Japanese subgroup has disintegrated somewhat, primarily because of new international linkages of Honda and Nissan. The leading American car makers, GM, Ford, and Chrysler still act independently of each other as far as their core activities are involved (except one link between GM and Chrysler: Chrysler's subsidiary Acustar is involved in a components joint venture with GM). There is also the emergence of suppliers such as Alcan, Siemens and Matsushita. The latter, for instance, teamed up with Mazda and Ford in order to develop and produce car air-conditioning and heating units. Siemens and Allied-Signal signed an agreement jointly to develop, manufacture and sell new products to the world motor industry. Other companies got network positions owing to take-overs, such as Olivetti which acquired French Valeo, and British Aerospace which got control over major parts of the Rover Group.

This disaggregated analysis of inter-firm networks confirms the findings on network density in the sense that the international automotive industry is less dense in terms of the multiplicity of inter-firm strategic technology alliances than the other sectors discussed in this paper.

3.4. Heavy electrical equipment

The international heavy electrical equipment sector is characterized by moderate partnering intensity during the first half of the 1980s which increased substantially during the second half of the 1980s. During the first half of the 1980s, Japanese industrial groups together with companies such as Toshiba and Hitachi form a clear separate block in the industry. These Japanese companies frequently work together as co-developers and consortium members in such areas as railway equipment and power generation (Fig. 5(a)). Some Japanese companies have strong ties with American companies, for instance Hitachi and in particular Mitsubishi, which maintains a broad array of ties with Westinghouse. Many of the other European and US companies have individual tie-ups with a small number of partners. Siemens is an example of a European firm with a higher degree of network centrality through its alliances with AEG, Allis-Chalmers, Brown-Boveri, MBB and Thyssen.

In the years after 1984 many restructuring activities have taken place in this industry which are also reflected in the strategic partnering behaviour of many of the leading firms. Particularly in Europe, strategic technology partnering in fields such as nuclear energy, railway equipment and heavy electrical equipment involving companies such as AEG, MBB (both controlled by Daimler), Brown-Boveri, Asea (now Asea Brown-Boveri), CGE, GEC, Siemens, and IRI play a crucial role (see Fig. 5(b)). Some examples of recent tie-ups are:

– in 1988 Britain's GEC and French CGE combine their interests in power generation, electricity and railway equipment in a new company, GEC-Alstom;

– GEC, CGE, and GE create a joint venture to develop, produce and sell gas turbines;

– GEC's Belgian Vynckier unit and GE's Italian COGENEC merge to form a new firm which will develop and produce a broad range of electrical items;

– ABB and Siemens (through KWU) design and construct low capacity high temperature reactors and develop railway signalling equipment;

– Siemens and Framatome combine their nuclear power industries, cooperate in related fields such as nuclear fuel reprocessing, and plan future generations of nuclear reactors;

– ABB merges its Italian industrial assets with units of Finmeccanica (IRI) to streamline Italy's electrical engineering industry;

– ABB and Rolls-Royce combine their expertise on gas turbines.

Fig. 5(b) also indicates that during the second half of the 1980s the Japanese industrial groups and leading US firms in heavy electrics (ITT, Westinghouse, GE) maintained their network positions within a clearly more dense network of alliances. In particular the Japanese companies in this sector form a clear "cluster" with a substantial number of national partnerships.

4. Conclusions

In a recent contribution by Parkhe [11] it is suggested that a major problem for research on international joint ventures, and I assume also for strategic alliances, is the lack of a strong theoretical framework that facilitates the understanding of inter-firm cooperation. This shortcoming is reflected in both the strategic management and the industrial economics literature-related aspects of this topic. The present contribution reflects this problem as the explanatory framework is still limited and the core of the contribution is found in the empirical and largely descriptive content of the paper. Nevertheless, some interesting conclusions from the present line of investigation can be drawn.

In previous work I presented an analysis of some of the characteristics of the inter-sectoral differentiation of strategic technology partnering and the sectoral determinants of corporate partnering behaviour [3]. A major finding of that analysis for a large number of industries is that the R&D intensity or the level of technological sophistication of sectors is positively correlated with the technology partnering intensity of sectors. In particular for new core technologies, such as information technologies, biotechnology and new materials, inter-firm strategic technology partnering seems related to the emergence of new technological paradigms. The development of these new technological paradigms demands the wider application of a range of technological capabilities that often go beyond the existing technological strength of individual firms. Exploring technological complementarities of companies through inter-firm cooperation becomes a viable and often necessary option in a world of increased international competition and rapid technological change. In that sense the dynamics of technological and economic development in sectors affected by new core technologies to a large extent appears to explain the notable role played by these fields, which cover about 70% of all strategic technology alliances made during the 1980s.

Although technology partnering in the new core technologies has attracted most public attention, the impact of this aspect of corporate behaviour on a wider range of sectors of industry should not be neglected. The internationalisation of the economy, increased competition through innovation and the general national and international restructuring of industries also affects the four sectors studied above. The analysis so far demonstrates that there, too, this phenomenon has clearly become more important since the second half of the eighties. As it has become so widespread, affecting so many companies, strategic technology partnering is expected to remain an important aspect of corporate behaviour for a substantial period of time. The absence of a long history of alliance-building and also the smaller numbers of partnerships in some sectors could indicate less pervasive experience of large groups of companies in these fields. This lack of experience or the early stages of learning to manage alliances could positively affect the propensity of firms to engage in technology partnerships owing to a certain degree of "naivety". Future research with longer time-series is necessary to provide more insight into the effect that both positive and negative experience will have on corporate partnering behaviour, in the sense that exposure to partnering makes companies somewhat more selective in their use of strategic partnerships.

So far, the growth of strategic technology partnering seems to have led to an increase of the partnering density among a relatively large group of companies. Important market structural factors in this context are the dominance of companies from the USA, Japan, and Europe (the Triad) and the significant role that is played by many of the leading multinational companies. The analysis of the four sectors in this paper suggests that the dominance of the Triad has not necessarily led to a truly internationalisation of partnerships. In particular, for sectors such as the aviation/defence industry and heavy electrical equipment, a clear number of in particular Japanese, but also US and European, blocks of partnering firms can be identified. For the automotive and chemical industries, strategic technology partnering seems to have become less clustered within regions of the Triad. An explanation for these differences could be found in the "globalisation" of markets and production for chemicals and motorcars and the like, whereas manufacturing-related activities in the aviation/defence and automotive industries are still more closely linked to their region of origin.

Although inter-firm networks have become more dense and also exhibit a large degree of stability, one cannot interpret these findings in terms of "closed shops". There is too much movement, as in each sector companies leave and enter the group of leading cooperating firms. Such findings are generated both at the more aggregate level and in the detailed studies of corporate networks as well as in the analysis of the role of nodal companies in sectoral patterns of partnering. As this supports previous findings on the structure of strategic technology partnering in new core technologies, I conclude that a number of traits of inter-firm technology cooperation, as it developed during the 1980s, are clearly of a general character. This implies that strategic technology partnering is manifest in a large number of sectors of industry and fields of technology, where its growth has led to tighter networks of cooperation. In these networks nodal companies increasingly weave webs with a large number of partners through a wide variety of inter-organizational modes of cooperation such as joint ventures, joint R&D pacts, and technology-sharing agreements. The "open" character of these networks, with some degree of stability, indicates the dynamic character of the partnering behaviour of many leading companies that use their alliances as part of a wider competitive strategy. Given the modest objective of the present contribution it is obvious that only a few trends and structural determinants of strategic technology partnering were studied. Substantial future research is necessary to further improve our understanding of what clearly has become an important aspect of current corporate behaviour.

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Appendix A. The Cooperative Agreements and Technology Indicators (CATI) information system

The CATI databank is a relational database which contains separate data files that can be linked to each other and provide aggregate, disaggregated and combined information from several files. So far, information on nearly 10 000 cooperative agreements involving some 3500 different parent companies has been collected. Systematic collection of inter-firm alliances started in 1986. If available, many sources from earlier years were consulted, enabling us to take a retrospective view. In order to collect inter-firm alliances we consulted various sources, of which the most important are 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 we did not register when surveying alliances.

This method of information gathering, which one might call "literature-based alliance counting", has its drawbacks and limitations.

(1) In general we have only come to know those arrangements that are made public by the companies themselves.

(2) Newspaper and journal reports are likely to be incomplete, especially when they go back in history and/or consider firms from countries outside the scope of the journal. Furthermore, in earlier years some journals simply did not exist, whilst existing periodicals might grasp the collaboration subject less thoroughly.

(3) A low profile of small firms without well-established names is likely to have their collaborative links excluded.

(4) Some journals emphasize fashionable items, such as superconductivity or high definition television (HDTV), while interest in "outdated" topics, such as solar and wind energy, seems to fade away.

(5) The fact that we read mainly articles written in English probably causes some bias and distortion as well.

(6) Another problem is that information about the dissolution of agreements is not systematically published. This is in particular true for licensing and customer–supplier relationships. On the other hand, research contracts and joint product developments have often disclosed time schedules. Equity joint venture and dissolutions of investments are published fairly systematically in specialized journals.

(7) One final problem is that the number of customer–supplier relations and licensing agreements is subject to great underestimation, owing to the fact that these more casual agreements are little reported publicly, even in the professional literature.

Altogether, these handicaps in the first place lead to a skewed distribution in the distribution of modes of cooperation, followed by some geographic, i.e. Anglo–Saxon, bias. Next, one has to reckon with a possible underestimation of certain technological fields and finally, there is some over-representation of large firms.

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. Some of the weaknesses of the database can easily be evaded by focusing on the more reliable parts, such as strategic alliances.

The databank 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, second-sourcing and licensing agreements 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 on 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. We are discussing 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, partnerships are omitted 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 regard as relevant input of information for each alliance: the number of companies involved; names of companies (or important subsidiaries); year of establishment, time–horizon, duration and year of dissolution; capital investments and involvement of banks and research institutes or universities; fields of technology; modes of cooperation and some comment or available information about progress. Depending on the actual form of cooperation we collect information on the operational context; the name of the agreement or project; equity sharing; the direction of capital or technology flows; the degree of participation in the case of minority holdings; some information about motives underlying the alliance and the character of cooperation, such as basic research, applied research, or product development possibly associated with production and/or marketing arrangements. In some cases we also indicate who has benefitted most from the agreement.

Appendix B

A full listing of companies appearing in the MDS networks

Company label	Name of company	Country
ABB	ABB Asea Brown Boveri AG	SWI
AEG	AEG	FRG
AÉROSPAT	Aérosnatiale (SNIAS)	FRA
AKZO	Akzo NV	NET
ALCAN	Alcan Aluminium Ltd	CAN
ALLIED-S	Allied-Signal Inc	USA
ALLIS-CH	Allis-Chalmers Corp.	USA
AMMOTORS	American Motors Corp. (AMC)	USA
AMOCO	Amoco (Standard Oil-Indiana)	USA
ARCO	ARCO (Atlantic Richfield Co.)	USA
ASAHI-CH	Asahi Chemical Industry Co. Ltd.	JPN
ASEA	Asea AB	SWE
BABCOCK	Babcock Int. Plc	UK
BASF	Basf AG	FRG
BAYER	Bayer AG	FRG
BECHTEL	Bechtel Group Inc	USA
BICC	British International Cable Corp.	UK
BOEINGAC	Boeing Aerospace Co.	USA

Appendix B (continued)

Company label	Name of company	Country
BORG-W	Borg-Warner Corp.	USA
BOSCH	Bosch GmbH	FRG
BP	British Petroleum Co. Ltd	UK
BRAEROSP	British Aerospace Plc	UK
BROWNBOV	Brown Boveri&Co. AG (BBC)	SWI
CELANESE	Celanese Corp. (Hoechst Celanese)	USA
CFP	Cie. Francaise de Pétrol (CFP) SA	FRA
CGE	Cie. Générale d'Électricité (CGE)	FRA
CHIYODA	Chiyoda Group	JPN
CHRYSLER	Chrysler Motor Corp.	USA
COGEMA	Cogema SA	FRA
COMBUST	Combustion Engineering Inc. (C-E)	USA
CONTIN	Continental AG	FRG
CUMMINS	Cummins Engine Co.	USA
DAF	DAF Trucks NV	NET
DAIMLER	Daimler-Benz AG	FRG
DASSAULT	Avions N. Dassault-Breguet Aviation	FRA
DENKIKAG	Denki Kagatu Kogyo Co. Ltd	JPN
DKB	Dai-Ichi Kangyo Bank (DKB) Group	JPN
DOW	Dow Chemical Co.	USA
DSM	DSM NV	NET
DUPONT	Du Pont de Nemours	USA
EATON	Eaton Corp.	USA
EFIN	EFIN	ITA
ELECTROB	Electrobel SA	BEL
ELEK-S	Elektro Sandberg	SWE
ELF-AQUI	ELF Aquitaine	FRA
ENI	Ente Nazionale Idrocarburi (ENI)	ITA
ENIMONT	Enimont SpA	ITA
ERICSSON	Ericsson AB	SWE
EVT	Energie&Verfahrungstechnik GmbH	FRG
EXXON	Exxon Corp.	USA
FAIRCH-I	Fairchild Industries Inc	USA
FERRANTI	Ferranti Plc	UK
FERRUZZI	Ferruzzi SpA	ITA
FIAR	Fiar SpA	ITA
FIAT	Fiat SpA	ITA
FLUIDCAR	Fluidcarbon Int. AB	SWE
FOKKER	Fokker NV	NET
FORD	Ford Motor Co.	USA
FRAMATON	Framatoma SA	FRA
FRUEHAUF	Fruehauf (K-H Corp.)	USA
FR.FLICK	Friedrich Flick Industrie KGaA	FRG
FUJISAWA	Fujisawa Pharmaceutical	JPN
FUJI-HI	Fuji Heavy Industries Ltd	JPN
FUYO	Fuyo Group	JPN
GE	General Electric Co. (GE)	USA
GEC	GEC	UK
GENDYNAM	General Dynamics Corp.	USA
GHH	Gutehoffnungshütte Aktienverein AG	FRG

Appendix B (continued)

Company label	Name of company	Country
GM	General Motors Corp.	USA
HERCULES	Hercules Inc	USA
HITACHI	Hitachi Ltd	JPN
HOECHST	Hoechst AG	FRG
HONDA	Honda Motor Co.	JPN
HUGHES-A	Hughes Aircraft Co.	USA
HYUNDAI	Hyundai Corp.	SK
IBJ	Industrial Bank of Japan (IBJ)	JPN
ICI	Imperial Chemical Industries Plc	UK
INI	Instituto Nacional de Industria	SPA
IRI	IRI	ITA
ISHIKAWH	Ishika-Wajima Harima Co. Ltd	JPN
ISUZU	Isuzu Motors Ltd	JPN
ITT	Int. Tel.&Telegraph Corp. (ITT)	USA
JGC	JGC Corp.	JPN
JPN-SR	Japan Synthetic Rubber Co. Ltd	JPN
KEPCO	Korea Electric Power Corp.	SK
KHD	Klöckner-Homboldt-Deutz AG	FRG
KHIC	Korea Heavy Industries &Construct	SK
KIA	Kia Motors Corp.	SK
KOMATSU	Komatsu	JPN
KYOWA-HK	Kyowa Hakko Kogyo	JPN
LOCKHEED	Lockheed Corp.	USA
LUCAS	Lucas Industries Plc	UK
MANNESMN	Mannesmann AG	FRG
MARTIN-M	Martin-Marietta Corp.	USA
MASCO	Masco Industries	USA
MATRA	Matra SA	FRA
MATSUSHT	Matsushita Elect. Industrial Co. Ltd	JPN
MAZDA	Mazda Motor Co. (Toyo Kogyo Co.)	JPN
MBB	Messerschmitt-Bölkow-Blohm (MBB)	FRG
MCDERMOT	McDermott Int. Inc	USA
MCD-DOUG	McDonnell Douglas Corp.	USA
METALLGE	Metallgesellschaft AG	FRG
MITSUBIS	Mitsubishi Group	JPN
MITSUI	Mitsui Group	JPN
NONSANTO	Nonsanto Co.	USA
MONT-LAD	Montadel Laden	ITA
NAVISTAR	Navistar Int.	USA
NESTE	Neste Oy.	FIN
NIP-STEE	Nippon Steel Corp.	JP
NISSAN	Nissan Motor Co. Ltd	JPN
NOBEL-IN	Nobel Industries AB	SWE
NORSK-HY	Norsk Hydro A/S	NOR
OCC-PETR	Occidental Petroleum Co. (Oxy)	USA
OERLIK	Oerlikon Bührle Holding Ltd	SWI
OLIN	Olin Corp.	USA
OLIVETTI	Olivetti SpA	ITA
PETROFIN	Petrofina SA	BEL
PHILIPS	Philips Gloeilampenfabrieken NV	NET

Appendix B (continued)

Company label	Name of company	Country
PHILLIPS	Phillips Petroleum Co.	USA
PIRELLI	Pirelli SpA	ITA
PLESSEY	Plessey Co.	UK
PORSCHE	Porsche AG	FRG
PSA	Peugeot SA (PSA)	FRA
RAYTHEON	Raytheon Co.	UK
RENAULT	Renault	FRA
RHONE-P	Rhöne-Poulenc	FRA
ROCKWELL	Rockwell Int. Corp.	USA
ROLLS-R	Rolls Royce Ltd	UK
ROVER	Rover Group Plc	UK
RTZ	Rio Tinto-Zinc Corp. Plc	UK
SAABSCAN	Saab-Scania	SWE
SAGEM	Sagem S.A.	FRA
SANWA	Sanwa Group	JPN
SAUDIBIC	Saudi Basic Industries Corp. (SABIC)	SAR
SENER	Sener Ingenieria y Sistemas SA	SPA
SHELL	Shell Plc NV	NET
SIEMENS	Siemens AG	FRG
SIGNAL	Signal Companies Inc.	USA
SNECMA	Snecma	FRA
SOCGEN	Société Générale SA/NV	BEL
SOLVAY	Solvay&Cie. SA	BEL
SONACA	Sonaca SA	BEL
SPIE-BAT	Spie Batignolles	FRA
SULZER	Sulzer AG	SWI
SUMITOMO	Sumitomo Group	JPN
SUZUKI	Suzuki Co.	JPN
TEXACO	Texaco Inc	USA
TEXTRON	Textron Inc	USA
THOMSON	Thomson SA	FRA
THYSSEN	Thyssen AG	FRG
TOKAI-G	Tokai Group	JPN
TOSHIBA	Toshiba Corp.	JPN
TOYOSODA	Toyo Soda (Tosoh) Corp.	JPN
TOYOTA	Toyota Motor Corp.	JPN
TRACTEBL	Tractebel SA	BEL
TRW	Thompson Ramo Woolridge Inc	USA
UNION-C	Union Carbide Corp.	USA
UN-STIR	United Stirling	SWE
UN-TECHN	United Technologies Corp. (UTV)	USA
VALEO	Valeo SA	FRA
VALMET	Valmet Oy	FIN
VDT	Van Doorne's Transmissie BV	NET
VEBA	Veba AG	FRG
VMF-STRK	VMF-Stork	NET
VOLVO	Volvo AB	SWE
VW	Volkswagen AG	FRG
WESTINGH	Westinghouse	USA
WESTLAND	Westland Plo	UK
WR.GRACE	W.R. Grace	USA
YAMAHA	Yamaha Motor Co.	JPN

Source: MERIT/CATI.