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# Inter-firm R&D partnerships: an overview of major trends and patterns since 1960

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## Abstract

This paper explores 40 years of data on R&D partnerships. These R&D partnerships are examples of inter-firm collaboration or strategic partnering, a topic that has recently attracted attention in both the academic literature and the popular press. The paper presents an analysis of some basic historical trends and sectoral patterns in R&D partnering since 1960. It also provides an overview of some major international (sectoral) patterns in the forming of R&D partnerships within the Triad (North America, Europe and Asia). © 2002 Elsevier Science B.V. All rights reserved.

*Keywords:* Inter-firm collaboration; R&D partnerships; Sectoral patterns

## 1. Introduction

This paper presents an initial analysis of some major trends and patterns in inter-firm R&D partnering since the early 1960s. The paper focuses on collaboration between independent companies through formal agreements, such as contractual agreements and joint ventures. Although companies can cooperate in many activities, I will mainly look at partnerships where R&D is at least part of the collaborative effort. R&D refers to the standard research and development activity devoted to increasing scientific or technical knowledge and the application of that knowledge to the creation of new and improved products and processes.

As will be explained below, joint R&D by companies is considered by many observers as one of the, until recently, least expected activities that companies would be willing to share with others. This is

probably also one of the reasons why R&D partnering has attracted so much attention during the recent years, both in the academic and in the popular press. However, so far most empirical studies on R&D partnerships and other forms of inter-firm collaboration are based on survey–research and, therefore, usually of a cross-sectional nature. In the 1980s, a number of attempts were made to set up databases that would allow longitudinal research, but the work on most of these databases was terminated after a number of years. Apart from some ‘commercial’ databases, that are mainly focused on the biotechnology and information technology sectors, there are few databases that generate both cross-sectional and longitudinal insight (Hagedoorn et al., 2000).

The MERIT-CATI database (see Appendix A) is one of the few still existing databases and it will be explored in the following to discover a number of general trends and patterns in R&D partnering. Given its history and coverage this is also one of the few databases that allow us to study patterns in R&D partnerships in several industries, both domestic and international, in

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different regions of the world over an extended period of several decades.

The paper is organized as follows: first, I will briefly discuss the rationale for inter-firm partnering and present some definitions that are useful to understand what phenomenon is actually being studied. Second, the MERIT-CATI databank allows me to present a general overview of trends in R&D partnerships since 1960 in the light of the current literature. This part of the analysis looks at both growth data and the distribution according to major organizational features of these partnerships. Third, sectoral patterns are of major importance to the understanding of R&D partnerships, because the literature suggests that partnerships are somewhat sector-specific as the propensity to enter into partnerships differs from industry to industry. Fourth, the same applies to the further understanding of international patterns in the forming of R&D partnerships, for which I will consider both international patterns as such and some sector-specific elements in the international distribution of R&D partnerships. The closing section of this paper presents some conclusions that can be drawn from this contribution.

## **2. Some background to understanding R&D partnerships: their rationale, organizational settings and some definitions**

R&D partnerships are part of a relatively large and diverse group of inter-firm relationships that one finds in between standard market transactions of unrelated companies and integration by means of mergers and acquisitions. When inter-firm relationships began to attract attention in both the economics and the business and management literature, a number of taxonomies of different modes of inter-firm relationships were introduced that have gradually become well-integrated in the literature to the extent that it now seems sufficient to only outline the main forms of inter-firm relationships studied in this article. See Auster (1987); Chesnais (1988); Contractor and Lorange (1988); Dussauge and Garette (1999); Hagedoorn (1990, 1993); Narula (1999); Nooteboom (1999); Osborn and Baughn (1990); Yoshino and Rangan (1995) for some of these taxonomies.

In the following I will refer to R&D partnerships as the specific set of different modes of inter-firm

collaboration where two or more firms, that remain independent economic agents and organizations, share some of their R&D activities. These R&D partnerships are primarily related to two categories, i.e. contractual partnerships, such as joint R&D pacts and joint development agreements, and equity-based joint ventures.

Joint ventures are certainly one of the older modes of inter-firm partnering. Joint ventures, including those with a specific R&D program, have become well-known during the past decades (Berg et al., 1982; Hagedoorn, 1996; Hladik, 1985). Joint ventures are organizational units created and controlled by two or more parent-companies and as such they increase the organizational interdependence of the parent companies. Although joint ventures can be seen as 'hybrids' in between markets and hierarchies, they do come close to hierarchical organizational structures as parent companies share control over the joint venture (Williamson, 1996). However, joint ventures can also act as semi-independent units that perform standard company functions such as R&D, manufacturing, sales, marketing, etc. It is this semi-independent status that enables companies to apply joint ventures in a broader strategic setting where companies enter into new markets, reposition themselves in existing markets or use exit strategies in declining markets (Harrigan, 1988).

According to Hagedoorn (1996) and Narula and Hagedoorn (1999) joint ventures seem to have become gradually less popular if compared to other forms of partnering. This decreasing popularity is probably due to the organizational costs of joint ventures in combination with their high failure rate (Kogut, 1988; Porter, 1987). More specifically, problems with the continuation of joint ventures are related to the risk of sharing proprietary knowledge, the 'appetite for control' by one partner and a variety of different strategic objectives as mentioned in the above (Dussauge and Garette, 1999; Harrigan, 1985, 1988; Hladik, 1985; Nooteboom, 1999).

Recent studies have established that non-equity, contractual forms of R&D partnerships, such as joint R&D pacts and joint development agreements, have become very important modes of inter-firm collaboration as their numbers and share in the total of partnerships has far exceeded that of joint ventures (Hagedoorn, 1996; Narula and Hagedoorn, 1999; Osborn and Baughn, 1990). These contractual

agreements cover technology and R&D sharing between two or more companies in combination with joint research or joint development projects. Such undertakings imply the sharing of resources, usually through project-based groups of engineers and scientists from each parent-company. The costs for capital investment, such as laboratories, office space, equipment, etc. are shared between the partners. Although these contractual R&D partnerships have a limited time-horizon, due to their project-based organization, each partnership as such appears to ask for a relatively strong commitment of companies and a solid inter-organizational interdependence during the joint project. However, compared to joint ventures, the organizational dependence between companies in an R&D partnership is smaller and the time-horizon of the actual project-based partnerships is almost by definition shorter (Hagedoorn, 1993).

An interesting subject in this context refers to the motivation of companies to enter into these different R&D partnerships. The cost-economizing motivation applies when at least one company enters the partnership mainly to lower the cost of some of its R&D activities by sharing the costs with one or more other companies. This cost-economizing rationale appears to particularly play a role in capital and R&D intensive industries, such as the telecom capital goods industry, where the cost of single, large R&D projects are beyond the reach of many companies (Hagedoorn, 1993). However, the strategic rationale becomes important if, for instance, companies decide to selectively enter into R&D partnerships that are not related to their core activities, while keeping their main R&D activities within their own domain (Teece, 1986). The strategic intent of R&D partnerships is also apparent in those cases where companies jointly perform R&D in new, high-risk areas of R&D of which the future importance for their technological capabilities remains unclear for a considerable period of time. For many R&D partnerships, however, cost-economizing and strategic motives are intertwined. This becomes most apparent if one looks at the results of some studies on motives for inter-firm partnerships. Most studies on R&D partnerships or similar forms of alliances stress a variety of strategic and cost-economizing motives for these partnerships (see amongst others, Das et al., 1998; Eisenhardt and Schoonhoven, 1996; Hagedoorn, 1993; Hagedoorn

et al., 2000; Lorenzoni and Lipparini, 1999; Mowery et al., 1998). However, it is important to realize there is a dynamic aspect to all of this as the motives of a company can change over time due to both developments in the company itself, its environment and changes within the partnership (Harrigan, 1988).

### 3. General patterns in R&D partnerships

Previous research (Chesnais, 1988; Hergert and Morris, 1988; Hladik, 1985; Mariti and Smiley, 1983; OECD, 1986, 1992) has established that, after a small growth during the 1960s and 1970s, inter-firm partnerships through all sorts of agreements seem to flourish during the 1980s. This general growth pattern is also found for the particular group of partnerships studied in this paper, i.e. R&D partnerships (see Fig. 1).

During the 1960s the number of yearly established R&D partnerships, found in the MERIT-CATI database, remained at a very low level of between a couple of partnerships to around 10 made each year during most of that decade. At the end of 1960s and early 1970s there were about thirty of these partnerships established each year. Already these relatively small numbers attracted some attention in the literature, because as mentioned by Hladik (1985), this phenomenon puzzled academic observers. Most of these partnerships were organized as joint ventures and the existing literature assumed that companies would simply exclude R&D from joint ventures because of the risk involved in such sensitive activities.

During the 1970s there is a gradual increase in the newly made R&D partnerships from a couple of dozens in the early years of that decade to about fifty partnerships at the mid of the decade. At the end of the 1970s there is a sudden increase to nearly 160 new R&D partnerships. This phenomenon appears to be taken to a next level during the 1980s. Those years mark a steep increase from about 200 annually made partnerships to over 500 new R&D partnerships made each year at the end of the 1980s and the turn of the decade. The first couple of years of the 1990s show a drop in the newly made partnerships to about 350 and 400, but in 1995 there is another peak with a record of nearly 700 new R&D partnerships. At the end of the nearly 40 years on which I have been able to find data, the number of new R&D partnerships is

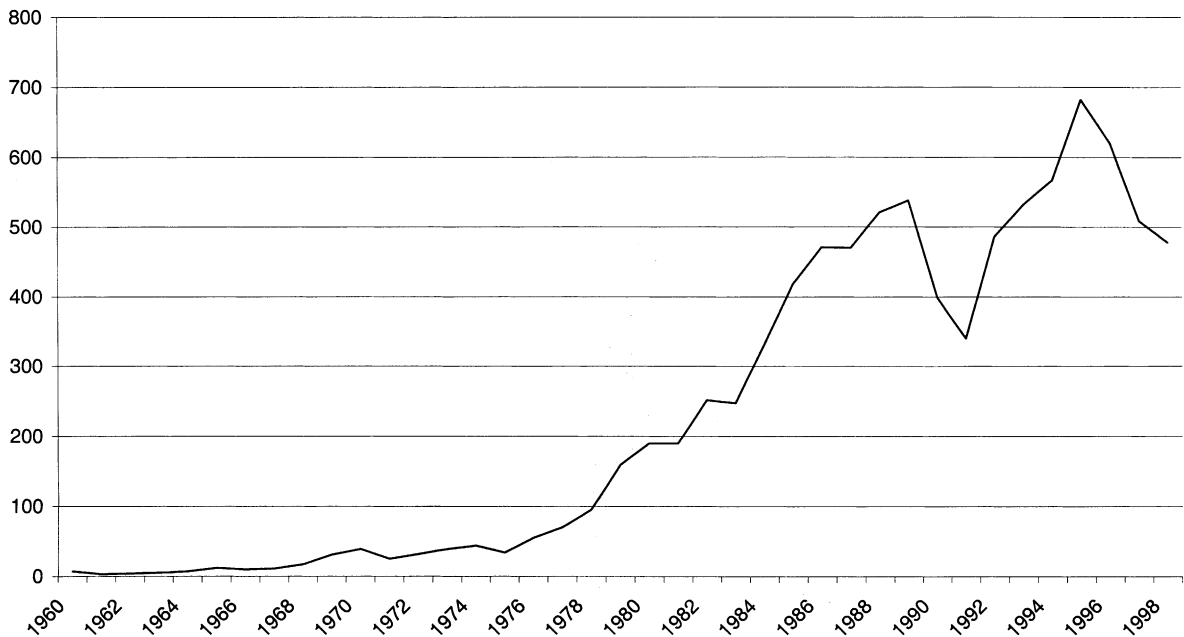


Fig. 1. The growth of newly established R&D partnerships (1960–1998).

decreasing again, to about 500 new partnerships. However, this number is still considerably higher than the figures found for most years since the early 1980s.

In other words, there is a clear pattern of growth in the newly made R&D partnerships if one looks at the historical data since 1960. In the early years of these four decades, there is a steady growth pattern with an acceleration since the 1980s. Although there is definitely need for both more data on a longer period and more extensive research on this pattern of growth, data on the recent period could reveal a more cyclical growth pattern as indicated by the clear peaks and downturns in Fig. 1.

In the literature, the explanation for this overall growth pattern of newly made R&D partnerships is generally related to the motives that 'force' companies to collaborate on R&D. Major factors mentioned in that context are related to important industrial and technological changes in the 1980s and 1990s that have led to increased complexity of scientific and technological development, higher uncertainty surrounding R&D, increasing costs of R&D projects, and shortened innovation cycles that favor collaboration (see Contractor and Lorange, 1988; Dussauge

and Garette, 1999; Hagedoorn, 1993, 1996; Mowery, 1988; Mytelka, 1991; Nooteboom, 1999; OECD, 1992).

It is important to note that this growth pattern of inter-company partnerships seems an autonomous phenomenon and it does not appear to be directly influenced by increased public funding of R&D partnerships, for instance through a variety of programs in the USA and the European Union. First, the MERIT-CATI data only refer to partnerships that are exclusively sponsored by participating companies and they are not established through public funding. Second, there could be a more indirect effect of public funding as partnerships that were previously funded are, at a later stage, continued by the same partners as if they were 'new' partnerships. However, research by Hagedoorn and Schakenraad (1993) and Peters et al. (1993) reveals that for major fields of technology, such as information technology, biotechnology and new materials, public funding has little or no effect on the growth of R&D partnerships of companies.

In the above I indicated that previous contributions had already established that during the 1970s and 1980s the relative share of joint ventures in the

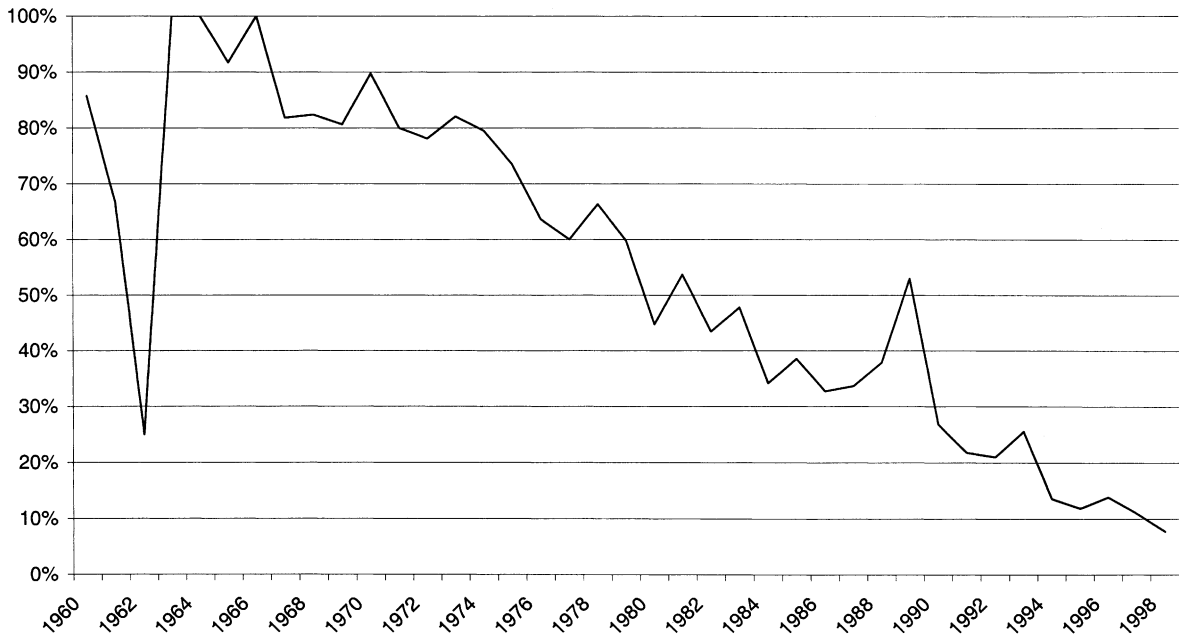


Fig. 2. The share (%) of joint ventures in all newly-established R&D partnerships (1960–1998).

total number of partnerships had dropped considerably. It appeared that in particular contractual forms of partnering had become an important instrument of inter-firm collaboration. If one considers the specific trend for R&D partnerships during the past four decades, one arrives at a similar conclusion (see Fig. 2).

During the very first couple of years of the 1960s, when there were very few R&D partnerships, the share of R&D joint ventures in all R&D partnerships was subject to strong changes from year to year. However, with the increasing number of newly made R&D partnerships, a clear pattern emerges in the share of R&D joint ventures. Ignoring some small oscillations around an overall trend in Fig. 2, there is a sharp decline from a 100% share in the mid-1960s to less than 10% in 1998. During the mid-1970s the share of R&D joint ventures was still at a level of about 70%, in the early 1980s this share reached slightly over 40%. After a 'sudden' increase in the late 1980s, the downward trend reached a level of 20% during the first half of the 1990s until it arrived at a small share of less than 10% at the end of the decade.

These overall trends in inter-firm R&D partnering do indicate two major developments.

1. By and large, companies seem to increasingly prefer contractual partnerships to joint ventures.
2. The growth of newly made R&D partnerships since the early 1980s is largely caused by an overwhelming increase in the absolute numbers of contractual partnerships.

#### 4. Sectoral patterns in R&D partnerships

Contributions by amongst others Ciborra (1991); Dussauge and Garette (1999); Eisenhardt and Schoonhoven (1996); Gomes-Casseres (1996); Harrigan and Newman (1990) and Oster (1992) suggest that inter-firm partnerships are associated with so-called high-tech sectors and other sectors, where learning and flexibility are important features of the competitive landscape. These partnerships enable companies to learn from a variety of sources (partners) in a flexible setting of (temporary) alliances for various company activities across the value chain. Dussauge and Garette (1999); Hagedoorn and Schakenraad (1993); Link and Bauer (1989) and Mytelka (1991) also indicate that many of these partnerships are concentrated in a limited number of, mainly R&D

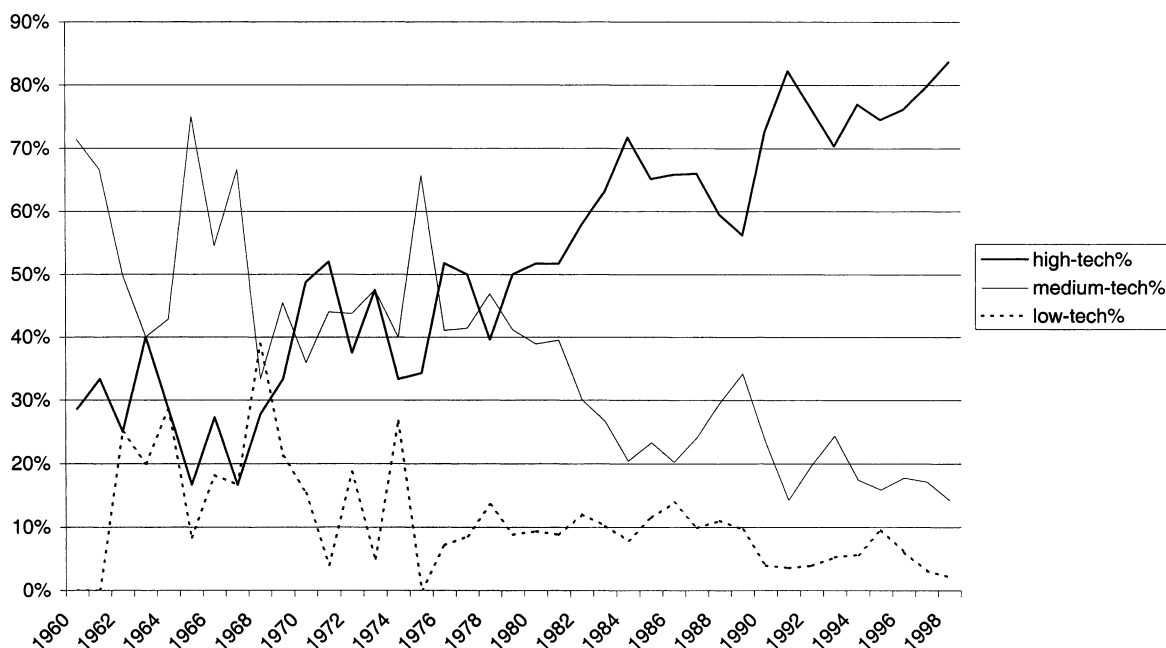


Fig. 3. The share (%) of high-tech, medium-tech and low-tech industries in all newly established R&D partnerships (1960–1998).

intensive, industries. As this paper concentrates on R&D partnerships, one can expect that, given the asymmetrical distribution of R&D efforts across industries, this particular group of partnerships will also be concentrated in R&D intensive industries.<sup>1</sup>

Interestingly, Fig. 3 demonstrates that the expected dominance of R&D partnering by high-tech (R&D intensive) industries has only gradually developed and did not become apparent until the mid-1980s. During the 1960s R&D partnerships in high-tech industries (pharmaceuticals, information technology sectors and aerospace and defense) counted for only between 20 and 40% of the overall number of newly made R&D partnerships. This was substantially lower than the share for medium-tech sectors (instrumentation and medical equipment, automotive, consumer electronics

and chemicals) that on average accounted for over 50% of the newly made R&D partnerships in that early period. During the 1970s the share of high-tech industries varied between 35 and 50%, whereas the share for medium-tech industries during that same period by and large remained still close to 40%.

The 1980s and 1990s, however, mark a period where the growth of R&D intensive industries, influenced by biotechnology and a range of information technologies, is reflected in the increasing importance of these high-tech industries in R&D partnering. From 1980 to 1998, the share of high-tech industries in newly established R&D partnerships increased from about 50 to over 80%. During the same period the share of medium-tech industries in these new R&D partnerships decreased sharply from about 40 to less than 20%.

As high-tech industries have become so dominant in R&D partnering, I also looked at the trends in the share of individual high-tech sectors (see Fig. 4). It is well-known that the information technology sector (computers, telecom, semiconductors, industrial automation, and software) has become important in terms of its contribution to the total of industrial R&D efforts, production and services. This importance is

<sup>1</sup> Following the OECD (1997) sectoral R&D intensities (the share of total R&D expenses in total turnover) pharmaceuticals (including biotech), information technology and aerospace and defence are high-tech sectors with R&D intensities between 10 and 15%. Instrumentation and medical equipment, automotive, consumer electronics and chemicals are medium-tech industries with R&D intensities ranging between 3 and about 5%, other industries such as food and beverages, metals, oil and gas have a relatively low R&D intensity of below 1%.

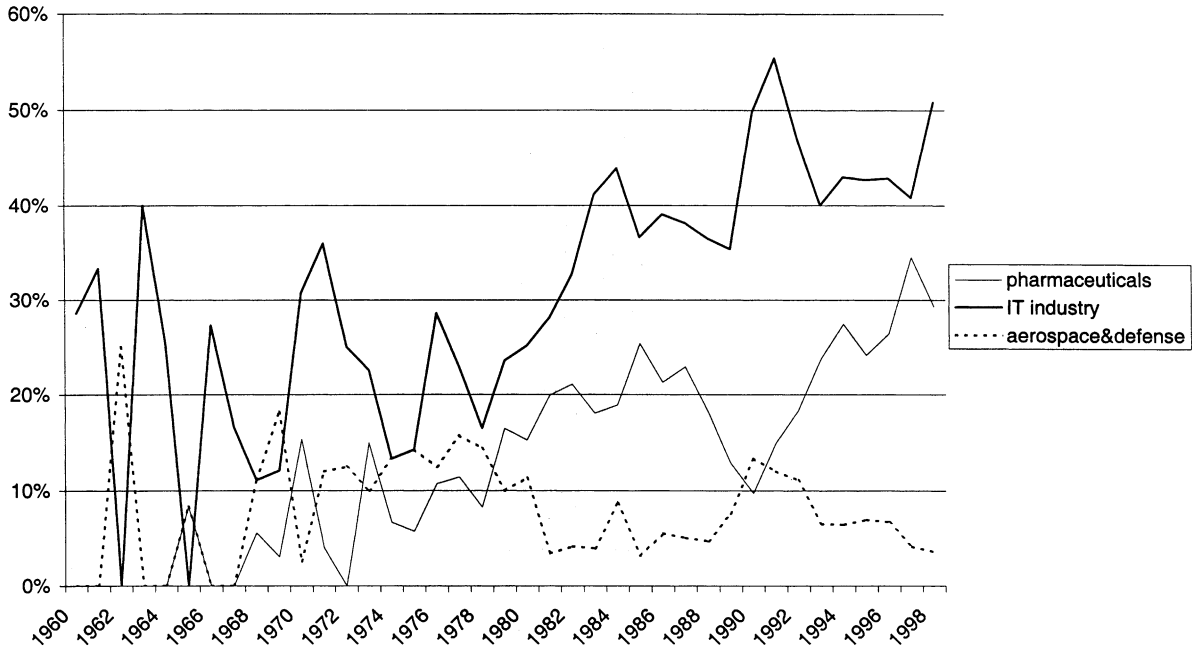


Fig. 4. The share (%) of high-tech industries in all newly established R&D partnerships (1960–1998).

certainly reflected in its share in R&D partnering. With a few exceptional years during the 1960s, the information technology sector has by far the largest share in the sectoral distribution of R&D partnerships. During the mid-1970s, it had an average share of about 25% of all these partnerships, a share that quickly rose to 40% in the mid-1980s and approximately 50% during the late 1980s. After a brief period with declining shares during the first part of the 1990s, the share of the information technology sector rose again to about 50% of all newly made R&D partnerships at the end of the 1990s. The pharmaceutical sector (including pharmaceutical biotechnology) played no role during most of the 1960s. This is no surprise if one recalls that pharmaceutical biotech research did not take off until the 1970s, when there was the gradual increase of new companies that entered into a wide variety of partnerships with the established pharmaceutical industry. Since the 1970s there is a gradual increase in the share of pharmaceutical R&D partnerships which rose from about 10% during most of the 1970s to approximately 20% during most of the 1980s. After a decline to about 10% at the turn of the decade, the share of the pharmaceutical R&D partnerships has

risen to about 30% at the end of the 1990s. As the information technology sector and the pharmaceutical industry have become so dominant in the R&D partnering in high-tech industries (or R&D partnering at large), the share for the third high-tech industry (the aerospace and defence industry) has remained relatively small. Until the 1980s this industry had a share in newly established R&D partnerships that remained on average above 10%. Since, then the share of the aerospace and defence industry has, with a few outliers, declined to about 5% of all newly made R&D partnerships during the 1980s and 1990s.

Given the above it will be no surprise that low-tech industries (for instance food and beverages, metals, oil and gas) do not seem to play an important role in all of this. If we discard some ‘peaks’ in low-tech R&D partnering during the late 1960s and mid-1970s, the share of low-tech industries in R&D partnering decreased from about 20% during the 1960s to slightly above 10% during most of the 1980s. During the 1990s the share of these newly made low-tech R&D partnerships has decreased to less than 5%.

In the above I already noticed that contractual partnerships had become the dominant form of inter-firm

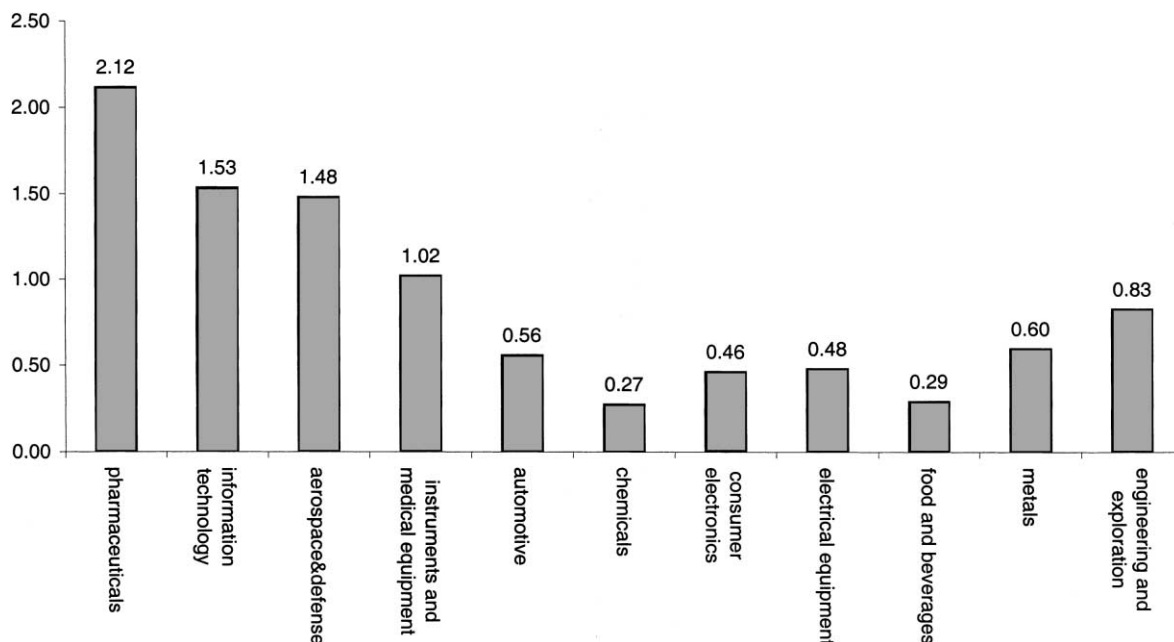


Fig. 5. Relative contractual partnering indexes, per sector (1960–1998).

R&D partnering which, combined with the current dominance of R&D intensive industries, would suggest that high-tech industries are probably also the industries where contractual arrangements are more important than in the medium-tech and low-tech industries. The literature also seems to suggest that the degree of technological sophistication or the degree of technological change in industries might influence the preferred form of partnering by companies. According to Harrigan (1985, 1988) rapid technological change in sectors of industry induces the formation of somewhat informal forms of partnering such as non-equity, contractual partnerships. Osborn and Baughn (1990) and Osborn et al. (1998) suggest that the technological instability of industrial sectors is a crucial factor in explaining different patterns for joint ventures and contractual partnerships. Yu and Tang (1992) emphasize that stable sectoral environments favor joint venturing as the main form of inter-firm partnering, whereas unstable sectoral environments lead to a preference for contractual arrangements. Although these contributions differ with respect to their theoretical framework, their major research questions and the actual indicators used in research, the general

picture that emerges is that contractual agreements are particularly preferred in high-tech industries, whereas joint ventures still play some role in other sectors. I submit that a similar pattern can be expected for joint ventures and contractual alliances in R&D partnering.

In order to measure the sectoral differences in contractual R&D partnerships, I will apply a simple 'relative contractual partnering index' per sector, which expresses the degree to which contractual R&D partnerships are more important in some sectors than in others.<sup>2</sup> This index can be calculated by setting the ratio of contractual partnerships versus joint ventures for each sector against the overall contractual partnerships–joint ventures ratio.

If one considers the relative contractual partnering indexes for high-tech, medium-tech and low-tech

<sup>2</sup> This relative contractual partnering index (RCI) is calculated per sector as the relative distribution of the number of sectoral contractual partnerships ( $CP_i$ ) and sectoral joint ventures ( $JV_i$ ) set against the distribution of all contractual partnerships (TCP) and all joint ventures (TJV).

$$RCI_i = \frac{CP_i/JV_i}{TCP/TJV}$$



Table 1  
Relative contractual partnering indexes of all sectors during 1960–1998

Sectors	1960–1969	1970–1979	1980–1989	1990–1998
Pharmaceuticals	2.65	2.48	2.29	1.48
Information technology	1.06	0.91	1.27	1.64
Aerospace and defense	7.94	5.34	3.57	0.58
Instruments and medical equipment	0.00	0.18	0.92	1.64
Automotive	1.32	3.16	0.46	0.57
Chemicals	0.38	0.26	0.35	0.24
Consumer electronics	0.00	0.99	0.28	1.18
Electrical equipment	1.99	0.34	0.66	0.83
Food and beverages	0.00	0.21	0.43	0.27
Metals	0.00	0.29	0.99	0.44
Engineering and exploration	0.81	1.24	0.75	1.20

industries during the period 1960–1998, one finds that this index for high-tech industries is about 1.7, the index for medium-tech industries is about 0.4 and for low-tech industries it is about 0.55. These figures do indicate that R&D partnering in high-tech industries is of a disproportionate contractual nature. A more detailed overview of these relative contractual partnering indexes during the four decades of this analysis at the level of industries is found in Fig. 5.

Fig. 5 indicates that R&D partnering in the pharmaceutical industry (including relevant biotech activities) is over twice as much concentrated in contractual R&D partnerships than the average for all industries. The information technology industries and the aerospace and defense industry have about 1.5 times as many contractual R&D partnerships as the industry-wide average. Given this dominance of these high-tech industries it will not come as a surprise that the medium and low-tech sectors are (with the exception of the most R&D intensive non-high tech sector, instruments and medical equipment) below the industry-wide average.

Further information on trends in these relative contractual partnering indexes is found in Table 1. Some major characteristics of the importance of contractual partnering or joint ventures at the level of individual sectors and changes over time worth mentioning are the following.

- In pharmaceuticals and the information technology industry, one sees an above-average preference for contractual R&D partnering throughout most of the past decades, whereas, the aerospace and defense industry shows a rapid decline in the importance

of contractual R&D partnering, in particular during the most recent decade.

- In chemicals, electrical engineering industries, food and beverages, and metal products, which are all non-high tech industries, joint ventures have had a disproportionate importance throughout most of the past decades.
- In instruments and medical technology, a rather R&D intensive sector within medium-tech industries, joint ventures have gradually become less important as contractual R&D partnering has become the dominant mode of partnering.
- In the automotive industry and consumer electronics, there appears to be two opposite developments: in the automotive industry it seems that contractual partnering is becoming less important, whereas the opposite seems to hold for consumer electronics.

## 5. International patterns in R&D partnerships

In many contributions to the literature (Auster, 1987; Contractor and Lorange, 1988; De Woot, 1990; Dunning, 1993; Duysters and Hagedoorn, 1996; Hagedoorn and Narula, 1996; Mowery, 1988; Mytelka, 1991; Ohmae, 1990; Osborn and Baughn, 1990; Yoshino and Rangan, 1995) international partnerships or alliances are considered an important element in the international strategies of a growing number of companies. The basic argument in most of these contributions is that increased international competition between companies forces them to pursue international strategies. Through, these international strategies companies do not only seek

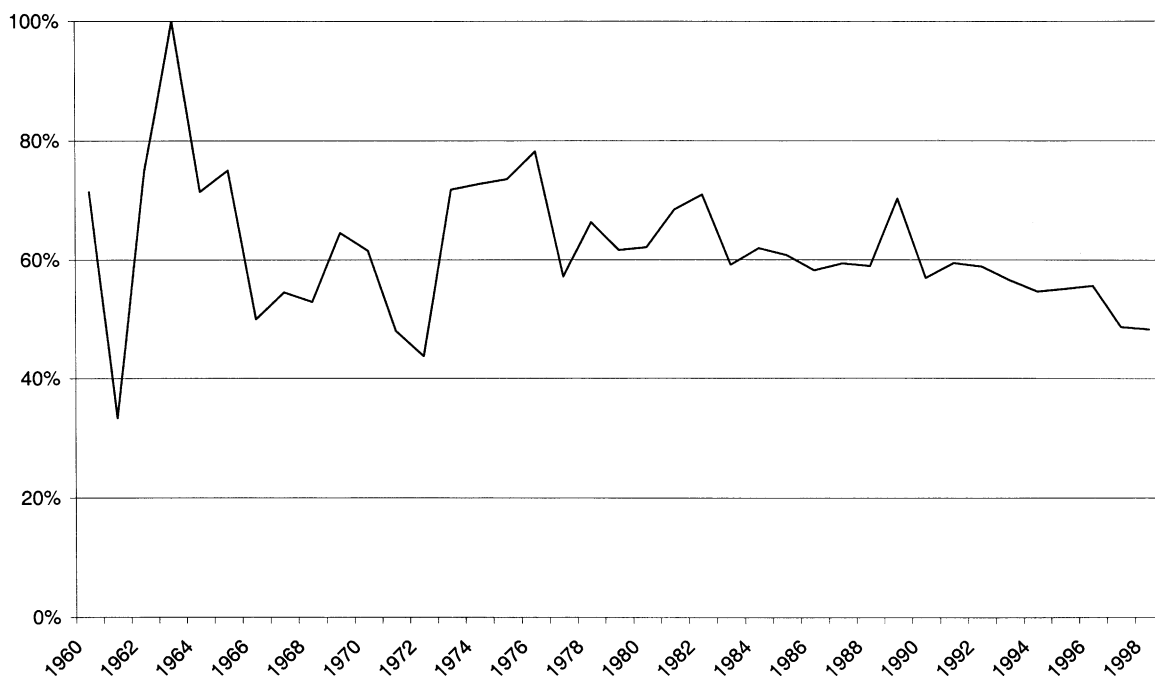


Fig. 6. The share (%) of international partnerships in newly-established R&D partnerships (1960–1998).

foreign market entry, but they also seek foreign assets (both of a tangible and an intangible nature) and build international inter-firm partnerships for international source of R&D, production and supply. From a traditional transaction cost economics perspective (Williamson, 1996) one would expect that companies are somewhat hesitant to enter into R&D partnerships with foreign companies due to the lack of control in long-distance collaboration, lack of trust between companies from different countries and the high asset specificity of R&D. However, as increased international competition has led many companies to follow a strategy of gradual internationalization, one can assume that this experience gradually also opens the way to non-domestic R&D partnerships (Hagedoorn and Narula, 1996). Consequently, one could expect that, in the context of the overall importance of internationalization to companies and their partnerships, the share of international R&D partnerships in the total number of R&D partnerships should also have increased during the last four decades.

However, the past 40 years indicate a somewhat irregular and slightly downward trend in the share of

international R&D partnerships (see Fig. 6). During the 1960s and early 1970s, when there were only few of these partnerships, the share of international R&D partnerships dropped from an average of about 75 to close to 40%. During the mid-1970s the share rose again to nearly 80%, after which the trend gradually turned slightly downward from about 70% during the first years of the 1980s to about 60% during in the early 1990s. The late 1990s end with a share of international partnerships below 50% of all newly made R&D partnerships.

For a further understanding of this development and the sectoral differences that might have occurred I calculated a simple 'relative international partnering' index per sector.<sup>3</sup> This measure is somewhat similar

<sup>3</sup> As with the previous index, the relative international partnering index (RII) is calculated per sector as the relative distribution of the sectoral number of international partnerships ( $IP_i$ ) and sectoral domestic partnerships ( $DP_i$ ) set against the distribution of all international partnerships (TIP) and all domestic partnerships (TDP).

$$RII_i = \frac{IP_i / DP_i}{TIP / TDP}$$

to the relative contractual partnering index, as it indicates the degree to which international R&D partnerships are more important in some sectors than in others. This index can be calculated by setting the ratio of international partnerships versus domestic ventures for each sector against the overall international partnerships/domestic partnerships ratio.

The relative international partnering indexes during the period 1960–1998 are 0.9 for high-tech industries, 1.5 for medium-tech industries and 0.85 for low-tech industries. These findings, in particular for high-tech sectors, are somewhat surprising and they certainly merit a more detailed look at the data. A first step towards a more detailed overview of relative international partnering indexes at the level of individual industries is found in Fig. 7.

This indicates that the propensity for international partnering is unevenly distributed across industries. Most medium-tech industries, with the exception of the instruments and medical equipment sector which is close to the all-industry average, have an above average propensity to engage in international R&D partnering. As mentioned in the above, somewhat surprisingly, both high-tech and low-tech sectors appear

to be less internationalized in their R&D partnering. High-tech industries such as pharmaceuticals and the information technology sectors, but not aerospace and defense, are clearly below the industry-wide average of international R&D partnering since the 1960s.

Some additional information on relative international partnering indexes is found in Table 2, but this information at the level of individual sectors does not suggest a very clear pattern for most industries. Only two major industries demonstrate a clear pattern in their international R&D partnering. In the information technology industry international partnering has remained below-average throughout the past decades, whereas international R&D partnering has been of a disproportionate importance in the chemical industry. For most other industries it appears that there is no clear pattern as the relative international partnering indexes fluctuate from decade to decade.

Given this somewhat unclear pattern in international R&D partnering, I decided to take a closer look at the role that the different international economic and trading blocks play in all of this. In the following I will differentiate between partnerships and companies from Europe (the EU and EFTA countries), North

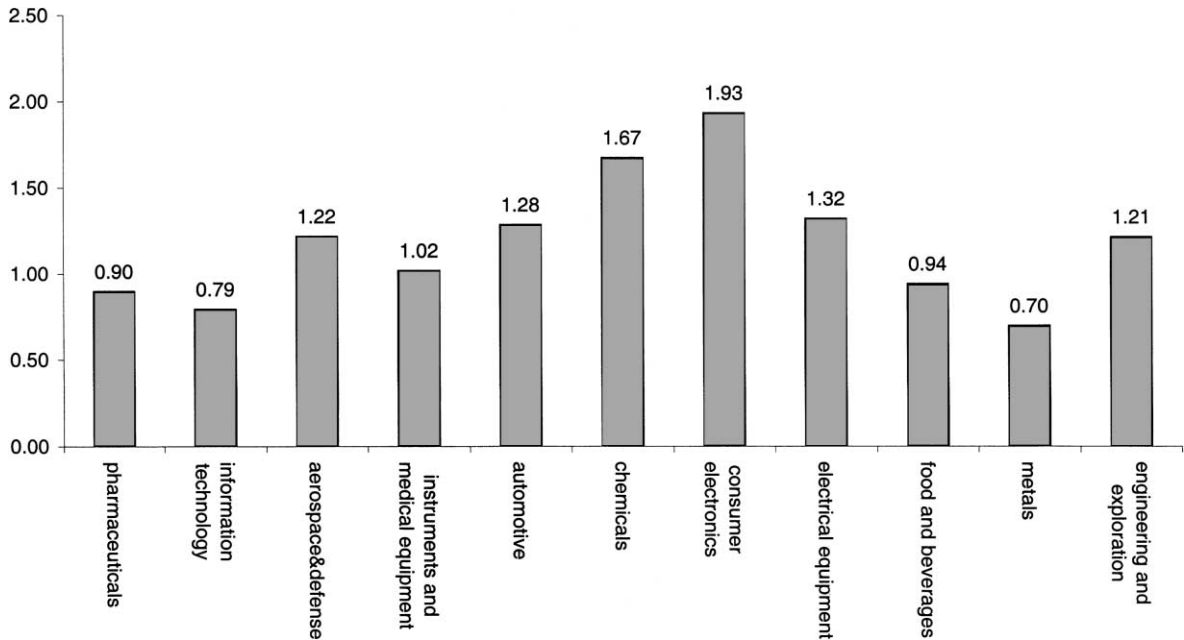


Fig. 7. Relative internationalization indexes, per sector (1960–1998).

Table 2  
Relative international partnering indexes of all sectors during 1960–1998

Sectors	1960–1969	1970–1979	1980–1989	1990–1998
Pharmaceuticals	0.00	0.60	0.64	1.18
Information technology	0.90	0.55	0.94	0.76
Aerospace and defense	1.34	0.63	0.85	1.74
Instruments and medical equipment	0.57	0.66	1.77	0.77
Automotive	0.86	1.43	1.90	0.83
Chemicals	2.87	1.90	1.47	1.61
Consumer electronics	3.44	4.87	3.35	0.98
Electrical equipment	0.13	1.33	1.63	1.06
Food and beverages	1.15	1.59	0.63	1.14
Metals	0.86	2.62	0.46	1.29
Engineering and exploration	0.50	1.00	1.45	1.18

America (USA and Canada), Asia (Japan and South Korea) and all other countries. Previous work by Freeman and Hagedoorn (1994); OECD (1992); Ohmae (1990, 1985) and Yoshino and Rangan (1995) already revealed that the Triad (North America, Europe and Japan) dominates inter-firm partnering. South Korea is mentioned by Freeman and Hagedoorn (1994) and Duysters and Hagedoorn (2000) as a recent ‘player’ of some importance.

If one looks at the overall pattern in R&D partnering during the past four decades (see Fig. 8), it becomes clear that companies from the Triad (Europe, Asia and North America) participate in over 99% of the R&D partnerships. North America (of which between 90–95% stands for US companies) clearly dominates the world of R&D partnering. Almost 70%

of the R&D partnerships I found for the past four decades has at least one North American partner. Partnerships within North America account for nearly a third of all the R&D partnerships. Nearly a quarter of the inter-firm R&D partnerships are made between European and North American companies, which is substantially higher than the nearly 16% share found for intra-European R&D partnerships. R&D partnerships made between companies from North America and Japan and South Korea account for about 11%. Intra-Asian R&D partnerships and partnerships between Europe and Japan and South Korea remain at a relatively low level of about 5%.

Fig. 9a–d reveal some striking changes in the overall distribution of R&D partnerships since the 1960s. First of all it becomes clear that the important role

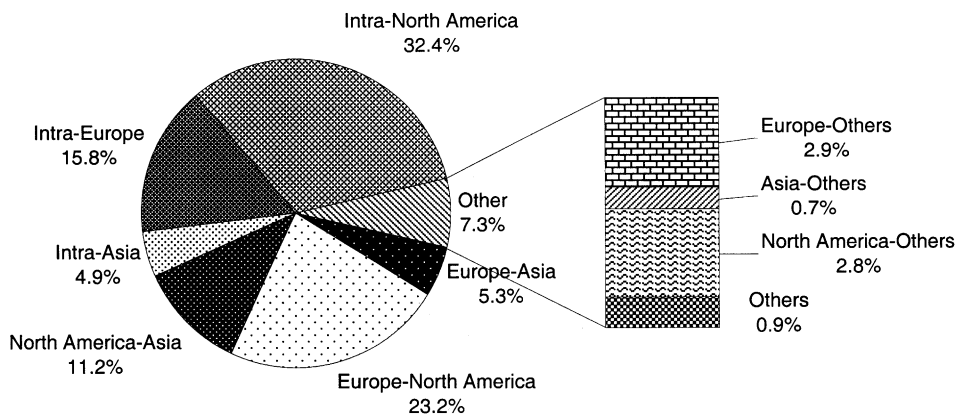


Fig. 8. Distribution of R&D partnerships, economic regions (1960–1998).

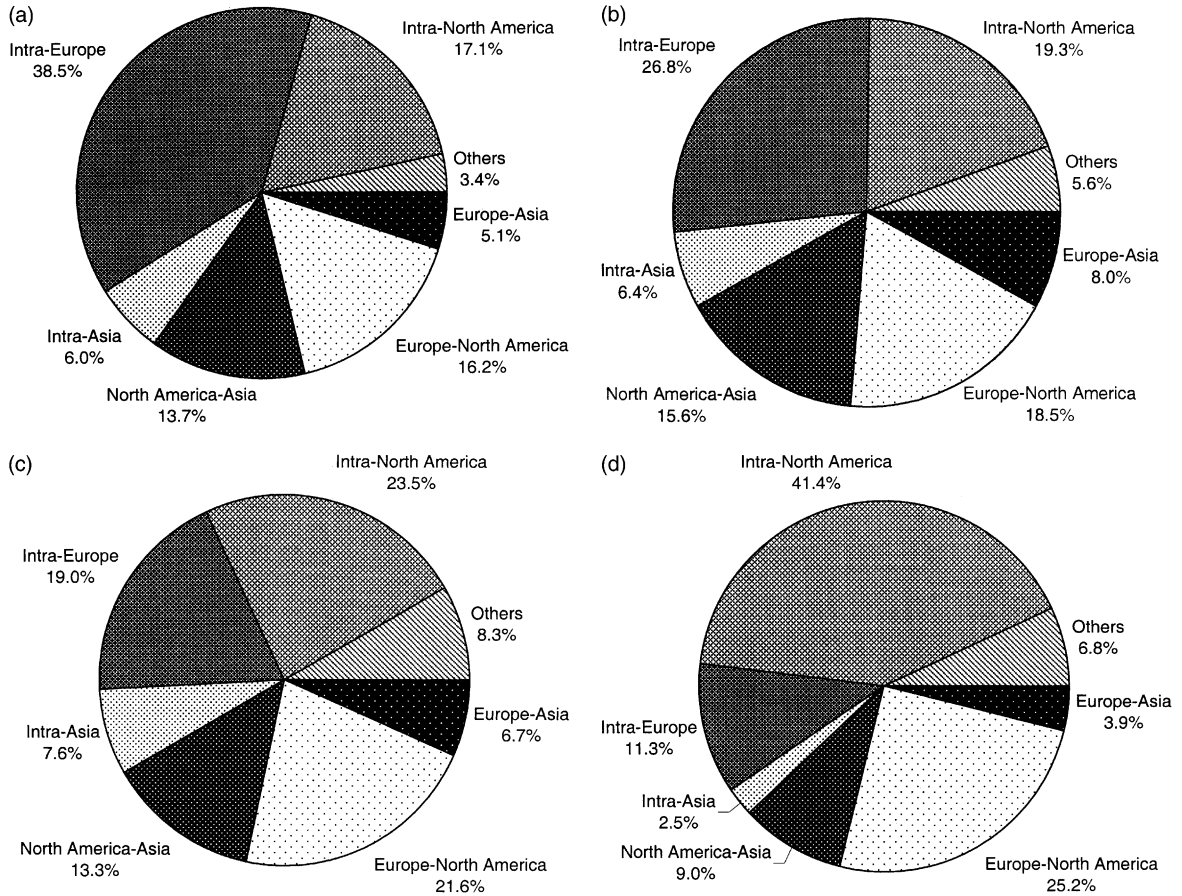


Fig. 9. (a) Distribution of R&D partnerships, economic regions (1960–1969); (b) distribution of R&D partnerships, economic regions (1970–1979); (c) distribution of R&D partnerships, economic regions (1980–1989); (d) distribution of R&D partnerships, economic regions (1990–1998).

of intra-North American partnerships is only a relatively recent development. During the 1960s and 1970s less than 20% of these R&D partnerships were established within North America and even in the 1980s less than a quarter of all R&D partnerships were made between two or more North American companies. However, the 1990s mark a sudden increase in the share of intra-North American R&D partnerships to over 41%. Second, the share of intra-European partnerships has gradually eroded from nearly 40% during the 1960s and 27% during the 1970s, to 19% during the 1980s and to only 11% during the most recent decade. Third, European–North American R&D partnering has gradually grown from

about 16% during the 1960s to about 25% during the 1990s. Additional analysis of these data reveals that the dominance of intra-North American R&D partnering is particularly strong in high-tech industries such as pharmaceuticals (biotechnology) and information technology. These sectors also represent a large share of the European–North American R&D partnerships.

## 6. Conclusions

A major conclusion from the above is that R&D partnering is a ‘game’ dominated by companies from the world’s most developed economies. As companies

from the developed economies participate in 99% of the R&D partnerships and 93% of these partnerships are made amongst companies from North America, Europe, Japan and South Korea, little appears left for companies from other regions. Grim as this picture might look, it does parallel the current world-wide distribution of R&D resources and capabilities (Freeman and Hagedoorn, 1994). In that context the dominance of North America, particularly the USA, also reflects the leading role that this continent plays in R&D and production in major high-tech industries such as the information technology sectors (computers, telecom, software, industrial automation, semiconductors) and pharmaceutical biotechnology (OECD, 1992). This dominance had not only led companies from other countries to actively search for R&D partnerships with US companies, the US dominance of technological development in many of the above-mentioned fields has also led to a situation, where most of the recent R&D partnerships are formed between companies within in the USA. The growing importance of intra-US R&D partnerships also largely explains why international partnerships, despite a strong growth in absolute numbers, still take only about 50% of all R&D partnerships and why the trend towards a further internationalization appears to be stagnating.

Apart from the technological dominance of US companies in major high-tech sectors, there are probably a few other factors that can partly explain the trend towards the 'domesticized' nature of R&D partnerships by US companies. Given the absence of a direct effect of publicly funded programs on R&D partnering in high-tech sectors, these publicly funded joint R&D activities are, as discussed in the above, not a likely candidate for such an explanation. Two other factors might, however, have indirectly affected the 'domesticized' nature of R&D partnerships of US companies. One factor is the changes in the US antitrust policy that begun in the early 1980s and that continued through the 1990s. This reduced the post-war hostility of the US federal competition authorities toward R&D collaborations among established firms. The other factor relates to the Uruguay Round that reduced some of the non-tariff trade barriers in sectors such as telecommunications equipment or pharmaceuticals that formerly constituted an important motive for

international collaboration that included a prominent R&D component.<sup>4</sup>

These specific developments have to be understood against the background of an overall growth in world-wide R&D partnerships. This general growth pattern as established during the past decades is largely due to the growth in the number of contractual agreements, i.e. R&D pacts and joint development agreements. If joint ventures once dominated inter-firm R&D partnering, this activity is now almost completely dominated by contractual agreements as about 90% of the recently established partnerships are of a contractual nature.

Contractual R&D partnerships enable companies to increase their strategic flexibility through short-term joint R&D projects with a variety of partners. This flexibility in R&D partnerships ties into the more general demand for flexibility in many industries, where inter-firm competition is affected by increased technological development, innovation races and the constant need to generate new products. There is an interaction between these strategic incentives per se, those that increase the flexibility of companies, and cost-economizing incentives for these partnerships, which relate to the sharing of the increasing costs of innovative efforts with some other companies for, at least part of, the costs of the overall R&D budget.

The role of technological development in all of this is also apparent in the sectoral background of R&D partnering. Over the past 40 years there has been a gradual increase in the share of high-tech industries in R&D partnering. At the end of the 1990s over 80% of the newly made R&D partnerships are found in the information technology sectors and the pharmaceutical industry. It is also here that we find an over-representation of contractual partnerships, which again stresses the role that flexibility should play in an understanding of inter-firm R&D partnering. Joint ventures, which are less flexible as companies have to set-up separate organizations with a variety of functions, are primarily found in medium-tech and low-tech industries, where technological development is usually less turbulent and of a more gradual nature. In contrast, contractual R&D partnerships that

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<sup>4</sup> I thank a reviewer for pointing out these important points that provide an explanation for the recent trend in the 'domesticized' nature of US R&D partnerships.

regulate relatively small-scale collaboration in a flexible setting of multiple companies are major drivers of inter-firm networks that have become so apparent in many high-tech industries.

### Appendix A. The MERIT-CATI database

The CATI data bank is a relational database which contains separate data files that can be linked to each other and provide both disaggregated and combined information from several files. So far information on thousands of technology-related inter-firm partnerships has been collected for the period 1960–1998. Systematic collection of inter-firm partnerships started in 1987. Many sources from earlier years are consulted to establish a retrospective view. In order to collect information on inter-firm alliances various sources are consulted: newspaper and journal articles, books dealing with the subject, and in particular specialized journals which report on business events. Company annual reports, the financial times industrial companies yearbooks, and Dun and Bradstreet's 'who owns whom' provide information about dissolved equity ventures and investments, as well as ventures that were not registered when surveying alliances.

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

The data bank contains information on each agreement and some information on companies participating in these agreements. The first entity is the inter-firm cooperative agreement. Cooperative agreements are defined as common interests between independent (industrial) partners which are not connected through (majority) ownership. In the CATI database only those inter-firm agreements are being collected that contain some arrangements for transferring technology or joint research. Joint research pacts and second-source are clear-cut examples. Information is

also collected on joint ventures in which new technology is received from at least one of the partners, or joint ventures having some R&D program. Mere production or marketing joint ventures are excluded. In other words, this material is primarily related to R&D collaboration and technology cooperation, i.e. those agreements for which a combined innovative activity or an exchange of technology is at least part of the agreement.

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