Research partnerships.

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Hagedoorn, J., Link, A. N., & Vonortas, N.S. (April 01, 2000). Research partnerships. *Research Policy, 29(4-5) 567-586.*

Abstract:

This paper synthesizes the academic, professional, and policy literature on research partnerships with an eye toward technology policy. Based on available theory and empirical investigations, there are a variety of important reasons why firms participate in research partnerships and a number of reasons why governments encourage them. We conclude that technology policy authorities need to be aware of these reasons and accordingly be cautious when comparing the benefits with the downside effects associated with collaboration.

Keywords: research & development | technology policy | joint ventures | research partnerships | research policy

Article:

1. Introduction

As with most public policy-related subjects, important contributions to the literature of what we call research partnerships have been made by scholars from a number of disciplines. While most of the research reviewed herein has appeared in economics and management journals or in scholarly books, it is important to emphasize that the contributing authors represent not only those disciplines but also others — such as public administration, philosophy of science, and science and technology policy — and, they come from a host of countries. As such, there is a variety of indigenous terminologies at play.

Accordingly, our first order of business is to bound the topic of research partnerships by establishing a common set of terms. What we offer here is but one interpretation of the various terms and concepts that will be reviewed in this paper. Certainly, those in the field may agree or disagree with our taxonomy of terms, but a starting point is needed to navigate systematically through the literature.

As our starting point, we define a research partnership broadly as an innovation-based relationship that involves, at least partly, a significant effort in research and development (R&D).4 This definition of a research partnership follows, in spirit, from that recently used by the Council on Competitiveness (1996)(p. 3):

> Partnerships are defined… as cooperative arrangements engaging companies, universities, and government agencies and laboratories in various combinations to pool resources in pursuit of a shared R&D objective.

The purpose of this paper, therefore, is to synthesize the academic, professional, and policy literature on research partnerships. Our review is presented with an eye toward technology policy — the theme of this special issue.

In Section 2, we offer a simple taxonomy of research partnerships. The principal value of this taxonomy is to provide one vehicle for discussing not only the literature, but also the data related to research partnerships that are being analyzed by empirical researchers and policy makers. In Section 3, the theoretical literature on research partnerships is overviewed. This theoretical literature has primarily focused on two broad issues: Why is a research partnership formed? and What are the results from the formation of a research partnership? Section 4discusses the related empirical literature. With the availability of systematic databases on research partnerships during the last few years, this literature has grown rapidly and is becoming the foundation for evaluating the effectiveness of related policies. Section 5offers a brief description of current technology policies that relate to research partnerships in various industrial nations. Section 6summarizes our review.

2. Toward a taxonomy of research partnerships

Based on our definition of a research partnership, namely that a research partnership is as an innovation-based relationship, it follows that there are at least two ways to characterize such a relationship and hence to characterize research partnerships.5 Research partnerships can be characterized in terms of the members of the relationship, or they can be characterized in terms of the organizational structure of the relationship; however, these two dimensions need not be independent. We consider both characterizations in this section, but we devote greater attention to the latter because the theoretical and institutional literature has so developed.

2.1. Partners in a research partnership

At a broad level, the partners in a research partnership can come from either the public sector or the private sector. Obviously, when a partner is a governmental agency, such as a federally funded research laboratory in the United States, it represents the public sector; when a partner is a private firm, it represents the private sector. Many partnerships also involve universities, and from the perspective of ownership authority a university can be public or private. However, it is rarely the case that a university's research is not, at least in part, publicly funded. Thus, we view for purposes of this taxonomy universities as part of the public sector.6

Given these parameters, research partnerships can be public, they can be private, or they can be public/private. From a technology policy perspective, public/private partnerships have attracted the greatest attention because they represent a relationship that directly embodies government intervention into the innovation process and hence are scrutinized more carefully.

2.2. Organizational structure of research partnerships

2.2.1. Informal arrangements

Our organizational structure taxonomy of research partnerships is visually described in Fig. 1. Research partnerships can be formal or informal. Very little is known about informal partnerships. We do know that many firms informally partner with one another in short-term research endeavors, but by the fact that they are informal there is not a systematic way to track these partnerships quantitatively much less to study them in detail. Link and Bauer (1989)reported that nearly 90% of the research partnerships in which cooperative-research active firms from a sample from the U.S. manufacturing sector were involved were informal in nature. Not only do firms informally partner with one another, but also they informally partner with universities, and, generally, in these relationships, the university is serving in the role of a short-term project-specific research subcontractor (Hall et al., 1998).

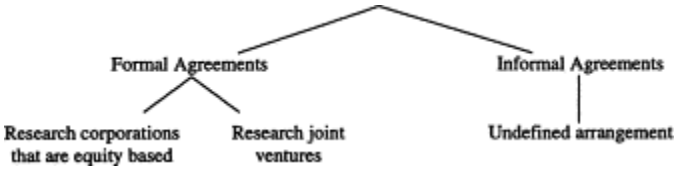

Fig. 1. Taxonomy of research partnerships by organizational structure.

Fig. 1 also illustrates two categories of formal research partnerships — research corporations and research joint ventures (RJVs). Each is discussed below.

2.2.2. Formal arrangements

During the 1980s and early 1990s, a number of classification schemes of inter-firm relationships were introduced in the management and economic literature that we find particularly relevant for understanding research partnerships. Based on these schemes, we distinguish two types of formal relationships between firms: equity joint ventures that focus on R&D, which we call research corporations; and RJVs which are mainly contractual arrangements.7

Research corporations are created by at least two firms that combine their R&D skills and resources through equity joint ownership of a separate firm, and generally this new firm or child performs only R&D that fits within the broader context of the research agenda of the parent firms (Hagedoorn, 1990). Equity joint ventures can be analyzed in the context of transitional firm strategies in different market situations. Berg and Hoekman (1988)and Harrigan (1988)have argued that market entry, repositioning, and expansion in existing markets, as well as exit strategies in declining markets, are well known rationales for firms to enter into equity joint ventures. The equity joint ventures are associated with the spreading of risks, sharing of fixed costs, capturing of economies of scale, gaining access to new markets, achieving competitive repositioning, and sharing of research efforts. These same general arguments hold for research corporations.

Many observers (e.g., Hladik, 1985; OECD, 1986) have argued that research corporations became popular during the 1980s. Despite the still existing popularity of research corporations, the economic and organizational stability of this mode appears questionable. Several studies have estimated that about half of all R&D-related equity joint ventures fall short of expectations or are disbanded (Berg et al., 1982; Kogut, 1988b). Major reasons for these so-called failures are found in either different views of participating firms on strategy, or difficulties associated with the management of the venture. More specifically, problems in maintaining research corporations are generally thought to derive from the risks of sharing proprietary know-how, the desire for control by individual partners, coordination of different time-horizons, disagreement on design specifications, government policies, and the effects of minimum efficient scale in R&D that can make decentralization of R&D both costly and difficult to control (Harrigan, 1985; Hladik, 1985; OECD, 1986; Obleros and Macdonald, 1988).8

RJVs, such as joint R&D pacts or consortia to cover non-equity agreements, are created so that firms and other organizations can pool resources in order to undertake joint R&D activities. Although the success of such agreements is dependent upon a strong commitment of the partners, the organizational interdependence is usually less than in a research corporation

because no new organizational entity is established. If certain RJV projects are not successful, they can be terminated with only a relatively small loss compared to the loss that would be incurred when a research corporation is dissolved (Hagedoorn and Schakenraad, 1990; Duysters, 1996).

A specific subset of RJVs are research contracts that concern R&D cooperation in which one firm contracts another firm, frequently a smaller one, to perform a particular research project. For the contract-initiating firm, advantages can be found in the possibility to focus on particular areas of research with substantial cost saving compared to in-house research facilities. Disadvantages for that firm can be found in the lack of in-house expertise to assess the value of contract research and the dissociation of development expertise from manufacturing expertise. The advantages for the other (smaller) contractor are found in R&D funding and cooperation with a larger entity. Disadvantages are found in low profit margins on contract research and licensing, and in the transitory nature of these agreements (Hagedoorn, 1996).

3. Theoretical perspectives on research partnerships

There is a vast literature that attempts to explain, from a theoretical perspective, why firms enter into formal research partnerships and what are the results of such relationships to the partners, industry, and society at large. We distinguish in Fig. 2 between three broad categories of literature in addressing these issues: transaction costs, strategic management, and industrial organization theory. The basic rationale for these categories is the long-standing division of labor between theorists. Management theorists have traditionally focused on the firm and the internal organization of its activities. Industrial organization theorists have, until recently, typically taken the firm as the unit of observation to examine strategic intent and the effects of firm actions on industrial structure, economic efficiency, and social welfare. Transaction cost theory can be viewed ex post as a hybrid of the two. It tries to explain the reasons for firms to organize internally, while addressing market or industry forces.

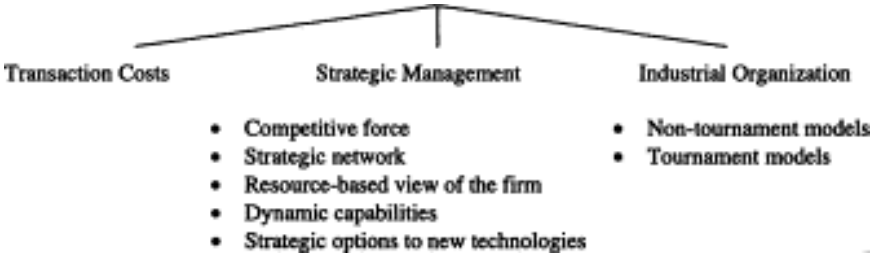

Fig. 2. Formal research partnerships.

Any literature taxonomy is partially an arbitrary exercise, and the taxonomy in Fig. 2 is no exception. It can be argued, for example, that most if not all approaches listed under the strategic management category have used arguments from the transaction cost and industrial organization categories.9 Similarly, the transaction cost and industrial organization approaches have undoubtedly drawn on strategic management to support various arguments. Rather than mutually exclusive, the analytical approaches presented here are complementary as viewed both across and within individual categories.

3.1. Transaction costs

A natural starting point for explaining the emergence of research partnerships is the theory of the firm, a formidable branch of which is transaction cost economics. According to this school of thought, entrepreneurs try different ways to organize a transaction, including arm's length markets and market displacements through internal administrative organizations or hierarchies (Williamson, 1975 and Williamson, 1985). Assuming a market with no external interference, the most economically efficient organizational design is believed to prevail over time. The boundary between the market and the firm will then be determined by the relative costs of carrying out a transaction under each organizational structure.

Transaction cost theorists have more recently begun to explore alternative forms of adaptation, such as involving cooperation among organizations (Menard, 1996a and Menard, 1996b; Williamson, 1996) and research partnerships generally fall into this category.

In order to explain why research partnerships form, one must determine why such organizations would have a cost advantage over either the market or a hierarchical organization form of operation for the specific type of activity. Students of transaction cost theory have posited two kinds of relevant costs: production costs and transaction costs. Production costs may vary from firm to firm according to proprietary knowledge, abilities to learn, and economies of scale and scope. Transaction costs may vary from transaction to transaction. They refer to “the expense incurred for writing and enforcing contracts, for haggling over terms and contingent claims, for deviating from optimal kinds of investments in order to increase dependence on a party or to stabilize a relationship, and for administering a transaction” (Kogut, 1988a, p. 320).

Transaction costs increase steeply when contracts are incomplete, that is, when they do not fully specify the actions of each party in every contingency. Intangible assets, including technical knowledge, are a primary cause of incomplete contracts. Technical knowledge can be explicit, if

in the form of a patent or design, or implicit if in the form of know-how shared among the employees. Technical knowledge is subject to positive externalities or spillovers, its production is subject to significant uncertainties, and its dissemination can induce opportunistic behavior. Research partnerships are thus explained in transaction cost economics as a hybrid form of organization between the market and the hierarchy to facilitate carrying out an activity specifically related to the production and dissemination of technical knowledge.

What makes this hybrid form of organization preferable to the internalization of the market for technical knowledge by bringing the necessary capabilities under unified control? According to Kogut (1988a), the situational characteristic favoring the research partnership is higher uncertainty over specifying and monitoring the performance of the other party. Research partnerships achieve a mechanism to provide the necessary incentives to perform to required standards by turning the expected hostage situation in the market transaction into a mutual hostage situation in a cooperative agreement through the commitment of resources by partners to the common cause.10

3.2. Strategic management11

There are several approaches taken by strategic management scholars. Five such approaches are reviewed below.

3.2.1. Competitive force

The competitive force approach toward research partnerships (Porter 1980, Porter 1985; Harrigan, 1988) derives, in part, from the traditional structure-conduct-performance paradigm of industrial organization theory. An effective competitive strategy involves the firm taking offensive or defensive action in order to create a defensible position against competitors or influence them in its favor. Collaboration is seen as a means of shaping competition by improving a firm's comparative competitive position.

Coalitions involve coordinating or sharing value chains with partners that broaden the effective scope of the firm's own activities. By using coalitions, a firm can benefit from a broader scope of activities without spending precious resources to enter new market segments (Porter, 1986). Inter-firm technological collaboration permits firms to react swiftly to market needs and allows them to bring technology to the marketplace faster.

3.2.2. Strategic network

The strategic network approach argues that the network is a new form of organization and strategy. Multiple cooperative relationships of a firm can be the source of its competitive strength. In general, three categories of theoretical rationales can explain the formation of strategic networks: efficiency, synergy, and power.

Networks can achieve efficiencies via scale and scope economies and via the reduction of transactional inefficiency in the open market. The network arrangement allows a firm to concentrate on those parts of the value chain that better reflect the firm's competitive advantage. Firms within a network are thus able to capture the benefits of specialization, focus, and scale. The effectiveness of a network can be attributed to technological reasons, the opportunity for lowering transaction costs (Gomes-Casseres, 1996), and the possibility for joint value creation (Jarillo, 1988).

With respect to exploiting synergies, Miles and Snow (1984)argued that networks can be formed to link and exploit the different competencies of a group of firms within a quasi-organizational framework. Network formation can also be understood by using power as the central concept, meaning the ability to influence the decisions or actions of others (Thorelli, 1986). Early adopters of network strategies can enjoy a first-mover advantage in securing resources, gaining market position and political influence, controlling information, and brokering new cooperative arrangements (Miles and Snow, 1984).

3.2.3. Resource-based view of the firm

This view, traceable to Penrose (1959), has recently become popular among strategic management analysts (Rumelt, 1984; Wernerfelt, 1984; Barney, 1991; Mahoney and Pandian, 1992; Peteraf, 1993; Mowery et al., 1998). According to this approach, the sources of sustained competitive advantage are firm resources that are valuable, rare, and not easily substitutable. Performance is based on the strategic differentiation that the firm achieves in the marketplace, that is, the firm's unique capabilities and its competitors' difficulty in imitating them. In high technology industries, such capabilities relate primarily to the development and exploitation of advanced technologies.

Access to external complementary resources may be necessary in order to fully exploit the existing resources and develop sustained competitive advantages (Teece, 1986). Alliances,

including research partnerships, can facilitate access. Alliances may, however, work better in some environments than in others (Chesbrough and Teece, 1996).

3.2.4. Dynamic capabilities

This approach is a related dynamic view of resource and capability accumulation (Teece and Pisano, 1994; Teece et al., 1997). The primary focus is on the mechanisms by which firms accumulate and deploy new skills and capabilities, and on the contextual factors that influence the rate and direction of this process. Teece et al. (1997)define dynamic capabilities as the firm's ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments.

Inter-firm collaboration can be viewed as a vehicle for organizational learning, that can be used to analyze the motive, process and outcome of strategic technical alliances (Hamel and Prahalad, 1989; Mody, 1993). Prahalad and Hamel (1990), for example, point to cooperative relationships as a means for internalizing core competencies and enhancing competitiveness. A primary factor influencing a firm's ability to develop technology-based competencies via a cooperative venture is the potential to learn from that relationship. Hamel (1991)takes a skill-based view of the firm, considering an alliance primarily as a route to acquire the skills of another firm.

A rapidly expanding stream of literature has emerged during the last few years focusing on corporate learning and organizational modes that facilitate such learning (Foss, 1993; Kogut and Zander, 1993). Cooperation is considered a mechanism to facilitate the transfer of certain types of knowledge and enhance the firm's learning capabilities. It is not so much the cost of the transfer (which would be the focus of the transaction cost approach) but the effectiveness of the transfer and the ability or experience of the firm in accessing and handling new knowledge that may create the need for collaboration. The literature on the learning organization is clearly related to the resource-based view of the firm and the dynamic capabilities approaches (Hodgson, 1998; Sachwald, 1998). Research partnerships are seen as mechanisms enabling firms to learn and enter new technological areas (Dodgson, 1991) and to deal more effectively with technological and market uncertainty.

3.2.5. Strategic options to new technologies

This approach to explaining collaboration complements the dynamic capabilities approach by considering how managers can determine prospectively the set of resources and capabilities

necessary for superior future performance in uncertain market environments (Sanchez, 1993). Strategy can be considered as a process of continuously maximizing the strategic options of a firm (Sanchez, 1995). This model can be applied to evaluating the ways in which different organizational schemes (market, network, and hierarchy) contribute to or impede the firm's ability to optimize its strategic options (Dixit and Pindyck, 1995; Trigeorgis, 1996). It is suggested that a research partnership that allows resources to be incrementally committed, contingent on positive outcomes, will often be more attractive than precommitting the full expected cost for developing a new technology especially in the presence of high market and technological uncertainty. Collaboration may assist companies to gain valuable experience and increase their exposure to related markets and their ability to sense and respond to new opportunities (Kogut, 1991).

3.3. Industrial organization

Industrial organization scholars have been interested in the resource allocation and economic welfare effects of inter-firm cooperation in R&D as part of a broader concern over the potentiality of failure in the market of scientific and technological knowledge. This failure is due to the perceived public good nature of knowledge that makes its production relatively more expensive than its transmission.12 The difficulty in appropriating the returns from knowledge is said to account for inadequate incentives to invest in it.

Recent theoretical literature dealing with technological competition has depended heavily on game-theoretic tools and formal mathematical modeling. The models can essentially be categorized into two categories: non-tournament models and tournament. The expectation of market failure has driven the analyses, and it is reflected in under-investment and duplication of non-cooperative R&D effort in non-tournament models and the over-investment in R&D in tournament models.

3.3.1. Non-tournament models

Non-tournament models focus on the extent of innovation, approximated by the degree of cost reduction or product differentiation. Firms are assumed to invest in R&D in order to, for example, decrease costs and then compete in terms of prices or outputs in the product market. The model's defining characteristics are a setup with many different research paths that firms in an industry can follow in pursuit of technological advance, and the possibility of more than one winner. An advance made on one research path may be used irrespective of whether competitor firms have also made similar advances on other research paths. These paths, however, are

sufficiently similar to be viewed as perfect substitutes. This similarity allows for the incorporation of R&D spillovers into the models, meaning that knowledge can escape the control of the firm and benefit the competitor pursuing another research path.

The vast majority of the theoretical work on cooperative R&D has, until recently, followed the non-tournament approach. Strategic, static, multistage models comparing the performance of cooperative and non-cooperative industrial setups in the presence of imperfectly appropriable, cost-reducing R&D are replete in the literature. Such analyses followed the seminal contributions of Spence (1984), Katz (1986)and D'Aspremont and Jacquemin (1988), including, for example, De Bondt and Veugelers (1991), De Bondt et al. (1992), Kamien et al. (1992), Suzumura (1992), Simpson and Vonortas (1994), Vonortas (1994), and Brod and Shivakumar (1997). The basic focus has been the investigation of the relative efficiencies of competition and cooperation in R&D — specifically in RJVs — in raising final output production and enhancing social welfare.

A consistent finding across most of this literature has been that spillovers have an important role in defining the relative efficiencies of non-cooperative and cooperative industrial setups. In the absence of spillovers, the market (non-cooperation) seems to do better. The reverse happens in the presence of spillovers. By internalizing knowledge spillovers, partnerships tend to break the trade-off between spillovers and R&D investment. Cooperation may, then, improve firm incentives to undertake highly inappropriable R&D, especially when the product market is relatively not concentrated and/or independent and competing R&D is also undertaken. R&D cooperation performs consistently better — in terms of resulting in more R&D investment and greater output — the higher the rate of knowledge spillovers. Moreover, the extent of information sharing among partners is positively related to the ability of the research partnership to raise social welfare. In symmetric industry settings, partnerships that both coordinate R&D efforts and that achieve greater information sharing among partners yield the highest technological efforts and social welfare, surpassing research partnerships that simply coordinate R&D efforts (Kamien et al., 1992; Combs, 1993; Vonortas, 1994).13

3.3.2. Tournament models

Tournament models emphasize the timing of innovation where the winner of an innovative race earns the right to an exogenously or endogenously determined monopolistic return.14 This essentially implies a single path to the technological advance, and the game often takes the form of a patent race. The analytical focus of tournament models has been on determining the number of firms entering the race; the aggregate R&D investment, and its distribution across firms and

time; and the effects of market power, technological advantage and technological uncertainty (Reinganum, 1989).

In the models with knowledge sharing, cooperation may well decrease overall R&D expenditures compared to the non-cooperative setup (Martin, 1994). Even so, if partners compete in the product market following the innovation, cooperation will, in general, be socially beneficial by passing more of the gains to the consumers. However, the requirement in such a model that the winner shares the available information with the losers means that the partnership will not form unless it is subsidized. Such results can be extended to the case where the partnership does not incorporate all firms in the industry. The socially optimal market structure for organizing R&D proves to be complex, however, depending on the number of firms and the ability of the partners to exclude rivals from the technology.

One example of the tournament approach to R&D collaboration is found in Katsoulacos and Ulph (1997), who address two basic issues.15 The first issue relates to the endogeneity of knowledge spillovers in RJVs; in addition to the amount of R&D expenditure, firms can choose their spillover parameter both inside and outside the partnership.16 The second issue related to whether firms undertake complementary or substitutive R&D. These two issues are important in the context of policies subsidizing information-sharing research partnerships that have been implemented in the United States and European Union. It is shown that firms choose to cooperate fully when they undertake complementary R&D (and the cooperative equilibrium then is the social optimum). If the firms undertake substitutive R&D, they share no information outside the partnership. While they are better off joining a partnership, subsidies are necessary to turn the cooperative equilibrium to a socially optimum solution.

Overall, as summarized in Table 1, the theoretical literature on research partnerships has varies in terms of both research focus and results. This variability reflects the fact that industrial setups differ in terms of market organization, the environment for innovation, strategic interaction between firms, and the objectives and organization of inter-firm collaborative agreements. And in addition, no two firms are alike, and their strategies differ even within the same industry (Nelson, 1995).

Table 1. Theoretical arguments to two basic questions related to research partnerships

Question	Transaction costs	Strategic management	Industrial organization
Incentives to form a research partnership	· Minimize cost of transactions involving intangible assets (technical knowledge)	· Share R&D costs	· Share R&D costs
	· Circumvent incomplete contracts	· Pool risks	· Pool risks
	· Avoid opportunistic market behavior	· Economies of scale and scope	· Economies of scale and scope
	· Avoid high costs of internalizing the activity	· Co-opt competition	· Co-opt competition
		· Improve competitive position	· Accelerate return on investments
		· Coordinate value chains with coalition partners	· Access complementary resources
		· Increase efficiency, synergy, power through network	· Decelerate rate of innovation
		· Access complementary resources to exploit own resources	· Increase market power
		· Use collaboration as learning vehicle to accumulate and deploy new skills and capabilities	
		· Learn from partners; transfer technology	
		· Create new investment options	
Expected results of research partnerships			
Partners	· Successfully meet incentives	· Successfully meet incentives	· Successfully meet incentives
		· Interdependency	· Interdependency
			· Increase R&D efficiency
			· Increase flow of information

Question	Transaction costs	Strategic management	Industrial organization
Industry, society	· Better resource allocation	· Industry competitiveness	· Increase overall R&D expenditures when spillovers are high
			· Increase social welfare
			· Subsidize on certain occasions

4. Empirical perspectives on research partnerships

The empirical literature on research partnerships has over the years taken one of two approaches. One approach investigates research partnership activity through analyses of existing data sets or through specialized surveys, and the other approach investigates using the case studies. Both research methods have reached important conclusions and have provided useful insights into science and technology policy.

The database analyses are, however, fragmented, and somewhat limited both in numbers and in scope because few systematic databases exist and because survey work has been constrained as scholars are still in the learning stage with regards to research partnership behavior.

4.1. Existing databases related to research partnerships

Three major databases related to research partnerships are described in this section.

4.1.1. The MERIT-CATI database

The MERIT-CATI (Cooperative Agreements and Technology Indicators) database is a relational database covering over 13,000 technical cooperative agreements involving about 6000 different parent companies. It contains information on each agreement and selected information on those companies participating in agreements. Cooperative agreements are defined as common interests between industrial partners that are not connected through ownership. Joint research pacts, second-sourcing, and licensing agreements are examples of inter-firm agreements in this database.17

Relevant input of information for each alliance relates to: 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, field(s) of technology, and modes of cooperation.

The MERIT-CATI database is maintained by John Hagedoorn and his colleagues.

4.1.2. The CORE database

The CORE (COoperative REsearch) database was constructed under the sponsorship of the National Science Foundation and is maintained under their support by Link. Its resource base is information contained in filings with the U.S. Department of Justice as reported in the Federal Register (discussed in Section 5).18

Research partnerships gain two significant benefits from such voluntary filing with the Department of Justice: if subjected to criminal or civil antitrust action, they are evaluated under a rule-of-reason criterion that determines whether the venture improves social welfare; and if found to fail the criterion, they are subject to actual rather than treble damages.

The unit of observation in the CORE database is the RJV. All public domain information contained in each new and updated Federal Register filing is coded in the CORE database, and that information is supplemented with other sources of information to describe the industry represented in the research partnership.19

4.1.3. The NCRA-RJV database

The NCRA-RJV database also uses information on U.S.-based RJVs from the Federal Register. The particular characteristic of this database is that it enables research where the unit of analysis is the partner rather than the partnership. Federal Register information is supplemented with information on the characteristics of the business partners from independent sources, including CompuStat for publicly traded firms and CorpTech for privately owned firms. Important features of the NCRA-RJV database include:

• the database, like CORE, covers partnerships consistently classified as RJVs under a single official definition;

• the database has been designed to support both qualitative and quantitative research; and

• the database combines the information on joint venture characteristics with longitudinal financial performance information on business participants and their industrial diversification.20

The NCRA-RJV database is maintained by Vonortas.

4.2. Empirical research issues

The empirical research related to research partnerships focuses on four general issues: (i) trends in research partnerships, (ii) composition and focus of research partnerships, (iii) motives for participating in research partnerships, and (iv) benefits from participation in research partnerships.

4.2.1. Trends in research partnerships

Research on the MERIT-CATI database has revealed a number of worldwide trends in the inter-firm technology partnerships during a period of more than 25 years. Specifically, the number of new partnerships set up annually gradually increased from about 30–40 in the early 1970s to 100–200 in the late 1970s. The 1980s marked a period of a further rapid increase. Starting from around 200 per year, the number of new partnerships announced every year reached around 600 or more later in the 1980s and 1990s.

Although formal research partnerships were little known about during the 1970s, researchers have found some indications that this organizational form was gaining in popularity. Hladik (1985)documented how researchers of the well-known Harvard Multinational Enterprise project were somewhat puzzled by the increasing number of international R&D joint ventures. At the time, it was thought that joint ventures would be aimed mainly at manufacturing activities and not at critical, firm-specific activities like R&D and innovation.

The MERIT-CATI data reveals that during the early 1970s about 80% of the research partnerships were research corporations. Gradually, this distribution changed. By the mid-1990s, more than 85% of research partnerships did not involve equity investments. Globally, RJVs rapidly became the dominant form of research partnerships.

Two additional trends are noteworthy; the degree to which inter-firm research relationships are made between domestic or international partners, and the role that high-technology sectors play in inter-firm technology collaboration. The share of domestic inter-firm research collaboration recorded in the CATI database as occurring during the 1970s and 1980s was only about 35% of the total. The share of domestic partnerships has gradually risen to about 45% during the 1990s. Further, this change has largely been caused by the notable role of intra-U.S. collaboration in two major fields, biotechnology and information technology. The very important role that United States firms have played in leading edge research in these two fields not only makes them attractive partners for international collaboration, but also raises the probability of intra-U.S. joint research at the scientific and technological frontier (Hagedoorn, 1996).

Following the OECD classification of industries (OECD, 1997), during most of the 1970s (when some current high-technology activities such as biotechnology and advanced materials research were almost non-existent), the share of high-technology sectors was on average about 40% of the total number of inter-firm partnerships. During the late 1970s and early 1980s, the share of high-technology research collaboration increased to between 50% and 60%. From the mid-1980s to the mid-1990s this share increased even further. According to the most recent data, about 80% of the inter-firm research relationships are established in high-technology industries. In other words, inter-firm research partnerships have become mainly concentrated in a small number of high-technology industries.

Research by Freeman and Hagedoorn (1994)and Hagedoorn (1996)revealed a number of other trends in the international distribution of inter-firm research partnerships based on their analysis of the CATI database.

· The majority of research relationships have been established within the Triad — North America, Japan, and the European Union. During the 1970s and 1980s the share of the Triad in all these partnerships was over 95%. In the 1990s, this dominance became less strong as the share of other combinations rose to about 20%.

· The growth of inter-firm research partnerships with partners from outside the Triad reflects the growth of the share of alliances with companies from South East Asian countries, such as South Korea, Taiwan, Singapore, and Hong Kong.

· In high-technology industries, the share of the intra-Triad research relationships has remained high. Only during the mid-1990s did this share for the developed economies decrease to about 90%.

· The growth in the share of non-Triad countries is primarily in the non-high technology sectors, including the more traditional engineering and manufacturing industries. The share of countries outside the Triad in partnerships in these sectors increased from about 15% in the 1970s and early 1980s to about 30% during the 1990s.

The time trend of formation of U.S. research partnerships registered with the Department of Justice in the United States has been studied extensively through the CORE and NCRA-RJV databases. The significant increases in registrations during 1985–1995 have been followed by decreases in the last 3 years, which have been particularly steep in 1997 and 1998. The reasons for this change are not clearly understood. The changing fortunes of the Advanced Technology Program (ATP) — a rapid increase in the funding of partnerships during 1994–1995 and a significant drop afterwards — may explain part of this change. Examining the formation of partnerships from the CORE database, Brod and Link (1996)concluded that another part of this trend is due to changes over time in announced public attention by the Department of Justice toward antitrust violations. This so-called announcement effect gives firms a greater incentive to seek indemnification and file their cooperative R&D intentions.

4.2.2. Composition and focus of research partnerships

As previously discussed in Section 2, a research partnership can be classified as public, private, or public/private on the basis of the composition of its membership. Research on the composition of members in RJVs is being conducted by a growing number of scholars, with many paying particular attention to the role of universities.

Baldwin (1996), Baldwin and Link (1998), and Vonortas (1997)document the extent to which university participation in partnerships has changed over time; and Baldwin and Link (1998)and Hall et al. (1998)have gone beyond descriptive analyses to investigate possible economic motives for why a research group of firms would invite a university to participate. Relatedly, Leyden and Link (1999)asked a similar question with regard to a federal laboratory being a research partner in a partnership (and federal laboratories have similar public characteristics to universities). Both Baldwin and Link (1998)and Leyden and Link (1999)conclude that only the larger partnerships — where size is measured in terms of number of members — invite a public

partner to participate. The reason is that in large partnerships appropriability has already been diminished due to the size of the venture.

Regarding the research focus of RJVs, Vonortas (1997)found for the United States that information technology was the dominant field, followed by advanced materials. This findings largely agreed with the more global evidence provided by Hagedoorn (1995)and Hagedoorn and Schakenraad, 1990 and Hagedoorn and Schakenraad, 1992.

4.2.3. Motives for participating in research partnerships

Link and Zmud (1984), in what may be the first broad-based empirical analysis of research partnerships, documented that firms in the then video display terminal industry undertook research cooperatively (and informally) with other firms in an effort to maintain and increase their market share. RJV participation was a strategic means to be at the forefront of new technological developments in the field.

Relatedly, Link and Bauer (1989)and Link (1990)examined three possible strategic motives for a firm to participate in a partnership: to gain technical ability to diversify horizontally into new product lines, to gain technical ability to vertically integrate production activities, and to gain technical ability to leap-frog competitions within their primary line of business. Leap-frog competition was not a strategic factor that influenced manufacturing firms' decisions to participate in partnerships.21 Rather, those firms that faced market threats from foreign competition were using partnerships as a vehicle toward horizontal diversification, and those not facing such pressures were using partnerships as a vehicle to increase their market share by becoming vertically integrated.

On the basis of this analysis of the European semiconductor industry, Martin (1996)has argued that firms will engage in research partnerships, be they domestic or international, to further their competitive strategic goals. Public policies, at least in the semiconductor industry, have not been successful in Europe to redirect firms from these competitive strategic goals toward an agenda that favors domestic growth.

The strategic motives of firms to engage in research partnerships were also emphasized in the empirical analysis of Vonortas (1997). The examined partnerships appeared to provide a vehicle for virtual diversification into fluid technology fields — lacking well specified technological

trajectories — characterized by high technological and market uncertainty but also high technological opportunities and growth potential.22 In addition, firms participate in order to raise the necessary R&D funds or leverage their own, access complementary resources, exploit research synergies, and create new investment options. These results strongly supported the argument of the resource-based view of the firm and related management approaches.

There is a well-documented history of informal industry/university research relationships, but it has only been the more recent literature that has focused on the motivations and incentives to industry and to academe to enter into such relationships.23 While this so-called behavioral empirical literature is just developing, there appears to be a consensus of opinion about certain issues. The first motivation is access to complementary research activity and complementary research results.24Cohen et al. (1997)provide a selective review of this strategic literature, emphasizing the studies that have documented that university research enhances firms sales, R&D productivity, and patenting activity.25 As Rosenberg and Nelson (1994)(p. 340) note: “What university research most often does today is to stimulate and enhance the power of R&D done in industry, as contrasted with providing a substitute for it.” The second motivation is access to key university personnel.26 The administration-based financial pressures for faculty to engage in applied commercial research with industry are growing.27Zechhauser (1996)(p. 12,746) is subtle when he refers to the supposed importance of industry-supported research to universities as he describes how such relationships might develop: “Information gifts [to industry] may be a part of [a university's] commercial courtship ritual.” Overall, however, there is a void of information about the nature of the industry–university interaction that occurs when the two informally partner in an research partnership.

4.2.4. Benefits from participation in research partnerships

Link and Bauer, 1987a, Link and Bauer, 1987b and Link and Bauer, 1989have shown a positive correlation between cooperative R&D conducted by a firm, the firm's market share, and the productivity of the firm's in-house R&D. The latter result has been interpreted to suggest that participation in a research partnership increases the absorptive capacity of firms with regard to their R&D activity.

Along these same lines, Scott (1996)reports, for an analysis of a small sample of firms that formed research partnerships to develop new processes for reducing toxic air emission, that cooperation appears to foster new research that would not have been initiated without the cooperative experience. This conclusion for toxic air emission is similar to the conclusions reached by others that cooperation in R&D does expand the scope of the firm's R&D horizon.

Besides case study work, however, the empirical evidence on this point is severely limited. The earlier concern of Scott, 1988 and Scott, 1993is that widespread cooperation could lead to a decrease in competition, and this decrease may not be offset by an increase in innovation-related benefits, may indeed have merit. A related argument, combining some initial evidence on multimarket and multiproject contact between pairs of firms in U.S.-based research partnerships has also echoed by Vonortas (forthcoming).

Link (1998a)Link (1998b)reported that members of two ATP-sponsored research partnerships experienced gains in their R&D efficiency as well. These gains were realized from reduced duplication of research costs and reduced cycle time. Two additional case studies reached similar conclusions in terms of reporting significant benefits to the participating firms (Vonortas, 1999). Relatedly, a similar experience was reported by the members of SEMATECH from the organizations collaborative efforts. Link et al. (1996)estimated that research collaboration through SEMATECH earned member firms a return of about 63% on their membership dues. These benefits accrued primarily through reduced duplication of research costs.28

The empirical evidence of benefits to partnership members has depended primarily on case studies. While this literature has shown generally high returns to collaboration, it must be emphasized that it does suffer from selection bias; the partnerships studied often tend to be some of the most successful, and hence those with high returns.

5. Policies toward research partnerships

A major objective of policies toward research partnerships in the early 1980s in both the United States and the European Community (EC) was to arrest the relative decline in the international competitiveness of high technology sectors. R&D featured prominently on the policy agenda. Both regions introduced major changes in the law to accommodate the policy shift. The United States moved forward with a twin strategy of relaxing its relatively strict antitrust laws and of strengthening its intellectual property rights policy laws. The EC moved forward by creating the legal basis for central science and technology policy in the Single European Act of 1987, and by institutionalizing a series of 4-year, successive Framework Programmes on Research and Technological Development (FWPs). Interestingly, the promotion of cooperative R&D became a central policy tool for both the U.S. and the EC at about the same time. Meanwhile, Japan continued its long-standing policy on cooperative R&D, having undergone a major shift in the focus of most government sponsored research partnerships in the late 1970s. The rationale for the Japanese partnerships changed from assisting various industries to catch up with the world's state-of-the-art technology to assisting high technology firms and industries push the state-of-

the-art forward. Highlighted below are selective national policies related to research partnerships; no effort is made to comprehensively describe or critique these policies.29

5.1. U.S. policies

The U.S. government acted on research partnerships in the early 1980s under mounting evidence that an increasing number of firms in high technology sectors had started to choose cooperative R&D agreements routinely to carry out technological activities. The willingness of policy decision-makers to promote cooperative R&D rested on concerns about the relative loss of international economic competitiveness. These fears were fueled by the apparent success of fast-follower countries that promoted cooperative R&D to access, assimilate, and diffuse technology quickly. Japan served as a prominent example. The necessary policy justification for collaboration was provided by traditional economic argument of market failure in R&D.

This new competitive policy approach was underlined in the United States by the extensive changes in antitrust and intellectual property rights regulation beginning in the early 1980s. The Department of Justice and the Federal Trade Commission promoted a new approach to examining the competitive effects of partial mergers, which included research partnerships. Rather than a per se approach, such mergers should be judged on a rule-of-reason basis where the static anticompetitive effects would be weighted against the dynamic benefit effects from the partnership. This change in approach eventually led to the passage of the National Cooperative Research Act (NCRA) of 1984, and its 1993 amendment the National Cooperative Research and Production Act (NCRPA).30 All filings are published in the Federal Register.

Also, in the early 1980s, there was a series of legislative actions, starting with the Baye–Dole Act in 1980, that created a legal framework for permitting government contractors to benefit financially from the results of the research undertaken with or for the government (excepting national defense items). This legislation spurred research cooperation between industry, universities and government laboratories. Part of the induced collaborative activity (involving government labs) is conducted under Cooperative Research and Development Agreements, or CRADAs.

5.2. EC policies

Similar to the United States, the EC entered the 1980s with increasing anxiety over the perceived gradual loss of competitiveness and the effects of globalization in high-technology industries. In

the EC's case, however, there were other factors influencing policy in addition to the widely perceived change in the global forces affecting R&D and innovation. These other factors included the continuing expansion of the Community and the wide disparities between the industrial and technological capabilities of the various country members; the already well established, but very different, S&T policy infrastructures in a number of the larger and wealthier country members, and the total lack of such infrastructures in the cohesion country members; and the absence of the appropriate legal framework and institutions at the EC level for supporting a consistent technology policy.

The catalytic events in the early 1980s in the form of rapid technological advances and the loss of market share by the indigenous European electronics industry led the European Commission in 1981 to establish the pilot ESPRIT program with the endorsement of the twelve largest European producers of electronics. ESPRIT served as the progenitor of the European Framework Programs on R&D (FWPs) to which it lent many of its features. One such feature was the support of cooperative R&D. Another was the public support of pre-competitive or pre-normative research that was sufficiently far from the market. FWPs have become the vehicle for the implementation of the S&T policy of the European Union. FWPs provide the policy umbrella encompassing all programs through which the EC supports R&D in particular areas.

Four FWPs have already been completed: 1984–1987, 1987–1991, 1990–1994, and 1994–1998. The fifth (1998–2002) has just been initiated. A prerequisite for support — up to 50% of total joint research costs — of a research partnership is the inclusion of agents based in at least two EU member countries; industry, universities and research laboratories can participate.

Needless to say, European policies for cooperative R&D go beyond the EC level; they spread across all EU member states.31 Given the wide variety of national S&T policy systems in Europe, policies targeted to cooperative R&D vary significantly. Among EU member countries, one can distinguish between the four large industrialized and R&D spending countries (France, Germany, Italy, and United Kingdom), the seven small to medium size industrialized countries (Austria, Belgium, Denmark, Finland, Luxembourg, Netherlands, and Sweden), and the four less industrialized cohesion countries (Greece, Ireland, Portugal, and Spain) that formally introduced S&T policy only during the last few decades. Even within these groups, there are great differences between countries with traditionally more centralized S&T policy systems (e.g., France) and others with more decentralized systems (e.g., Germany); or between countries with traditional mission-oriented polices (e.g., France and UK) and those with a tradition in diffusion-oriented polices (e.g., Germany).

This diversity has also been reflected in policy approaches to cooperative R&D, including the nature and extent of government involvement in promoting and regulating research partnerships.32 There are, nonetheless, some general trends across regions. One trend is that, while the European Framework Programs have tended to support pre-competitive cooperative research, national/regional policies have often supported partnerships dealing with research closer to market. A second trend is that national and regional governments across Europe have tried to use research partnerships as one of the mechanisms for strengthening the links among industries, universities, and government laboratories. A third trend is that governments at all levels have increasingly seen strategic partnering and network building as mechanisms to enhance technological prowess and economic competitiveness in high-technology manufacturing and service sectors.

5.3. Japanese policies

Japan was a pioneer in supporting cooperative R&D in the post-War period. Like industrial policy and general S&T policy, the objectives and organization of Japanese cooperative R&D organizations have changed over this time period. The idea of research associations was basically imported from the UK after the war, but the use of research associations was transformed from an instrument for assisting declining firms and industries to an instrument for gathering, adapting, and distributing technological information more efficiently in high technology industries. Following the Mining and Manufacturing Industry Technology Research Association of 1961, a large number of Japanese Engineering Research Associations (ERAs) were established in a wide variety of sectors (Sigurdson, 1986). More recently, Sakakibara (1997)documented 237 government promoted ERAs set up between 1959 and 1992; however, it is hard to know exactly how many ERAs have been established due to the lack of a unified source of information.

In the mid-1970s, the focus of ERAs changed significantly from generating/adapting specific technologies, to assisting sectors catch up with world technology, to undertaking state-of-the-art research to provide a broader technological superstructure for high technology sectors (Oshima and Kodama, 1986). An early example of the more aggressive ERAs is the very large scale integration circuit (VLSI) association.

While many ERAs have reportedly met their objectives successfully, it is rather doubtful that any of them produced the returns to industry that western countries thought at the time. Government

funds were small, measurable technology outputs fairly modest, and collaboration often meant an agreement to share only the cost but not the research process.

ERAs represent only one form of collaborative R&D in Japan. Such cooperation has also included trade associations, joint research institutes, collaboration within large firm networks (keiretsu), and private sector formal and informal collaborative agreements. Japanese firms have also been active participants in international research partnerships. The basic difference of ERAs is that they are formed under the auspices and guidance of the government and often include a significant proportion of the large players in a technological area.

6. Conclusions

According to available theory and empirical evidence, firms participate in research partnerships in order to:

• decrease transaction costs in activities governed by incomplete contracts;

• broaden the effective scope of activities;

• increase efficiency, synergy, and power through the creation of networks;

• access external complementary resources and capabilities to better exploit existing resources and develop sustained competitive advantage;

• promote organizational learning, internalize core competencies, and enhance competitiveness;

• create new investment options in high-opportunity, high-risk activities;

• internalize knowledge spillovers and enhance the appropriability of research results, while increasing information sharing among partners;

• lower R&D costs;

• pool risk; and

• co-opt competition.

Governments have promoted and supported research partnerships in order to:

• correct market failures in R&D investment, particularly in the presence of highly non-appropriable research;

• speed up technological innovation, aiming at increased international competitiveness; and

• increase technological information exchange among firms, universities, public research institutes.

Theory clearly warns public authorities, technology policy authorities in particular, to be cautious and to be aware of the downside effects associated with collaboration. With all their benefits, partnerships have the negative potential to block competition and create various kinds of static and dynamic monopolies (in existing and future markets, respectively).

Much research remains before contributions from economics, management, and public policy studies have a broader unified base of understanding of these phenomena. A unified framework to explain and analyze research partnerships is still lacking. Particular emphasis must continue to be paid to empirical research, even though it has tended to lag theoretical analysis in this subject because of data limitations. We expect that future empirical research will increase as more complete databases become available and expand in coverage, and it will systematically begin to evaluate both the private and social returns associated with collaboration.

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4 This definition resembles what others have called a strategic technical alliance which is a special case of a strategic alliance. Teece (1992), for example, defines a strategic alliance as a web of agreements whereby two or more partners share the commitment to reach a common goal by pooling their resources and coordinating their activities.

5 Surprisingly, there is no uniformly accepted definition of partnership in the academic or technology policy literature. For example, Coburn (1995)(p. 1) used the term synonymously with cooperation. Therein, he defined cooperative technology programs as “public–private initiatives involving government and industry — and often universities — that sponsor the development and the use of technology and improved practices to measurably benefit specific companies.”

6 Link (forthcoming)argues, on this basis, that all universities are public.

7 The difference in terminology with regard to different formal agreements as used in economics and management may be confusing. In the management literature, joint ventures are mainly equity joint ventures, whereas RJVs are usually categorized as contractual agreements. These different categories and classifications are also apparent in the contribution of Link and Bauer (1989), Hagedoorn (1996)and Vonortas (1997). In this paper, we follow the terminology generally found in the economics literature.

8 However, Contractor and Lorange (1988)and others doubt whether there is sufficient evidence to conclude that the failure rate of research corporations exceeds the normal failure rate for single-firm ventures.

9 Combs (1999), for example, uses a strategic management approach with transaction costs.

10 The term resources must be interpreted broadly to include both tangible and intangible resources such as goodwill, market reputation, and trust (Zajac and Olsen, 1993; Gulati, 1995aGulati, 1995b). For a discussion, see Vonortas (1997).

11 Strategic management analysts have tended to discuss strategic technical alliances, a much broader set of relationships than the research partnerships we focus on in this paper. We present the arguments for strategic technical alliances under the presumption that they also apply to the subset of research partnerships. This subsection draws on Lee and Vonortas, forthcoming and Porter, 1985.

12 It is now clear that transmission is not free as was essentially represented in earlier models (Cohen and Levinthal, 1989). Nevertheless, the fundamental resource allocation problem remains.

13 Recent work has shown that certain results from the static, multistage literature concerning the impacts of cooperation on the behavior of individual partners and on social welfare also carry over into dynamic environments. See, for example, Joshi and Vonortas (1997).

14 In addition to single innovations and single races, one can also have innovation sequences and corresponding race sequences (Vickers, 1986).

15 See also Grossman and Shapiro (1987)for a model of dynamic R&D competition in which the effects of both RJVs and patent licensing activities can be studied.

16 RJV partner incentives to share their know-how in the presence of uncertainty have been analyzed by Perez-Castrillo and Sandonis (1996).

17 Since CATI is primarily related to technology cooperation, it does not cover production or marketing joint ventures, agreements that simply regulate the setting of standards, and other non-technology partnerships.

18 The partnerships filing with the Department of Justice are classified by the Department as RJVs. Most of them are non-equity RJVs. It has become common in the literature to refer to Federal Register filings as RJVs.

19 The CORE database, and its annual updates, is available upon request from Link. See Link, 1996a and Link, 1996bfor an expanded description of the database and its variables.

20 The contents of the database are described in greater length by Vonortas (1997). The database is available upon request by academic researchers.

21 In contrast, Rosegger (1989)argued that leap-frog competition over international rivals was the strategic motive for cooperation in research by U.S. automobile manufacturers throughout the 1980s.

22 The term virtual diversification is used to differentiate business expansion by joining a partnership from more traditional kinds of diversification such as internal expansion and mergers/acquisitions.

23 See Rosenberg and Nelson (1994)and Hounshell (1996)for historical overviews.

24 See Blumenthal et al. (1986), Jaffe (1989), Adams (1990), Berman (1990), Feller (1990), Mansfield, 1991 and Mansfield, 1992, Van de Ven (1993), Bonaccorsi and Piccaluga (1994), Klevorick et al. (1994), Zucker et al. (1994), Henderson et al. (1995), Mansfield and Lee (1996), Zechhauser (1996), Campbell (1997), Cohen et al. (1997)and Baldwin and Link (1998).

25 Cockburn and Henderson (1997)show that it was important for innovative pharmaceutical firms to maintain ties to universities. Perhaps research ties with universities increase the absorptive capacity, in the sense of Cohen and Levinthal (1989), of the innovative firms.

26 See Leyden and Link (1992)and Burnham (1997). Link (1995)documents that one reason for the growth of Research Triangle Park (NC) was the desire of industrial research firms to locate near the triangle universities (University of North Carolina in Chapel Hill, North Carolina State University in Raleigh, and Duke University in Durham).

27 See Berman (1990), Feller (1990), and Henderson et al. (1995).

28 For earlier work on cooperative research as related to the semiconductor industry see, for example, Erdilek (1989). See also Mowery (1989)on high temperature superconductivity.

29 See Rothwell (1989)and Rosegger (1996)for earlier reviews of such policies in Europe, and Audretsch (1989)for an earlier review related to Japan. Martin (1996)and Vonortas (1991)have also analyzed policies for various countries.

30 For an institutional perspective of the NCRA see, for example, Scott, 1989 and Scott, 1993.

31 European S&T policy is still primarily determined at the national (i.e., EU member country) level. Moreover, the R&D budget of the European Union is still small in comparison to the R&D budget of nation states. For example, the annual budget of the Framework Programs is currently about 7% of the total civilian R&D spending by European countries, amounting to approximately US$60 billion in 1997. Additional R&D funds are dispersed by the European Commission through the structural programs.

32 Several recent research projects supported by the Targeted Socio-Economic Research Program of the European Commission have looked at various aspects of policies related to research partnerships in Europe.