\08

Fostering Cooperation: The Role of Esprit in Shaping Industrial Behavior

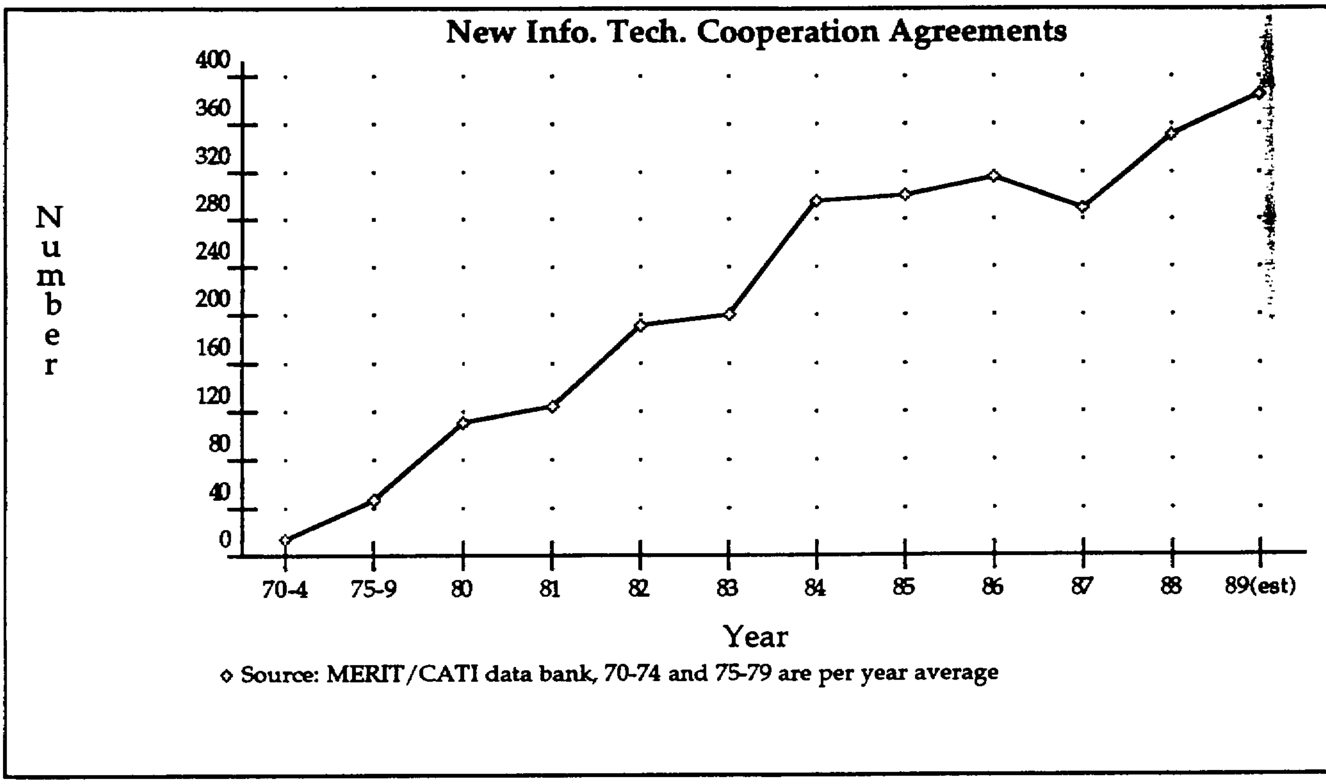
Todd A. Watkins
Harvard University
Science, Technology, and Public Policy Program
(Draft)

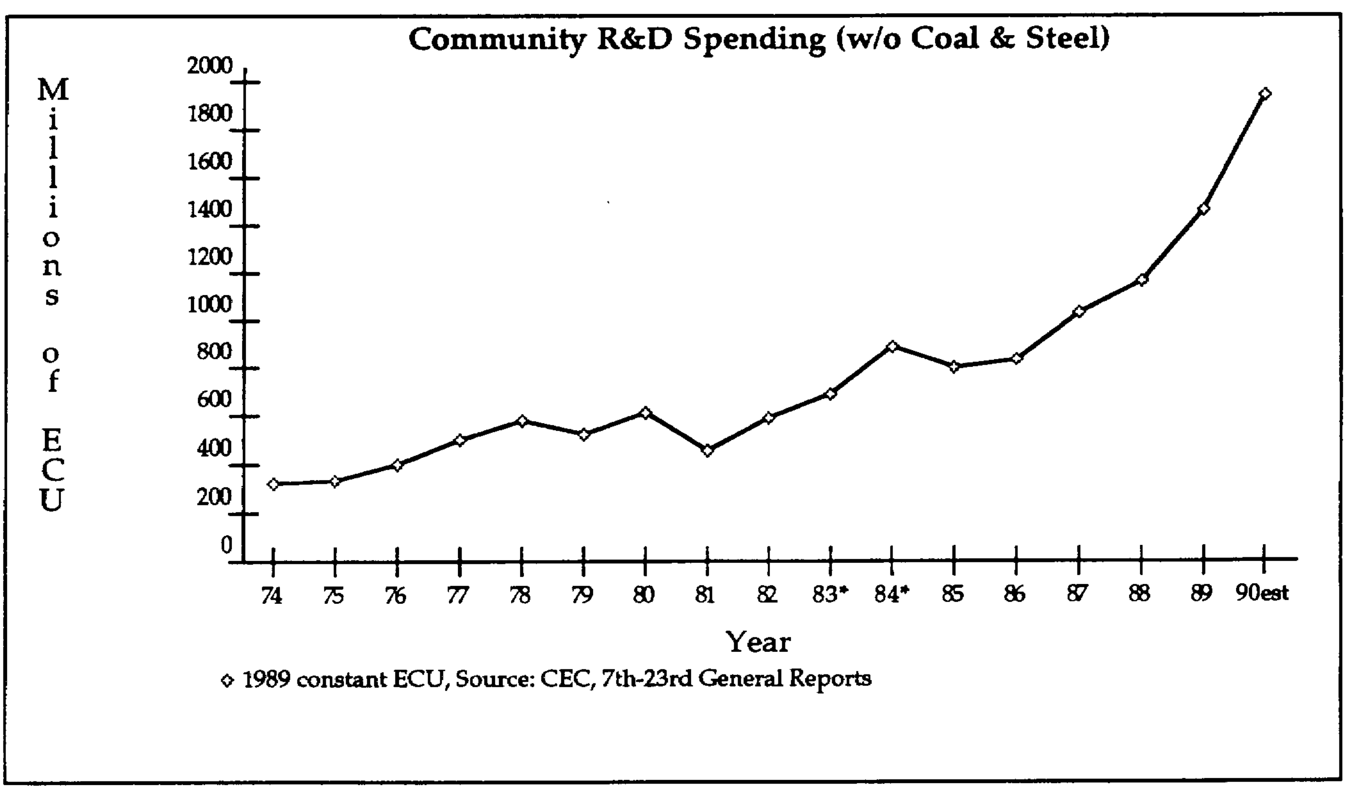
Introduction

The 1980s have brought a striking change in the design of European industrial research policies. In the "technology gap" 1960s the policy response to the American challenge was to emulate the apparent reasons of American success: large firms which could take advantage of multinational markets and economies of scale in research and manufacturing. Parochial distributional conflict and market concentration in government owned and trade-protected national flagship companies -- the national champions, like Siemens in Germany , and Thomson in France -- defined the European commercial high technology sector. The intra-European cooperative policies which did emerge, like Euratom, Airbus, and the two European space organizations were also based on obvious needs for sufficient economies of scale. Even then, the cooperation proceeded by fits and starts

In the 1980s, however, another approach has come to dominate European international collaborative programs. This approach is found, for example in more than 20 different R&D programs of the European Community, as well as in related programs such as the diverse Eureka Program and the large semiconductor research collaborative JESSI. They are organized as large numbers of independently managed, partly government financed, cooperative R&D consortia collected under the umbrella of a guiding body such as the EC. European governments are now investing several billions of dollars each year, matched by private industry, in such collaborative technology programs. In addition, the 1980s has seen a dramatic increase in the numbers and variety of purely private intra-European collaborative research and production ventures.[1] There has also been an associated set of changes in European laws and institutions to accommodate this shift towards industrial collaboration in technology. The paper argues that these changes

[1] Chesnais (1988), Hagedoorn (1990b), Hagedoorn and Schakenraad (1990) Mytelka and Delapierre (1988). See Figures


New Info. Tech. Cooperation Agreements
Number
400
360
320
280
240
200
160
120
80
40
0
70-4
75-9
80
81
82
83
84
85
86
87
88
89(est)
Year
◇ Source: MERIT/CATI data bank, 70-74 and 75-79 are per year average


Community R&D Spending (w/o Coal & Steel)
Millions of ECU
2000
1800
1600
1400
1200
1000
800
600
400
200
0
74
75
76
77
78
79
80
81
82
83*
84*
85
86
87
88
89
90est
Year
◇ 1989 constant ECU, Source: CEC, 7th-23rd General Reports

are signs of an evolution in European industrial behavior concerning technological innovation. The outlook less parochial and short term. Emphasis is moving towards cooperative reciprocity and towards attempts to change the balance of cooperation and competition to favor long term productivity growth.

The hypothesis explored in this paper is that the emergence of these new institutions of cooperative industrial behavior in Europe can be explained, in part, as a response to the high transactions costs associated with markets for technology innovation and diffusion. As the rate of technical change quickens, R&D costs rise, and the scope and variety of technical expertise needed to bring successful products to market widens, the importance of technology-based relationships among firms increases. Yet as this paper will argue, a fundamental tension exists in technological cooperation. The very characteristics of technologies which make cooperation valuable make the transactions required to carry on collaborative efforts costly, particularly when industrial behavior is parochial and the outlook short term. The shift in industrial behavior is serving to reduce that tension.

What the study highlights, in particular, is that analysis and policymaking for technological innovation and competitiveness might include not only market structure and the organization of the firm but also a focus on the nature on the interfaces -- the relationships and networks -- among technology actors. Because much technological expertise cannot be disembodied from its organizational or social surroundings, the broader social institutions within which technological relationships operate are an important determinant of their efficacy.

The paper is divided as follows. The first four sections develop the theoretic story on which the hypothesis is based. The remaining two sections then assess the evidence which support the premises for that story. Empirical data is drawn largely from a study of the earliest, by far the largest of the consortia-umbrella programs in the EC, the Esprit Program, which serves as the model for most of the others. Evidence is based on extensive field interviews with industrial participants in Esprit consortia as well as on EC policy documents. The first section discusses the economic theories and supporting evidence which suggest that collaborative innovative activities among firms may be broadly beneficial in terms of long term economic growth. The second section augments that theory by discussing the characteristics of "embedded technologies." Embedded technologies are difficult to embody in designs or specifications, nor can they be effectively transferred in codified form. The analysis suggests that failures of markets to provide such technologies may exist where cooperation does not occur. The third section considers the transactions costs consequences of embedded technologies. It argues that the nature of embedded technologies makes property rights difficult to define, and asymmetries of information the rule. Under these conditions bargaining and management costs could be expected to be high if cooperation were undertaken ad hoc, particularly within a regime emphasizing distributional conflict. The fourth section puts forward the theoretical basis for the hypothesis that the emergence of new institutions of industrial behavior can be explained as a functional response to the transactions costs described in the third section. Section five discusses the interview evidence on the transactions costs effects of embedded technologies in collaborative R&D, and section six documents the emergence of institutions which function as predicted by the theory.

I. Theories of Collaborative R&D

In R&D consortia firms agree to share expenses and jointly produce technical information. This is a middle ground between two traditional foci: markets and hierarchies. Coase (1937), Williamson (1975), Arrow (1969), and Schumpeter (1942) have all put forward hierarchically organized firms as a method of overcoming market failures such as the public goods problem, economies of scale and scope, uncertainties, asymmetries of information, and difficulties in finding and contracting with suppliers. These are often ubiquitous problems in markets for technologies.

Emerging theories attempting to explain the upsurge in R&D collaboration in the 1980s now claim that inter-firm collaboration can provide many of the same advantages over markets as hierarchies, without the attendant risks of monopoly power.[2] R&D collaboration can help firms overcome the appropriability problem, can permit firms to collectively spread the risks of R&D and obtain R&D economies of scale or scope, or the critical mass of skills and specialization they would be unable to achieve

---

[2] Bozeman et. al. (1986), Chesnais (1988), Hagedoorn (1990a), Jorde and Teece (1990), Katz (1986) Link and Tassey (1989), Mowery (1989), Ouichi and Bolton (1988)

alone. Firms can also avoid unnecessary duplication of research. Collaboration, then, is increasing as market uncertainty increases, technology life cycles shorten, R&D costs rise, and the technical scope of products widens.

Available empirical evidence suggests that the most important motivation for cooperative R&D is access to technologies external to the firm.[3] Firms can gain access to technologies in which they have limited expertise at lower cost than through in-house R&D. This is often a motivation for mergers or acquisitions. Yet, where the desired expertise is only one part of the other firm and there are high costs to divesting, or the real value of the capabilities to be acquired are uncertain, merger may not be preferable. Cooperation also offers firms a low cost way to maintain a window on new technical developments, to assess alternatives, or to monitor the technical capabilities of their competitors.

The question remains why licensing or cross licensing are not, then, used for this access to technologies. Here, consider the standard application of transactions costs theory to markets for technological information. By definition, if firms are looking for expertise external to the firm, they have less information about a technology than the supplier. Under such asymmetries of information, and given the inherent uncertainties of R&D, the value of technical information to a buyer is uncertain. The potential for opportunistic behavior can make contracting through market mechanisms costly.[4] As discussed in more detail below, these transactions costs will be particularly problematic under conditions where technologies can not be embodied in designs, specifications, or drawings, nor effectively transferred in codified form. Further, as we will see, there may be nothing specifiable or concrete *to* licence in the first place.

II. Embedded Technologies

In this paper "embeddedness" represents the degree to which a technology or technical expertise can, in principle, be communicated at low cost -- whether or not it is actually communicated.[5] While no attempt is made

---

3 Chesnais (1988), Fusfield and Haklisch (1985), Hagedoorn (1990b), Mytelka and Delapierre (1988), Mytelka ~~(1989)~~ 1991

4 Hennart (1988), Teece (1989), Williamson (1979)

5 The term borrows from Granovetter (1985)

to quantify the concept, embeddedness may be thought of along a range: zero under conditions where the costs of codifying and transferring a technology are negligible; one where the costs of communicating the technical expertise are equal to or greater than the costs of duplicating it independently. Much formal orthodox economic theory assumes that the costs of technology transfer are negligible. Indeed, Von Hipple (1987) has shown that when the channels for technological communication are well established know-how sharing can be straightforward. This is no doubt in some cases true, where the technical information can be readily described and specified by the technology supplier, and where the receiver is capable of understanding the information and its relevance to the receiver's application. Here the potential for traditional licensing is highest, although agency problems can still arise where asymmetries of information exist. However, as Von Hipple (1990), Nelson and Winter (1982) and others have also noted, under other conditions communicating technological information can be difficult and costly. Teece (1976), for example, shows that the technology transfer costs can be a significant fraction of total project costs. The proposition of this section is that R&D cooperation can be superior to licensing as an option for access to external technologies because of the embeddedness characteristics of technologies.

A brief discussion of a number of reasons technologies can be costly to communicate will help characterize embeddedness. A significant determinant of technology embeddedness can be described by what Polanyi (1967) called "tacit" knowledge. Polanyi noted that many of the rules which skilled artisans observe cannot be articulated, and are often not even known to them. His evidence included the long years of apprenticeship or lessons required where "no prescription" of a skill or art exists because it could not be specified in detail.[6] Much of technological expertise has this characteristic of artisanry or intuitive skill, and cannot be codified in any meaningful way. Where a skill can only be taught through example from supplier to receiver significant communications costs are likely. It is common, for example, for engineers in one firm to spend several weeks or

6 See Nelson and Winter (1982) for a lengthy discussion of skills and the economic applications of the notion.

sometimes years working within another firm in order to absorb or transmit the requisite set of technical skills.

However, the idea of embeddedness is broader than tacit technical knowledge which cannot be articulated in principle. A second major characteristic of some technical communication is that the parties do not fully understand which parts of their technical expertise are relevant to the problem at hand. The relevant information may not be readily transferred in practice even if in principle an engineer could articulate that information if she knew it was important. Technologies are not generally transferred wholesale into novel applications.[7] Rather, they are brought to bear and modified in situations where neither the problem nor potential solutions to it a fully understood. The real value of technology diffusion often comes from utilizing and combining technologies in novel ways. This often requires close cooperation among the parties. The most salient aspect of the process is that diffusion takes place through people communicating and learning what one another know. What turns out to be relevant about one party's technical expertise can be contingent on the other party's expertise and on the application. It can take some time and effort to uncover and begin to understand what information is jointly valuable and usable. This is particularly true at the intersection of different specializations. Both the tacit and contingent properties of technological expertise can preclude licensing because there may not be anything concrete 'out there' to license, one party may not know exactly what it needs, or the other what it has to offer.

A third element of embeddedness is that even if a set of information is understood to be important and could be articulated, in practice the set is too massive, complex or loosely coupled to easily summarize. It may simply be too costly for the supplier to first codify all the relevant information, then to specify the relationships among all the different parts of it, and then for the receiver to decode that information in a timely way. It may be easier for the receiver to duplicate the technology from scratch or to go through an apprentice-like learning process. For example, Von Hipple (1990) notes the problem of "indexing" relevant information. He cites the vital role of a card

---

[7] This section follows Watkins (1990).

catalog in a library. If the indexing rules are not known to the receiver, the information is useless even if perfectly codified.

A fourth characteristic is that it may not be possible, in practice, to disentangle a technology from the underlying socioeconomic infrastructure.[8] This is because many important technologies are not simply "artifacts." The technology base includes end products and the underlying science base, but also embodies the experience, skill and artisanry of the work force, as well as the manufacturing processes and the management skills which make up the whole infrastructure of the technological community. And here is where the paper borrows Granovetter's (1985) term in conceptualizing technologies as "embedded" in the specific economic, organizational, and cultural situations in which they are developed. For Granovetter economic relationships become "embedded" in social and cultural exchanges, and each party can learn about crucial non-economic aspects of the other. Over time these aspects are modified and become interdependent to accommodate the relationship. The argument here is an extension of Granovetter's in the sense that technologies are considered embedded in the relationships.

Communication of embedded technologies is most likely to be successful when the people involved are compatible in institutional culture and technical capabilities, and where the opportunity for sustained and directed intercourse among them is high. Thus, communications economies can be accrued by ongoing long-term relationships as people come to know one another's problems, working methods, and relevant expertise. In the language of transactions costs analysis, the technological communications costs could be reduced if firms internalized this specific asset -- the long term communications channels for technology diffusion. However, as already mentioned, it may not be desirable in all cases for a firm to integrate all sources of technological information.

Significantly, empirical evidence suggests that the long-term relationships among cooperative firms can provide these "learning about each other" transactions economies.[9] As discussed below, the evidence from the interviews conducted for this paper confirms this proposition. In

---

8 This paragraph follows Watkins (1991).

9 Mariti and Smiley (1983), Håkansson (1987)

addition, external social or personal links to suppliers or customers have also been found to be positively associated with technology diffusion.[10]

Cooperative R&D, then, is most beneficial when each party contributes embedded technologies. Otherwise more traditional licensing would be possible. Because technologies can be embedded, personal links among researchers appear to be important for efficient innovation and diffusion. Markets may fail due to high communications costs where significant barriers exist to forging these relationships. These failures may be particularly important in cases of new or emerging technologies where no stable industrial structure of personal networks yet exist. In helping to overcome these failures, cooperative R&D may be an important element of an efficient broad portfolio of individual and collective mechanisms for technological innovation. However, as the next section discusses, the very characteristics of embedded technologies which make cooperation useful, make negotiations and managing R&D cooperation difficult. It is this fundamental tension, the paper argues below, which led in part to the emergence of new institutions of industrial innovative behavior.

III. Negotiating and Managing Embedded Technologies.

Briefly, as described above embedded technologies can be characterized as follows. They can not be fully embodied in designs, specifications, or drawings, nor written descriptions. They can not be effectively transferred in codified form. People carry them, which means personal contact and careful attention to the interfaces among specialists is required for transfer.

Consider, then, the implications of these characteristics on negotiations about whether, how, and under what conditions to cooperate. Transfer remains desirable as long as the technology is less costly to communicate to a second party than for that second party (or multiple parties) to duplicate independently. Where there is such a spillover externality, the parties have an incentive to come to some sort of sharing agreement.

Coase (1960) argued that private agreements can deal with externalities and public goods as long as property rights are established, transactions costs (including bargaining) are low, and information (particularly about the sources and effects of the externality) is freely available to all. And,

---

[10] Kelley and Brooks (199[illegible])

indeed, the small but growing numbers of private collaborative R&D agreements supports the thesis.

However, to a varying degree depending on the technology, none of Coase's three conditions holds in the case of embedded technologies. First, property rights are difficult to define where technologies can not be codified well, and where the outcome of research is hard to predict. Second, asymmetries of information about the technologies, almost by definition, is what is driving the desire to cooperate in the first place. From the technology providers point of view, possible applications and users of the technologies are only partly understood. From the receivers side, information on possible sources is limited by the professional networks and publications the receiver has contact with. Where a source is known, the value to the receiver and the costs of transfer of an externally embedded technology are at best uncertain. The agency problems associated with such information asymmetries are well known. Third, because of these first two problems, the transactions costs of bargaining and searching for partners are likely to be high. Where potential partners are unknown, or the extent of known partners' skills not transparent, search costs are unlikely to be negligible. Once partners are identified, bargaining over the sharing of expected gains and costs could be difficult given the potential for opportunistic behavior, the problems of defining what is valuable and specifying contingencies. Agreement must be reached on, *inter alia*, management responsibilities and structures, voting rights, the work plan, division and location of work, mechanisms for technology integration, rights to and definition of intellectual property, who will provide or pay for equipment and personnel, how in-kind contributions will be valued, and legal liabilities in the event of project failure or the withdrawal of a partner. This is a tedious organizational and legal task under the best circumstances, much less under conditions of uncertainty, asymmetric information, and where there is no well established regime of property rights.

Coase (1937), Williamson(1975) and Arrow (1969) have all suggested that hierarchical organizational structures, such as the firm, will replace markets under such conditions. However, as Teece (1986) argues, complete internalization of all technical needs is unlikely to be possible, and from empirical evidence it is clear that firms increasingly seek external sources of expertise.[11] My hypothesis is that institutions of industrial behavior in cooperative R&D and organizations to foster them are emerging in part as a response to the tension between the increasing need to cooperate in embedded technologies and in the shadow these transactions costs issues. The next section discusses the theoretic basis for the hypothesis, and the rest of the paper then seeks evidence from the Esprit program.

IV. Norms, Regimes, and Transactions Costs.

The value and functioning of norms, regimes and social institutions in structuring and guiding social interactions has been explored in a huge variety of literatures which encompasses most of the social sciences. One result has been that there are various ways of defining the concepts.[12] Here, I will use the following: A **norm** is a principle, explicit or implicit, of behavior which serves to guide, control or regulate acceptable behavior for members of a group. Norms in this view are a not an all or nothing construct. Members of groups may follow them to a greater or lesser degree. I use **regime** to describe a set of explicit rules which regulate patterns of behavior. Thus the intellectual property rights regime is the set of legal and contractual obligations and liabilities governing intellectual property. Regimes can emerge from norms, and also influence the evolution of norms. An **institution**, more broadly, is a set of convergent expectations and patterns of behavior. An institution exists where people conform to a behavior, expect others to conform to it, and believe that the payoffs are higher if all conform to it than if all deviate. Expectations can converge without explicit regimes or guiding norms, as in the international institution known as the "balance of power," or with them as in the institution of marriage. I will use **organization** for the formal structures commonly indicated in the more narrow usage of "institution."

One principal conclusion of this diverse literature is that the probability or ease of cooperation can be increased by norms, regimes, and institutions, becuase they can reduce the costs of coming to and enforcing agreement. Oye (1986), for example, shows that conventions or rules of thumb in

---

11 See fn. 3.

12 The following discussion draws primarily on Haggard and Simmons (1987) Axelrod (1986) and Schotter (1981).

international behavior can reduce transactions and information costs. North (1984) maintains that norms of fairness and justice are key determinants of transactions costs, and that complex property rights regimes are necessary to enable modern industrial societies to function at all.

Some authors go a step beyond and make causal functional arguments. Schotter (1981) suggests that economic and social institutions emerge from commonly adhered to solutions to recurrent societal problems. Buchanan (1975) argues that property rights regimes emerge from the need to coordinate activities in order to carry on trade and avoid wasteful redistributional conflict. Inverting the Coase theorem and applying it to international organizations and regimes, Keohane (1984) explains their emergence as a response to problems of property rights, uncertainty and information, and transaction costs. He adds that the value of international regimes is higher under conditions of bounded rationality. These are precisely the problems confronting firms cooperating in embedded technologies. Yet telling a plausible causal story and showing the premises of the story to be true are different matters. It is this argument about the emergence of institutions of cooperative R&D because of their functional value in reducing transactions costs which I explore and which premises I test here.

The first premise is that technologies are embedded, as discussed above. The second premise is that the characteristics of embedded technologies make transactions in them potentially costly. Section briefly five explores evidence of these transactions characteristics. The third premise is that a regime of liabilities and intellectual property rights and norms of industrial behavior in cooperative R&D are emerging to help reduce those transactions costs. As will be shown in section six, clear elements of such institutionalization exist and are beginning to take hold outside Commission Programs. The most important impact of Esprit and the many programs modeled after it may be to institutionalize R&D cooperation, that is to provide convergent expectations about the likely benefits of cooperation, about what behavior is appropriate in entering a cooperative agreement, and about the terms on which cooperation will proceed, such as management structures and property rights.

V. Transactions Characteristics of Embedded Technologies

> "Everybody has his own area of expertise. You manage to make a successful product if you manage to bring these areas of expertise together. At each interface between the areas of expertise you have to negotiate, you have to discuss, first thing." -- An Esprit project manager

This section analyses the process of forming and managing consortia participating in Esprit. It addresses the second premise above that bargaining and search can be costly where the exchange involves embedded technologies. What were the major issues discussed in the negotiations? Was embeddedness an important variable in the decision making? In what ways? In particular, with reference to the inverted Coase theorem, did asymmetries of information exist? Did they significantly increase transactions costs in terms of bargaining, managing or searching? One case is discussed in some detail to illustrate the basic argument. Others are discussed to demonstrate that the phenomena appear to be far from unique.

V.1 An example

The illustrative case involves a group of thirteen European computer and telecommunications firms. They have formed a joint venture to promote development and technology transfer of a common architecture and software for distributed (i.e. advanced-networked) computing.[13] Decision makers organized the work to accommodate the asymmetric information characteristic of embedded technologies, and participating firms incurred significant transactions costs trying to collectively deal with that characteristic.

It is a large project: 180 manyears supporting 60 people directly, 20 of whom work full time at a joint central laboratory. The motive is typical of standardization efforts, avoiding wasteful duplication. According to the facility director: "If you are going to make distributed systems and you build them on an ad hoc basis you'll have a mess. What you need is an architecture, a set of interfaces, a style, a set of building blocks."

---

[13] This and the folowing cases are based on personal communication with Esprit project managers.

Standardization is, on its face, one of the most obvious motives for cooperation, where the potential for joint gains are clear:

> "The software runs on 14 different operating systems, which has to be done independently and vendor neutral. The partners all know they'll get great benefit if it is a success, compared to doing it in-house or licensing it from someone else . . . . They also get better commercial rights to it."

But, understanding the motive is not enough for understanding or explaining the bargaining and organizational problems which followed.

The case is a good test of the argument developed above for two major reasons. One, it strains the embeddedness hypothesis because the goal of standardization is to make the technology as transparent as possible by codifying the standard and making it available for all to adopt. Two, standardization is also arguably the type of negotiation where the most experience exists among European telecommunications firms. International organizations, such as the International Standards Organization (ISO), already exist to facilitate standardization. So, the process might be expected to be comparatively routine.

Embeddedness, however, did matter. With technology transfer an explicit goal, the consortium paid considerable attention to the expected embedded characteristics of their research when designing the organizational structure. A primary justification for putting the research under one roof was bridging the expertise gulf between the computing and telecommunications firms:

> "The problem is that computer companies understand how to do things fast, telecom's companies understand how to do things in the wide. A telecom's company can't conceive of a telecom' system that doesn't span the entire country. But, a computer company finds that kind of hard to understand, and does it rather badly. Trying to bridge the two is what we did in building the consortium"

Half the lab's employees are seconded from the sponsoring firms, and half are independently hired by the lab. In deciding on how to facilitate transfer of the technologies developed in the joint facility back to the parent firms, decision makers were primarily concerned that tacit knowledge of an organization can be an important determinant of the efficiency of transfer:

> "If you want to have technology transfer [back to the parent companies] you have to have some people who understand the companies. We decided to have a group of secondees, people who were on loan from the sponsoring companies -- for some long period of time, one or three years or so, certainly not less than three months, and hopefully not less than six months. They would be tasked to go back to their companies and carry the message back. They know how their company works, and that is kind of important."

When asked why he responded that:

> "If you had everyone on permanent staff in the lab you couldn't get the partners understanding what you're doing. The transfer to the companies would not work at all. You have to know how the company works, what its culture is, how it is driven and where are the points of leverage. . . . . Different companies work in different ways. Some companies work with champions. Some work by consensus, some by committees, some by general osmosis. It is very important that the staff people here know in their own companies where to go to get something done. The informal culture is just as strong as the formal culture, and quite often if you want to achieve something you don't go down the formal culture route. You go down the informal route."

He added:

> "The hard part is not taking the code and running it on their machines, but it is the level of perception. It is trying to get the concept of the architecture over to them and into product divisions. You can get it into research labs, but it is to get it beyond there into the product divisions which is kind of hard."

The central facility also was concerned with learning how to make the technology less embedded over time, in order to make the transfer easier. Here the desire is to make the standards as transparent and available to all as possible:

> "Some of the work packages were done deliberately at arms length. The lab said [to the parent firms] 'look, don't send anyone from [your] core team to the lab. Try to do it on your own.' If what the lab is trying to do is a success, we must be able to communicate it without being able to have

someone from the outside come to the lab for three years to brainwash."

If free-riding on this openness is possible, where is the incentive to join and pay for the consortium? The competitive lead time offered to participants in applying the technology of the standard because of the embeddedness of technology turned out to be a key consideration.

> "If you make the technology open to the world as a standard, then what do the collaborators get? They get a two year lead on everybody else because they see the stuff as it is being developed, and they know how it was intended to be used, as opposed to those who get it when it is released and then have to get up the learning curve. If that doesn't give you a few years advantage it ought to."

Despite the potential for free-riding on the transparency of standards once developed, cooperation can emerge from the drive for lead time.

Yet, the uncertainties about technical trajectories, and asymmetries of information about future plans and potential applications of the research results led directly to some difficulties. The director talked of the problems and extra costs they they encountered in bargaining to set up the joint organization. First, they set up a costly management structure in an attempt to ensure symmetrical access to information across partners.

> "For the original lab, [Company A] got up and said they'd run it. But, the rest said 'no.' There was a long argument which ended up with a firm of consultants being appointed to run it at arms length. No one would agree to one of the other firms running it -- nobody wanted the other to have an inside track . . . . The consultants, because they ran the lab from arms length, were forbidden from being involved in the technology. So all they got out of it was money. They got 15 percent of the budget off the top for providing management services. Their role was just to coordinate, and they didn't understand IT people."

The reason for the disagreement was fear of the competitive consequences of asymmetries of information. Clearly some fraction of this 15 percent would have been spent for coordinative functions regardless of the management structure. Yet the director's feeling was clearly that a large overhead had been paid because the partners could not agree to let a rival firm make the day to day operating decisions. The partners were unwilling primarily because a managing partner would get a jump on the competition by having a broader view of the project through communication with all the partners. With these unique lines of communication it would know more about the technology and its potential applications. To manage a joint research project he said, "you need to know in which direction all these computing and telecom' companies want to go . . . . We decided pretty quickly that [a Partner A] product planner is not going to tell where he wants to go to a [Partner B] employee."

The embeddedness problems continued even after the lab started work. As work progressed the partners began demanding more and more from the lab. The lab had produced potentially useful results, but they were not yet robust in the sense that they were not easy to use and bugs remained. So, the lab's embedded expertise was essential in dealing with problems that arose in novel applications at the parent firms: "Because people started to use the piece of software developed by the consortium, the lab started getting asked to provide support. The project is only funded to produce alpha release software, possibly beta release quality. People would say 'the software doesn't do this. It should. Will you fix it?' " Technology transfer was in process, but remained costly in terms of the facility staff's time. In addition, many of the partner's major outside competitors, "AT&T, also Toshiba, Unysis, NTT, Oracle, and Alcatel are banging on the door asking what is going on" and on what terms software could be obtained. However, as then organized the facility did not have the capacity to deal with these additional demands.

A series of discussions ensued about how to reorganize the lab. The management consultants were dropped as too costly and not close enough to the technical work to manage properly: "Nobody wanted them anyway since the staff was about to walk out because they didn't understand IT people." However, according to the director: "The partners couldn't get their act together, and eventually three people, the technical director of the project, the previous project director and the current project director said 'We will form the lab into a company.' "

The three incorporated an independent company with the intention of setting up a formal board of directors and advisory boards with representatives from the sponsoring companies. The three have written and rewritten several business plans, "there have been about eight goes at it," expending most of their management time over the course of more than a year. This is a significant cost when compared to the 20 full time people which comprise the company.

> "But the sponsors have never been able to get their act together [to agree on terms]. So the relationship to the sponsors at the moment is informal -- an informal directing board. [The independent company] keeps trying to formalize it. That is unsatisfactory in many ways and is creating many tensions. The tensions are that the three people who set up the lab are taking all the risk, signed the leases. It is their houses on the line if something goes wrong. There are no legal guarantees from the sponsors . . . . Eventually it will be resolved, but it relies on the good will of the three directors."

When the outside firms began asking to join, the partners could not agree on the terms of entry: "The major stumbling blocks are in how large companies can take shares or somehow sponsor a lab like this. None of the models we've tried has worked very well . . . . It has to do with who gets to vote, how you bring in new sponsors and what price they should pay."

The basic difficulty had to do with placing a value on the technology that had been developed. One source of delay was that "the consortium got caught up in a fight between the computer companies and the telecom' companies over manufacturing rights." In addition, the project manager traced much of the disagreement to the difficulties associated with valuing the output from the research and uncertainties about what kinds of information would unique. For example, outside the consortium:

> "[Partner C] had done a port of the software onto UNIX 5.4. At first they said they'd make it available to the consortium. When all the consortium said 'yes, when can we have that?' [Partner C] had second thoughts. [Partner D] did something similar, offering a piece of work and then having second thoughts. . . . They suddenly realize that this has given them a competitive lead, they have it and no one else does. . . . Rather naïvely, [Partner C] probably thought that naturally everyone else would have done a port to 5.4. When they found out everyone else hadn't, STC realized they were probably a year ahead of everybody else."

The case illustrates a number of points. First, the problem solving was co-located to deal specifically with the embeddedness-related problem of integrating different areas of expertise, telecommunications and computers, which the decision makers felt were not easily bridged. Second, because the applications of the technology would be novel and organization specific, they thought that effective transfer would require organization-specific knowledge. A system of seconding was the result. Third, even in this standardization effort bargaining was costly in part because the perceived gains were not fully joint or competitively benign. The gains were rival to some extent because of the asymmetries of information inherent in embedded technologies. Partners thought that the managing the project would yield particular competitive advantage because any managing partner would have access to more information than other partners. Both the original and the reconstituted management structures were designed to maintain symmetrical access to information. Fourth, problem solving was done largely at the laboratory where the technology was embedded. Because the software was not yet fully robust, the parent firms continued to rely on the laboratory's unique expertise, even after careful attention to technology transfer through seconding. Efforts were afoot, however, to reduce this need, make the technology more transparent and move the problem solving to the applications organizations. Fifth, the structures for cooperation were built ad hoc, which ended up adding significantly to total project costs. Decision makers looked for models for the organizational structure and the terms of participation, but found none acceptable.

A sixth point is that the work continued in parallel with the negotiations only on the faith of the three directors -- who all have close contacts and previously worked for partner firms -- that an eventual solution would be reached. When combined with emerging market potential for the software, new demands by the partners for services beyond the original goals of the lab strained available budgets and forced a reorganization. New partners wanted to join, but the existing partners had yet to agree on the value of membership or on voting rights, due in large part to uncertainties and asymmetries of information. Such bargaining consumed a considerable fraction of management's time. None of Coase's three conditions held. Had the three directors been unwilling to work with only informal trust relationships the bargaining tensions could very well have caused the collaboration to collapse, or at least the research work to slow significantly. This foreshadows the discussion below on the importance of such trust and emerging norms of cooperative behavior in reducing the transactions costs illustrated here.

V.2. The Costs of Asymmetries of Technical Information

Similar cost penalties and accommodations in the organizational structure due the the asymmetries of information inherent in embedded technologies were clear in other projects as well. For example, describing an earlier collaborative project he'd been involved in, the managing director of a small British firm said they had split the work into a number of different work packages. Most partners participated in most work packages. Again, the concern was maintaining symmetries of information. Their original fear was that without working within a workpackage a partner would not be able to track what was going on technically, and could not know whether the other partners were fully disclosing valuable technical information. However, unsatisfactory results, he said, were a lesson:

> "People can make a lot of mistakes at the planning stage. Those mistakes in previous projects were largely because people were afraid of collaboration . . . . Since you didn't trust the others you wanted to be in every workpackage. This wasn't the right way to do it because then you only have a small piece of work in each one."

No partner had enough work, he thought, to gain any depth of expertize or economies of scale in research.

Clearly, these participants did not perceive technical information as freely available. Where trust relationships were not developed, they were willing to pay a penalty in terms of potential advantages in scale, specialization, or concentration of effort in return for assured access to technical information they might otherwise not get.

V. 2a Technical opinions

Different technical backgrounds are also a source of transactions costs when these differences lead to divergent opinions about technical goals or the likelihood of success of different technical approaches. Differences of opinion are a traditional source of joint gain when contingent deals can be struck. However, where contingent contracting is not possible -- for example when only one path is possible within budgets -- they can also be dysfunctional and lead to costly bargaining and the failure of cooperation.

This was particularly costly in one project where differences in technical goals surfaced midway through. A key partner had different technical views about what hardware to use in a real-time-recognition computer vision system. Participants spent months trying to salvage the original project, only to have to redesign it when the recalcitrant partner left. The project manager described the problem:

> "[Partner Z] had very different ideas, which were technically incorrect, about how the system could function. It became unclear what their technical contribution would be. The consortium was going through a process of trying to sort this out, to agree on how to proceed. The intention was not to force them out, but that is what ended up happening because there was no way to reconcile the differences . . . . When they left, the group had to put together a new technical [plan]. . . . [Partner Z] were totally unwilling to compromise in this situation. . . . Keeping them in would have weakened the project. The group spent months trying to keep them in . . ."

The project was delayed by 9 months. As a result of the delay, two of the key people that the project manager planned to put on the project were no longer available. "They had no definite start dates, so those two people were put on other projects. You can't have them just sitting around. That meant that they were not available for even 9 more months after the project started . . . . The people that were put on it were not as good and were not doing as we had promised." So, in addition to missed opportunities due to delaying the research, and the direct costs of the time and resources used up in the bargaining process and rewriting the technical plan, the project manager's firm had to put in resources beyond those originally anticipated to make up for the lost expertise.

It is not clear in this situation whether there was no available bargaining solution at all to this impasse, or whether the bargaining simply became too dysfunctional to make it worth trying to find that core. Either case supports the argument advanced here that asymmetries of technical information and technical uncertainty can lead to significant transactions costs.

V. 2b Taxonomies

Even where there are no disagreements on what needs to be done, differences in technical expertise can make discussion coslty on how to proceed. A common practice within consortia is for the partners to develop a glossary or taxonomy of standard terms so that the different people can be sure they are speaking about the same ideas. This becomes particularly important when groups from different technical areas come together for the first time. The transactions costs generated do not arise from any conflicts of interest, but simply from the time and effort it takes to develop these taxonomies, and effort wasted where confusion has arisen because no common understanding has been reached.

A project director in a small German telecommunications research and consultancy firm described his surprise at the need for such a taxonomy in his project, and the costs associated with not having one:

> "It is always a problem if you bring together software people and applications research people -- they have their own languages. Software people specify certain things: a 'macro' for example for a software person is one particular thing -- a sequence of code. A 'macro' for an applications research person or a user interface designer can be totally different, because he knows 'macro' from his word processing system, for example. Other terms as well: what is a 'task?' A 'sub-activity?' A 'sub-task?' What is the hierarchy? Is an activity at the top of the hierarchy, is task next, sub-task third? Or is task top, sub-task second and activity part of sub-task? All these nitty-gritty bits, really basic things -- I was amazed how people use the same terms meaning totally different things. You could speak with them for half a day without any results until you notice, 'Jesus, we used the same terms differently.' We had this experience of losing half a day . . . . What is a 'tool?' Ask a tool-kit developer what a tool is. Ask the user-interface person what a tool is. Worlds between them. You would be in a pretty bad situation if you wouldn't have solved some of these problems at least. But, still, problems like that come up. Even at the end of the project there will be problems."

So, they developed a standard glossary of several hundred terms. They also had to agree on a standard format for the applications groups to specify their requirements for the software people. He put particular emphasis on the necessity of these discussions in terms of "economies of work." He said "it is very, very important that you negotiate these things, that you agree on a format." The discussion was an ongoing one as the project moved into new areas. Without this kind of thoughtful back and forth, he thought, they

> "could spend two thirds of our budget capturing requirements, describing requirements, passing them on to the software partners. And they'd tell us 'stupid! Can't do anything with it.' So, make sure that you spend these two thirds of the budget, but that its presented in a form which is usable, and that you capture *the* information which is required, and nothing else."

Numerous consortia included in the interviews had developed such taxonomies. In each of these cases the technical communication could not be fully effective until some common language was developed. How researchers understand technical terms depends on the context in which they use those terms. As a result people with different backgrounds understand terms in different ways, which might not become apparent for some time. Confusion or miscommunication was the result. The costs of communication were reduced after, but not before, some up front effort went into formalizing and codifying technical terms. Transactions costs were incurred because technology was embedded.

V. 2b Search Costs

Another kind of transactions cost involves the search for potential suppliers, customers or partners. These search costs can be considerable when the technologies involved are embedded.

In research efforts where the specific needs of the researchers are not yet clearly understood, the costs of searching for technology suppliers, for example, can be significant, even when suitable products are already available on the market. One project required an etching machine for trenching in multiple-layer semiconductor materials. On the first etching machine used, the project manager said, one of the semiconductor's boundary layers ended up "getting a much wider trench than the other layers" which he described as "a big hole." He reported that it cost on the order of "maybe a million dollars -- probably 4 or 5 percent of the purchase price of the tool" searching for the right tool to solve the problem. Those costs involved flying people around to a number of different tool suppliers, and providing sample materials for the suppliers to test to see if the tools did what was needed. The search slowed research progress for several months. A tool already on the market was eventually found and purchased.

In this case, the researchers had not anticipated the technical problem and were not familiar with the performance characteristics of other available etching machines -- knowledge embedded with the suppliers of those machines. On the other hand, because the suppliers were not familiar with the new application, without testing they did not know if their existing etching tools would satisfy the new requirements. Each party had embedded technical expertise which the other needed to make the transaction work, resulting in significant search costs. The project manager added "the more complex and leading-edge your needs, the more difficult it is to find the proper tools."

Other project managers described the process of searching for suitable partners in very much the same exploratory language. In R&D the search is more often for particular expertise rather than for a particular product. Over and again managers said that one of the primary considerations when looking for partners with a particular area of expertise is the level of technical skill. Yet, they also felt that the technical capabilities of individuals or research facilities was, except in extraordinary cases, not transparent unless people had worked together before.

Perhaps the best summary of this idea was given by one senior research engineer whose job was to coordinate all the Esprit projects for his firm:

> "In the primary phase of putting things together you have contacts with possible partners, and you agree to meet. You go to their labs, where they work. You see what they do and how they do it -- what types of things they work on. You smell the environment they work in. You try to have open discussions and get acquainted with each other and formulate ideas. You are trying to detect overlap and whether you can really collaborate."

As we have seen in this section, the transactions required to move cooperation forward can be costly primarily because of the asymmetries of information inherent in embedded technologies, and because of technical and commercial uncertainties about the future. It was sometimes difficult for each party to ascertain the capabilities of potential partners. It was troublesome to communicate ideas across areas of expertise, even when the goals of partners appeared to be in harmony rather than in any potential conflict. Differences in technical background lead to disagreements on technical and commercial goals, and also on the likelihood of technical and commercial success. Reliance on existing notions of fairness sometimes facilitated the bargaining process. But often it was not clear what an equitable or fair solution was. Bargaining solutions were difficult to find because the value of contributions was hard to measure. Contracts and business plans which spelt out the management structures and responsibilities, voting rights, the division of work and so forth were cumbersome to agree on. Costly delays resulted or cooperation failed altogether. Where partners felt it commercially valuable to keep abreast of all the technological developments in the projects, in the absence of trust relationships elaborate and costly management structures were established to maintain symmetries of access to information across partners. The next section addresses the consequences of the existence of these transactions costs.

VI. The Emerging Institutions of R&D Cooperation

> "You are creating a culture, which means that Europe can be a player in the high technology game . . . . Even if specific things you fund don't turn up, you are in fact creating an atmosphere where there are lots of people around with expertise who have worked on high tech projects and that you know. If you turn up winners as well, even better. The fundamental thing is to create the culture . . . . It is long term stability that has its own good."

If the functional argument about institutions reducing transactions costs is correct in explaining their emergence, we would expect to see several things.[14] First we would expect to see an interacting set of formal rules and informal norms governing the cooperative behavior of firms. The set would function to facilitate cooperation among firms. It primarily would serve to reduce transactions costs through reducing uncertainly and increasing symmetries of information. Cooperation could be fostered through explicit rules which influence firms' behavior. Compliance with the rules, once established, would be self-interested. That is, the rules would not be singularly useful in complying with the wishes or intricacies of, say, the EC bureaucracy, but more broadly useful in other cooperative R&D efforts. In

[14] This discussion draws on Keohane (1984).

addition, informal principles would be used by firms to guide and legitimate cooperative behavior. The key notion is that the formal rules or informal norms would provide incentives for firms to behave differently than they would have behaved in their absence.

The evidence that such a set is emerging can be divided into several themes: the normalization, codification, and professionalization of collaborative R&D. Each will be discussed in turn below.

VI.1 Normalization

R&D cooperation is becoming accepted as appropriate and normal behavior -- something engineers *should* be doing as part of the everyday course of their work. Probably the most striking aspect of speaking with European R&D managers who participate in these R&D consortia is their self-admitted change in attitudes towards cooperation in R&D. No longer is it looked upon quite as suspiciously in terms of fear about giving away the technology farm. Mangers report that they now feel free to telephone or visit competitors to discuss problems or general technological trends. In contrast, there was general agreement that before the early to mid-1980s even discussing research plans with other firms was not something one did. As a retired research director of one of the largest European electronics firms put it "cross country-contacts were virtually zero" before the 1980s, but now "this has completely changed . . . . You get a whole generation, in a specific field, where the hesitation to cross language borders or national borders has gone . . . ." Indeed, a number of executives expressed a desire to "teach" their technical people how to cooperate and the benefits of it. Several justified entering into cooperative projects specifically with this as a major goal. Many believed that their future competitiveness would in part be dependent on how well their technical staffs internalized the lesson.

Part of that normalization is the expectation that other people would not be surprised by requests for cooperation or think it unusual or inappropriate. This is a classic element of institutionalized behavior: people expect that other people will conform to the same behavior. Another significant development, discussed below, is that as people have more experience cooperating, the management structures and legal issues have become more similar over time. As one manager put it, he could "walk into" any collaborative project in the future and know how it would be run and what the rights and responsibilities of partners would be. That this sense of security could enhance the chances and efficacy of future cooperative efforts is clearly a major motivation for the desire of executives to "teach" cooperation.

At a more concrete and technological level, the process of designing and administering Esprit with the help of industry has provided, as Margaret Sharp writes, "a mechanism for creating, among top decision makers, convergent expectations about the future."[15] When EC Commissioner for Industry Davignon brought together the heads of Europe's largest IT firms -- the Big Twelve -- to provide the blueprint for Esprit, it was the first time this fragmented industry had worked together on a strategic vision of how to compete with the Japanese and Americans. In trying to design a program they had to agree on what their primary weaknesses were, whether and why current strategies -- in particular the national champion approach -- were inadequate, and what could be done.

This mechanism for bringing competitors together to work out a common vision has continued. With each new phase of the research programs, the Commission holds a series of planning meetings. Hundreds of industrialists and academics come together in different technical advisory groups to work out what technical directions the Commission should follow in the calls for proposals for the next round of project funding. Groups of industrialists and academics are also called upon to serve on peer-review committees to evaluate project proposals. A number of R&D managers reported that this dual process has helped them feel more secure that their technical visions were compatible with the prevailing collective wisdom. As a neutral broker with deep pockets the Commission is able to bring these decision makers together. They reduce their individual uncertainties about technical trajectories as they work out a common set of expectations about where investments are likely to pay off over the next few years.

Such roundtable discussion groups have continued and expanded outside of the EC. There is now a Brussels-based lobbying organization called the European Information Technology Roundtable, which includes, inter alia, all the major IT firms in Europe which came together under the Davignon Roundtable for Esprit, except ICL. ICL was expelled by the other members

---

15 Sharp (1989) p. 10.

after Fujitsu acquired an 80 percent stake in the company. In addition, in 1983 a cross-industry discussion forum formed, called The Roundtable of European Industrialists. It included some of the most influential businessmen in both EC and non-EC Europe, including its chairman Pehr Gyllenhammer, chairman of Volvo. They come together to work out and publish proposals for collective responses to leading European business issues. As one senior executive at Philips put it, the group has been "useful for creating awareness that we need each other in Europe." The group has become a powerful lobby at the national level pressing for ratification of the 1992 measures.

The norm that cooperating in technology is desirable behavior has developed to such an extent that for many managers R&D cooperation has become a legitimate goal in itself, rather than a means to some other economic end. R&D cooperation as a goal in itself has even edged its way into official EC documents. Prior to 1985, for example the stated goal of Esprit was to improve the competitiveness of European IT firms.[16] Cooperation was a means to that end. Since 1985, however, the standard three stated goals include competitiveness, but also on equal footing are "to promote European cooperation in IT" and "to pave the way for standards."[17] If this normalization has occurred and is sustained by other people, then cooperation is a social norm in the strict sense. The norm is simply "Do A" rather than the rationalist outcome-oriented statement "Do A if you want to achieve B."

Certainly if asked, most managers would and do claim that one should cooperate only when it is in the firm's interests commercially. Yet, it is hard to overstate the certainty with which most of these project managers trumpet the virtues of cooperation. Many seem to have taken it on faith that R&D cooperation is a good idea and jumped on the bandwagon. It is difficult to distinguish between claims for the benefits of cooperation distilled from experience and those claims lifted from Commission propaganda or absorbed from the fanfare of other participants. Moreover, the fraction of Esprit projects which are terminated is extraordinarily low. Mansfield et.al.(1977) reported that the average technical success rate of commercial R&D projects

---

[16] See, for example, Commission (2 June 1983).
[17] See Esprit Review Board (1985).

in US firms was 57%. This includes product-oriented development projects where the technical certainty -- as distinct from the market certainty -- is typically high. By contrast, only 17 of 227 (7.5%) of Esprit phase I projects were prematurely terminated, and only 6 (2.6%) of those on technical grounds.[18] This is particularly striking because the projects are billed as "pre-competitive" and still several years from market applications, where technical uncertainties should be higher. Cooperation persists even beyond where individual efforts would likely have taken the research.

Something is operating besides hard-headed technical rationality over whether or not to cooperate on individual projects. As we will see, firms appear to be behaving strategically. Because cooperation is seen as desirable as a long term strategy, firms may stay in individually undesirable projects in order to maintain their reputations as 'good partners.'

Reputations can develop because norms also exist about what constitutes appropriate behavior in cooperative R&D projects. Not only should people cooperate, but they should cooperate in certain ways. Firms who do not cooperate in the appropriate ways are subject to informal retribution. Cooperating in R&D means that each partner has to open, to some extent, its technology piggy bank to its partners. The partners typically set out a research plan at the outset of a project and agree on a division of work. Unscrupulous partners could, in theory, simply do no work, and try to get as much information out of the others as they could before being cut off. Existing social norms of fairness and honesty probably operate to eliminate this level of cheating. However, even firms with the best initial intentions can decide midway through a project for any number of reasons that they would rather take their research in a different direction. The project could demonstrate that a particular approach is not valuable to them. Company strategies might change. Budget problems could arise. The uncertain and rapidly changing nature of research in high technologies makes such events likely to occur frequently. Under these conditions, a firm has several alternatives. It could continue with the project as agreed. It could try to work out changes in the research program with its partners. It could unilaterally proceed down its own path. Or it could withdraw from the project altogether. All these have occurred in Esprit projects. However, the

---

18 Esprit Review Board (1989).

last two much more infrequently than one might expect of *homo economicus*.

According to a number of the project managers interviewed, it is important to maintain a reputation as a 'good partner.' As the functional theory would predict, this norm facilitates cooperation and serves to reduce asymmetries of information. The general meaning of this norm of how to behave to be a 'good partner' has two major elements. First, the technical work done must be of high quality. An early complaint in Esprit was that firms may not be willing to send their best technical people to do cooperative work. The general consensus is that while the very top-notch people are, of course, reserved for the highest priority company projects, firms must put good people on cooperative projects. In a number of cases, firms reported bearing extra costs to maintain their reputations. As the director of a mid-sized British company commented:

> "If you commit to do something when you're working with people, by God you better do it. If you're a bad partner and one of your guys lets the team down you've got to accept the blame. You can't afford to slip, trying to work it out. You've got to be honest. If you get a reputation as a bad partner people avoid you. People have only got so much time."

A second characteristic of being a good partner is acting in good faith towards the agreed upon goals. Participants in cooperative R&D projects understand that the projects will naturally have to be modified and technical goals updated over time. Reworking the technical plans three of four times over the course of a multi-year project is not uncommon. They are also willing to tolerate the withdrawal of partners, with fair warning and consultation, for sound business reasons. Most consortia agreements deal with this contingency. However, a partner violates the norm of good cooperative behavior if it strays off course, following its own commercial interests at the expense of a cooperative project. The retribution is kicking violators out of consortia and blacklisting. A number of managers said that there is an informal blacklist of partners known to have performed poorly technically or operated in bad faith within consortia.

Firms are willing to pay some costs in order not to be blacklisted for violating these codes of conduct. One project manger described early frustrations in their Esprit project with a large German conglomerate. In an early stage of the project it became clear, he said, that the German partner "was not interested in following the original technical [plan]." The other partners found it "necessary to push to insure that the goals of the project were not compromised to meet [the German partner's] commercial goals." Several letters went out to ever higher-level managers in the German partner. Little progress was made at first when this single small project was viewed in isolation within the German firm. However, a second Esprit project in an unrelated technical area and with different participants was experiencing, he said, similar problems involving the same German partner. That second project sent a letter too, "almost at the same time," to the Chairman of the German partner saying his firm was compromising that project as well. Shortly afterwards "things straighted out." The message had gotten through that the German company was behaving in poor faith in two projects. While the report is second hand, apparently the commercial interests of the German firm were better served by compromising somewhat on their goals in individual projects to maintain a reputation as a reliable partner.

In order for reputation to be an important concern, mechanisms must exist for potential partners to share information about other partners. Obviously, professional contacts, where developed, serve this function. These networks are expanding with the increasing frequency of R&D cooperation. An additional mechanism operates through the Commission. A standard practice among those looking to set up new consortia is to consult with the Commission's project officers about the reputations of possible partners. In this capacity the Commission is serving to increase symmetries of information about the capabilities and reliability of firms.

Participants in these cooperative projects conceive of themselves as in a repetitive game. Cooperation in innovative activities is seen as desirable and acceptable. Firms worry about their reputation for upholding cooperative norms because they hope to participate in future cooperative projects, either with the same partners or with others. As we've seen this facilitated collaboration. Some have behaved differently and been more cooperative than they might otherwise have been. In some cases it might even have *over* facilitated it from a static viewpoint.

VI. 2 Codification

The second theme of evidence is the codification of a set of formal rules which serve to facilitate R&D cooperation by reducing related uncertainties and transactions costs. The emerging regime has several broad elements in Community law, which will be briefly mentioned here. However, in the day to day activities of cooperating firms the principal element has been the standardized cooperation contracts developed by the Commission for contracting with and among firms participating in Commission cost shared R&D programs. So this section considers the effect of these standard contracts on the discussions among firms.

Two major broad elements of the codification of cooperative R&D are contained in the Single European Act, and in the 1985 White Paper which laid out the 1992 plan. The Single European Act was the first major revision since 1957 of the treaties establishing the European Economic Community. Before the Single European Act there was no explicit basis of Community action in R&D outside energy, iron and steel, and agriculture. Research programs in other areas had been promulgated under Article 235 of the EEC treaty. The full text is remarkably vague:

> "If action by the Community should prove necessary to attain in the course of the operation of the common market, one of the objectives of the Community and this Treaty has not provided the necessary powers, the Council shall, acting unanimously on a proposal from the Commission and after consulting the Assembly, take the appropriate measures." [19]

Included with a number of major changes with the ratification of the Single Act in 1987, an entire section, "Title VI. Research and Technological Development," was added to the EEC treaty. The first article therein made made fostering cooperative R&D an explicit mission of the European Communities, to encourage international competitiveness and technological strength.[20]

These provisions essentially provided the formal legal authority for what the Commission was already doing through the Esprit program, begun in 1983. Formalizing it in this way, however, allowed for the explosion of

---

19 Commission (1979).

20 Council (1986)

research budgets and the proliferation of countless provisions and regulations designed to stimulate intra-European technical cooperation among firms. While an exhaustive accounting of such efforts is beyond the scope of this paper, a mention of a few of them will provide a rough picture of what they entail. By 1990 there were about 40 R&D programs, most modeled after the collaborative, cost-shared provisions of Esprit. Total Community research funding had grown to about 2 Billion ECU per year in 1990 from 345 million in 1982. The scope of research now includes, *inter alia*, information technologies (ESPRIT II) biotechnology (BRIDGE), medical informatics (AIM), road safety information technologies (DRIVE), telecommunications (RACE), Basic industrial technologies and materials (BRITE/EURAM), food technologies (FLAIR), meteorological and chemical measurement (BCR), and Fisheries (FAR).

The Commission has also instituted a number of projects designed explicitly to improve the abilities of European firms to communicate with each other and find potential technology partners. These "marriage brokering" services include the Business Cooperation Center and Business Cooperation Network, the ECHO database, the Europartenariat program, the INTERPRISE project, and the Euromanagement project.[21] In addition, a number of the research programs such as Esprit have technology demonstration conferences or "proposal days" designed to bring potential partners together. The Commission also publishes a number of "sectorial lexicons," which provide standardized nomenclatures for different industrial sectors. The goal of the effort is to encourage cross-border subcontracting by helping overcome differences in the taxonomies used in different nations and sectors. The Council in 1989 also approved SPRINT, the Strategic Program for Innovation and Technology Transfer. SPRINT funds technology transfer projects, sponsors 'technology transfer days,' and works to aid existing "technology-oriented structures for cooperation," such as chambers of commerce, technology parks, and consultants.[22]

A second major element of the codification of R&D cooperation has been the White Paper which outlines the 192 program.[23] The White Paper listed a

---

21 Target 92, 8 (1990), 1 (1991), and 2 (1991).

22 Commission (May 1990).

23 Commission (1985)

number of legislative proposals for eliminating barriers to a fully unified internal market. As since modified, there are 282 general proposals, more than two thirds of which had been adopted as detailed directives by the Council of Ministers by the end of 1990. These directives cover a wide range of subjects from harmonization of safety standards, to tax rates, to mutual recognition of professional degrees.

White Paper directives on technical standards, company law and intellectual property are of particular relevance to R&D cooperation. Harmonizing technical standards would obviously facilitate cooperative research, and indeed the effort has stimulated a number of cooperative research projects to develop and promote such standards. In company law there are measures to harmonize the management structures of large companies, and to create new forms of companies. One new form, called a "European Company" is primarily designed to facilitate cooperation towards European mergers, the formation of European-wide holding companies, and joint subsidiaries. A second is the "European Economic Interest Grouping." Since July 1989 European firms who wish to cooperate in some non-profit-making aspect of their activities, such as R&D or marketing, can jointly establish an EEIG while still retaining their independence. For example, in July 1990 14 different electronics firms, television equipment companies, and program producers from the UK, France, Germany, Italy, and The Netherlands formed an EEIG named Vision-1250, to promote the commercial application of European HDTV technologies. It is specifically designed to help bridge the gap between laboratory and product.[24]

In the area of intellectual property rights the attempts are to create unified patents and minimum European standards for copyrights.[25] For example, in December 1990 the Council of Ministers decision adopted a Directive which treats original software in the same way as literary works for copyright purposes. In member countries software will be protected for the life of the author plus an additional 50 years. Existing European patent law falls under the European Patent Convention (EPC), which entered into force in 1977, and whose signatories do not include all Community countries.

---

[24] Target 92, 8 (1990)

[25] Target 92, 2 (1991)

It provides for a centralized application procedure for national patents. One application goes to the European patent office, and then a series of individual national patents are issued. A more centralized approach in the Community is awaiting ratification of the Community Patent Convention. Ireland and Denmark held up final ratification. Under this scheme one patent would cover the entire Community, significantly reducing the costs associated with firms managing all the different national patents they hold. It would eliminate the costs of multiple patent renewal applications and -- of particular interest to cooperative technology efforts -- eliminate the complications of patent licensing and cross-licensing in multiple countries, languages, and legal systems. In addition, any legal action for patent infringement would also be applicable Community-wide, eliminating the need for multiple suits. For biotechnology patents, the Commission proposed in October 1988 a Directive to harmonize and improve patent protection for biotechnology inventions.

As a third broad element of this codification, the EC revised competition regulations to reduce the uncertainties some firms had as to the legality of cooperative R&D. In late 1984, the Commission promulgated new antitrust regulations governing R&D collaboration.[26] The Commission revised its policies and provided a block exemption from EC antitrust rules for various kinds of cooperative R&D. It exempts those projects specifically under Commission programs. The exemption also includes cooperative R&D for "products or processes and joint exploitation of the results of that R&D." Certain time limits are placed on the exemption where the partners have more than 20 percent of the market share. Beyond the R&D stage, it has been reported that EC competition rules have been relaxed for products resulting from EC-sponsored research.[27]

These broad actions notwithstanding, in the daily practice of R&D cooperation and consortia formation the primary element of this codification has been the standard legal contracts used by the Commission for cooperative R&D projects. The contracts cover most of the key issues of intellectual property rights, management responsibilities, and legal liabilities -- all traditional sticking points in contract negotiations. This has greatly

---

26 Regulation 418/85

27 Sandholtz (1989) p. 310

simplified and reduced negotiations among firms over the terms of cooperation. Firms come to the negotiating table knowing what to expect and do not have to debate every clause in the contract. More significantly, these contracts are now being used as models in private agreements beyond the EC's programs.

Annex II to every Esprit contract has the unassuming title "General Conditions." Each partner must agree to the terms specified therein. The same terms are also now used in most other Commisison R&D programs. In addition many consortia sign private consortia agreements which establish the organization of the project, division of the work, voting rights, responsibilities of each partner, and the conditions of withdrawal. A standard unified text, sometimes called the Esprit "boilerplate," for these consortia agreements has now been worked out, primarily by lawyers from the Big Twelve. It is adopted by most consortia who do have an independent agreement.

What is significant about Annex II is that it not only deals with the terms of what the partners are to deliver to the EC, the allowable costs and so forth, but also lays out in some complex detail the rights of each partner with respect to exploitation and commercialization the technologies involved. Technical information and patents are divided into two types: "foreground" is results attributable to the joint R&D; "background" is what partners bring to the consortium. Annex II describes the conditions under which partners within the consortia will have access to each other's background information and patents. It is left to the partners to define for one another the background they bring to the project. Provisions are made in the event that the contractors or the Commission wish to terminate the contract early. Together with any private consortium agreement, it specifies the joint and individual liabilities of the partners in the event of the failure of any of them to carry out its responsibilities. It also lays out the conditions for the participation of any third parties such a subcontractors. In short, the standard contract is comprehensive and is applied without change to almost all Esprit projects. The director of a Philips division said it surprised him: "It was a take it or leave it situation. No discussion was possible, but it is not a harness. It is a good instrument for knowing what the partner's obligations are and what their rights are. It is rather detailed."

Perhaps the most telling comment was one by a project manger from a Belgian firm who had been involved in earlier Esprit projects and now a new large standardization project in a second EC cost-shared program. She described a meeting with her firm's lawyer to go over the consortium agreements. The partners had agreed to exploit the results of research through a central organization and that all would share the property rights. They agreed to jointly transfer their rights to the central organization for commercial exploitation. She said the lawyer "didn't even bring a pencil. It was the first meeting I've ever had with a lawyer where he didn't bring a pencil. There is nothing to change any more, and there are clear rules about exploitation which makes exploitation possible collaboratively." She contrasted this with her earlier experience "where you couldn't give anything away because potentially you were not sure what you were really giving away."

This standardization of rights and liabilities among the partners as well as between the consortium and the Commission is in stark contrast to other cost shared programs such as Eureka and Alvey, or to previous consortium contracting with national governments. As reported by a large number of interviewees the process of partners coming to agreement has been simplified considerably. A research executive from a mid-sized Dutch firm compared the Esprit case with Eureka, where there is no standard contract: "Eureka is less bureaucratic, but the start up [of projects] is harder because there is no common legal framework there. You have to pay your own lawyers to come up with an agreement." Similarly, the director of a British firm compared it to his experience with the UK information technology program, Alvey: "The standard contract from Esprit is powerful in that it stops the partners arguing, because they know they can't shift the Commission. In Alvey it took forever because there was no standard format. With Esprit either you take it or leave it, and it is interesting that the partners then took it." A managing director of a second small British firm compared it his firm's experience with contracting for national projects with the UK's Department of Trade and Industry :

> "We spent a whole awful long time negotiating the contract between the partners, because a lot of the things that are normally in the Esprit contract were not in the DTI contract, and so had to be negotiated outside the contract. Whereas in Esprit it is all laid out already and

> you just do it that way. With the DTI's you have to renegotiate. The standard Commission contract covers most of the IPR [intellectual property rights] issues. . . . It makes life simple."

A project manager in a German supercomputer firm, similarly, thought it useful not to have to "reinvent the legal texts. It speeds the process." Because the standard text is there, work can continue in parallel with the legal discussions, but "if you had to do it on your own you'd do the legal work in advance [of the technical work]." He thought it "gives all the partners the assurance that all are working on the same legal grounds. None worry that the others will get a better deal." He compared the management and negotiations effort for his current Esprit project to a previous national cooperative project in the same technical area, funded largely by the Federal Technology Ministry (BMFT). That effort for the earlier project had been "an order of magnitude more." He attributed this difference to the newness of collaboration when the BMFT project began and to the fact that "there was no such structure like Esprit to set you on a certain track" to guide the formation of the consortium. Esprit, he said, helps "the partners know what they are expected to do." As a result, he thought, there is not as much worry about the details of the legal texts and management structures.

The existence of the standard EC contracts are of particular interest because they are being used outside of the EC. If used only within Esprit and the other EC programs, their use could be explained as imposed by the Commission, rather than by the self-interested behavior of firms. Even then there would be a clear transactions cost advantage of bringing all these projects together under one umbrella program, compared to an ad hoc arrangement for sponsoring them. However, the Annex and boilerplate are being used as a model agreement outside the EC cost shared programs. A number of new cooperative projects, while not lifting the texts wholesale have used them as a starting point, a negotiating text, and have borrowed parts of the language. Firms are finding it useful not to have to, as one project manager put it, "reinvent the wheel" each time a cooperative technology agreement is reached. He said "we plan to start every contract with future partners with the idea that the agreement will be based on the Big Twelve agreement the Commission uses." A department manager at Plessey talked about his experience with the standard agreements: "Coming to the table already aware you are going to have to follow the Commission's rules really did smooth things out." Based on that effectiveness, he said, a new outside cooperative project he was involved in which "pretty much adopted that legal agreement framework too."

Of their own accord these firms are adopting and abiding by these rules explicitly because it saves on transactions costs. As we would expect from the theory of institution formation, the rules are not singularly useful in complying with the wishes or intricacies of the EC bureaucracy, but are more broadly useful in other cooperative R&D efforts.

VI.3. Professionalization

The codification of cooperative R&D does not only include legal texts. The third theme of evidence institutionalization is that Esprit participants are beginning to identify and codify a set of professional skills applicable to cooperative R&D. This professionalization has taken a number of forms, from internal "how-to" manuals, to a growing number of cooperative R&D management consultants, to recommendations to the Commission that they provide classes on managing cooperative R&D.

The Review of the first phase of Esprit described one recommendation Esprit participants had made during interviews: "it was recommended that the Commission should arrange short courses to spread the experience gained on managing projects of a multilateral and multinational nature."[28] This comment was also oft repeated in the personal interviews done for the current paper. Project managers almost uniformly felt that they had learned better how to cooperate, and that they were more effective at cooperating now than they were before. There is clearly a perception that a set of management skills could and should be learned in order to make cooperation more efficient.

One manifestation of this was that several firms had prepared sets of cooperation guidelines, or "how to" manuals for internal use. For example one research manager was responsible for overseeing the administration of all of his firm's Esprit projects. He created a guide for his firm's employees based on the firm's experience in Esprit. It tried to codify the basic goals for entering the projects, strategies for achieving them, stumbling blocks, a

---

[28] Esprit Review Board (1989) p. 70

number of actions which needed to be taken, and key variables of which managers should be aware.

Not only do these managers believe they are learning something to pass on internally, a number of them have marketed themselves that way or been hired specifically because of their previous experiences in managing cooperative research projects. A cadre of cooperation management professionals is developing. In one case a consortium had decided that to avoid giving one partner any advantages over the others they needed an independent manager, not from any of the partners. The manger they hired was chosen because of his previous experience in helping establish the Microelectronics and Computer Technology Corporation (MCC) in the US. MCC is a purely private joint research venture with 21 different US industrial partners, mostly in the computer, semiconductor, electronics, and aerospace industries. A second project manager employed by an Esprit prime contractor had previous experience at CERN. A third case involved a standardization project with a large number of partners. The original project manager was from one of the partner firms. In the middle of the project he decided to leave the firm and set up as an independent consultant. So, he was replaced as project manager by a second person from the same partner. By the second meeting of the consortium under this second manager it was clear he was unable to handle the complex management task of balancing the interests of so many masters. The other partners voted to get rid of the second manager, and hire the original manager back as an independent.

A number of cooperative R&D management consulting firms have sprung up throughout Europe. Some market "marriage brokering" services to help people find partners. In other cases they market their services as project managers. For example, a Danish-owned company has a subsidiary called Project Management Consultants (PMC) with an office in Brussels. One of the consultants there said that the firm has no technical expertise, but rather expertise in managing cooperative projects. The firm offers "Project Management in Information Technologies and Telecommunications Projects." They advertise skills in, and have indeed been hired as subcontractors to help with, consortium building, writing technical proposals, project start-up, project management and administration, and project review. They also sell a report on "Product Management Tools, Methodology, and Packages" which contains guidelines and recommendations on how to organize and manage cooperative research projects, and critiques project management computer software. It catalogs a number of "Project Management Disciplines" including "Project Organization," "Work Breakdown Structure" [i.e work packages], "Resources" "Control," "Working Methods" and others.

Another approach has been for existing firms to try to develop a marketable expertise in cooperative management. One project manager at an Italian software consultancy said his firm had agreed to be the prime contractor on a number of Esprit and Eureka projects in part explicitly because they wanted to gain the cooperative management expertise. The thought they would be able to win more consulting business later because larger firms with "slow reaction times" would want to have them manage cooperative projects, in order to "get a flexible company."

In some cases outside management consultants have been less than satisfactory. In two cases reported in interviews for this paper, consultants were hired and then released because they "did not understand" the technical people. However, even in these two cases where the professional consultants proved unacceptable, there were elements of the professionalization of cooperative project management. In one, described at length above, the hired consultants were released and an independent company set up by three of the principal project managers. In the second case, one of the small partners agreed to take on the project manager's role, because the firm was viewed as having the most experience with the EC bureaucracy.

Some firms have established internal positions for administration and oversight of cooperative projects. These positions can be found in the whole range of firm sizes. Before its acquisition by GEC and Siemens, the research division of Plessey at Caswell, on one end of the scale, had a technical staff member who "worries about the administration of these projects more or less full time." His entire job involved negotiating the collaboration agreements, lobbing various partners and the Commission, attending meetings at the partners, the UK ministries, and the EC, and getting the word out about what areas the company would like to pursue collaboratively. Similarly, Océ, an 11,000 employee Dutch copier company had one research manager in charge of all collaborate research projects. At the other end of the scale, a 15 person

Belgian subsidiary of Intecs Finaciaria in Italy also had one person who deals with administrative and contracting issues for cooperative projects. This person is not responsible for the technical or financial management of the projects. In the middle, the French Technical Research Center of the Mechanical Engineering Industry (CETIM) employs 520 technical people. A former head of one of their research departments is now employed expressly for maintaining international contacts and setting up new collaborative projects. There are also lawyers who specialize in the legal issues of research collaboration. One interviewee said the lawyer his firms uses to deal with collaboration agreements also oversees the legal aspects of 50 collaborative projects for Oxford.

The implication of this professionalization is that there are some economies of experience -- learning curves -- in R&D cooperation. Technological collaboration becomes less costly as experience with it grows, as uncertainties about how it will work are reduced, as it becomes an expected norm of behavior, as formal rules are codified to accommodate it, and as people become more aware of the technical capabilities of others.

VII. Conclusions

The Esprit program came with the beginning of an upsurge in R&D collaboration world-wide. In its wake, both informal norms and formal rules governing European industrial cooperation have changed. This paper has argued that R&D cooperation is becoming institutionalized -- becoming a regularity in industrial behavior in the sense that people expect it will occur, are beginning to standardize and simplify the process through which it occurs, desire to conform to it as long as others do, and believe that without it they will all be worse off. Because the process is understood as a repetitive game where reputation is important, incentives to deviate are mitigated by both formal rules and self-policing norms of good behavior. Long term joint gains are stressed rather than short term distributional conflict.

The paper also suggested that those changes emerged to facilitate cooperation, primarily through reducing the embeddedness-related costs of transactions among participants. Cooperation has been fostered through both formal and informal mechanisms which have emerged with that express purpose. Formally, the Communities' funding for collaborative research has increased by an order of magnitude. Its standard contracts have proved valuable in eliminating the need for much debate over rights and liabilities in R&D consortia, and have proved more broadly useful outside Commission programs. New European laws clarify the previously uncertain legality of joint efforts in technology, and even encourage them through new company laws. The intellectual property regime is moving towards unifying the treatment of patents and copyrights. Informal norms of cooperation also guide and legitimate cooperative behavior. Top and mid-level executives of European high technology firms now meet as a matter of course to share their views and vent their differences in industrial roundtable discussions and Commission advisory or evaluation committees. Technical people are actively encouraged to learn how to cooperate, to "discover Europe" and get past barriers like the "not-invented-in-Europe" outlook or the hesitancy which comes with treading previously uncharted ground. A growing cadre of R&D cooperation professionals market their skills in planning and managing joint projects.

It remains to be seen, however, how deep this institutionalization runs or whether it will be economically beneficial in the long run. The paper has not attempted to explore either point, focusing instead on why it might have occurred at all. The interviews conducted here involved those already cooperating, those who had overcome the barriers to cooperation and technology sharing. Yet, the firms which participate in Commission or related programs such as Eureka and JESSI, while including most major European firms, number only in the high hundreds. Tens of thousands of small and mid-sized firms remain on the periphery. The spending on collaborative projects is less than 5 percent of the total R&D spending in Europe. It is also not clear that the purported benefits of R&D collaboration have appeared. Firms like Groupe Bull and Philips, both among the leaders in numbers of European collaborative efforts, are struggling. Bull, for example, reported losses in excess of a billion dollars in 1990.[29]

This paper also has not addressed the wider picture of the drive towards European integration and the associated large wave of European corporate mergers. The merger wave is clearly a related phenomenon. Some authors have even attributed a catalytic role to the Esprit program.[30] R&D

---

29 Wall Street Jounal, 3/28/91, p. C12

30 See in particular, Sharp (1989)

cooperation can be a ground for testing the organizational compatibility of different firms or a method for de-fogging the embeddedness window on each others' technical capabilities prior to decision on mergers -- both methods of reducing uncertainties and asymmetries of information related to technological embeddedness.

The case study methodoiogy employed here can only be suggestive rather than conclusive. But, it does suggest that the embeddedness characteristics of technology may be important explanatory variables in the analysis of how firms structure innovative activities. If that is true, then the nature of the interfaces and networks among technology actors become a target for study and policymaking outside the traditional focus on firms' internal organizational structures and general market structures. Because technologies can be embedded in institutional structures, government policies can influence the efficacy of the innovation and diffusion process through a much wider array of policies than traditionally considered technology policy. Yet, if policies are to be designed to improve that process, much work remains to be done in understanding the the mechanisms of technological diffusion and the conditions under which technologies can be embedded.

References

R. Axelrod, An Evolutionary Approach to Norms, American Political Science Review 80 (1986) 995-1111.

J.M. Buchanan, *The Limits of Liberty: Between Anarchy and Leviathan* (University of Chicago Press, Chicago, 1975).

R. Coase, The Problem of Social Cost, Journal of Law and Economics 3 (1960) 1-44.

Commisison of the European Communities, *EC Research Funding: A Guide for Applicants*, 2nd ed. (Brussels, May 1990).

Commission of the European Communities, *Target 92* 8 (1990), 1 (1991), and 2 (1991).

Commission of the European Communities, *Treaties Establishing the European Communities*, Abridged Edition (Luxembourg, 1979)

Commission of the European Communities. Completing the Internal Market: White Paper from the Commission to the European Council (Luxembourg, 1985)

Council of the European Communities, *Single European Act* (Brussels, 1986).

Esprit Review Board, *The Mid Term Review of Esprit* (Commission of the European Communities, Brussels, October 15, 1985).

Esprit Review Board, *The Review of Esprit , 1984-1988 (Extended Version)*, (Commission of the European Communities, Brussels, June 1989).

J. Hagedoorn and J. Schakenraad, Leading Companies and the Structure of Strategic Alliances in Core Technologies, Maastrict Economic Research Institute on Innovation and Technology, Paper 90-001 (Limberg University, Maastricht, 1990).

J. Hagedoorn, Contributions to Theory of Inter-firm Technology Cooperation, Maastrict Economic Research Institute on Innovation and Technology, Draft Paper COTEC A 01.2 (Limberg University, Maastricht, May 1990a).

J. Hagedoorn, Organizational Modes of Inter-firm Cooperation and Technology Transfer, *Technovation* 10 (1990b) 17-30.

S. Haggard and B.A. Simmons, Theories of International Regimes, *International Organization* 41 (1987) 491-517.

T. M. Jorde and D. J. Teece, Innovation and Cooperation: Implications for Competition and Antitrust, *Journal of Economic Perspectives* 4 (1990) 75-96.

M.R. Kelley and H. Brooks, External Learning Opportunities and the Diffusion of Process Innovations to Small Firms: The Case of Programmable Automation, *Technological Forcasting and Social Change*, ~~forthcoming~~ (199[illegible]). 103-125

R.O. Keohane, *After Hegemony: Cooperation and Discord in the World Political Economy* (Princeton University Press, Princeton, NJ, 1984).

E. Mansfield, J. Rapoport, A. Romeo, E. Villani, S. Wagner and F. Husic, *The Produciton and Application of New Industrial Technology* (Norton, New York 1977).

R.R. Nelson and S.G. Winter, An Evolutionary Theory of Economic Change (Harvard University Press, Cambridge, MA, 1982).

D.C. North, Government and the Cost of Exchange in History, Journal of Economic History 46 (1984) 255-264.

M. Polanyi, *The Tacit Dimension* (Doubleday Anchor, Garden City, NJ, 1967).

W. A. Sandholtz, *Crisis and Collaboration in European Telematics* (Doctoral Dissertation, University of California, Berkely, 1989).

A. Schotter, *The Economic Theory of Social Institutions* (Cambridge University Press, Cambridge, 1981).

M. Sharp, *European Technology - Does 1992 Matter?,* Papers in Science, Technology and Public Policy 19 (University of Sussex, Science Policy Research Unit, 1989).

D. J. Teece, Inter-Organizatinal Requirements of the Innovation Process, *Managerial and Decision Economics* 10 (1989) 35-42.

E. von Hipple, The Impact of "Sticky Data" on Innovation and Problem Solving (MIT Sloan School of Management, Working Paper 3147-90-BPS, Cambridge, MA, April 1990)

T. A. Watkins, A Technological Communications Costs Model of R&D Consortia as Public Policy, *Research Policy,* ~~forthcoming~~ 20 (1991). 87-107

T.A. Watkins, Beyond Guns and Butter: Managing Dual-Use Technologies, *Technovation* 10 (1990) 389-406.

K. J. Arrow, Economic Welfare and the Allocation of Resources for Invention, in *The Rate and Direction of Inventive Activity: Economic and Social Factors* (National Bureau of Economic Research, Princeton University Press, Princeton, 1962) 609-25.

K. J. Arrow, The Organization of Economic Activity: Issues Pertinent to the Choice of Market Versus Nonmarket Allocation, *The Analysis and Evaluation of Public Expenditures: The PPB System* 1 (The Joint Economic Committee, Washington, D.C., 1969) 47-64.

B. Bozeman, A. Link and A. Zardkoohi, An Economic Analysis of R&D Joint Ventures, *Managerial and Decision Economics* 7 (1986) 263-266.

F. Chesnais, Technical Co-operation Agreements Between Firms, *STI Review* (1988) 51-119.

R. Coase, The Nature of the Firm, *Econometrica* 4 (1937) 386-405.

Commission of the European Communities, *Proposal for a Council Decision adopting the first European Strategic Programme for Research and Development in Information Technologies (Esprit)*, COM (83) 258 final (Brussels, 2 June 1983).

Commission of the European Communities, *Towards a European Strategic Programme for Research and Development in Information Technologies*, COM (82) 287 final (Brussels, 25 May, 1982).

H.I. Fusfeld and C.S. Haklisch, Cooperative R&D for Competitors, Harvard Business Review (November/December 1985) 60-76.

M. Granovetter, Economic Action and Social Structure, *American Journal of Sociology*, 91, (1985) 481-510.

H. Håkansson (ed.), *Industrial Technological Development: A Network Approach* (Croom Helm, London, 1987).

K.J. Hladik and L.H. Linden, Is an International Joint Venture in R&D for You?, *Research Technology Management* 32 (1989) 11-13.

J.F. Hennart, A Transaction Cost Theory of Equity Joint Ventures, *Strategic Management Journal* 9 (1988) 361-374.

M. Katz, The Analysis of Cooperative Research and Development, *Rand Journal of Economics* 4 (1986) 527-543.

A.N. Link and L.L. Bauer, *Cooperative Research in U.S. Manufacturing: Assessing Policy Initiatives and Corporate Strategies* (Lexington Books, Lexington, MA, 1989).

A.N. Link and G. Tassey, Editors Introduction, in: Link and Tassey (eds.), Cooperative Research and Development: The Industry-University-Government Relationship (Kluwar Academic Publishers, Boston, 1989).

E. Mansfield, J. Rapoport, A. Romeo, E. Villani, S. Wagner, F. Husic, *The Production and Application of New Industrial Technology* (Norton, New York, 1977).

P. Mariti and R.H. Smiley, Cooperative Agreements and the Organization of Industry, *Journal of Industrial Economics* 31(1983) 437-451.

D.C. Mowery, Collaborative Ventures Between U.S. and Foreign Manufacturing Firms, *Research Policy* 18 (1989) 19-32.

L. K. Mytelka, States, Strategic Alliances and International Oligopolies: The European ESPRIT Program, unpublished (~~1989~~). 1991

L. K. Mytelka and M. Delapierre, The Alliance Strategies of European Firms in the Information Technology Industry and the Role of ESPRIT, in: J. Dunning and P. Robson (eds.), *Multinationals and the European Community* (Basil Blackwell, Oxford, 1988).

W. G. Ouichi and M. K. Bolton, The Logic of Joint Research and Development, *California Management Review* 30 (1988) 9-33.

K. A. Oye (ed.), *Cooperation Under Anarchy* (Princeton University Press, Princeton, 1986).

J.A. Schumpeter, *Capitalism, Socialism, and Democracy,* Second Edition (Harper and Brothers, New York, 1942).

D.J. Teece, Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy, *Research Policy* 15 (1986) 285-305.

D.J. Teece, *The Multinational Corporation and the Resource Cost of International Technology Transfer* (Ballinger, Cambridge, MA, 1976).

E. von Hipple, Cooperation Between Rivals: Informal Know-How Trading, *Research Policy* 16 (1987) 291-302.

E. von Hipple, *The Sources of Innovation* (Oxford University Press, New York, 1988).

E. Von Hipple, Trading Trade Secrets, *Technology Review* (February/March 1988) 58-64.

O. E. Williamson, *Markets and Hierarchies: Analysis and Antitrust Implications* (The Free Press, London, 1975).

O. E. Williamson, Organizational Innovation: The Transaction-Cost Approach, in: J. Ronen (ed.), *Entrepreneurship* (Heath Lexington, Lexington, MA, 1983) 101-134.

O. E. Williamson, Transaction Cost Economics: The Governance of Contractual Relations, *Journal of Law and Economics* 22 (1979) 233-261.