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The EC Framework Programme and the technology strategies of European firms

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Finally, I would like to emphasize that this report is the result of collective work shared between myself, Philippe Laredo and Philippe Mustar of CSI in Paris, and Guido Reger and Markus Schroll of ISI in Karlsruhe. I cannot but express my gratitude to them. I must stress here the importance of the work of my French colleagues, the results of which are recorded only through my writing, while the valuable contribution of my German colleagues, presented also as a separate appendix, speaks for itself.

Summary of main findings

This report sets out the findings of a study concerned with the ways in which projects sponsored by the EC Framework Programme are approached and managed by firms and the factors that affect the exploitation of their results.

1. Introduction

The background to the study lies in the prevalent thesis that the competitiveness of European firms is related to their efficiency and effectiveness in exploiting the results of R&D. Two issues are put forward under this thesis. The first relates to the R&D management patterns prevailing in Europe, as opposed to those in other parts of the world. The second concerns the impact of the EC Framework Programme on the ability of firms to exploit results of EC Framework Programme projects.

The two issues are linked. At one level, the management of the R&D process is intimately elated to the ability to exploit its results. At a more basic level there is a relationship between the fundamental mission of EC R&D to promote Europe's industrial competitiveness, and the creativity and innovativeness of European firms.

These relationships define the object of this study, which focused on the ways in which firms manage the R&D process and the exploitation of its results, as much through their own initiatives as through EC sponsored projects.

2. Methodology

The findings are based on 41 interviews carried out in Germany, the UK, France, Italy, Denmark Belgium, the Netherlands, Greece, and Ireland, with firms leading ESPRIT, BRITE, ECLAIR, Raw Materials, and RACE projects. While the sample cannot be said to representative, the interviews provided in-depth insights to the impact of the Framework Programme on the technology strategies of firms and to the factors that affect their willingness and ability to exploit the results of EC R&D projects.

3. The Framework Programme and European Industry

A look at the literature on EC sponsored R&D reveals the multiplicity of factors that encourage firms to participate in EC R&D activities. This indicates the importance of firms' technology strategies, as it shows that different firms participate for different reasons and with different objectives, anticipating different benefits.

Technology strategy involves business strategy and technology acquisition. According to the role of technology in business strtategy, three types of firm were distinguished: networks (business based on all possible ways of technology exploitation), machines (business based on production; technology acquisition serves existing production lines), and portfolios (business is based on a coupling of technology acquisition activities within the R&D department, with technology exploitation activities at the level of individual business units).

The Framework Programme had a lot of response from network firms. For them it provides a good business environment that orientates their technology strategies, and provides them with a facility to make the contacts necessary for their business. EC programmes have often provided the stimulus for such firms to engage in R&D activities.

Such firms commercialize technologies at a very fast pace; they enhance the availability of technologies in the market and thus enhance the innovative potential of European industry as a whole.

The fast pace of innovation by these firms creates problems for technology users, especially those with machine type technology management, who often do not have the capability to follow the pace and make the most beneficial technological choices. The standardization aspects of the EC programmes are very important in that respect.

Although the Framework Programme provides firms with machine type technology management with the stimulus and the means to develop technological capabilities and strategies, their participation in its activities is limited.

Large "portfolio" corporations broaden the scope of their R&D portfolios in view of the Framework Programme. In practice it provides their corporate R&D laboratories with more room to manoeuvre in terms of both developing certain technologies and personnel management.

4. The exploitability of results of Framework Programme projects

In only a few cases, projects aimed solely at process technologies. In these cases the participating organizations aimed at using the results themselves. These projects were technically successful, although their results were not always exploited. In one such case the results were commercialized because of a radical change in corporate strategy, due to a take-over. In another the results were kept "on the shelf" in case the organization needed them in the future. The difference in technology management played an obvious role. The first was a network firm while the second had "portfolio" type technology management.

In most cases, the projects had both product and process goals. According to the importance of collaboration for the product goals of the project leader, projects were distinguished between the categories collaboration-sensitive and collaboration-insensitive. In collaboration-sensitive projects, the project leader aimed at the development of a system incorporating the work-packages performed by the partners. In collaboration insensitive projects the work-packages of the other partners were not an essential part of the leader's goals, regarding the outcome of the projects. Consideting the goals of users participating in consortia, it becomes evident that for users projects are collaboration-sensitive.

In the choice of partners, the extent to which partnership was necessary for project implementation was a major factor. Accordingly the "collaboration-sensitivity" of projects was defined in relation to the goals of the project-initiating actors. The more sensitive the project the more the technical ability of the partners was important. The more insensitive the project the greater the importance attached to the origin of the partners, which was seen as a political factor increasing or decreasing the possibilities to get EC funding. The quality of the communications infrastructure in less favoured regions of the Community, as well as the financial viability of their industries, emerged as important factors influencing decisions to collaborate with firms from these regions.

The design of the project had to strike a balance that would satisfy the goals of the Programme, the goals of the initiator and the goals of the partners. Increasing the dependence of the goals of the partners on the goals of the initiator provided the means for controlling the direction of the overall project as well as potential competition. Limits to this were posed by the size of the initiating firm and the extent of work it could perform. Academic partners were often chosen to perform important parts of the projects in view of their low potential for competition after the project.

Detailed consortium agreements were signed to guarantee the coincidence of goals between the partners and the initiator and to limit potential competition. Patents previous to the projects provided effective means to that end.

It appeared that all the organizations acknowledged that project goals shift in time as a result of the partners' changing strategies or of new data arising from project implementation. A number of projects collapsed under these changes. To keep the right balance between the goals of the actors involved under changing conditions was the role of project management.

Three ways of dealing effectively with changes in a project's direction were found. The first, emphasizes coordination effort to guarantee a consensus between consortium members on all decisions related to project implementation. The second is to start the project with a consortium agreement for joint exploitation of its systemic goals, which emphasizes the community of interests between the partners in the exploitability of the results. The third, refers to the internal project management structures of firms, and in particular in the existence of a department and/or a project interfacing between their technology strategy and their EC R&D project.

Technology flows within consortia did not seem to be more than what was required for project implementation. Only one case was found involving an inter-organizational research team which worked together in all partners locations at the various stages of the project, and this case was governed by a consortium agreement for joint exploitation of the results.

Technology flows within firms depended on their structures and on the interest of product developers and top managers in particular projects. The smaller the firms and the more informal their structures, the more results were communicated and screened and the more product developers and top managers were informed. Large business units located their R&D activities close to production and involved production personnel in them. Corporate R&D laboratories used formal reporting procedures to transfer technologies to users, after their development had been completed.

The product technologies developed in EC R&D projects in the sample were rarely commercialized. Consortium agreements for joint exploitation seemed to characterize these cases. Such agreements were an important mechanism for compromizing the diverse goals of the partners regarding the projects and directing them towards commercialization or not of the outcomes.

Even in successful projects the level of development reached was rarely adequate for commercialization, in accordance with the principle of pre-competitiveness. The extent to which further development effort was needed for commercialization varied, and was not directly related to the willingness of firms to invest in it. This willingness was stronger in firms following a "hardening" strategy (of moving their business from contract development to production of their own products). In all such cases, the hardening was based on the results of EC projects.

In many cases firms pursue further development of their EC projects' results through subsequent EC projects. Great value was attached by the firms to the results of EC projects, in terms of process and training. One of the most important aspects of training is the accumulation of "international project management" skills, which seem to be important for the ways business practices are developing in Europe.

Some firms reported that they learned a lot about managing projects from the Commission's scientific officers. The staff of ESPRIT seems to worth special mention here as their commitment to monitoring the projects and enforcing strict management rules was emphasized in many cases as one of the factors that helped project management a lot.

5. Conclusions and lessons

On the basis of the evidence and the analysis in the previous sections the following general conclusions may be drawn:

i) The technology strategies of actors that participate in consortia are a key factor in the exploitability of EC R&D results. The way firms perceive their EC R&D projects in relation to their business, determines the directions they will pursue in project implementation and exploitation. Technology strategies also play a key role in project design and management. The dissemination of results also serves these strategies. Studies of the industrial impact of EC R&D programmes have to take this into account.

ii) The extent to which the Framework Programme has affected the technology strategies of European firms varies according to their structures and their types of technology management. It has contributed to the generation of a fierce competitive environment in the markets for technology as it has been offering business opportunities to technology producers, promoting thus the innovativeness of an important part of Europe's technological potential.

iii) The Framework Programme offers opportunities to technology users to develop technological capabilities and strategies. However, the host of technologies generated creates problems in the development of technology strategies by technology users, and even more problems to users without technology strategies, who operate in a rapidly changing environment. In this respect, there may be a role for the Community in intensifying its standardization efforts to reduce this type of problems. Complementary to this can be assistance to firms to develop technological capabilities and strategies and to understand the changes required by the competitive environment of the 1990's.

iv) The various dissemination fora do not effect technology transfer from firms that perform projects to their audience. Rather they provide marketing frameworks for ideas and results. Thus, commercial exploitation is the principle means for dissemination of EC R&D projects' results. In this sense there can be arguments either for stricter rules governing dissemination, or for R&D closer to the market. In view of the existing pre-competitiveness principle that covers EC R&D projects, firms with network type technology management clearly play an important role in the economy of the Community.

v) The importance of collaboration for project implementation and exploitation, can be seen as adding value, by increasing the productivity of the R&D process. On the other hand, collaboration-sensitivity poses great problems in project management, especially when shifts in the goals of the project and/or the strategies of firms occur. To the extent that the Commission's programmes aim to increase the productivity of the R&D process, collaboration-sensitivity can find a place in project selection criteria. However, further research is required to determine the ways collaboration-sensitivity appears in various collaborative structures, and accordingly its desired levels.

vi) As EC R&D projects are different from companies' wholly self-financed projects, effective exploitation of their results requires somewhat different management patterns; firms which realized it have been very effective in achieving their goals. The ability of firms to realize such differences and respond by establishing appropriate R&D management processes, depends very much on company size, structure, management style and culture. However, such changes are very important as in an evolving world change is often synonymous to survival.

Contents

1. Introduction

This document reports the findings of a study concerned with the interface between the EC Framework Programme and the technology strategy of European firms in general, and in particular with the management of EC sponsored R&D projects by firms, and the exploitation of their results. The study was carried out by the Programme on Policy Research in Engineering Science and Technology (PREST), University of Manchester, in collaboration with the Fraunhofer Institut fuer Systemtechnik und Innovationsforschung (ISI) in Karlsruhe, Germany, and Centre de Sociologie de l' Innovation (CSI), Ecole des Mines, in Paris, France.

The background to the study lies in the prevalent thesis that the competitiveness of European firms is very much related to their effectiveness in exploiting the results of R&D. Two issues are put forward under this thesis. The first relates to the relative nature of effectiveness in a competitive world, and thus concerns the R&D management patterns prevailing in Europe, as opposed to those in other parts of the world. The second concerns the impact of the EC Framework Programme on the ability of firms to exploit results of EC Framework Programme projects. The two issues are linked. At one level there is an obvious relationship between ways of managing the R&D process and the ability to exploit its results. At a more basic level there is a relationship between the fundamental mission of EC R&D to promote Europe's industrial competitiveness, and the creativity and innovativeness of European firms.

These relationships define the object of this study, which focused on the ways in which firms manage the R&D process and the exploitation of its results, as much through their own initiatives as through EC sponsored projects. At the first level the issue is one of firms' internal technology transfer structures and processes from R&D to production (See: Reger and Schroll 1993, appendix 2). However, EC sponsored R&D projects are different from normal company projects in a number of ways, and it is in these differences that their impact on European industry can be looked for. These differences bring about the object of the study at the second level. At this level, the study focused on the interface between the Framework Programme and the technology strategy of European firms.

The structure of the report is as follows:

Section 2 presents the methodology followed, focusing on an interview programme carried out with 41 firms in Germany, the UK, France, the Netherlands, Italy, Belgium, Denmark, Greece and Ireland, covering projects from ESPRIT, BRITE/EURAM, ECLAIR, Raw Materials and RACE projects.

Section 3 provides a background to the impact of the Framework Programme on European industry based on past studies. This demonstrates the importance of the way EC R&D programmes and projects interact with the technology strategies of firms, for the exploitability of their results. Further, it introduces the concept of technology strategy and analyses the factors that shape it. It distinguishes between broad technology management patterns and relates them to the participation of firms in Framework Programme activities. A description of the firms covered by the interview programme and their technology management types is included in appendix 1.

Section 4 analyses in depth the management of EC R&D projects and the factors that affect the exploitability of their results. It looks at project initiation, choice of partners, project design, patterns of project management within the project and within the firm, technology flows related to these patterns, and prevailing patterns of exploitation of the results. The analysis is illustrated by examples drawn from the cases examined, (which often include detailed case descriptions).

Section 5 presents the findings of the analysis, and draws conclusions on the key factors that affect the impact of the Framework Programme on European Industry in general, and project success and failure and the exploitation of the results in particular.

Appendix 1 includes a description of the firms covered by the interview programme and their technology management types.

Finally, appendix 2 includes the report of Guido Reger and Makrus Schroll on the German part of this study.

2. Methodology: the interview programme

Work proceeded in the form of semi-structured interviews with executives of companies leading R&D consortia engaged in EC projects. The choice to interview only the leading partner reflected the assumption that leading partners are strategically poised towards exploitation of the results, as they have a large influence on the way the project is implemented. Indeed in most cases the coordinating organization was the organization which initiated the project. In a few instances this has not been the case, but still the coordinator was strategically poised to exploit project results. Sometimes the project leader was the administrative rather than technical coordinator. These were cases when the initiator was an academic and the partners preferred to have a commercial organization dealing with the Commission. Again the coordinators were able to provide a good picture of the project.

In all cases the people interviewed gave a good picture of the way the projects developed and the results were exploited. The choice to attach emphasis to finished projects rather than on-going ones payed off in that respect. The whole interview programme has been dominated by the need to collect in depth information about the ways in which companies manage their projects in general and EC projects in particular, as well as about the history of the projects under investigation, from their inception to their results and their exploitation. While the depth which the interviews managed to reach varied, especially in relation to company management structures and processes (companies often considered it confidential know-how), in all cases the interviews managed to throw light on the relations between the company's technology strategy and the way the project in question was perceived, managed and exploited.

Initially it was anticipated that two people had to be interviewed in each company: the project leader and an executive from one of the businesses who exploited the results. This methodological rule was bent in practice for a number of reasons. For example, typically through its history a project has more than one project leader. Often the initial project leader is impossible to locate, as he/she has changed business or even company. The degree of involvement of internal users to EC projects varies enormously as a result of company sizes and management structures. In practice, the number of interviewees in each company varied between one and five. It must be noted that this does not reflect the quality of information obtained. This was determined by the seniority of the interviewee, largely because of the broadness of perspective that high-standing executives have and their ability to interpret the companies' confidentiality rules.

Interviews were carried out by ISI in Germany, CSI in France, and PREST in the rest of Europe. Project selection was random, nonetheless complying to a number of criteria. Thus, it concentrated on programmes with industrial participation. The higher the industrial interest expressed in a programme, the higher the priority that was attached to it in our sample. Effort was made to ensure that the number of cases from each programme was not disproportionate to its overall weight within the Framework Programme. In practice RACE and DRIVE were excepted from these criteria, due to their peculiar character, but most of all because of practical difficulties with arranging interviews with project leading companies. Effort was also made to encompass companies of all sizes and types in the sample. While geographical criteria were secondary, interviews took place in most Community countries. The following table gives the number of companies/cases investigated, categorized by programme and by country.

Table 1: Interviews by country and programme:

	UK	F	NL	I	B	DK	GR	IRL	D	Total
ESPRIT	2	2	4	1	3	1	1		9	23
BRITE/ EURAM	1			2		1	1		5	10
RAW Mat	2	1								3
ECLAIR		1		1	1					3
RACE								1	1	2
TOTAL	5	4	4	4	4	2	2	1	15	41

The interview guide consisted of a checklist of issues that had to be addressed, arranged in four sections, and concerning the company's businesses, its technology strategy and R&D management, the project, and the exploitation of its results in relation to the firm's technology strategy.

3. The Framework Programme and European Industry

While the first ESPRIT programme provided the developmental momentum that led to the establishment of the Framework Programme, the EC since its foundation has been sponsoring R&D in a number of areas. However, it was only in the mid 1980's that industrial R&D gained in importance, under the assumption that there is a relationship between the amount of R&D performed by industry and industrial competitiveness (C.E.C. 1992-a)

Programmes addressing industrial R&D, varied in their levels of industrial participation. ESPRIT, BRITE and RACE attracted significant industrial participation, while the Materials and Biotechnology programmes did so to a lesser extent (CREST 1992, Costa et al 1988, Malmborg et al 1990). Furthermore, the way the programmes function varies. Concentration on certain technologies was obvious in the early ESPRIT, RACE and BRITE. In time this situation changed. BRITE and ESPRIT broadened considerably their scope in both topics and range of participants, while RACE remained concentrated on the vision of Integrated Broadband Communications. This has important implications for the ways these programmes impact on industry. RACE projects build on previous RACE projects, and while early projects concentrated on developing pre-standards, later projects started delivering commercializable results within the environment set by the pre-standards (RACE 1992)[1]. Very few BRITE projects build on previous BRITE projects. In ESPRIT the situation is mixed, with old projects providing the basis for new ones, but also including many new stand alone projects.

Evaluations of programmes carried out by the Commission, mostly deal very briefly with the subject of their industrial impact. An exception is a recent evaluation of BRITE/EURAM finished projects (CEC 1992-b). This evaluation used quantified qualitative indicators, such as the exploitation potential offered by the project results and the capability and will of actors to exploit them. The study found that the exploitation potential is 0 for 24% of the projects, less than ECU 5M for 19% of the projects, between ECU 5M and 100M for 41% of the projects, and more than ECU 100M for 16% of the projects. However, the willingness and capability to exploit these results was strong for only 37% of the projects. While the quantification is somewhat problematic, these findings are important in two respects. First, they indicate the subjectivity surrounding accounts of benefits deriving from EC R&D and second, they demonstrate the importance of firms' technology strategies, which incorporate the will and capability of firms to exploit EC R&D results.

1 This derived also from the single RACE interview. The interviewee however, had a long experience with RACE projects. Only at the time of the interview he was overseeing four such projects.

These benefits have been addressed in a study by Research Associates (1989) who asked a number of organizations industrial and non-industrial, from all over the Community, participating in a number of programmes, about the factors that encouraged their participation. The value of their findings is enhanced by their method. In particular instead of using a specified questionnaire that would elicit a range of specific possible answers, they preferred semi-structured interviews. The points drawn are presented in Table 2.

Table 2: Factors that encourage participation in Framework Programme schemes

Reasons	Times indicated
1. Funding for research,	59
2. Increase in cooperation,	54
3. Exchange of information,	36
4. Project progress*,	22
5. Improvement of reputation,	8
6. Outward orientation**,	5
7. Better directions in product development,	4
8. Provide for easier partnership formulation,	4
9. Risk sharing in research,	3
10. Access to equipment.	2

Source: Research Associates (1989) Evaluation study on contribution to cohesion of EC Framework Programme.

* EC programmes allow projects to progress more quickly or further than they would with the existing state of an organization's capabilities

** Provides for enhancing the extent to which an organization takes into account development in its environment. It includes such points as "helps us to extend our markets", or "helps us act like a European company".

From table 2 at first glance it seems that organizations perceive EC programmes as clearly additional to their own activities. EC provides R&D funding which they need but do not have, and through this incentive it provides for the establishment of collaborative relationships which would have not been established otherwise. It provides the means to organizations to monitor and position themselves in the European environment and to improve their reputation. However, considering that the survey included interviews with 145 organizations the argument can also be reversed. If funding was significant for 59 organizations only, then what was the major incentive for the remaining 86? If collaboration was significant for only 54 organizations, then what was the major incentive for the remaining 95? In short, what these results clearly indicate is that different organizations attach different value to different aspects of their participation in Framework Programme activities.

Similarly, but through a questionnaire based on possible benefits for companies, Andersen Consulting (1989) attempted an analysis of the effects of EC R&D programmes on Dutch companies. Their findings are summarized in table 3.

Table 3. Effects of EC R&D on Dutch companies

Effect	Percentage of companies indicating this effect
1. More financial resources and manpower available for R&D	67
2. A positive influence in the company	62
3. Improvement of name and image	62
4. A better competitive position	56
5. A better technological position	49
6. Activities in new markets	46
7. Accelerated introduction of new products or processes	38
8. Involvement in standardization	35
9. Influence on R&D strategy	34
10. A better preparation for 1992	33
11. Commercial applications	28

Source: Andersen Consulting (1989) Strategic Effects of EC R&D Programmes in the Netherlands.

Some of the effects indicated, such as "a positive influence in the company", and "influence on R&D strategy" are too vague, and it is not clear in what way they are beneficial. Furthermore, while additional R&D was performed in 67% of the companies surveyed, only in 28% it led to commercial applications. This again indicates the importance of the firms' technology strategies and the way EC sponsored R&D projects fit into it. This has been the focus of this study.

3.1 The concept of technology strategy: technology and business strategy

Technology strategy incorporates the ways in which firms plan and implement technology acquisition and the ways they appropriate their technologies. Ford (1988) sees technology strategy evolving around the "make or buy" choice, "make" referring to the launch of internal R&D projects, while buy referring to acquisition of technologies from external sources. He argues that technologies that are strategic to the company's competitive advantages should be developed internally, while technologies which are not important for these advantages are better bought in the market. As Metcalfe and Boden (1990) argued, technology strategy develops within the framework of a strategic vision of where technologies and markets are going, and of relevant ways in which the firm can gain competitive advantages. Justification of internal investment in developing a technology, vis a vis the possibility for external acquisition, depends on the way competitive advantages accrue from the use of this technology in the firm's businesses.

There is, however, an absolute minimum, a critical mass in R&D, without which the "make" option is not available. At first sight this seems to be related to the size of the firm, as it is often assumed that the larger a firm is the more R&D it will be able to perform. However, the association is not direct. There are very large firms which do not perform any R&D activities. Pavitt (1984) argued that for some sectors R&D is more important than in others. In sectors where technical change comes from suppliers of equipment, materials, human capital and ideas, firms can become very large without any internal R&D effort. It must be noted that even in such sectors firms may find it advantageous to perform R&D, if only to enhance their ability to absorb technologies. Nonetheless, the argument follows that in sectors where technological change comes from within there is an R&D threshold, that is a minimum amount of R&D that firms in the industry have to perform if they are to stay in business (See: Kamien and Schwartz 1982). A necessary condition for this is that the "buy" option is not available for firms in the sector. To the extent firms in the sector are willing to let their technologies diffuse, or cannot avoid imitation, the buy option is unavailable to first movers only. This again indicates the importance of strategy rather than sector. If the firm follows an offensive strategy, then it would have to perform internal R&D. Firms which are followers will perform less or not at all (Freeman 1982).

The importance of sectoral factors for technology strategy stems from the fact that there are limits to the extent a firm can grow in a business without pursuing market leadership. These limits are set by the size of the market and its pace of development. In the same way that cost advantages and economies of scale in production can erode the financial position of leaders, technological innovation can erode the market position of followers by making their products obsolete. Where the rate of change is very fast there might be no room for imitators. Where the leaders are large in relation to the size of the market they might pursue a rate of change that leaves no such room.

All these elements affect the strategic visions of firms which shape the framework of their technology strategies. Sectoral perceptions answer questions such as: "what is our business?". Strategic visions relate to questions such as: "how does the firm sees itself in the business?", "how do other firms in the business behave?", and "what should it do to fulfil its vision for its position in the business?" These are the questions that concern business strategy. A number of aspects of business strategy relate to technology. The business may be defined in technological rather than market terms, e.g. lasers. Accordingly the firm may perceive its position in the market in terms of its technologies, i.e. technological leader, follower etc., and relate its strategies to technology acquisition. The way the aspects of a firm's businesses that relate to technology are decided upon and managed constitutes the technology strategy of the firm. Firm structures and established decision-making processes play an important role here.

In a seminal work, Burns and Stalker (1961) distinguished the structures of firms as organismic or mechanistic. Their analysis focuses on the flexibility of the structure which determines its adaptability to changing environments. Important characteristics are the degree of hierarchy (high in mechanistic low in organismic), the delegation of power to the divisions (high in organismic, low in mechanistic), and the flexibility of the communication structures established for decision-making. The size of the firm plays an obviously important role in these characteristics, as the larger the firm the more formalization of structures and processes is required in order to achieve coordination between the various functions. However, size is not determinant. Very large companies can be organized in flexible "matrix structures", and very small companies can be characterized by rigid hierarchies.

Burns and Stalker (1961) argued that mechanistic structures hinder innovation. The more innovative a firm is the greater the need for organismic structure. The more the business strategy of a firm is based on exploitation of its technologies through continuous innovation the more organismic it needs to be. Thus, small firm-size facilitates the function of the self-organizing coordination processes that characterize organismic structures, and small firms can follow strategies of continuous innovation and technology exploitation easier than large firms. The other side of the coin is that small innovative firms have to rely on external technology acquisition more than innovative large firms as the latter by definition have more resources to dedicate to R&D.

Sector, size, structure and strategy are all factors that affect the way a firm sees innovation and the way it formulates its technology strategy. In analyzing the relations between business and technology strategies, Allouche and Pogorel (1990), distinguished between three types of technology management: networks, portfolios and machines. The first corresponds to a strategy centring on technology and following all the possible exploitation lines. Technology dominates business strategy. The second corresponds to a coupling of technologies to production into a portfolio, which results from case by case negotiation on its contents. The third corresponds to a dominance of business strategy over technology. It is the portfolio of production activities that dominates technology management.

These three types of technology management are discussed in detail in the following section, which analyzes their implications for R&D organization. In doing so, data from this study will be used in order to understand the limitations of the categories but also to describe in a meaningful way the sample of the interviews carried out. A presentation of our sample in these terms can be found in Appendix 1.

3.2 Implications for R&D performance and organization: technology management in the firms studied

Firms with machine type management

Firms with machine type technology management exploit technologies only to the extent they are applicable to their existing production lines. Thus, this type of management is dominated by a perception of competitive advantage in economies of scale rather than scope. As efficiency in production is imperative, mechanistic structures prevail. However, competitive advantages offered by economies of scale depend on the sector of operation, and costs of capital and labour determine the threshold of fixed costs associated with production capabilities. Thus, in areas with similar labour and physical capital costs machine type strategies will be associated with large firms in sectors characterized by relatively low rates of technical change. For such firms, the scope inherent in R&D is associated with inefficiency. Thus these firms perform no or very little and very specialized R&D close to their production activities. In the technology strategies of these firms the "buy", rather than "make", option dominates. Sectors where this type of firm predominates, such as metallurgy, textiles, mining etc., are characterized by the existence of sectoral R&D laboratories which provide technology to a variety of firms, thus exploiting the scope associated with R&D activities.

During the study, two textiles firms were looked at. Firm A had some 5000 employees and firm B had some 100,000 employees. Firm A was following a clear "machine" strategy. It performed no internal R&D, and it was a member of a joint research institution together with a number of other European textile manufacturers. Firm B had been following a "portfolio" strategy, incorporating the operation of a corporate R&D laboratory and diversification of businesses into chemicals and new materials (for textiles). The businesses of chemicals and new materials involved much more intensive technology exploitation than the textiles businesses. As a result the company was split into two, one focusing only in the textile sector and following a "machine type" strategy, while the rest of the businesses together with the corporate R&D laboratory were incorporated in the other company which follows a portfolio type strategy.

Firms with portfolio type management

Portfolio type technology management can be found in firms trying to exploit economies of scale and scope. The portfolio itself can be seen as a means to manage the scope of technology generation by identifying synergies between R&D projects and production activities. The existence of a portfolio of production activities indicates that these firms can be found in any sector. To the extent that economies of scale are important in their sectoral production activities, these firms cannot be small. Mechanistic structures prevail to facilitate economies of scale, as well as to ensure control in very large organizations. The wider their production portfolios, the more internal R&D they perform. Specialized R&D close to production supplements the activities of a corporate R&D laboratory. Indeed the existence of a corporate lab is typical of this technology management type, as this is where the scope in technology generation appears. The degree of influence of the corporate R&D laboratory in the shape of the portfolio is an important factor in the relationship between business and technology strategy. The more the influence of corporate R&D, the more technology strategy dominates business strategy.

During the study a number of firms' corporate R&D laboratories were looked at. These belonged to corporations with operations ranging from automobiles to electronics, and from textiles to steel. The interviews made it clear that during the 1980's there had been a shift towards greater influence of the businesses on the shape of the portfolios of these laboratories. The trend has been for the corporate R&D laboratory to develop into an internal 'contract' R&D organization, and to shift the decisions about which technologies are important for the enterprise from corporate R&D to the business divisions. Only in one case was the corporate R&D laboratory the technology strategy-maker of the enterprise. In this case the lab was performing R&D, monitoring suppliers, customers and competitors and deciding the technology strategy of the whole corporation. This can be explained by the fact that the corporation in question was relatively small, with less than 5000 employees, and so corporate management was closely involved in all aspects of the business. Furthermore, the range of their businesses was relatively small. Even in this case, however, there was a movement towards strengthening the technology strategies of the business divisions and weakening the strategy making capacity of corporate R&D.

The rest of the corporations with corporate R&D laboratories looked at had over 50000 employees. In these cases some 70 % of the corporate R&D budget came from contracts with the product divisions. The rest 30% of the budget is typically financed by corporate management through "strategic funds" as well as from external sources. The freedom of the corporate laboratories to perform research for external customers varies significantly. In all cases there was a clear commitment to consider the product divisions first. What varied was the consideration of R&D projects for external customers, in particular to what extent the decision to undertake such projects related to strategic or to monetary gains. This, however, seems to be related to the cash-flow situation in the enterprise rather than to sectoral differences. When asked about the general cross-sectoral uniformity of structures and processes related to R&D management in very large corporations, an R&D manager of an electronics corporation commented on corporate cultures:

"our managers must read the same journals".

Firms with network type management

Network type management indicates strategies for exploitation of all the scope offered by technology generation. They can be seen as strategies exploiting in full core technological rather than production skills. The more generic the skills the more scope there is for such strategies. Firm structures with organismic characteristics prevail to facilitate exploitation of the full scope of the core technological skill; R&D is performed to enhance it. This type of strategy would be inefficient in sectors where economies of scale in production are important, to the extent the opportunity cost of investing in the core skill would be higher than that of investment in extra production capacity. As a result this sort of strategy is likely be found in sectors that produce "soft" products, where customization is an essential part of the business. As each customized development project enhances the core skill, the firm's projects have characteristics of R&D activities. R&D is an integral part of production.

During the study a number of software and engineering companies with network type technology management were looked at. Two software companies were large with more than 5000 employees and two were medium sized with approximately 500 employees. The rest of the firms were small with less than 100 employees. The characteristic of these companies is that they had been carrying out little or no R&D with own funds, at least until the mid 1980's, mainly exploiting the skills of highly qualified personnel rather than internal R&D findings. Close contacts with clients and suppliers (hardware vendors) are considered as the key to performance, as companies aiming at growing through a network strategy have to keep at the leading technological edge.

However, as markets "harden", that is as dominant designs are being established, such companies face increasing pressures to turn into producers. The alternative strategy is to specialize in "advanced" niches, being amongst the first who will start developments around new hardware or new applications, and attempt to transfer these advanced technologies to traditional uses emphasizing the superiority of customized products over packages. One of the four larger software firms has already turned into a producer of software packages. Another two are still following a clear network strategy emphasizing the core technological skill which is related with successful applications in advanced niches. However, these two firms face increasing pressures to perform internal R&D. The fourth one, which was established in the mid 1980's, follows a strategy of commercializing advanced applications. This strategy has the company dedicating some 20% of its turnover to R&D, which takes place in two laboratories; one owned by the company and one being a joint venture with a public research organization.

Other "transitional" types

It must be noted that the distinction of technology management practices in machines, portfolios, and networks is not at all clear-cut. An example provides a biotechnology company. The company was a new, largely research based SME (65 researchers out of 100 employees), which had not any established line of businesses, as it was based on a technology for genetic alteration of agricultural products which for legal reasons could not be commercialized at the time of the interview. It was funded by shareholder's capital, "having enough money in the bank to sustain its operations for another eight years without any staff-cuts". The company was managed via a portfolio of technologies and potential markets, having established very strong mechanisms to monitor the moves of its potential competitors. However, the portfolio was used as part of a strategy for exploiting all lines of technological development pursued. Thus it was combined with a network type technology management.

The categorization of technology management practices in machines, portfolios, and networks, by Allouche and Pogorel (1990), was based on a survey of large corporations. In these corporations management practices are well established and change is slow. It is more difficult to apply these categories in small firms where normally as part of strategies for business growth technology management practices change more quickly and long periods are spent in transitional stages. Furthermore, the outcome of the transitions is difficult to predict, and often does not fit neatly into one of the three categories. As part of strategies for growth firms might follow a "hardening" strategy, which implies developing production portfolios, while still managing technologies which do not affect their competitive position in production through a network type; or they could follow a "softening" strategy which involves developing technologies relevant to their production activities but that can be appropriated outside these activities through "network" type management. While both cases can be seen as transitions from network to machine management styles and vice versa, they do not fit to the portfolio management category, and often they are not seen as transitional.

A number of firms in our study were in this state of affairs, including engineering firms who were trying to develop their own products, and manufacturing firms that were developing technological capabilities in order to diversify vertically and horizontally. The former transition was accompanied by a perceived need to move away from contract development and to develop internal R&D for support to production. The latter was accompanied by a perceived need to develop R&D in order to accumulate the technological skills needed. External funding was seen as very important in these cases. It is important to note that it appears that these states of affairs are the norm rather than the exception in firms with a limited range of business that perform R&D. It is also important that these inter-mediate types of technology management are normally seen not as transitional but as established business practices. For example in one subsidiary of a very large corporation, internal R&D was serving both, the production needs of the company (machine) and its customized micro-chip production business (network).

3.3 Technology Strategies of firms and participation in the Framework Programme

The categorization of technology management types followed, serves the purpose of categorizing ways in which business strategies are linked to technology acquisition and exploitation. This is important in examining the interface of a firm's activities with EC R&D programmes. EC programmes link to the firm in three dimensions: it's R&D activities which they finance; its technology strategy which relates to decisions about partnerships and type of projects to be financed; and its business strategy to the extent that this relates to technology strategy. From the previous sections it becomes evident that the organization of R&D activities within firms varies according to whether they have technology management of a portfolio, machine, or network type. Therefore the motives to participate in EC R&D activities, their importance for, and their impact on, firms will be different for each of these types. This section presents the points that stem from such considerations.

Large corporations with portfolio type technology management

All the large corporations interviewed which had portfolio type technology management, participate in a large number of EC R&D projects. Within corporate R&D laboratories, proposals for research projects, which do not attract the immediate attention of the business units but are judged as potentially useful, are packaged in a portfolio for external funding, sometimes even in a specific portfolio for EC funding. These portfolios then are put forward to specific departments which monitor the R&D funding mechanisms of governments and the Community. When relevant calls for proposals are published, proposals are submitted. These proposals have normally to be approved by top management. This has recently become mandatory by ESPRIT and possibly other Community programmes. In some firms an indication of interest by a product division is also required according to their own procedures.

It is very difficult to judge to what extent these projects would have been carried out by the company irrespective of EC support. The extent to which they are strategic to the company and the way in which they are strategic, varies according to the way the company's environment develops. In some cases portfolios for external funding are being set simply to justify the employment of researchers who are not engaged in other projects, because of product divisions squeezing their R&D budgets because of cash-flow problems. In other cases external funding can be a way to quickly launch a project that appears strategic because of radical changes in the environment which were not foreseen at the time of the establishment of the R&D portfolio. In still other cases collaboration with external expertise is crucial for the project. Finally, the product divisions sometimes fail to recognize the innovative potential of inventions, and top management's "strategic R&D funds" are not enough to cover the costs.

Case 1:

When it looked as if the West was going to launch an embargo of South African exports, companies dependant on South African raw materials started looking for ways of exploiting marginal sources. For one firm looked at during this study, EC funds provided the means to launch a project quickly and to develop the mechanisms to deal with such a crisis. Collaboration with sources of raw materials were crucial for such a project and the EC framework seemed very appropriate for it. However, political developments in South Africa led to the abandonment of the embargo and the results of the project were never used. Furthermore, if the embargo had been enforced the company would have been forced to launched such a project.

Case 2:

When a technological breakthrough was achieved in the corporate laboratory of a major electronics company, funds were difficult to get from the product divisions as marketable applications seemed far ahead. The company then decided to move ahead in collaboration with another electronics company, which had managed a similar breakthrough, through ESPRIT. It is difficult to tell whether the company would have known about the similar breakthrough in the other company if they had not been together previously in ESPRIT projects. Furthermore, it is difficult to tell whether the two companies would have moved forward at the rate they did without EC funding. The most probable outcome would have been that it would have taken them much longer to achieve the results they finally did. The outcomes of the project provided a major innovation for both companies.

In both cases 1 and 2, the advantages of carrying out the projects within the framework of EC were very clear. However, in both cases it would have been difficult to argue that the companies would not have moved in the direction they did without EC support. Furthermore, these circumstances do not apply to all EC projects. In one case the manager of the project clearly stated that the project was so important for his company that it would have been carried out irrespective EC funding. In another case the manager made it clear that the results were there before the application for EC funds. What these stories tell is that the corporate R&D laboratories of very large corporations have enormous R&D budgets, and established formal ways to manage their projects. While participation in EC programmes has had some influence on the way of operation of their technology management, this influence is little more than adaptation to the requirements of yet another source of funds. It affects little if at all the orientation and operation of their technology business strategies.

Firms with machine type technology management

Firms with a machine type technology management approach EC R&D programmes as users who can benefit from using technologies developed within projects. During this study only two firms that clearly belonged to this type were looked at. The reason was that this study was looking at project leaders, and these are usually organizations with experience in developing the technology in question. While this type of firm can provide a good test-bed for the results of projects, internal development of technologies normally lies outside its activities. It is important to note that one of the two firms looked at was not a project leader, but as the leader was a research organization, the study looked at the firm as the user of the project results.

Despite the above restriction, information about users with machine type technology management was gathered on a non-systematic basis as part of the general discussions concerning partnerships and the appropriation of the results. For this type of firm EC projects represent an alternative to buying-in technologies. In all cases they were not satisfied with the technologies available in the market and decided to get into a joint project in order to acquire more advanced technologies. In this sense EC programmes had an impact on the orientation of their technology strategies. Considering that some of these companies did not perform any R&D outside their EC sponsored activities, EC programmes were also a stimulus for these companies to become involved in R&D activities.

For companies that were already developing internal R&D as a means for diversification and vertical integration, participation in EC programmes provided a valuable source of funds, as well as a way of learning quickly what sort of expertise was available and where to look for it. Furthermore, participation allowed them to gain valuable skills in R&D and collaboration management. In this sense EC programmes provided a means for these companies to develop technology strategies and to move into a "transitional" technology management type. Considering that this type of firm has limited resources for R&D, in both monetary and personnel terms, EC projects were very important. In both the cases looked at, EC funds provided for carrying out projects that were attempted previously in collaboration with other organizations but had failed because of lack of funds.

Firms with network type technology management

In firms with network type technology management, technology and business strategies are virtually indistinguishable. These firms approach EC R&D programmes as business environments. Not surprisingly, it is on this type of firm that EC programmes have the most prominent impact. They provide indications about the directions in which businesses develop, valuable funds for R&D, and contacts with potential users of their technologies. Depending on how they are approached, they provide opportunities for a "hardening" of business strategies or for further continuation of "soft" business strategies. Finally, as it was pointed out by Laredo and Callon (1990) EC programmes act as a powerful mechanism for the generation of "soft" firms.

It would not be an exaggeration to argue that EC programmes have altered the nature of the engineering and consultancy business in Europe. By acting as a stimulus for the generation of firms, they resulted in fierce competitive environments which forced firms to engage in more R&D in order to sustain their competitive edge. The two large software companies looked at had grown rapidly until the beginning of the 1980's without performing any internal R&D. The launch of ESPRIT altered the perception of top management about the need to perform R&D, both because of the dominant rhetoric and because of the realization that competition was growing fiercer.

While some of the companies in our sample admitted to having been EC R&D generated "soft" firms, they all argued that they are no longer based on EC funding, and that they have developed further clients. One EC generated soft firm which went bankrupt before it managed to do so was mentioned in an interview. In all such firms interviewed, EC funding is recognized as an important part of their income. As competition both at the level of EC funds and at the market is intensifying, some of these firms chose to harden their businesses and to involve in production. In this process, the contacts with other producers and users acquired through collaborations within EC programmes are of great value. Others chose to remain in the soft market, either feeling quite confident that they could be amongst the winners in competition within the "engineering" and consultancy markets, or being unable to develop production capabilities. There again EC programmes are invaluable.

Finally, another impact worth mentioning here is that of EC project management procedures on some engineering firms. As many of the new "soft" companies have been of academic origins, their project management procedures are informal and sometimes they are considered as inefficient and as creating barriers to growth. A number of firms mentioned that they benefitted from the work of the EC official responsible for their projects, and that they have adopted the progress monitoring and reporting procedures enforced by the Commission in their other projects. One UK engineering company, which, it must be noted, was not of academic origin, was particularly impressed by these procedures. Formalization of their project management procedures along the lines imposed by the Commission was seen as a means to increase productivity and to prepare the company for further growth. This was very important for them in view of the fierce competition characterizing the UK economy within the current recession. In other similar cases firms indicated their initial frustration with the amounts of paperwork involved in the Commission's monitoring procedures, nevertheless mentioning that their experience indicated that benefits outweigh costs.

Networks versus Machines: innovativeness and standardization

As it was argued earlier, network type technology management is compatible with "soft" strategies of commercializing technologies rather than products. Soft firms are developers, not producers. Their increasing presence in the European scene, assisted by the existence of the Framework Programme, leads to an increasing presence of technologies in market. As the competitive strength of such firms lies in their ability to innovate at a very fast pace and to differentiate their technologies from the ones of rival firms, these technologies are characterized by a large degree of differentiation.

On the other hand, firms with machine type technology management are exploiting technologies compatible with their existing production lines. They are not developers of technologies. Rather they are users. In order to gain competitive advantages they largely buy in the technologies that offer them the best performance. In short they are the best customers of soft firms' developments.

However, this is also a source of problems, as the differentiation between the technologies offered by soft firms, leads to "lock-in" situations, in which machine type firms find it difficult to shift from one supplier of technologies to another, in order to maximize the benefit from the fast rate of development of the technologies they use. In short, the increasing presence of soft firms in the European scene through the Framework Programme entails standardization problems that work against the ability of part of European industry to benefit from the fast rates of innovation.

While the participation of machine type of firms in the Framework Programme assists them in developing internal technological capabilities which can be of great help in surviving in this environment, not many such firms participate. Furthermore, standardization issues are dealt with by individual programmes to a varying extent. RACE, dominated by the presence of large users, the European Telecom Companies follows an approach which puts standardization first. The standardization activities in ESPRIT and BRITE, however, are dominated by large suppliers and users whose approaches are very much based on their own technologies. In the light of the presence of a host of smaller technology producers in ESPRIT and BRITE, it seems that standardization is an increasingly important issue to be tackled by these programmes.

4. The management of EC R&D projects

This section focuses on EC R&D projects within the technology strategy of firms. It analyzes the management of all of their aspects by the project leaders, from their initiation to the exploitation of their results. The distinction between systemic, modular and potential exploitation of the project results, is introduced as a useful tool for this analysis. The first two types refer to commercialization of a project's results. Systemic exploitation refers to commercialization of the product or process goals of the project as they are revealed in its demonstrator. Modular exploitation refers to commercialization of autonomous parts of these technologies. Potential exploitation refers to non-commercial exploitation of results, such as process technologies developed within projects with product aims, and other tangible or intangible assets generated such as better understanding, levels of skills etc. To the extent systemic or modular results required significant development effort to be commercialized that was undertaken outside the project, they are treated as potential exploitation.

The collaboration aspects of the projects play an important role in the analysis, for two reasons. The first lies in the important differences between collaborations, which are not depicted by treating them as an intermediate option between the "make" and the "buy" choice which characterize technology strategies. In some projects collaboration is necessary for their technical success. This is the case when the organizations involved have complementary expertise which is essential for the project. When complementary expertise is accompanied by control over complementary assets, collaboration is essential for the commercial success of their results. Such projects are called collaboration-sensitive. This is to distinguish them from projects in which complementarities are not essential, which are called collaboration-insensitive. Georghiou et al (1992) found significant collaboration-sensitivities between industrial partners for some 66 % of the cases they examined in the UK.

The second reason is that EC projects are a special case of collaborative projects, because of the subsidy involved and because of the role of the Commission as a client. The former is important in businesses where competition focuses on efficiency in development (e.g. software) or production (e.g. textiles). In these businesses the subsidy creates a slack within organizations which can allow them to perform R&D and enhance their scope for innovating. It must be noted that a number of firms in these businesses were found either not to perform R&D without associated subsidies, or to have started performing R&D stimulated by the existence of subsidies.

The Commission's role as a client is important in relation to the characteristics of the collaborations. First, it may induce some collaboration-sensitivities to be built in the design of projects, in order to demonstrate their value as such. It is important to note here, that systemic exploitation implies a collaboration-sensitive project, as this provides added value in performing one project rather than a number of different ones. Second, sometimes the Commission imposes the addition of partners in consortia by linking it to the subsidy. Third, via the various dissemination events it organizes, the Commission provides fora for organizations to enhance and enrich their relations with other organizations and to create networks that are very important for their innovative activities (Lundvall 1988, Teubal et al 1991).

The need to differentiate between modes of exploitation of project results stems from the fact that collaboration-sensitivities and systemic exploitation are not always consistent with the technology strategies of organizations as regards their EC R&D projects. In this study some of the projects looked at had to be collaborative. Others could have been performed by the individual firm and the added value from the collaboration was limited or even negative as it imposed additional management costs. Thus, collaboration-sensitivities relate to the exploitation strategies associated with the projects, which in turn determine how they are designed and managed and how their results are exploited.

Taking all this into account, this section presents and analyzes in detail the way the projects examined were initiated, the factors that affected the choice of partners, the design of the projects and the management of the collaboration. Then it goes on to discuss technology transfer within consortia, as well as within individual firms from R&D to production. Finally, the factors that affect the exploitability of project results are presented together with cases of exploitation in the modes presented above.

4.1. Initiation of EC R&D projects

In the majority of the cases examined the initial idea came from within the firm that later became the project-leader. This was the case in all large firms that were interviewed. Furthermore, in all but two cases of large firms the idea came from within the organizational unit that initiated and coordinated the project. These two cases which are in many ways interesting follow:

Case 3:

In this large corporation the origin of the idea had significant network dimensions. The idea was generated as a result of a discussion between a top-manager of the company with a top-manager in another organization. This manager promoted the project within the corporate R&D laboratory. As they needed partners, they decided to apply for EC funding. The "other organization" did not participate in the project as it was located in the same country as the laboratory.

Case 4:

In this large corporation the idea came from the top-management who seemed to be trapped in the discourse of contemporary international rhetoric. In particular it decided to use EC funding to engage in a project similar to ones initiated by very large corporations in USA and Japan, which had national support. The project failed as did the equivalent American and Japanese projects. The interviewee argued that the rhetoric prevented them from thinking out important aspects of the project, and realizing earlier that it could have not succeeded given the state of the art in the relevant technologies and the functional requirements of the system.

The general argument in all large corporations interviewed is that top management should prescribe general directions for technology strategy but should not decide on the sponsorship of specific projects. This is seen as the remit of R&D managers who liaise between R&D, top-management, and business units. These business units of large corporations were a significant case here, as they had specialized innovation departments which were acting as R&D managers and technology strategists. Another significant case was that of large firms with offices in Brussels which sometimes provided ideas about specific projects that the firm could initiate within the EC context, and played thus a role in the shape of their "EC R&D portfolios".

In SMEs the situation was quite different. In most cases the idea came from outside the company, or when it came from within it had significant network dimensions. Only two cases were found where the idea came from within the company and the decision to launch the project was taken without ex ante discussions with suppliers and customers about the merit of the idea. In both cases, the project was aiming at developing around a patent held by the initiating firm. Another case which is worth mentioning involved two small firms who saw it as their business to develop ideas for EC R&D projects. One was a joint venture between two large European corporations, and was designed explicitly to do so. The other was a British firm which was looking towards EC funding as a way to overcome the cash-flow problems it was facing within the recession in the UK economy.

Finally, it must be noted that in three of the cases investigated the coordinator was a "collective agency", that is an R&D organization funded by firms within an industrial sector. In one of these cases the idea came from a client organization, while in the other two the idea came from organizations that supply external expertise to the agency when it is needed. In all three cases the project was in the main direction of the agency's technological interests.

4.2. The choice of partners

While in most cases there were previous contacts between some of the partners, it was hardly ever the case that exactly the same consortium had worked on another project. In the cases where the idea came from outside the project-leader, or where there were strong network dimensions in the initiation, the network formed the heart of the partnership, as collaboration within the network allowed for a constant re-evaluation of the merit of the idea. However, often such networks were national, or needed external expertise to perform the project and thus more partners were looked for.

Partners were looked for in the light of their reputation for technical competence and trustworthiness. The Commission's programmes and data-bases were often used to find partners. In a number of cases a partner was found as s/he was "very active within the Community fora". Primarily two aspects of the project as it was seen by the initiator determined the criteria for the choice of partners. As it is explained further on in this section, these are the collaboration-sensitivity of the initiator's goals and the potential for competition between the partners. These aspects were very important for the extent to which the national and institutional origins of partners played a role. National origins were also seen as politically important especially in the light of the commitment of EC R&D policies to promote "cohesion" in the Community.

Collaboration-sensitivities and the technical ability of the partners

Collaboration-sensitivities stem from lack of expertise and resources needed to carry out aspects of the project as well as lack of resources necessary to exploit the results of the project in the envisaged way. Thus, the degree to which a project is collaboration-sensitive varies between partners. To the extent a project was collaboration-sensitive for the initiator, the reputation of the partners in terms of their technical ability played the major role.

The most collaboration-sensitive cases where those of initiators who would have been the users of the results but could not produce them without external expertise. All these cases led to projects for which collaboration was important, as there was a large degree of interdependence between the roles of the partners, at least as far as success of the targets of the initiator were concerned.

However, in a number of cases collaboration was not as important. This meant that at least the project-leader aimed at appropriating the results of the work-package s/he performs in the project, and there is limited interdependence amongst work-packages. This in turn implied that each firm had the expertise to perform a project to which it attached value. A number of such projects were packaged into one EC funded project and the participants took advantage from any synergies as well as from EC funding. However, these synergies were limited.

A type of collaboration-insensitive project is what Georghiou et al (1990) define as risk-sharing collaboration, which investigates the value of competing processes. A number of companies investigate the process they are most likely to use and at the end they share results. Collaboration is used as an information exchange mechanism but is not essential for the project to the extent this information exchange is not its primary goal. Standardization projects can be seen as a variant of this type.

To the extent projects are collaboration-sensitive, there are "first mover advantages" in participation in EC R&D projects, in the sense that once an organization has created a reputation of being a good and competent partner, it is asked to participate in other of projects. However, as collaboration-sensitivity decreases, the politics of the partners increase in importance.

The importance of national origins

The national spread of the partnership seemed to be considered by managers as an important factor in the choice of the Commission to fund specific projects. Thus, in many cases the introduction of many partners with non-essential roles was seen as enhancing the chances to get funding. In particular there seemed to be a "Southern bias" in these choices, justified by the perceived preference of the Commission in funding projects involving partners from Less Favoured Regions.

In this light, it would seem that organizations from Southern Europe would be the favourite partners for collaboration-insensitive projects irrespective of their competence. To a certain extent this is the case. Competent Italian, Greek, Spanish and Portuguese organizations are highly valued as desired partners. However, this does not extend to organizations that are not as competent, even in collaboration-insensitive projects. Managers with bad experiences with partners from one country often stated that they would avoid collaborating with others of that nationality in the future, because of the management problems this entails.

Two more factors counteract the desirability of even competent organizations from Less Favoured Regions as partners. First, the quality of the communications infrastructure in these regions is considered as poor and this creates difficulties in project-management. Second, within the EC programmes, if a partner goes bankrupt during a project it has to be replaced by a partner in the same country. As in Southern European countries there are few organizations competent in state-of-art technologies, this rule often creates problems. In particular, considering that not many industries of the South are characterized by financial strength, this rule creates a major disincentive to cooperate with firms from the South.

Collaboration-sensitivities and potential competition

Collaboration-sensitivities in project implementation sometimes apply with respect to exploitation of results and sometimes do not. In both cases potential competition in exploitation of the results is an important factor in the choice of partners. Its possibility can be alleviated by choosing partners from universities or non-profit research centres or even companies whose business strategies are of a different kind, e.g. a manufacturing firm can collaborate with an engineering firm as their exploitation strategies are different by nature.

However, this can take place only in cases where collaboration-sensitivities do not extend to exploitation of the results. In the opposite case, collaboration between firms always entails the possibility for potential competition. In such cases the business intentions of the partners were always screened, and reference was made in their reputation for being trustworthy. All firms indicated that they would never collaborate with direct competitors. However, collaboration with indirect competitors such as firms in the same business in different countries was a frequent case.

The importance attached to potential competition was related to the importance of the project for the business strategy of the project leader. However, in all cases the technical ability of the partners seemed to be more important than their business intentions. The potential for competition was usually dealt with at the project design stage.

Collaboration-sensitive projects involving suppliers and users, were typically built around very complex consortium agreements to prevent potential competition. Even in collaboration-insensitive projects, cases of suppliers and customers working together in a project render potential competition a very sensitive area. This type of project is usually launched on the basis of trust generated through years of a supplier-customer relationship. In the one such case encountered during this study, the interviewee said:

"They are our customers not our competitors. If they wanted to compete with us we would have been out of business a long time ago. In terms of competition they belong to a different league".

However, after more discussion the same interviewee said that because of the kind of competitive pressures their customers were facing, it was very unlikely that they would compete with them, and in any case for their project the competence of their partners was more important than their business intentions.

4.3. Collaboration and project design

In the design of a project, the partners' work-packages and their relations are specified. It is at this stage that the way collaboration-sensitivities are built in a project is decided upon. In most cases examined the initiator played a major role in designing the project, and kept for him/herself the coordinating role. This allowed a degree of control over the work of the consortium which was seen as necessary for the achievement of its initial goals. When there was a network dimension in the generation of the initial idea, the organizations involved formed the core of the consortium which designed the project.

Collaboration-sensitivities were an important element of project design, as they provided the means to the designers to:

a) make sure that the objectives of the individual work-packages will not shift during its implementation towards directions that would possibly emerge in the partner's technology strategies; and

b) limit the possibilities for competition between the partners after the project.

Collaboration-sensitivities between the partners and the initiator in implementation and exploitation were serving these two elements respectively. In the words of a project leader

"some parts of the project were too critical for the project and its exploitation to be left or even revealed to other partners".

However, the extent to which such project design was possible varied according to the capability of the initiator to perform critical parts of the project him/herself, that is to the extent s/he was involved only in the use, or also in the production of the project's results.

Collaboration-sensitivities and vertical relations

A factor that greatly affects collaboration-sensitivities is the existence of vertical supplier-user relations within a project. Such relations in project implementation reflect the provision of performance specifications by the user to which the output of the supplier must comply, and evaluation of the results by the user. Collaboration-sensitivities in such projects depend on the extent the supplier-user relationship is considered important for the exploitation of the results. In the case of the user commercializing the results, the vertical relationship remains intact after the project, and the interests of the supplier coincide with those of the user.

On the contrary, in the case in which the supplier will commercialize the results and the user will use them there is an obvious source of conflict. The competitive advantages stemming from the use of the results will be alleviated by their commercialization which will make them widely available. Furthermore, the risks incurred by a user in a project are larger than those incurred by a producer. In the case of failure to reach the project's objectives, the producer is closer to achieving them but the user has little to use. This explains the opinion expressed in a number of our cases, that the Commission's collaboration contract does not adequately protect the users in consortia.

Furthermore, often the user cannot protect itself by designing collaboration-sensitivities because of lack of expertise. In these cases users protected themselves by becoming the project coordinators and by consortium agreements. The former can guarantee that the project directions will follow the user's criteria of success, but it cannot guarantee the way the results will be exploited. Thus, users experienced in collaborative R&D put a lot of effort into drafting detailed consortium agreements. While it has become conventional wisdom that the size of the firm is equivalent to the time spent in drafting consortium agreements, the character of participation in a project seems to throw new light into this.

The importance of consortium agreements

In our cases there was a tendency for firms participating as users in consortia to be larger then their producer-partners. A reason for this may be that producers would prefer a large firm as a client after the project is over, as user firms would tend to place limits to the ability of producers to appropriate the results without them. This hypothesis applied to the majority of collaborations involving producers and user-firms. Large producer-firms often involve government research institutions or "collective agencies" such as users' associations in their projects. Only two small user firms were found to be involved in EC R&D projects, and they participated together with such collective agencies. One of them had a peripheral role, in the sense that they assisted in requirements specifications, but they did not perform the evaluation of the project results and in general they were not essential to the project. In the other case the user was where the idea originated and their role in the project was more substantial. This case, which is presented as case 5, can be used as an example of what can happen to inexperienced user firms which do not prepare long and detailed consortium agreements.

Case 5:

The initiator of the idea was a leader in equipment manufacturing for the textiles industry. The firm had very automated design and production and their strategy was to achieve further integration between the two. It had an idea about how to do it and approached a collective national research organization in mechanical engineering. Together they decided that the idea was worthwhile pursuing and tried to get funding from national programmes. As this proved difficult, the research organization proposed EC programmes and the firm accepted. The research organization, which at this stage acquired the leading role in the project, found another user-firm in another country, played the main role in project design and proposed the project to the Commission with itself in the coordinating role. The Commission insisted that in order to support the project two large systems houses had to participate, one working mainly in customized and the other in packaged markets. This was accepted and a simple consortium agreement was signed, through which in case of project success the users would have had free maintenance by the systems houses for two years.

The project was very successful. After its end the system was installed by the user with good results. The only problem was that it was a little slow. This did not prevent productivity gains anticipated from materializing, but it was annoying for the engineers who were using it. The engineers of the user-firm knew what to do to make the system faster, but they could not do it because they had to alter software copy-written by one of the systems houses. While they were trying to find a solution to this problem, the systems house commercialized a similar system in which the slowness problems had been dealt with. So, the user firm had to buy this new system as otherwise productivity gains in their competitors would have been larger than theirs. While they did not doubt the benefits from participating in the project in terms of better understanding of their operations and better understanding the issues involved in systems design, they were very frustrated by this development.

The important elements of case 5 are the following: First, when the research organization undertook the leadership of the project the initial idea changed in an essential way. From aiming to develop a system that would satisfy the specific needs of the user firm, it became to develop "such a system". However, the firm assumed that being the large user, and being situated close to the project leader, which in turn was a research institution with no specific interests in the shape of the system, it would be able to control the project specifications. This assumption seemed reasonable at the time. However, when the two large producers were placed into the project, the firm did not realise that its degree of control over the project specifications and the interests invested in them had radically shifted. And not being the project coordinator, it could not control the subtle but important shift in the project's goals through the management of the project.

4.4. Management of collaboration

While project design has to strike a balance between the goals of the initiator, the partners and the Commission, the management of the project has to keep this balance throughout its implementation. This is not an easy task. First, the achievement of systemic goals often involves different technical choices from those that would allow for modular exploitation. Second, the initial goals of the project often shift as a result failure of initial technical choices.

One way of dealing with such problems is to design collaboration-insensitive projects, in which these shifts do not affect much the exploitation plans of the partners. These projects are modularized in largely independent modules executable from start to finish by individual partners who come together at the end to build a demonstrator. Such were the 15 cases examined in Germany and none of them revealed plans for systemic exploitation. It seems that German firms, in view of the potential problems generated by collaboration-sensitivities, identify strict modularization of tasks with good project management.

A different way of dealing with this problem was revealed in the cases of Danish firms. From the cases investigated in Denmark, together with discussions in other countries about projects involving Danish firms, another cultural dimension in EC R&D project management seems to have emerged. Danish firms have a reputation, which is verified by the findings of this study, of insisting in project management processes involving very long consensus-generating discussions between the partners. Thus, when a decision is taken it is a consortium rather than an individual partner decision and serves the goals of the project rather than the exploitability requirements of a module.

The extent of cultural uniformity revealed in the cases of Germany and Denmark was not found elsewhere. However, the technology management structures of firms emerged as another important factor in the way firms manage collaboration-sensitive aspects of their projects. To the extent they are not dealt with at the project design level through strict modularization, such inter-dependencies often create discrepancies between project goals and technology strategy goals as both these shift in the course of the projects. In most cases this is approached as one of the expected problems with EC R&D projects. Their pre-competitive character which implies relatively low target specificity seems to be a contributing factor. However, the type of mechanisms that would deal with such discrepancies so that they would not affect the exploitability of the results, such as some type of strategic monitoring of the project and in particular the firms' individual work-packages by internal users, often do not exist. Only in two businesses units of large corporations were there specific mechanisms built into the firms' structure to deal with these aspects. These are presented as case 6.

Case 6:

In two firms R&D was performed under the supervision of an "innovation" or "technology strategy" department and without the existence of a dedicated R&D department. R&D was performed mainly by production personnel working part-time. In these cases the R&D work followed the relevant appropriation strategy of the firm. The work was supervised, monitored and directed by the innovation department, which was responsible for the collaboration within the EC project. To the extent the EC project covered the appropriation requirements of the firm, there was one project going on under two reporting procedures, one dealing with the needs of the EC project and one with the needs of the firm. To the extent the two sets of needs were different, project implementation was broadened to cover the interface between the firm's technology strategy and the project. However, the two reporting procedures helped the firm to differentiate in practice between the part of its effort that goes into the EC project and its own. This duality was stronger in one of the two projects examined as there was a risk of potential competition between some of the partners involved.

The way of managing EC R&D projects presented in case 6 has advantages, as it allows for a clear demarcation of what the EC and the partners should learn, and what is found out by the organization. Thus, there is a great degree of control of ideas and technology transfer from the firm to the partners and the Commission. And as the knowledge generated cannot be less than what is needed for the EC project, whenever there is a surplus it can be appropriated only by the performing firm and nobody else.

4.5. Collaboration and technology transfer in consortia

The more collaboration-sensitive a project is, the more inter-organizational knowledge flows it results in. This is because of the cumulative character of knowledge acquisition at two levels. The first is the level of an organization. An organization learns by relating information to what already constitutes its knowledge base, thus altering this knowledge base (Weingart 1977). The second is the level of the R&D project. This progresses cumulatively as targets are set on the basis of what is known, and modules are built on the basis of the results of previous modules. The more interdependent the modules of an R&D project, the larger the amount of knowledge that has to be shared between their implementors. Thus, in general the minimum requirements in inter-organizational knowledge flows are higher between partners in inter-dependent roles within R&D consortia. Furthermore, the more coordination is needed, the more often people meet, the more "informal know-how trading" takes place, and the more cooperation is described as "close".

Here one should distinguish between the three aspects of technology, that is knowledge, skills and artefacts (Metcalfe and Reeve 1990). It must be noted that these three aspects are not technologies on their own. Rather the three together constitute technology. Thus, while artefacts can be purchased they are useless without knowledge of what they can do and skills related to their use. Knowledge and skills related to how they are made can be invaluable when an artefact has to perform a function within a system. Small modifications often increase functionality rapidly. Artefacts can be seen as incorporating knowledge. Learning by doing and using are on the one hand an essential element of relevant skills, and on the other hand related to specific artefacts. Thus, collaborations that involved exchange of physical artifacts were described as "real collaborations".

Knowledge is transferable through communication, and according to the findings of this study closeness of collaboration clearly depends on the frequency and content of communication between people from partner organizations. However, close collaborations between different research teams rarely exceed the minimum requirements in knowledge flows. These can be identified by using Vincenti's (1990) distinction between procedural and descriptive knowledge. Collaborations between teams require flows in descriptive knowledge. Two interdependent teams have to share knowledge of what the expected outcome of the two modules is and how the two modules combined will produce this output. However, procedural knowledge on how the modules were built is not often exchanged, at least within EC sponsored R&D projects. In one particular case, it was mentioned that procedural knowledge was deliberately kept secret to alleviate possibilities of potential competition.

Even in cases where the collaboration involved procedural result-sharing, that is in cases where two or more organizations were involved e.g. in evaluating the usefulness of competing techniques, transfer of procedural knowledge was limited. When interviewees leading such projects were asked if they could after the project implement the results of their partners, their answers were something close to:

"Well, we have a good enough guide of roughly what to do, and what sort of errors we can avoid. Yes, I think it will take less effort than starting from scratch."

In other words, reports of project results can transfer only the codifiable aspects of technology (Saviotti and Metcalfe 1986), and these aspects are of little use without the tacit knowledge that makes them directly implementable.

Transfer of tacit knowledge takes place only when transfer of people is involved. In this sense, transfer of tacit knowledge between partners in consortia takes place only when the work packages of different partners are collocated, that is when the project or parts of it are performed by an inter-organizational research team. However, the benefits of these flows can be more easily realized when projects aim at systemic exploitation. In the single case in which the project was implemented through forming an inter-organizational project team and moving it between the sites of the partners, it is anticipated that the results will be commercially marketed by the consortium. Other studies have found that in cases of firms aiming at modular exploitation of results and collocating their activities, the joint knowledge base of the research team creates problems in the transfer of results to each individual firm (Georghiou et al 1990). However, this type of case was not found during this study.

4.6. From R&D to exploitation: technology transfer within firms

While the essence of technology transfer within firms lies in the frequency and content of communication between people in their various departments, it differs fundamentally from technology transfer in consortia, as cooperation between a firm's departments should be, by definition, closer than that between firms, and possibilities for potential competition should be, by definition, zero. Indeed, a firm can be seen as a set of established cooperative structures. These structures display a certain degree of formalization and departmentalization, and incorporate aspects of a firm's life such as technology-strategy-making and innovation. Thus, technology production, monitoring, screening, transfer, and exploitation are reflected in a firm's structure.

As far as technology transfer is concerned, the closeness of collaboration can be analyzed in a dimension starting with formal reporting procedures which transfer only codifiable knowledge, and ending at collocation of activities. Thus, location can be used as a first approximation of closeness of collaboration. In this sense one can distinguish between technology transfer channels that refer to projects performed at a corporate R&D laboratory, R&D department of a business unit and R&D located at the same site as production. This distinction also reflects the way R&D performance is accounted for, as well as the way this performance is monitored and strategic decisions are taken at that level.

Corporate R&D laboratories and formal technology transfer channels

As it was argued earlier, there is a strong uniformity in the ways corporate R&D laboratories are integrated within the structures of firms. Typically, they follow their projects through to development, irrespective of whether these projects are requested and paid for by a business unit or not. The monitoring procedures differ for different projects according to the interest the business units take in it. However, most of the strategic monitoring takes place within the corporate laboratory. By and large, it is the laboratory that decides what the useful products and by-products of R&D are and in what directions they could be appropriated. Thus, corporate R&D laboratories can be seen as having a business strategy of their own. One such laboratory was found to have established its own business in producing customized products based on its expertise.

The communication structures surrounding the corporate R&D laboratories consist of committees which bring together managers of similar levels from the corporate laboratory and the business units. The work of these committees extends from defining the corporation's technology strategy to defining the items of the R&D budget. However, the extent to which these committees deal with monitoring the projects of the corporate laboratory rarely extends further than the progress towards the specified goals, and the extent to which this happens depends obviously on the investment the project represents for a business unit. Thus, even this type of monitoring was very weak in most cases examined during this study.

Once the results that have been achieved by the corporate laboratory are judged to be exploitable, then technology transfer takes place through formal channels. Reports are circulated, sometimes demonstrations take place within the corporation, and blueprints are given to product development or even to production departments. The corporate laboratory undertakes the training of "production people when necessary". Thus, technology transfer from corporate R&D laboratories to business units has many of the characteristics of technology transfer between two different organizations. A large degree of organizational autonomy in monitoring and strategic screening of a project, monitoring of progress rather than content by the client organization, and formal technology transfer channels. When business units wish to be more actively involved in a project, then they participate as partners. Thus, corporate R&D laboratories can be seen as very similar in function to sectoral R&D organizations.

Collocation of R&D and production

At the other end of the spectrum, in firms where R&D takes place as part of production, technology transfer cannot be separated from technology generation. The cases of this study revealed two types of such collocation of activities. In the first type the project takes place at the same site as production but uses different people than production. Thus, production people can see how the project develops, and both, R&D and production people can benefit from the tacit knowledge of their colleagues. In the second type, the project is performed by production people working on it on a part-time basis. In such cases there is literally no need for technology transfer. While, there were projects of both categories examined, typically the later stages of the former type involved production people and belonged, thus, to the latter type. Such project organization was found mainly in mature industries, where production people were used to working with very different technologies to the ones developed by the project, while there were R&D people within the firm familiar with them.

Collocation and strategic monitoring

While collocation was being used in firms of sizes ranging from 6 to 5000 employees as a means of quick and effective technology transfer, the extent to which the projects were strategically monitored and screened varied according to the type of technology management. This type of monitoring is an essential element of network type technology management. Thus, in firms with this type of management internal seminars and presentations are often held, in order to re-evaluate the exploitation possibilities offered by the progress of their projects. In firms with machine type technology management such monitoring was not part of the firms' practices. Firms following "transitional" types of technology management related to a softening of their business strategies, often had not adopted such monitoring procedures. In cases of "hardening" strategies on the contrary such procedures were still considered as an essential element of technology management.

R&D departments of firms

In the cases where there was an R&D department within the firm, the extent to which strategic monitoring was left to the R&D department depended on the degree of organizational autonomy it enjoyed. However, it must be noted that this type of R&D organization is not clearly demarcated from the other two. Such "R&D departments" examined in this study where either product development departments which had a central strategic role within the business but operated with production engineers, or information technology departments which were dealing with process and office automation, or finally the "technology strategy" and "innovation departments" described previously in case 6. In all these cases the job of these department was "to know what is going on and to find ways of improving it". Thus, they were surrounded by informal structures through which their projects were monitored and their technologies transferred. Only the departments mentioned in case 6, were clearly demarcated, and liaised strategically between production and R&D. They had control over the internal technology transfer structures judging each time to what extent certain reporting procedures, formal training and collocation of activities are required.

4.7. Technology strategy and the exploitability of EC R&D results

The difficulties of defining exploitability of R&D results in an objective manner is one of the basic assumptions behind this study. A number of factors have been identified in the literature as affecting it. Schmoch et al (1991) argue about the utility of patents as an indicator. However, whether or not a firm would apply for a patent is a matter of strategy. The argument so far has been that the exploitability of results of EC R&D projects is related to the way the projects are being incorporated into the technology strategies of participating firms. This argument is further supported by the findings presented in this section.

Exploitability and dissemination

Results of EC R&D projects are exploitable only for the organizations that have carried them out. The results that are disseminated and come into the public domain concern broad descriptions of what and how was found, rather than detailed descriptions of data, method and results. In this sense conferences and other dissemination events are used as marketing fora, rather than as a means of scientific communication governed by the norm of total disclosure (Dasgupta 1987). As an executive put it:

"I tell them this is what I found and that is why I think it is useful. Now, if they want to know my algorithms, they would have to look for them themselves".

Thus, it is only the participating firms that have the detailed knowledge that can allow them to exploit the results, and it is their technology strategy that determines perceptions of what exploitation opportunities exist.

Patents and EC R&D projects

In general in the projects looked at during this study, patenting was not a major issue. While in some projects individual partners applied for patents, the systemic goals of the projects were normally too complicated to be patented. As expected, different organizations in different sectors had different attitudes towards patenting, and only two of the organizations looked at had a strong patent-oriented strategy. One was a "collective agency", a sectoral research organization in minerals. They indicated that the industries they work with are currently becoming increasingly scientific in their methods, and thus patents provided effective means to acquire a good market position. Also, as this organization served more than 40 firms from a variety of countries it could easily detect infringement of its patents, while having no ambition to move into production, licences provided one of its main sources of income. The other was a biotechnology firm. Similarly to the minerals organization, they said that biotechnology is

"a field where patents are very important and offer good protection, while they are easily monitored as there are not many actors in the game".

In both these cases patents were seen as means to grasp developing markets, as parts of a strategy for technological leadership.

Larger firms in the electronics sector who mentioned patents, indicated that they use them as part of a "co-leadership" strategy.

"Our target is not to grasp whole markets", a manager said. "Rather we are looking for strong patents that we could trade with our competitors through cross-licences in order to continue to do our job".

In general patents acquired before the projects, on which the projects were based, seemed to be more important for the exploitability of project results than patents applied for because of the projects. This is because such patents allow for total control over potential competition in the exploitation of project results, while, as it will be shown further on, EC R&D projects are a wide spread way of developing results of previous EC R&D projects.

4)

Exploitability and the R&D-production interface

The R&D-production interface is an integral element of a firm's technology strategy, as it determines what aspects of the scope for exploitation are taken into account and pursued. In narrow terms of technology transfer, the pattern followed relates to the way firms normally transfer technologies, and the exploitability of results was judged on the basis of achievement of the projects' objectives. To the extent these objectives or the direction of the firm's technology strategy shifted over time, the exploitability the interviewees attributed to the results depended on the extent the firm monitored strategically the project and was able to manage the interface between the project and its technology strategy.

Collocation and separation of R&D and production activities offer different advantages to different locations. For example a number of firms preferred to leave development and testing activities to public research laboratories, in order not to "disrupt the operation of their production lines". However, this decision would delay the transfer of results to their production activities, and in a number of projects timing was very important, as they were competing with similar projects at other parts of the world. In these cases collocation was essential for the rapid transfer of results to production. Some of these projects succeeded in moving faster than competition. Project design and management were very important in these cases.

Project design, management, and the exploitability of results

Case 7:

The coordinator who was the producer of a module was located virtually next to the user of the module who had the initial idea. As the project had to be multinational, they added a partner from a different country with another module which was not central to the operation of the system for the user, but was part of the demonstrator for the project. The central module aimed on its own at an innovation in the sense that it achieved performance that had not been achieved before, while it was known that a number of companies worldwide were investigating the area. The producer firm was small and its R&D and production activities were collocated. The project was very successful, and both modules delivered commercializable results. For the coordinator, its neighbouring location to the user was an important factor in this success. The fact that the project did involve limited inter-dependencies between the two producers also helped, as they both could orientate their efforts to producing functional modules rather than a functional system, in which they would have competing interests.

This case illustrates the importance of good project design that allows partners to manage the collaboration-sensitive aspects of their projects, and to move quickly towards their goals. In this project the collaboration-insensitive design allowed the partners to work quickly and effectively. It must be noted that the third partner acquired a patent on his/her module. Case 8 demonstrates the same point from a different angle.

Case 8:

This project was initiated by a university and coordinated by a firm. Its collaboration-sensitivities stemmed from the fact that the coordinator was a small firm and needed not so much external expertise as external effort, which meant that and potential competitors were involved. Thus, wanting to avoid leakages, the partners were left very much on their own modules, until the demonstrator had to be prepared. Then compatibility problems emerged that took a long time to solve and when they did, the performance of the system was not as satisfactory as that of an American project on the same topic. The project leader said that this was to be expected, as the American firm had as much money to do the project on its own, while the leader had to cooperate with another four organizations.

Consortium agreements for joint exploitation of the results were an effective way of managing collaboration-sensitivities. In such cases, all partners had an interest in systemic exploitation and potential competition was regulated at the outset. While in most consortia strong cases could be made for joint exploitation as partners had complementary expertise and complementary resources, in only three cases was there clear initial commitment to engage in cooperative business ventures. All three projects were successful. However, only two of them seem to be moving towards joint exploitation. In the third, the Commission imposed an extra partner who in their turn decided to compete with the project coordinator. Thus, the project's modular results are currently marketed individually or in pairs, but not as part of the developed system.

4.8 Modes of exploitation

Often the "exploitability" of R&D results is related to their quality (e.g. see: Fasella 1988). While quality can relate to sets technical criteria, it must be noted that different such criteria apply, not only on different projects, but also on different partners within the same project. It is not only the difference between technical and economic success. These are often linked as the former is a precondition for the latter. It is also the criteria for technical success that differ between partners. This has been a fundamental element of the analysis so far presented. The distinction between collaboration-sensitive and -insensitive projects is based on the way criteria for the success of a project are perceived.

The more collaboration-sensitive a project is, the more related the technical success criteria of the individual partners are. This provides the link with technology strategies, as these strategies determine those criteria.

The way a project fits in the initiator's technology strategy determines whether systemic, modular or potential exploitation is being envisaged. To the extent that a project is collaboration-sensitive, success implies achievement of all secondary and tertiary technical objectives of its modules and sub-modules. Indeed, the possibility for systemic exploitation implies that the project is characterized as such in exploitation terms; that there is a systemic dimension in the way its modules relate to one another, which provides them with added value that cannot be exploited by means of exploiting individual modules.

Systemic exploitation

Systemic exploitation of EC R&D project results occurs rarely for a number of reasons. The first is that the level of system development required in order to be exploitable is hardly ever attained during the lifespan of EC R&D projects. In most projects not all the performance targets were achieved. Furthermore, these performance targets rarely coincided with real-life user requirements due to the pre-competitive character of EC R&D.

Real-life user requirements were targeted by user initiated projects. Five such projects were looked at. In two of them the users were the coordinators. Both projects had problems in achieving their performance targets. One of them was considered as a failure and its results were abandoned at least by the user initiator. The other was expected to last two years longer than anticipated, but at the time of the interview it was close to achieving performance objectives that would render it exploitable. This was largely due to changes in the directions of the project over time. Managing this change was helped by the fact that this project was based on a consortium agreement which provided for a joint venture that would exploit the results.

In most cases, some shift in projects' directions and objectives seems to be related to their success. As in all three user-initiated but producer-coordinated projects, the system finally developed and exploited was quite different to the one initially envisaged. And while these differences affect the usability of the system by the user initiator, by increasing the costs of re-tailoring the system to the specific needs of the specific user, they do not significantly affect the usability of the system in general.

This points to a second reason for the rarity of systemic exploitation which is the way collaboration-sensitivities are built into projects. While collaboration-sensitivities in project implementation occur for all projects with systemic aims, the standard agreement provides exploitation rights to any of the individual partners. However, systemic exploitation by individual partners implies that each individual partner has all the expertise needed to commercialize the system. Then, either the project is collaboration-insensitive, or its collaboration-sensitivities lie in vertical relations. The former case was not met during this study, as in collaboration-insensitive projects the interfaces between the modules are hardly developed to levels that would allow the system to be commercializable. However, there were four cases of the latter, in which results of projects involving one producer and one or more users if commercializable could be exploited by the producer.

Horizontal collaboration-sensitivities in project implementation usually extend to exploitation. In only one case such collaboration-sensitivities were accompanied by a consortium agreement for joint exploitation, and this was the only such case of systemic exploitation. In all other such cases, a consortium agreement on this issue was not attained and there was only modular or potential exploitation. In one case a change of the composition of the consortium by the EC affected the possibilities for such consortium agreement.

Modular exploitation

For similar reasons, modular exploitation was not a frequent case either. It appeared in one collaboration-insensitive project which achieved a "suitable" level of module development, and in one project with horizontal collaboration-sensitivities where the partners did not manage to achieve a consortium agreement for joint exploitation. The latter, however, is an exceptional case. Typically horizontal collaboration-sensitivities restrict the compatibility of a project's modules with other systems to avoid potential competition. Thus, when such a project aims at producing an innovative system, commercialization of its modules is related to commercialization of the system. This indicates the great economic importance of systemic exploitation.

Potential exploitation

A number of projects examined did not achieve a level of development "suitable" for exploitation. This "suitability" however, relates to the links between the technology strategy of the firm and the nature of the results. A few projects aimed directly at "process" technologies which were not seen as commercializable, as the participating firms did not follow a "network" type technology management and a "soft" strategy of commercializing such technologies. These projects were successful in technical terms because of the identity of suppliers and users in the projects, and most of them led to internal use of the results by the participating firms. The results of the project referred to in case 1 were not exploited as the market scenario on which it was based did not materialize.

In most cases process technologies were dealt with in the context of the product aims of the projects. In parallel with system or module development, suitable processes were looked for. The development of processes and their application in producing similar systems or modules was one of the ways of potential exploitation of results.

Few of the firms interviewed judged that commercialization of their modular or systemic results were worthy of internal development investment. This was the case when project results were fitted well into the technology strategy of firms. Such were the cases of soft firms pursuing a hardening strategy. Such were also cases of business units of large corporations.

A number of firms, however, were looking for further development funds through participation in subsequent EC R&D projects. One of our cases was such a subsequent project. The use of the results of an EC R&D project to access more external R&D funds in order to develop these results further is one of the most frequently met ways of potential exploitation. It must be noted that this type of exploitation suits network type technology management and "soft" strategies, as for such firms technology development takes place only through external funds. This is their business.

However, in a number of cases this development investment was not undertaken at all, while the projects achieved their technical objectives. This took place in projects the exploitability of which was based on expectations which did not materialize. New materials projects based on the expectation that the material at hand will become cheaper belong to this category. While the materials and the processes developed in the projects examined have applications, the difference in performance does not justify the difference in cost from working with conventional materials. This was often due to the fact that in the materials sector there is great technological inter-relatedness between processing stages creating indivisibilities as investment barriers.

Potential exploitation applies in the cases where the project failed to lead to commercializable results. Such failure implies the generation of knowledge and skills which would have been exploitable under certain conditions that have not materialized. These conditions concern either the level of technical development envisaged or the state of related markets. In the former, EC R&D projects enhance the level of knowledge and skills of firms, and thus bring them closer to attaining the level envisaged. In the latter, EC R&D projects create technologies that could be exploitable under different states of markets, which may well materialize.

In any case, two factors affect largely the extent to which potentially exploitable results are achieved. The first is the way the relationship between a firm's technology and business strategy interact. Network type technology management clearly facilitates commercialization of EC R&D results. The second is the way collaboration-sensitivities are managed within a project. Firms that managed their collaboration well were very effective in benefiting from their EC R&D projects. In relation to this, all interviewees stressed the importance of the experience gained in "international project management", which allows them to do "good business" within the framework of changing inter-institutional relations in the 1990's. And being successful in benefiting from Framework Programme projects is a "good business".

5. Summary and Conclusions

This section reappraises the analysis and summarizes the emerging firm-related factors that affect the impact of the Framework Programme on European industry. While the focus on firm-related factors, necessarily emphasizes the individuality of each case, some general points about the impact of the Framework programme on categories of firms can be drawn and are presented in the first subsection. The second sub-section summarizes the factors that affected the success of the projects and the exploitation of their results. Finally attempts to draw lessons for the Commission as a sponsor of either industrial R&D, or evaluations of its industrial impact.

5.1. The Framework Programme and European Industry

A look at the literature on EC sponsored R&D shows the multiplicity of motives and benefits that encourage firms to participate in EC R&D activities. The concept of technology strategy has been introduced to analyze these motives and perceived benefits. Technology strategy involves the vision of a firm about directions in which technologies, relevant to its businesses, develop, together with its technological activities to position itself favourably within competition in these businesses. Technology strategy has been identified as a major factor involved in the exploitation of EC R&D results.

Technology management can be seen as a subset of technology strategy. However, it incorporates the structural characteristics of a firm which relate to strategy. The technology management modes of the firms investigated, were analyzed in relation to three broad types: networks (business based on technology exploitation), machines (business based on production and technology management functions to that end) and portfolios (technology management based on ad hoc balancing production and technology acquisition). These types indicate ways in which firms position themselves in relation to technological changes and the way in which they move to exploit technology in the market-place.

The Framework Programme had a lot of response from firms, as well as other organizations, which follow a network type technology management, that is which sell technologies rather than, or as well as, products. For these organizations the Framework Programme provides a business environment that orientates their technology strategies, and a facility to make the contacts necessary for their business.

The Framework programme undoubtedly played a major role in the recent growth in "soft firms" (i.e. firms that commercialize of technology and develop customized products) which manage technology in a network fashion. As these firms commercialize technologies at a very fast pace (each project has to lead to commercialized outputs), they enhance the availability of technologies in the market, enhancing thus the innovative potential of European industry as a whole.

The other side of the coin is the destabilization of markets, on which the strategies of these firms are based. Standardization problems are increasing for the users of their outputs, as each commercialized output is individual. User firms can easily become locked-into technology producer firms. The standardization aspects of the EC programmes are very important in this respect.

The Framework Programme, together with the plethora of technologies in the market resulting from the activities of these organizations, plays a major role in directing and facilitating the innovative efforts of firms with technology management of the machine type. However, as these firms are normally not very capable in leading edge technologies their participation in framework programme is often accompanied with problems in the exploitation of the results.

For large corporations with portfolio type technology management, the Framework Programme has little direct influence on their technology strategies. One of its main "strategic" effects lies in the fact that, through the subsidy, it provides their corporate R&D laboratories with more room to manoeuvre in terms of both developing certain technologies and personnel management.

The subsidy provided by EC programmes is of great importance. EC programmes have often provided to firms who did not perform R&D with the stimulus for to do so, by allowing a financial critical mass to be established.

Furthermore, some firms reported that they learned a lot about managing projects from the Commission's scientific officers. The staff of ESPRIT seems to warrant special mention here, as their commitment to monitoring the projects and enforcing strict management rules was emphasized in many cases as one of the factors that helped project management a lot.

Project management in general was one of the areas in which EC programmes seem to have affected the knowledge-base of all participants. Irrespective to the success or failure of their projects the interviewees stressed that through their projects they are better prepared for all aspects related to their participation, from writing proposals to screening partners and managing their collaborations. In some cases it was emphasized that having a proposal accepted in one programme opens the door for more to come. This has to do with a number of factors, such as becoming known to the bureaucracy, and becoming known as a good partner within the networks of organizations which work under the various programmes.

5.2. Success, failure and exploitation of the results

As CEC (1992-a) argued the willingness and ability of partners to exploit the results of R&D is not analogous to their exploitability. Indeed, there are problems in dealing with the exploitability of EC R&D results as it cannot be defined in an objective way. Exploitability depends on the technology strategies of the participant firms. For example for firms with network type technology management virtually all results are exploitable.

Projects are designed aiming at product and/or process technologies. Only a few cases were examined in which the projects aimed solely at process technologies. In these cases the participating organizations aimed at using the results themselves. These projects were successful in technical terms, but their results were not always exploited. In one of these cases the results were commercialized because of a radical change in corporate strategy due to a take-over. In another the results were kept "on the shelf" in case the organization needed them in the future. The difference in technology management patterns played an obvious role. The first was a firm with network type technology management while the second with portfolio type.

In most cases, however, the projects incorporated both product and process goals. According to the importance of collaboration for the achievement of the product goals of the project leader (which was the organization interviewed) projects were distinguished between the categories collaboration-sensitive and collaboration-insensitive. In some cases there were partners within the consortia who were users of the projects' systemic or modular goals. For them, these projects were always collaboration-sensitive as their success depended on the work of the other partners.

The collaboration-sensitivity of the project was a major factor in the choice of partners. The more sensitive the project the more the technical ability of the partners was important. The more insensitive the project the greater the importance attached to the origin of the partners, which was perceived as an important political factor increasing or decreasing the possibilities to get EC funding. Still, the quality of the communications infrastructure in less favoured regions of the Community, as well as the financial viability of their industries emerged as important factors influencing decisions to collaborate with firms from these regions.

Collaboration-sensitivities were also important in project design. The design of the project had to strike a balance that would satisfy the goals of the Programme, the goals of the initiator and the goals of the partners. A number of organizations design largely collaboration-insensitive projects, in which they perform the parts that are important for their technology strategy. This means that they do not engage in projects that involve "radical" changes in their technologies as they have the capabilities to perform the projects, or the parts of projects, they are interested in. It appeared that in Germany there is a cultural commitment in this type of project design.

However, increasing the dependence of the goals of the partners on the goals of the initiator provided the means for controlling the direction of the overall project and for restricting potential competition. Limits to this were posed by the size of the initiating firm and the extent of work it could perform. Academic partners were often chosen to perform important parts of the projects in view of their low potential for competition after the project.

Detailed consortium agreements were often signed to guarantee the coincidence of goals between the partners and the initiator and to limit potential competition. However, patents previous to the projects were the most effective means to that end. User firms had a stronger incentive to engage in the formulation of detailed consortium agreements as their benefits depended almost entirely on the work of the other partners.

It appeared that all the organizations acknowledged that the goals of all projects shift in time as a result of the partners' changing strategies as well as of new data arising from project implementation. A number of projects collapsed under these changes. To keep the right balance between the goals of the actors involved under changing conditions was the role of project management, and the more the dependencies between the partners the more difficult it is.

Three ways of dealing effectively with changes in projects' direction were found. The first, which seems to characterize the culture of Danish firms, is to make sure that there is a consensus between consortium members on all technical decisions that may affect the directions of the project. While this requires a large coordination effort it seems to pay off as no decision is taken until the right balance is struck. The second is to start the project with a consortium agreement providing for joint exploitation of its systemic goals. Thus, the goals of each partner coincide with the goals of the project and each shift in direction takes place in order to increase the commercializability of systemic results. The third approach refers to the internal project management structures of firms. In some cases firms manage the interface between their technology strategy and the directions of the project by launching, when necessary, internal projects interfacing between the two. This is done with the help of a specialized department that liaises between the people working on the project and the partners. This is also an effective means to control the technology flows from the firm to the other parties involved.

In general technology flows within the consortia did not appear to be more than what was required for project implementation. The results shared within the whole of a consortium are typically codifiable, and again these are shared only to the extent they will not create potential for competition between partners. Greater flows than required for project implementation were found in only one case involving an inter-organizational research team which worked together in all partners' locations at the various stages of the project. It is important to note that this case was governed by a consortium agreement for joint exploitation of the results.

Technology flows within firms depended on their structures and on the interest of product developers and top managers to the particular projects. The smaller the firms and the more informal their structures, the more results were communicated and screened, and the more product developers and top managers were informed. In large corporations the interest of product divisions and top managers in the projects was by definition low, as their investment in EC sponsored projects was limited (the EC payed for some of it). Furthermore, often within the structures of large corporations it is the job of the R&D department to develop fully the results, even when the project is contracted for by product divisions. The less the investment of a product division on the EC project, the more it is up to the R&D department to demonstrate its value. One such case, in which a product division revealed great interest, was a project developing the results of a previous one, which had demonstrated their value for this product division's activities. When product divisions have a great interest in a project they usually participate in it as partners.

Cases of commercialization of product technologies developed by the EC R&D projects were characterized by strategic commitment and good management within the firm as well as the consortium. Obviously, the last factor was less important in collaboration-insensitive projects. In many cases the level of development reached was hardly adequate for commercialization, in accordance to the pre-competitiveness principle.

The extent to which further development was needed for commercialization varied significantly. However, the size of the investment required was not directly related to the willingness of firms to undertake it. This willingness was stronger in firms following a "hardening" strategy, which in all such cases examined was based on the results of their EC projects. In many cases, the development needed was planned to take place within subsequent EC projects.

Using the results of a project to get funding for subsequent projects is one of the ways of potentially exploiting EC R&D results. Even in the absence of a directly subsequent project, great value is attached by the firms to process and training results of such projects. One of the most important aspects of training is the accumulation of "international project management" skills which seem to be important for the ways business practices develop in Europe.

Finally, even in cases of failure to exploit the results, potential exploitation still applies. This is because failure implies knowledge and skills gained which are exploitable under certain technological and/or market conditions which do not materialize. EC R&D projects enhance the level of knowledge and skills of firms, and thus bring them closer to attaining desired technological development levels. They also generate technologies that could be exploitable under different market conditions, which may well materialize.

5.3. Concluding Lessons

On the basis of the analysis the following lessons can be drawn:

i) The technology strategies of actors that participate in consortia are a key factor in the exploitability of EC R&D results. The way in which firms perceive their EC R&D projects in relation to their business determines the directions they will pursue in project implementation and exploitation. Technology strategies also play a key role the design of projects and consortia and affect the ways project are managed. The dissemination of results also serves these strategies. Studies of the industrial impact of EC R&D programmes have to take this into account.

ii) The Framework Programme has promoted a fierce competitive environment in the markets for technology, as it provided business opportunities to technology producers. While this supported firms which engage in contract development, competition created pressures for such firms to engage in production. Thus the Framework Programme has provided not only for a quantitative growth in the technological base of the Community, but also for a qualitative improvement relating to the innovativeness of an important part of the Community's technological potential.

iii) The Framework Programme offers opportunities also to technology users to develop technological capabilities and strategies. However, the host of technologies generated creates problems in the development of technology strategies by users, and even more problems to users without technology strategies, who operate in a rapidly changing environment. In this respect, there may be a role for the Community in intensifying its standardization efforts to reduce this type of problems. Complementary to this can be assistance to firms to develop technological capabilities and strategies and to understand the changes required by the competitive environment of the 1990's.

iv) Noting the inadequacy of the various dissemination fora to effect technology transfer from firms that perform projects to their audience, commercial exploitation is the principle means of dissemination of EC R&D projects' results. In this sense there can be arguments either for stricter rules governing dissemination, or for R&D closer to the market. Nonetheless, in view of the existing pre-competitiveness principle that covers EC R&D projects, firms with network type technology management clearly play an important role in the economy of the Community.

v) The importance of collaboration for project implementation and exploitation, can be seen as adding value by increasing the productivity of the R&D process. On the other hand, collaboration-sensitivity poses great problems in project management especially when shifts in the goals of the project and/or the strategies of firms occur. To the extent that the Community's programmes aim to increase the productivity of the R&D process, collaboration-sensitivity can find a place in project selection criteria. However, further research is required to determine the way collaboration-sensitivity applies in various collaborative structures, the way levels of collaboration-sensitivity can be identified, and the way they can be related to programme objectives.

vi) Finally, as far as the ability of firms to exploit EC R&D results is concerned, it must be noted that indeed EC projects are different from companies' wholly self-financed projects and that effective exploitation of their results requires different management patterns. Firms which realized this, have been very effective in exploiting EC R&D results. The ability of firms to realize such differences and respond by establishing appropriate R&D management processes, depends very much on company size, structure, management style and culture. However, such changes are very important as in an evolving world change is often synonymous to survival.

References

Allouche, J and G Pogorel (1990) Networks, Machines and Portfolios: Technology Decision Making in Large Corporations. Franco Angeli, Documenti ISVET, Milano

Andersen Consulting (1989) Strategic Effects of EC R&D Programmes in the Netherlands. Bureau of EG Liaison. Hague

Burns, T and G M Stalker (1961) The Management of Innovation. Tavistock, London

C.E.C. (1992-a) Research after Maastricht: An Assessment, a Strategy. COM (92) 682

C.E.C. (1992-b) BRITE & EURAM Evaluation Study of Finished Projects - projects completed by December 1991: Synthesis Report. C.E.C. Office for Official Publications of the EC.

Costa, P et al (1988) Evaluation of the European Advanced Materials Research Programmes -EURAM- (1986-1989) C.E.C., EUR 11358 EN

CREST (1992) Evaluation of the Second Framework Programme of RTD. Report from CREST to the Council, CREST/1212/1/92 REV1-EN

Dasgupta, P (1987) The economic theory of technology policy: an introduction. In P. Dasgupta and P. Stonemann / eds. Economic Policy and Technological Performance.

Fasella, P (1988) The Need to link Science and Technology Policy with Regional Development Policy. Presentation at the European Conference on Science and Technology Policy and Economic and Social Cohesion. Waterford, Ireland, 3-4 October.

Ford, D (1988) Develop your Technology Strategy. Long Range Planning 21

Freeman, C (1982) The Economics of Industrial Innovation. Pinter (2nd Edition)

Georghiou, L et al (1990) The Strategic Management of International Collaboration. Paper presented at the Workshop on "Process of Knowledge Accumulation and the Formulation of Technology Strategy" Rosnaes, Zealand, Denmark 20-23 May.

Georghiou, L et al (1992) The impact of European Community Policies for Research and Technological Development upon Science and Technology in the United Kingdom. Report to CEC and the UK Office of Science and Technology

Kamien, M I and N L Schwarrz (1982) Market Structure and Innovation. Cambridge University Press

Laredo, P and M. Callon (1990) L' impact des programmes Communautaires sur le tissu scientifique et technique Francais. La Documentation Francaise

Lundvall, B A (1988) Innovation as an interactive process: from user-producer interaction to the national system of innovation. In Dosi, G et al / eds Technical Change and Economic Theory. Pinter

Malmborg, Ch et al (1988) Evaluation of the Biomolecular Engineering Programme -BEP- (1982-86) and the Biotechnology Action Programme -BAP- (1985-89). C.E.C. EUR 11833 EN

Metcalfe, J S and M Boden (1990) Strategy, Paradigm and Evolutionary Change. Paper Presented at the Workshop "Process of Knowledge Accumulation and the Formulation of Technology Strategy" Rosnaes, Zealand, Denmark 20-23 May.

Metcalfe, J S and N Reeve (1990) On Technology Taxonomy. PREST, Manchester, Report to the Department of Trade and Industry

Pavitt, K (1984) Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory. Research Policy 13

RACE (1992) Research and technology in advanced communications technologies in Europe. C.E.C. Luxembourg

Research Associates (1989) Evaluation Study on Contribution to Cohesion of EC framework Programme. Report to SPEAR, EEC 495

Saviotti, P and J. S. Metcalfe (1986) The exchange of Technology in Italian Foreign Trade. University of Manchester. Mimeo

Schmoch, U et al (1991) Patents as Indicators of the Utility of European Community R&D Programmes. C.E.C. EUR 13661 EN

Teubal, M et al (1991) Networks and Market Creation. Research Policy 20.

Vincenti, W. G. (1990) What engineers know and how they know it. John Hopkins University Press

Weingart, P (1977) Science Policy and the development of science. In S. Blume / ed. Perspectives in the Sociology of Science. John Wiley and Sons

Appendix I

Sample description

Sample description: Description of the organizations interviewed

	Type of organization	Technology Management	Sector
1	Small Firm (30 employees)	Network	Telecom / Electronics
2	Small Firm (20 employees)	Network	IT / consultancy
3.	SME (400 employees)	Network	IT systems
4.	Collective agency	Network	Mechanical Engineering
5.	Small firm (15 employees)	Network / Hardening transition	IT systems
6.	Small firm (15 employees)	Network	IT / consultancy
7.	Large Business unit of corporation (500 employees)	Transitional involving Machine and network characteristics	Semiconductors / engineering
8.	Large Corporate R&D	Portfolio / Network	Electronics
9.	Large Corporate R&D	Portfolio	Machinery
10	Large (5000 employees)	Network / hardening transition	IT systems / packages
11	Small (35 employees)	Network / hardening transition	Telecom / Engineering
12	Small (30 employees)	Network/ hardening transition	Robotics / engineering
13	Large (7000 employees)	Network	IT systems
14	Large business unit of corporation (6000 employees)	Transitional involving network and portfolio characteristics	Electrical
15	Large (5000 employees)	Machine	Textiles
16	SME (285 employees)	Machine in softening transition	Aerospace
17	Large (100000 employees)	Portfolio	Textiles diversified
18	SME (120 employees)	Network	Engineering
19	SME (105 employees)	Network / portfolio	Biotechnology
20	Large corporate R&D	Portfolio	Many
21	Large corporate R&D	Portfolio	Metals
22	Collective agency	Network	Minerals

23	SME (300 employees)	Network	IT systems
24	Small firm (60 employees)	Network	IT systems
25	SME (100 employees)	Network	Engineering
26	Collective agency	Network	Minerals
27	Large corporate production and logistics centre (700 employees)	Portfolio	IT/electronics
28	Large business unit of corporation	Portfolio	IT
29	Large business unit of corporation	Portfolio	Semiconductors
30	Business unti (900 employees) of a corporation	Portfoilo	IT
31	Large business unit of corporation	Portfolio	Seminconductors
32	Corporate research centre	Portfolio	IT/consumer electronics
33	Large business unit of a corporation (18,000 employees)	Portfolio	Telecommunications
34	SME (200 employees)	Network	Software engineering, consulting
35	Corporate research lab	Portfolio	IT/electronics
36	Corporate research centre (250 employees)	Portfolio	Non-ferous metals industry
37	Corporate R&D centre	Portfolio	Construction industry
38	Corporate R&D centre	Portfolio	Aviation/aeronautics
39	SME (8 employees)	Network	Software engineering
40	SME (50 employees)	Network	Software engineering
41	Large business unit (6,300 employees) of a corporation	Portfolio	Telecommunications

Horizontal Evaluation of the Industrial Impact of EC R&D Programmes

Element 5: Technology Transfer within Firms

(German Main Contractors of EC Projects)

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1. Introduction

This study "Technology Transfer within Firms (German Main Contractors of EC Projects)" is part of Element 5 of the study "Horizontal Evaluation of the Industrial Impact of EC R&D Programmes". It focusses on the hypothesis that whatever the technical achievements may be, a key barrier in European firms to exploitation of R&D results lies in the functioning of the interface between those carrying out R&D and those responsible for application and marketing of the results.

This part of the overall study investigated R&D projects within firms co-funded under the EC Framework Programme and conducted by German firms as main contractor and concentrated on the following questions:

- How is research and development organized within the firm?
- How does the transfer of knowledge from R&D to the production units take place within the firm?
- How did the idea for the R&D project arise?
- What technical, economic and other results was the R&D aiming at?
- How were these results applied and/or marketed, and what factors had a negative influence on this?
- What role did EC policy measures play in the firm's innovation process?

FhG-ISI questioned 15 firms in Germany which had participated as main contractors in the ESPRIT Programme (9 firms), the BRITE/EURAM Programme (5 firms) and in the RACE Programme (1 firm). The idea of looking only at main contractors is a compromise due to funding restraints and the thought that the main contractor may gain the largest part of the benefits from an EC project.

Information was gathered through semi-structured face-to-face interviews which lasted between two and five hours. If available we expanded these interviews with information from the annual reports of the firms and the final project reports. The interviewees were the project leaders and the heads of research. The projects were either already completed or were coming to a close. In some cases the project had finished four years before, which had the advantage that possible applications or marketable uses of the project results could be investigated. However, people interviewed in connection with these less recent projects often had difficulties in remembering exact details of how the project had arisen and developed.

It was difficult to arrange interviews with suitable partners: one problem was that especially in the case of less recent projects the responsible project leaders were no longer working for the same firm or in the same department. In these cases the firms and responsible successors were unwilling to give an interview. If the selected project had already been a subject of other EC evaluation studies, interviews were not given either. The responsible project leaders did not see why they should be questioned several times on the same topic, and complained about frequent questioning by various institutes and consulting bureaux for studies commissioned by the EC. Firms were also less willing to discuss when the project could not be used for publicity, or when its strategic importance for the firm was assessed as being very low. Thus the concentration of our investigation on the EC programmes ESPRIT and BRITE/EURAM was not deliberate, but arose because a sufficient number of interviews with leaders of projects from the RACE and DRIVE programmes could not be arranged.

The following results relate to the 15 EC projects and the evaluation of the interviews conducted; they do not constitute in-depth studies, nor can they be considered to be representative.

We confined the interviews to a consideration of technology transfer within the firm. The results of the EC project as a whole, and the importance of the cooperation of the consortium for the success of the project, were examined only to the extent that appeared necessary to us in order to describe the transfer of technology within the firm and the exploitation of results. Moreover, the aspect of cooperation between partners in EC projects is examined more closely in element 7 of the overall study.

Of the 15 R&D establishments which carried out the EC R&D projects in our investigation, 12 belong to multinational enterprises (MNE). These are active in the fields of telecommunications, semiconductors, image processing, sensors, multimedia, electronics, aluminium production and construction engineering. Only three of the R&D establishments investigated belonged to small or medium sized firms (SME); these developed software and supplied engineering services.

The letters in italics mark examples from our interviews which illustrate the generalized results of our investigation.

2. Internal Technology Transfer and R&D Management Structure

We understand technology transfer within the firm as the transfer of technical and scientific knowledge from one area of the enterprise to another, and its application in new products or processes. Two types of transfer, vertical and horizontal, can be distinguished: Vertical technology transfer follows the various stages of the innovation process, from research and development through production, diffusion and economic exploitation. Horizontal technology transfer denotes the transfer of knowledge between organizational units of an enterprise (e.g. research laboratory and business units), between enterprises or between branches of industry.

A distinction also has to be made between demand-induced R&D and technology-pushed R&D. The demand-induced R&D is carried out in response to an external stimulus by a (potential) user. Since there is a recognized need for a new product or new process, there are forces acting to pull the R&D project along and the risk of failure may be frequently lower than for technology-pushed R&D. The forces which give rise to technology-pushed R&D projects arise within R&D as a development of the areas of expertise which grow over a length of time and are likely to be far riskier than demand-pull R&D. In our investigation we found both demand-pull and technology-pushed R&D projects.

2.1 Technology strategies and location of EC projects

Technology strategies of the large companies

The technology strategy of the large companies investigated was directed towards global markets; technological requirements demanded a broad scientific base for research and development. The large companies concentrated on main points in selected areas of technology (key areas) in which they aimed at a technology leading position. Due to the necessity for this scientific research and development basis, national and international cooperations with other firms' R&D laboratories, with universities, publicly supported R&D institutes and other companies were regarded as an important part of technology strategy. The aims of these cooperations were to transfer externally available know-how to one's own company and to exchange information. To assist these technology strategies based on the transfer of knowledge and the exchange of information, large companies made deliberate use of national and international R&D programmes. Generally, the technology strategies of these large companies could be characterized as follows:

- Market leadership in key technology areas through concerted R&D activities,
- internal research and development in R&D centres and in the R&D departments of the various business units,
- external cooperations with universities, publicly supported R&D institutes (such as e.g. the Fraunhofer Institutes, big research institutions, public testing centres), R&D laboratories of other firms and with other firms as such,
- European and international orientation of research and development activities.

The R&D projects supported by Brussels served as a catalyst for the cooperation of the large companies with European universities and firms. The large companies investigated only applied for EC projects if they suited their technology strategy and their product portfolio. For this reason the EC support could not generate new ideas but joined existing R&D activities.

Technology strategies of the SMEs

The three SMEs also conducted their own R&D efforts but performed R&D as part of their business activities without a R&D department detached from other operating departments. The main emphasis was on development activities. These SMEs were specialized in the development of new and improved customized software and in professional services such as consulting, training and customized problem solving of software applications in working processes. They also engaged in external cooperations with other firms, universities and publicly supported R&D institutes which is a fact of growing importance in Germany (e.g. Kuhlmann/Kuntze: R&D cooperation by small and medium sized companies, 1991). A crucial role for the SMEs' collaboration strategy was played by firms from the industrial and services sector as potential users of their software.

In addition these SMEs aimed at a technology leading position and oriented their technology strategy towards the European market. There are two reasons for this European orientation: one is that the three SMEs already had a good market position within Germany and were thus searching for new markets. The other reason is that the three firms were all participants in networks of firms which themselves had a European or international orientation, which is not representative for German SMEs. For instance, one small engineering firm is engaged in ship-building and has worldwide contacts with internationally active shipbuilders. The second firm, an engineering bureau, develops software for the foundry industry; it has customers in the USA, Canada, the Philippines, Japan, Korea, China and both eastern and western Europe. The third firm is embedded in a network of enterprises from the automobile industry and related suppliers, and besides activities in other business areas is developing software for CIM applications for these branches.

These existing "European oriented business networks" shaped the basis for "European oriented R&D networks". Partners of these business networks applied for EC support as parts of existing networks. The EC projects encouraged these network-relationships on European level and favoured the enlargement of the business networks with R&D activities.

Location of EC projects

The EC projects were carried out in different operational contexts. Of the 15 R&D projects studied,

- six were conducted in a central R&D unit at corporate level or in a central R&D laboratory,
- six were performed in the R&D department of the firms,
- the three SMEs operated R&D as part of their business activities and had no separate R&D department.

The central R&D laboratories and central R&D units of the large companies are engaged in applications-oriented research which they themselves described as "... basic research oriented towards possible uses". Their aim is to gain new knowledge for previously defined application purposes. These six EC projects had a clearly precompetitive character and were aiming at basic acquisitions for a specific purpose: new materials, technological processes, process technologies, concepts and methods whose suitability for commercial exploitation had yet to be demonstrated.

The further removed the R&D projects were from the corporate level of the central R&D laboratories or central R&D units of the companies, and the more they took place in the R&D department or as part of the SMEs' business activities, the more the character of the project departed from this pattern. Development activities and direct transfer of the results into marketable products came into the foreground. Thus, for instance, the three SMEs developed software solutions that matched the requirements of the users, who themselves tested and used the programmes in their design and/or manufacturing departments. The area of such projects was very close to the market or to the stage of industrial development and the boundaries between the so-called precompetitive and competitive area were shifting.

2.2 Origin of project ideas

At what management level do the ideas for R&D projects arise ? What role is played by internal users such as production units of the firm ? What role is played by users of new technologies in the generation of ideas ?

In approximately half the EC projects examined, the ideas came from the R&D unit in which the EC project was subsequently performed. The projects were clearly technology-pushed and were based on technology lines already present in the R&D laboratory or the business unit. Thus EC support did not have an "initiator" function for the R&D project.

For instance the idea for a project was generated in the central research laboratory of a large company. The technical experts in the research laboratory and the head of the research department assessed the technological trend and discussed proposals; market studies or trend prognoses were not performed, and were not considered helpful. Within so-called "project reviews" proposals are discussed and compared with the overall research strategy and product strategy of the company. The idea for the EC project arose from general consideration of a problem and the goals were first formulated in general terms: in the field of multimedia, communication was to be made visually and a contribution was to be made to reducing costs. In the responsible research group of the research laboratory these general notions were then converted into technologically realizable aims. The project was based on a technology line that was already followed by the research group, and had technological links with other EC projects.

The process of idea generation in the EC projects carried out by the three software firms, on the other hand, was quite different. The development firms were aware of customer-specific problems and requirements. On their initiative, the project content was more or less jointly developed and submitted for EC support. The software firms placed a high value on the generation of ideas; nevertheless the project idea was discussed at an early stage with the customer, with whom the firm was already in contact. Thus the project idea was developed in interaction between software developers and users. In these three EC projects, both the developer and the user were subsequently represented in the consortium. The group of potential users was also extended to include firms outside the consortium and with which the developers had had previous contacts or customer relations.

In another case the initial impulse for a project came from a different direction.

The initiative for the R&D project came from a public testing centre which brought the idea to the firm. There were already good personal contacts between the two actors; the idea was then developed in a process of continuous interaction between both partners. The firm took over the role of the main contractor, while the testing centre defined the technical requirements and supervised their fulfilment.

The idea and the selection of an EC project could also be made via a "top down approach". Some large companies maintained EC offices in Brussels. In one case the initiative for an EC project was taken by the company's EC office in Brussels which passed the project idea on from there to the head of the central R&D unit, where it was examined and passed on to the responsible specialist department.

Another example for a "top down approach" described an EC project which was initiated by the management on corporate level and represented a strategic significance for the company. This project was then passed on to the responsible business unit of the MNE and performed in the R&D department.

2.3 Different types of technology transfer within firms

Technology transfer within firms varies according to the organization of research and development within the firm. In the 15 EC projects investigated, three types of technology transfer could be distinguished. Their characterization depended on the location in which the EC projects were carried out, and on the division of work between research and development and the other functions of the firm. We identified the following types:

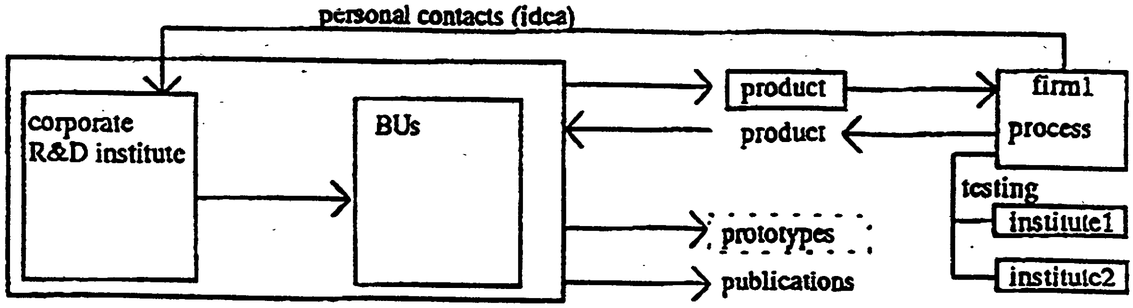
- R&D at corporate level,
- R&D in a R&D department of a business unit,
- R&D as part of the business/production activities.

Type 1: R&D at corporate level

Of the 15 EC projects questioned, 6 were performed at corporate level in a central R&D laboratory or central R&D unit, with subsequent technology transfer to the business units. The MNEs maintained at corporate level either central R&D labs or central R&D units; the latter were part of other corporate divisions. The domain of the corporate R&D was in applied research. The type of R&D of the EC projects also was applied research and the project idea mainly was technology-pushed.

Figure 1

Type 1: R&D at corporate level



For instance, one EC project was carried out in the central R&D laboratory of a MNE (see figure 1). Research and development constituted a central part of the corporate strategy of the MNE. The intention was to create synergetic effects by the centralization of R&D activities; thus half of all R&D tasks were performed in the central R&D laboratory. Approximately 70% of the finance for the laboratory was provided by the individual business units and about 30% by the board for cross-departmental project topics. About two-thirds of the main activities of the central research laboratory were strategic projects; the remaining third was made up of service activities such as measuring, testing and laboratory services, available to the operative units. The strategic R&D projects were developed by the central R&D laboratory in accordance with the predetermined strategic orientation of the MNE, i.e. the R&D laboratory often played a preliminary initiation role subsequently discussing and defining the project ideas with the business units.

The EC project was concerned with applied research in the area of new materials, and was carried out in order to increase internal competence in this area. The technical project goals could only be achieved using new materials. The EC project was intended at that time to build up the strategically important area of new materials in the hope of gaining new customers and opening up new markets. At that time the EC project was part of the core R&D of the research centre and was based on the existing strategic technology line. It should be stated at the outset that the idea of gaining new markets was not realized, as the new materials subsequently lost significance and potential customers did not show the degree of acceptance hoped for.

The idea for the EC project came from a manufacturing firm which approached the central R&D laboratory because of existing personal contacts. In close liaison between both people the project idea was more specifically defined, and project leadership was given to the central R&D laboratory (see figure 1).

Within the project consortium work was divided as follows: the research centre developed alloys, and sent them to the manufacturing firm, which then converted them into powder and forwarded the powder to the two universities for testing. These informed the firm of the test results. The powder was then given back by the manufacturing firm to the research centre, which used it to make semi-finished products. The research centre then manufactured a limited number of improved semi-finished products as prototypes. These prototypes were given to potential customers for testing. Customer interest in the prototypes declined, however, because the prices were too high. The technical goals of the EC project were achieved and the technological competitive position of the company improved. However, the project results were not converted into marketable products due to lack of demand. There was no transfer of products to the business units of the MNE, only a transfer of knowledge. The research work on the new materials induced new awareness in the research centre of the use of conventional materials: Because of the poor sales chances of the new materials, an investigation is now taking place to find out whether the characteristics aimed at with the new materials might not after all be achieved using conventional materials.

It was not due to lack of technology transfer within the firm or between the partners that the EC project did not lead to a marketable product. The cause is to be found rather in an erroneous assessment of the market potential of the new materials, as possible customers were not prepared to pay higher prices for better semi-finished products.

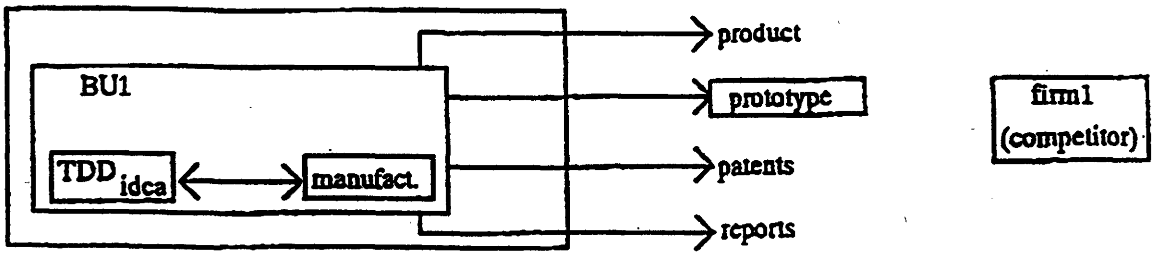
Type 2: R&D in a R&D department of a business unit

Six EC projects were conducted in the R&D departments of MNEs' business units, which were directed much more intensely towards product and process development than towards applied research. The project ideas were mainly technology-pushed, even if there was an interaction between the R&D department and the other operating departments of the business unit.

The following example describes the process of technology transfer of an EC project within a business unit of a MNE. All in all, the aims set for this EC project were achieved, the new elements were manufactured and were used in products. The idea for the project was technology-pushed. Cooperation between the manufacturing unit and the R&D department obviously presented no problem within the business unit. However, some problems existed between the participating firms, because they were direct competitors in this field.

Figure 2:

Type 2: R&D Department of a Business Unit



The business unit had its own R&D department, working in close collaboration with manufacturing (see figure 2). R&D activity concentrated on development. Due to the technical requirements (semiconductors) the R&D unit was closely associated with manufacturing; thus the strategy was to develop, from present production, pilot lines for production and new products. Technology development was carried out for the unit's own products and for other business units within the MNE. The R&D department of the business unit collaborated closely with the central R&D unit at a corporate level and obtained the necessary basic knowledge from the central unit. This close collaboration also applied to the elaboration of project proposals and the acquisition of EC R&D projects. The technology strategy focused on internal research and development and on cooperation with the central R&D unit.

The proposal for the EC project was developed by the R&D department of the business unit itself (see figure 2); the R&D department scanned the call for papers and the main topics of the EC framework programmes for possible project contracts which might fall within their field of activity. However, proposals for projects supported by the EC were also passed on to the business unit's department by the central R&D unit.

The aim of the R&D department in participating in the EC project was to continue its technological development line in a particular business area. The EC project was in a technological core area of the business unit and was based on already existing technology lines; several "forerunner" technologies were already present. Thus the EC support did not initiate the R&D project, which would in all probability have been carried out anyway without support as it was in a core area of the enterprise. The generation of ideas was *also strongly technology-pushed, but with collaboration and mutual adjustment of R&D and manufacturing.*

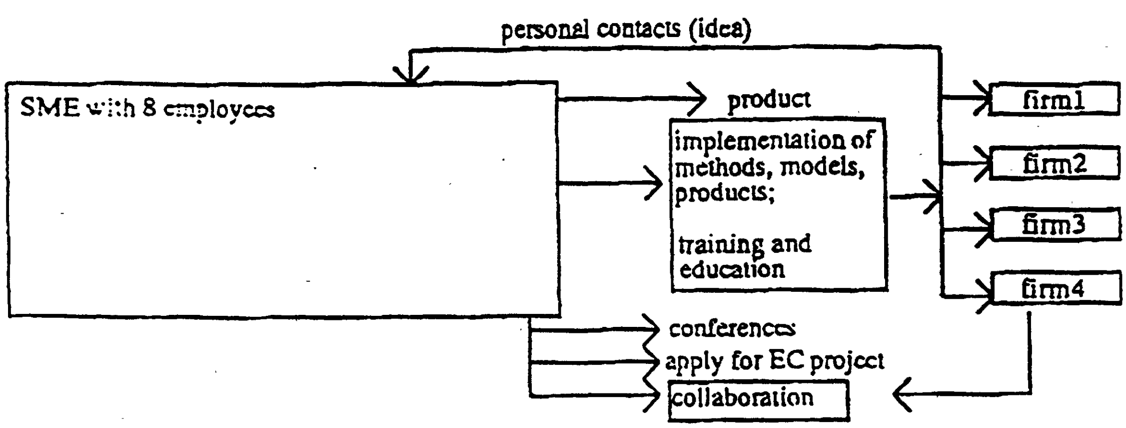
The technical goals of the EC project were achieved. In a new pilot line in the business unit the new elements were produced and used in entertainment electronics and advanced computers. The newly-developed elements were also used in production by the partner firm. However cooperation proved difficult, as the two firms are direct competitors. Thus cooperation was characterized by the fear that too much know-how might be transferred to the other firm.

Type 3: R&D as part of the business/production activities

The three small and medium sized software (engineering) firms had no separate R&D department and carried out the EC projects as part of their business/production activities. This type described here should demonstrate that where there was a relationship between developer and (potential) user, the project ideas were not - or hardly - technology-pushed, compared with the other two types. The idea for the development project was demand-induced and elaborated jointly and interactively by the users and the software developer. This interaction between them enabled the requirements of the firms to be taken into account, so that the project was very strongly customer- and application-oriented. The interplay between actors enabled the software programmes to be tested under manufacturing conditions and optimized. The EC projects of this type were very close to the market and to the stage of industrial development, which was in conflict with the existing idea of precompetitive EC support.

Figure 3:

Type 3: R&D as part of the business production activities



One EC project we investigated was carried out in the area of software by an engineering bureau as main contractor (see figure 3). The firm had eight employees, four of them engaged in software development activities. The developers were concerned with the analysis of manufacturing processes and the definition, development and implementation of software solutions. The engineering bureau was a world market leader in the area of computerized casting simulations for the foundry industry. By taking part in EC projects it wished to improve its market position in the EC even further, as it already had a very good market position in Germany. The technology strategy aimed at a leading position in computer aided simulation, internal development activities and international cooperation with universities and industrial enterprises.

The EC project was based on the existing technology line and was highly important for the software firm. The aim of the project was to extend the application spectrum of computer aided simulation by new and further developments, in order to open up new markets and further increase its know-how in this area. The initiative for the EC project came from the manager of the engineering bureau (see figure 3). The project idea was then developed further, together with customers with whom the firm already had personal contacts. The partners had had certain problems in processing technology which could only be solved by more intensive development work. As the partners were also small and medium sized firms, they did not have the necessary financial resources and were on the look-out for public support. Since the engineering bureau already had experience in project management it was given the project leadership. For two of the four partner firms, this was the first EC-supported R&D project in which they had participated.

The technical and mathematical goals of the EC project have already been achieved, although at the time of our investigation only half the project time had elapsed. The computer aided simulations developed by the engineering bureau were used by the partner firms for testing purposes. The results of these tests were then fed back to the engineering bureau, which made further improvements to the simulation programmes. By using the improved simulation programmes the partner firms made substantial savings in time, costs and materials, as well as improving the quality of their manufacturing processes.

As a result of the EC project, the engineering bureau was able to develop a new software package which was already being used by non-participants. In addition new physical data were gained, extending and improving the data bank of the engineering firm. The engineering firm considered that the EC project has secured its competitive position, and it was able to use the project as a marketing instrument. Without the EC support, the project could not have been carried out in its present form or extent for reasons of finance; it would only have been possible to tackle some of the individual topics.

3. Results and Exploitation of the EC R&D Projects

An EC R&D project does not necessarily lead to a marketable product. It is useful to distinguish between results of an EC-supported project and exploitation of the results to identify the barriers of exploitation at this interface. The results aimed at in the 15 EC projects can be divided into technical results and other results (see figure 4).

Two general types of cases can be clearly distinguished within the 15 EC projects investigated:

Case 1:

The goal of the project is the joint development of a demonstrator or prototype. These EC projects are precompetitive in character; economic impacts can only be detected several years after completion of the project. The participating firms make individual use of the acquisitions of knowledge and experience for the development of new products, or for the internal introduction of new processes. This firm-specific technical exploitation of the results achieved in the project may produce economic impacts after several years.

Case 2:

The aim of the project is the closely application-related development of marketable products. These EC projects are no longer at the precompetitive stage and economic impacts - if they occur - can be observed within a short time. The participating firms develop marketable products in close collaboration; these are marketed by the developer and exploited in-house or by the user as a process innovation. These projects already produce improvements in the economic competitive position of the participating firms shortly after the end of the project, e.g. by the sale of new products and/or by reduction of costs in the manufacturing process.

Apart from the technical and economic exploitation of the results, there have been additional benefits such as enhancement of the firm's scientific reputation, the building up of new cooperative relations, and participation in further EC projects.

Figure 4 shows the relationship between the project results achieved and their (later) possible exploitation by the individual firms.

3.1 Results of the EC R&D Projects

The kind of results achieved are determined largely by the aims and content of the EC projects being examined. If the pre-planned goals are compared with the results actually achieved, the following picture emerges: from the viewpoint of the firms in our study, product innovations were mainly being aimed at which could be used as new process technologies by future users. Generally speaking, the more application-oriented the content of the project, the closer to the market were the results actually achieved.

Technical Results

All large companies investigated have developed a demonstrator, or in some cases a prototype, jointly with their partners. These targets were stipulated in the EC programmes and were fulfilled in the EC projects investigated. The purpose of the demonstrator is to show technical feasibility, whereas the prototype already incorporates manufacturing and marketing aspects. A modular working method predominated here between the partners, i.e. the individual components were developed by the responsible partner in each case, and then assembled into a demonstrator or prototype. Often the prototype was only used within the project consortium. Only in two projects in which semi-finished products or new materials/new alloys were being developed were the prototypes sent for testing to potential customers outside the consortium.

The technical aim of one project investigated was to develop an advanced communication system for the private market. In particular it was hoped to achieve communication compatibility between various types of peripheral equipment (ISDN and analogue telephones, work station, PC, multimedia terminal, etc.). The distribution of work between the project partners was as follows: the main contractor was responsible for the local switch unit in the area of telecommunications and for the systems, and one partner was responsible for the fibre-based network and the data, transfer, while another dealt with resource management and call control. Three associates worked mainly on software and hardware specifications and on software implementation. The individual components were then assembled to form the demonstrator.

In other projects, application-oriented development and direct conversion of the results into marketable products was in the foreground. An example of the development of marketable products in cooperation with the partners in the consortium is provided by the three SMEs. The participating software companies and engineering bureaux implemented customer-specific new methods, models and products with their partners, who had generally had a customer relationship with them before the project was launched.

The customer-specific solutions were then tested by the partners and improved if necessary. The result of this interactive process between developer and user was optimization of existing products and the development of new products by the software firms.

In one project the major working areas were in the problem domain of inter-organizational business processes within logistics chains, the required logistics applications and integration of the underlying technologies. In close cooperation between developers and users several hardware and marketable software products were developed. Software components (in most cases extensions to existing systems) will be directly imbedded in a commercial environment and released for products. One software product had already been sold five times while the project was running.

In four projects there was an input to standardization bodies, even leading in one case to the introduction of a new norm. The main reason for this input is that the projects, or parts of them, are concerned with new basic methods.

The aim of one project in the area of automation technology was the development of specific integrated switches and the methodical description of their function in algorithms. In the course of the project the development of the method came strongly into the foreground, as it had been recognized that it formed the basis for the hardware and software solutions. Thus substantial method results were achieved, and many parts of them were subsequently incorporated into international norms.

As well as these "direct" technical results there were several "indirect" technical results whose importance was differently assessed by the various participants:

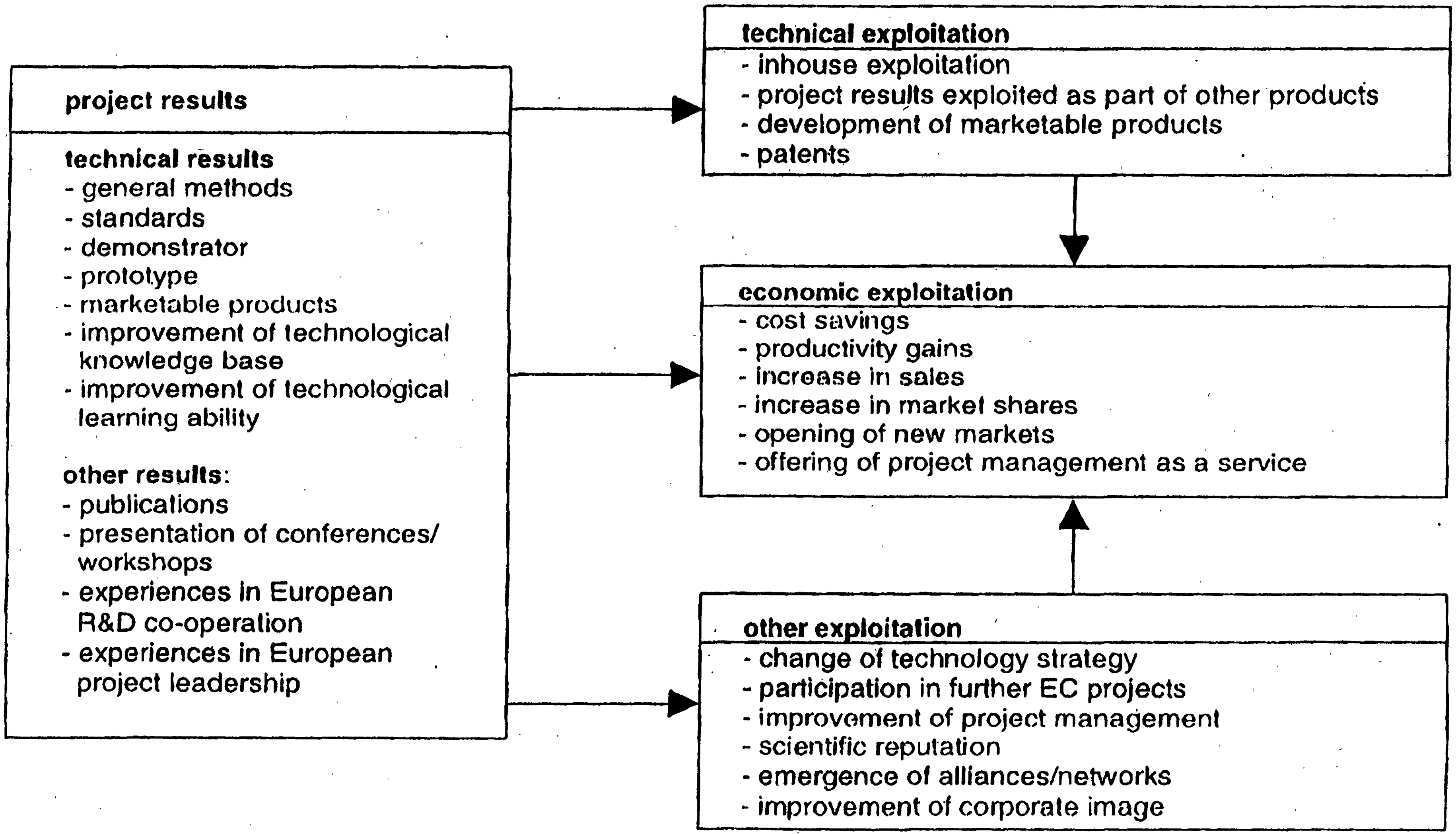
- increase in technological knowledge base,
- improvement in technical learning capability,
- publications in specialist journals and/or books,
- presentation of the results at conferences/workshops.

The indirect technical results (increase in technological knowledge base and improvement learning capability) were important for all participants questioned, as they form the basis for future R&D and improve the ability of employees to transfer (acquired) technological know-how into new products/processes, an important factor in the success of R&D projects.

Publications on the project results in the form of articles in specialist journals or books were seen by some of those questioned as being important for the research workers involved in the project. Firms used the publications as external presentation of the firm's technological competence, and as publicity for newly-developed products and processes.

Figure 4

(Possible) Results and Exploitation of EC R&D Projects



This "advertising" use also applies to presentation of the results at conferences and workshops.

Other Results

The so-called "other results" such as increased experience in European cooperation and experience in (international) project management were differently assessed by the project leaders. The importance is largely dependent upon whether the participants or the cooperating project workers were already experienced in carrying out international projects. Since large companies in particular have experience of project management and international cooperations, they tended to assess these other results as being relatively unimportant. However, increased experience of cooperation and project management at a European level plays a considerable role for first-time participants in EC projects. This applied in the case of large companies if the project under investigation was their first EC supported project, and for participating SMEs, whose experience in the management of international R&D cooperations tended to be smaller.

3.2 Exploitation of the results

In accordance with the aims of this element of our study we investigated the exploitation of the project results mainly within the firms and the exploitation of the complete project results within the consortium only as far as necessary.

In all cases investigated, the exploitation of project results was modular, i.e. the project results are being further developed and exploited by the partners individually. In none of the cases investigated were the results of the project marketed as a whole (as a "system") by the participating firms. This exploitation of results is generally regulated by contracts between the partners.

The following different forms of exploitation could be distinguished:

- technical exploitation,
- economic exploitation,
- other exploitation.

As seen in figure 4, these types of exploitation are interlinked. Whereas technical exploitation is relatively easy to record, it was difficult to obtain concrete figures on economic exploitation. In some cases customers for the new products still have to be found; in others the products are components of other products, so that their share in the turnover is not quantifiable. Moreover it was often not possible for the interviewees to ascribe savings or increases in turnover concretely to a specific cause.

If the projects were concerned with software development, the partners took on a user function, testing both hardware and software products. The marketing of the new products remained the province of the developing firms - in one project the main contractor even sold a newly developed software package while the project was still running. These firms also made use of the knowledge acquired in this way to improve existing products. Technical exploitation by the partners took the form of internal use of hardware and software in production processes. By the introduction of process innovations the partners were able to cut their costs and/or improve their productivity. In these investigated projects the results were being exploited economically by all participating firms.

In projects in which a prototype was developed, the further development/marketing of the components and/or their internal introduction as a process innovation were also left to the individual firms.

In almost all the projects, one or more marketable products were developed by the large companies investigated. Only in three projects is the demonstrator/prototype still at the testing stage. In two of these, however, possible products are expected to be ready for the market within the next two years; in one, some parts of the project results have already been incorporated in other products.

Often it is difficult to distinguish exactly between exploitation of results as a product innovation or a process innovation.

For instance, in one EC project concerned with image processing and its use in robotics, a demonstration system was built up. The prototype consisted of three modules which were developed independently of one another. The main contractor, who contributed to two of the modules, used one module (grey image processing) in-house in another part of the firm to improve existing manufacturing processes, while the other (grey scale sensor) was directly incorporated as a component in another product.

In five projects, process innovations were developed which were used in-house, i.e. within the firm or within the MNE, to improve existing manufacturing processes. These led to reduced costs and/or improved productivity, about which we only have concrete information in one case. This project is the only one of the 15 projects examined which was accompanied by a value analysis, thus documenting the project results and their exploitation.

In one EC project we investigated, the main contractor and the subcontractors developed and tested more than 50 products and made use of them in the areas of production planning, quality assurance and servicing/maintenance or in other areas of manufacturing. Of the 38 results of this project included in a value analysis, 11% were general methods (standards), 45% were prototypes, 21% were being used internally as *process innovations within the enterprise and 23% of the results were able to be converted into marketable products. Process innovations already installed while the project was running achieved savings of 2.4 million ECU in the first year.*

Patents were applied for in approximately one third of the projects studied, but were not regarded by interviewees as an important indicator of the success of the project. It should be noted that in the area of software the newly-developed programmes are not able to be protected under patent law.

Exploitation of the results by participating firms has not only been technical and economic; participation in EC projects and the added experience gained from them has led to other potential benefits, whose economic impacts cannot be assessed at the present time.

In about half the EC projects investigated they provided the basis for one or more successor projects. These were (or are) sometimes carried out with the same partners and sometimes with new ones. In some instances, the EC project has also formed the basis for a subsequent cooperation between the main contractor and one or more of the partners.

As already mentioned above, both publications and presentations at conferences and workshops were used by participating firms as a means of advertising.

It is difficult to assess the extent to which experience gained in the projects in the management of international R&D cooperations, especially by the SMEs included in our study, led to a general improvement in internal project management. In a few cases firms made use of the additional experience to offer (international) project management as a service.

In none of the firms investigated was the technology strategy changed because of the project results. A few firms changed their technology strategy due to a takeover by another enterprise or due to a changed technological environment.

3.3 Problems to Achieve Project Objectives and Barriers to Exploitation

It is important to distinguish between the problems arising whilst project objectives are being achieved and the barriers of exploitation. The first **can** occur during the running of the project and **can** have an impact on the achievement of project goals, e.g. technical problems need more time than planned or cooperation problems lead to a project breaking-off. Due to our definition of results and exploitation the barriers to exploitation **can** only occur if project results already exist. They **can** influence or even prevent the technical, economic and/or other exploitation of project results.

In five projects no problems have been identified and the technical aims were achieved. As mentioned above, the exploitation of project results was modular and no exploitation barriers exist according to the interviewee. It is particularly worth noting that the three projects conducted by the SMEs belonged to this group. These projects could be characterized as follows:

- the consortium was made up of developers and users, or of complementary firms,
- the partners were (technically) competent partners,
- the project was in an important business area for the firms,
- the individual sub-tasks to be performed were clearly defined and complementary in the consortium,
- project leadership was "tight" and disciplined.

For instance, in one of the investigated EC projects with five participants, the interviewee ascribed the success of the project to the following measures: project partners were chosen for both technical and competition policy reasons; a technically immature firm would not be considered as a partner, any more than a direct competitor. The individual modules and subsidiary goals were defined very precisely beforehand, including their timing and finance; common aims were incorporated into a higher-level framework and linked with the sub-systems of the partners. The sub-tasks of the individual partners were clearly defined and separated. The main contractor (project leader) was answerable on the one hand to the steering group of the EC committee (made up of EC representatives and other industrial firms) for economic procedure and project success, and on the other hand to a specialist committee of project and sub-project managers regarding the specialist development of the project.

Problems to Achieve Project Objectives

In three of the projects investigated there were **cooperation problems**; however, only in one case did these problems - emphasized by the attitude of the responsible EC representative - lead to the project being broken off prematurely. In both the other projects the technical aims were achieved and the main contractors developed and sold marketable products.

Altogether there were **technical problems** in three projects. The technical goals being aimed at were not fulfilled during the running of the project. This was not so much due to the technical feasibility aspect; either the procedure originally chosen proved to be too cost-intensive or not economically feasible, or the technical development proved more complex and thus more time-consuming than planned at the beginning of the project.

Barriers to Exploitation

Changes in organizational structure and changes in entrepreneurial strategy were identified as **internal barriers** to economic exploitation. The technical goals of the project were achieved, but due to the changed internal circumstances the involved unit or firm could not exploit the project results in an economic way.

For instance, the firm under investigation was taken over, with the result that the high-performance switch developed in the project was tested by another member of the MNE and also put to use there as the results were positive. The ultimate goal of the project when it began had been to establish the new process as a field of business. However, as the new parent MNE does not wish to open up any new fields of business and the functional field in which the project lay is losing importance within the MNE, the interviewee suspects that the MNE will approach an external enterprise and offer to sell it the process. The project was started under different conditions, and due to restructuring the aims of the relevant business unit have changed. Thus it should be noted that "the project would no longer be possible, given the present aims and would no longer have been carried out today."

External prevailing conditions such as general technological development or lack of customer demand can influence the exploitation of the project results. In a few cases the general technological development literally overtook the project and prevented a technical and/or economic exploitation.

For instance, the lack of technical success of one of the projects investigated could not have been foreseen with the know-how available at the time when the project was started. This project was "overtaken" by software development. The hardware solution being aimed at was never built, as the goals it was initially intended to pursue were now able to be achieved more cheaply using software.

Lack of acceptance by potential customers, or lack of demand, caused in part by general technological developments, prevented market introduction of the developed, marketable products from taking place in two projects. The knowledge gained was not transferred into marketable products but tended to be "put away in a drawer".

As seen above, these external barriers to exploitation influence respectively prevent an exploitation of the project results in a technical and/or economic way. The question of how helpful market forecasts or technology forecasting instruments could be in assessing future market potentials and technological developments was not examined.

4. The Role of the EC

In order to assess the impact of EC supported projects on technology transfer of firms it has to be taken into account that 12 of our R&D establishments investigated belonged to MNE. For these companies EC funding only plays a minor part in financing their R&D activities and can be considered as a "drop in the ocean". For instance, a MNE located in Germany funded nearly all of its R&D expenditure internally; publicly supported R&D by Bonn and Brussels amounted to barely 3% of the total R&D expenditure in 1990.

The selection and controlling of the projects by the EC is based mainly on project related criteria and not on one firm's specific criteria. The applicant must prove his scientific qualifications and the ability to manage a project in EC dimensions. Therefore in the projects investigated, no factors on the part of the EC could be identified which influenced internal technology transfer. If the EC were to want to exert any influence on this aspect, it would have to stipulate when awarding EC projects how the project should be organized internally, and what functional groups should participate.

We could not ascertain any impacts of the EC support on the internal R&D management of firms in the projects we investigated. If need be - and in a few cases only - the participation in an EC project improves the ability, especially of the project leaders, to manage European cooperation R&D projects. This basically only affects firms which are cooperating for the first time at a European level and have to find partners from other countries. These firms, especially SMEs, have to familiarize themselves with the requirements of European project management.

In some of the projects investigated, the EC influenced the choice of partners. This did not generally affect the project as a whole but only individual partners. These consortia assembled for "policy reasons" were judged with scepticism by the main contractors, who considered that the "political" partners lacked the technological competence and management capabilities necessary to participate in R&D projects of this kind.

In almost all cases the interviewees criticized the administrative demands of EC projects. Especially SMEs with their limited number of employees and financial resources have problems to finance the procedure of application, which needs, including the seeking and choosing of suitable partners, up to 3 months. Some interviewees, even managers of MNEs, said that the expenditure was out of all proportion to the achieved results: "EC projects are a subsidized business."

The great importance of the EC in this respect lies in its support of European R&D cooperation on the strategic level of the enterprises and in its financial support of R&D projects on the tactical (executive) level of the enterprises. In our study, three projects would have been carried out without the EC support; this was a pure "free rider" effect. In the rest of the projects, the EC fulfilled a necessary financing function. In these cases, according to statements by the interviewees, the projects would not have been carried out in their final extensive form without EC support. Especially in the case of the three SMEs, whose partners in the projects were also mainly small and medium sized firms, the projects could not have carried out without support, due to limited research and development budgets.

5. Summary

In approximately half the EC projects examined, the ideas came from the R&D unit in which the EC project was subsequently performed. The projects were clearly technology-pushed and were based on technology lines already present in the R&D laboratory or the R&D department of the business unit. The process of idea generation in the EC projects carried out by the three small and medium sized software firms, on the other hand, was quite different. These SMEs placed a high value on the generation of ideas; nevertheless the project idea was discussed at an early stage with the customer, with whom the firm was already in contact. Thus the project idea was developed in interaction between software developers and users. In these three EC projects, both the developer and the user were subsequently represented in the consortium.

One project was discontinued in an early stage. In almost all the other projects investigated, one or more marketable products as well as new or improved processes were developed by the enterprises. Only in three projects the demonstrator/prototype was still at the testing stage. In two of these, however, possible products are expected to be ready for the market within the next two years; in one, some parts of the project results have already been incorporated in other products.

In all cases investigated, the exploitation of project results was modular: The project results were being further developed and exploited by the partners individually. In none of the cases were the results of the project marketed as a whole ("as a system") by the participating firms.

Exploitation of the results by participating firms had not only been technical and economic; participation in EC projects and the added experience gained from them has led to other potential benefits. In about half the projects the basis was provided for one or more successor projects. These were (or are) sometimes carried out with the same partners and sometimes with new ones. In some instances, the EC project had also formed the basis for a subsequent cooperation between the main contractor and one or more of the partners.

It is difficult to assess the extent to which experience gained in the management of international R&D cooperations, especially by the SMEs included in our study, led to a general improvement in internal project management. From the view of the interviews there was no impact of the EC projects on the internal management or organizational structure of the enterprise.

A few firms made use of the gained experience as a project leader of the EC consortium and offered project management as a service for other enterprises to manage cross-border projects.

The R&D projects supported by Brussels served as a catalyst for the cooperation of the large companies with other European firms. However, for these companies EC funding only played a minor part in financing their R&D activities. The large companies only applied for EC projects if they suited their technology strategy and their R&D portfolio. For these reasons the EC support could not generate new ideas and had less (or no) impact on the technology transfer process within the firms.

In the case of the three SMEs we found that there existed "European oriented business networks" which shaped the basis for "European oriented R&D networks". Partners of these business networks applied for EC support as parts of existing networks. The EC projects encouraged these network-relationships on European level and favoured the enlargement of the business networks with R&D activities.

European Commission

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This report sets out the findings of a study concerned with the ways in which projects sponsored by the EC Framework Programme are approached and managed by firms and the factors that affect the exploitation of their results.

The background to the study lies in the prevalent thesis that the competitiveness of European firms is related to their efficiency and effectiveness in exploiting the results of R&D. Two issues are put forward under this thesis. The first relates to the R&D management patterns prevailing in Europe, as opposed to those in other parts of the world. The second concerns the impact of the EC Framework Programme on the ability of firms to exploit results of EC Framework Programme projects.

The two issues are linked. At one level, the management of the R&D process is intimately related to the ability to exploit its results. At a more basic level there is a relationship between the fundamental mission of EC R&D to promote Europe's industrial competitiveness, and the creativity and innovativeness of European firms.

These relationships define the object of this study, which focused on the ways in which firms manage the R&D process and the exploitation of its results, as much through their own initiatives as through EC sponsored projects.

The findings are based on 41 interviews carried out in Germany, the UK, France, Italy, Denmark, Belgium, the Netherlands, Greece and Ireland, with firms leading ESPRIT, BRITE, ECLAIR, Ray Materials and RACE projects which provided in-depth insights to the impact of the Framework Programme on the technology strategies of firms and to the factors that affect their willingness and ability to exploit the results of EC R&D projects.

The report presents a number of key observations and lessons.

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