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Project coordinator: Yannis Caloghirou
Laboratory of Industrial and Energy Economics
National Technical University of Athens

Partners:

1. Laboratory of Industrial and Energy Economics, National Technical University of Athens, (LIEE/NTUA), Greece (Project Coordinator)

2. Maastricht Economic Research Institute on Innovation and Technology (MERIT), University of Maastricht, The Netherlands

3.Strategic Industrial Research Networks (SIRN), United Kingdom

4.Centre of Research on Internationalization (CESPRI), Universita Commerciale Luigi Bocconi, Italy

5.Bureau D' Economie Théorique et Appliquée (BETA), University of Strasbourg (ULP), France

6.International KonkurrenceEvne (IKE), Department of Business Studies, Aalborg University, Denmark

7.Zentrum für Europäishe Wirtschaftsforschung Mannheim (ZEW), Department of Industrial Economics and International Management , Germany

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Final Report

INNOVATION - RELATED KNOWLEDGE FLOWS IN EUROPEAN INDUSTRY : Extent, Mechanisms, Implications

KNOW FOR INNOVATION

Yannis Caloghirou
Laboratory of Industrial and Energy Economics
National Technical University of Athens

Natasha Constantelou
Laboratory for Industrial and Energy Economics
National Technical University of Athens

Nicholas S. Vonortas
Director, Center for International Science and Technology Policy
&
Department of Economics
The George Washington University

Consortium Partners:	***1. Laboratory of Industrial and Energy Economics, N ational Technical University of Athens, (LIEE/NTUA), Greece (Project Coordinator)***
	2. Maastricht Economic Research Institute on Innovation and Technology (MERIT), University of Maastricht, The Netherlands
	3.Strategic Industrial Research Networks (SIRN) , United Kingdom
	4.Centre of Research on Internationalization (CESPRI), Universita Commerciale Luigi Bocconi, Italy
	5.Bureau D' Economie Théorique et Appliquée (BETA), University of Strasbourg (ULP), France
	6.International KonkurrenceEvne (IKE), Depa rtment of Business Studies, Aalborg University, Denmark
	7.Zentrum für Europäishe Wirtschaftsforschung Mannheim (ZEW), Department of Industrial Economics and International Management, Germany

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EXECUTIVE SUMMARY

1.1. CONTEXT

There is by now a large body of theoretical and empirical research that supports an active Science and Technology (S&T) Policy. In the case of the European Union (EU), a complex nexus of S&T policies are already in place at three levels of govern ance: European Union, EU member state, and local/regional. Core S&T policy concerns of the EU include raising the competitiveness of European industry, developing a European "economic space" and European "research area", narrowing the "technology gap" amon g EU member states, and improving the economic and social cohesion within the region. These pan -European goals require policies to enhance linkages among knowledge -intensive activities in different EU member states and regions.

Contemporary S&T policies a re complex both in terms of programme coverage and implementation. The complexity is due to the effect on policy making of intensified global competition, political and economic constraints, and significant advances over the past fifteen years in our under standing of the process of technological advance. These advances have led to a better understanding of the impact of technological innovation on competitive advantage and economic growth, and the direct and indirect effects of an accelerating pace of innovation on modern economies. One must add to these the development of a theory of National Innovation Systems (NIS), which has emphasized the institutional and spatial dimensions of the technological innovation process.

Still, few would doubt that the devel opment and application of sophisticated S&T and related policy instruments has been subject to considerable uncertainty. A major problem is the lack of systematic empirical evidence to verify theories of the process of technological innovation, to determi ne the needs of the innovation system, and to test the efficacy of different policy instruments. The problem is especially acute in service industries, an embarrassing omission for service -based economies. Analysts are often forced to base their reasoning on relatively circumstantial and/or fragmented empirical evidence or on a limited range of innovation proxy indicators such as research and development (R&D) expenditures and patent counts, which frequently prove inadequate for the task at hand. In respons e, serious efforts are currently underway at the OECD, the European Commission, and individual countries to create better innovation indicators, to improve data coverage, and to harmonize methodology and analytical practice. These efforts have already bare d fruits: a considerable amount of relevant empirical data has become available recently which has not been fully exploited.

1.2. OBJECTIVES

The goal of the KNOW programme has been to empirically appraise the diffusion of knowledge of relevance to the innova tive activities of European industry, including both manufacturing and service sectors. The appraisal has focused on questions of interest to regional, national, and pan -European science, technology and innovation policy.

To achieve this goal, we've launched a major empirical investigation of the traditional and emerging routes of innovation related knowledge dissemination in European industry. This includes knowledge flows between industrial firms as well as between firms and other sources of relevant knowledge such as universities, technical institutes, and government laboratories. Recent advances in the theory of innovation systems have guided the empirical investigation. The results have been used to evaluate the successes of implemented policies, suggest improvements to existing policies and to point out future policy options regarding the creation and transmission of new technological knowledge in the European Union.

The KNOW programme has had several research *objectives*:

(1) Examine the extent, magnitude, and type of innovation-related knowledge flows affecting European industry.
(2) Evaluate the effectiveness of the identified knowledge transmission mechanisms in raising the ability of European industry to innovate and create economic value.
(3) Evaluate the effect of the nature of economic agents, of the nature of market competition, and of the nature of the technology on the mechanisms and frequency of knowledge flows.
(4) Determine the spatial dimension of national, regional, and transnational innovation-related knowledge flows. Specifically, determine whether these flows are largely limited to national or regional systems of innovation or whether they are increasingly becoming pan-European or global.
(5) Appraise the degree of convergence of national innovation systems in Europe, to the extent that such convergence may be indicated by knowledge flows between economic agents.
(6) Derive recommendations to guide future policy options towards facilitating the access to and the transmission of innovation-related knowledge in order to encourage innovation in European industry and sustain/create new competitive advantages.

The programme has dealt with the extent, density, and mechanisms of innovation-related knowledge flows affecting the innovative capacity of European industry and the mechanisms that support such flows. The programme has also examined the incentives to access and transmit knowledge and the determinants of knowledge transmission. *On the basis of the observed knowledge flows and of the evolution in the determinants and transmission mechanisms of such flows, the programme made inferences about the nature of the innovation systems that sustain and are influenced by such flows as well as about the tendency for these innovation systems to converge into a larger European Innovation System.*

1.3. METHODOLOGY

The KNOW programme has focused exclusively on disembodied knowledge flows. These utilize channels such as inter-organizational cooperation through both formal and informal partnerships; accessing the intellectual property of others through both traditional and modern means of communication (e.g., scientific journals, internet); movement of skilled personnel; scientific and community memberships; and other sources of competitive intelligence. Embodied knowledge flows, inc luding the transfer of knowledge between buyers and sellers incorporated in products, even though very important, were determined to be out of this programmed's domain.

In order to achieve the research objectives listed above, the seven members of the KNO W consortium pursued the following analytical goals:

- Review the evolution of policies within the EU that are of relevance to knowledge diffusion and the current policy context, using, among other sources, the *Green Paper on Innovation* and the *First Action Plan for Innovation in Europe*. This review of the current menu of policy options and policy concerns would assist in the identification of the types of information and data analysis that can assist policy making in this area.

- Describe the sources of inno vation-related knowledge, the extent of knowledge flows and the routes of knowledge transmission for industrial innovation in both the European Union and seven member states, using four existing data sources: the European Patent Office (EPO) patent applica tions and citations database; the first Community Innovation Survey (CIS); the PACE survey of Europe's largest R&D performing firms; and the STEP-TO-RJVs databank of cooperative research projects (research joint ventures) established in Europe through the Framework Programmes on RTD and EUREKA.

- Supplement the information from these data sources by conducting extensive field research – focused survey of a large number of companies followed up by in -depth interviews of a select sample of them – to obtain mis sing information at the level of the firm and of specific events of knowledge dissemination.

- Appraise the methodological issues that arise when combining qualitative and quantitative information from diverse data sources that are not necessarily easily li nked.

- Examine mechanisms of access to and dissemination of innovation -related knowledge in terms of the type of knowledge and the nature and geographic location of the agents involved. Analyze the influence of several firm, sector and national characteri stics on the ability of firms to be active partners in European knowledge flows. Try to determine if there are missing links/mechanisms of transmission for some types of knowledge and the extent to which these are more pronounced in the case of regional, n ational, or international knowledge flows.

- Evaluate the effect of "knowledge spillovers" on the innovative performance of European industry.

- Link the results from the above analyses to the innovation policies of the EU and EU member countries in order to discuss:
  - (i) The success of S&T policies in assisting European industry to access and benefit from innovation -related knowledge flows;
  - (ii) Progress in NIS convergence and emergence of a European Innovation System;

(iii) Policy options to improve the flows of innovation-related knowledge across EU member countries and regions in order to enhance cohesion and ensure the long-term viability of a European Innovation System.

The KNOW programme was heavily empirical, involving the exploitation of several large databases and new information from extensive business surveys and in-depth company interviews. The program evolved in five stages. During the first two the partners created the methodology, prepared the data, and collected new information. The last three stages supported analytical work. The programme has used empirical information from six different databases, some of which were modified and enhanced during the course of the programme. These databases include:

(a) The EU-RJV database which records information on transnational collaborative research projects funded by the European Framework Programmes on RTD (FWPs) and on their participants. The current version covers projects initiated by the first four FWPs during 1983-1998.
(b) The EUREKA-RJV database which records information on transnational collaborative research projects selected by the EUREKA! initiative during 1985-1996.
(c) The PACE database which contains the results of an innovation survey for 604 of Europe's largest R&D performing firms. The original survey was conducted in 1993.
(d) The RJV-EPO database which has combined information at the firm level from the EU-RJV database, the EPO-CESPRI database, and the EPO-MERIT database. The EPO-CESPRI database contains information about all patents applied for and granted by the European Patent Office (1978-1998). The EPO-MERIT database contains information on patent and non-patent literature cited in European patents.
(e) The first Community Innovation Survey which was carried out during 1992-1993 in thirteen European countries, including twelve members of the European Community. It contains information on the innovative activities of approximately 40,000 European firms.
(f) The KNOW survey database which contains the results of a new, focused survey of 558 innovative firms in five industries and seven countries. The industries are food and beverages, chemicals (excluding pharmaceuticals), communication equipment, telecommunication services, and computer-related services. The countries are Denmark, France, Germany, Greece, Italy, the Netherlands, and the United Kingdom. The survey gathered detailed information on the specific internal and external mechanisms and institutions that support innovation-related knowledge flows and of the procedures that facilitate learning.

Finally, an additional source of information has been a large number of in-depth interviews with a subset of the surveyed companies, again concentrating on mechanisms and institutions supporting knowledge flows but also emphasizing related firm strategy.

1.4. RESEARCH RESULTS

The KNOW programme supported extensive empirical research, both quantitative and qualitative. Key research findings are listed below.

Descriptive Analysis

1. *CIS 1 (Firms of all sizes; manufacturing sectors)*

- Customers are of the highest significance as e xternal sources of information, followed by suppliers and competitors. Unweighted tallies of firms may, however, bias the results by over representing the preferences of SMEs. For example, larger companies reportedly prefer to cooperate in R&D with univers ities and other public research institutes (PRIs)much more frequently than their smaller counterparts.

- Traditional mechanisms of external knowledge transfer such as fairs and exhibitions, conferences and other meetings, and journals remain very important sources of innovation.

- Innovative companies tend to cooperate above all with suppliers and clients in vertical relationships.

- The probability of knowledge inflows and outflows and the probability of cooperating in R&D rise with firm size.

- National chann els of knowledge communication are still used more often than international channels.

2. *KNOW Survey (heavily SMEs; three manufacturing, two service sectors)*

- Traditional activities such as a ttending trade fairs and conferences, and reading scientific and b usiness journals are reportedly the most important source of new ideas for innovation in the examined seven countries. Reverse engineering has lost none of its lustre.

- European SMEs do not search patent databases for creative ideas.

- In most countries, se crecy is the preferred strategy of intellectual property protection. Developing lead-time advantages is also very important. With the exception of chemicals, patenting is way down the list in terms of frequency of use. The value of patents is particularly low in the two ICT service sectors.

- Firm size seems partly related to the reported low priority of patents as a mechanism of intellectual property protection. A larger share of mid -sized firms (above 250, below 1250 employees) than smaller firms cite pate nts while smaller firms are more likely to cite secrecy as more important. Almost twice as many mid -size companies as small firms have patented their economically most important innovation. Other factors apparently relate to the nature of the technology (c hemicals patent more), industrial structure (firms with many competitors prefer secrecy), and the innovatory activity in the firm (R&D continuity positively influences the propensity to patent). The tendency to patent also varies across countries.

- Customers, suppliers, and competitors are very important sources of information for innovation in the surveyed SMEs. This agrees with the picture emerging from the extensive CIS 1 and CIS 2 pan -European surveys.

- The economically most valuable innovations are pul led by demand: customers are the dominating sources for the original ideas of innovations. On average, suppliers and competitors also seem to be important sources of knowledge for innovation. Significant differences between countries exist.

- In addition to serving as frequent sources of the original idea, customers and suppliers are most frequently mentioned as the important contributors to the completion of the innovation.

- Internal knowledge is highly valued as a contributor to innovation in all countries , especially in Germany and Britain. Italian firms seem to have the most balanced approach to internal versus external source of information. Dutch firms seem to be more open to external sources of innovation than their European counterparts.

- National sources continue to dominate as the important external sources of innovation - related knowledge, at least as far as the surveyed SMEs are concerned. Firms of smaller countries like Greece, Denmark and the Netherlands tend to be more internationally orientated than those located in the large countries.

- The dominant reasons for obtaining knowledge from the most important external source reportedly include reducing development costs and risks, increasing the technical expertise of the firm, and building on the re search findings of others.

- Previous experience is by far the most effective way of getting in contact with the most important external source of knowledge, followed by participation in trade fairs and conferences. Business and professional associations se em to play a quite distinct role in that respect in the United Kingdom. British first, and then French, Dutch and Italian firms also use the Internet for that purpose. German firms seem to behave differently.

- Scientific and technical information is the do minant type of knowledge obtained from the most important external source, followed by knowledge relevant to market introduction. By far, the most frequent method of communication with external source of knowledge is informal personal contacts, followed by research cooperation. Exchange of personnel and other methods are also used in some countries (e.g., France, Netherlands) more than in others.

- The large majority of surveyed firms use the Internet regularly in every-day business. Firms in the computer services sector lead in Internet use, followed by firms in the chemical sector. Dissemination of the Internet technology is still poor only in the food and beverages sector. The lowest use of the Internet was reported in Greece. Almost all users reported using the Internet to access scientific and technical information and to communicate with their suppliers, customers, and collaborators. Internet use is found positively related to the level of scientific personnel, the R&D intensity of the firm, and to the size of the firm.

3. RJV-EPO Database (Firms of all sizes; all sectors)

- The RJV network of projects initiated through Framework Programmes during 1992 - 1996 is quite dense. The network is also highly heterogeneous: a few agents with many ties coexist with a much larger number of agents with few ties placed in more peripheral position in the network.

- A relatively small number of agents have played a very important role as co-ordinators of cooperative projects. These agents are, on average, more innovative and they occupy more central positions in the RJV network.

- Universities and other large research organizations have played a disproportionately larger role than private sector firms as core actors the RJV network during the examined time period. In contrast, large companies have been much more central than universities and research organizations in the European patent network.

- Only a small fraction (less than 15%) of all participating entities in the examined RJVs had registered patent applications at the European Patent Office in the period 1978-98.

- Apart from very large innovative firms, there is no clearly detectable relationship between RJV participation and the position in the RJV network, on the one hand, and between the extent of innovative activity and the position in the citation flow network, on the other.

- The knowledge-intensive network to which the RJV participants refer in their patent citations has a clear European rooting. About half of all citations are directed to European organizations of all kinds, with the remaining directed primarily to organizations in the United States and in Japan.

<u>Statistical Analysis</u> (All databases except CIS)

- European research networks show "small world" properties, an ideal form of network featuring high levels of local clustering and higher speeds of knowledge transmission. The network of Framework Programme sponsored RJVs comes closest to the "small world" model. The network of EUREKA RJVs and the more informal network of European patent citations also resemble small worlds. The theoretical model fits less well the latter two cases. Overall, the analysed European research networks, and particularly the network of Framework Programme RJVs, are relatively efficient means of knowledge transfer.

- There is a need to address more aggressively in the future the issue of *self-selectivity of RJV members* in European Framework Programme RJVs. That is, the identified positive correlation between patenting activity and participation may reflect the higher propensity of more innovative agents to participate, rather than the success of these RJVs to raise the innovativeness of participating companies.

- The evidence of self-selection blurs when distinguishing between different technological areas and becomes more difficult to detect in different size classes. A comparison between the field of information and communication technology (ICT) and medical and biotechnology (MB) is stark. The examined set of RJV participants tend to be more innovative than non-members in both cases. However, while in the ICT area European programmes have attracted highly R&D-intensive firms that were already remarkably more innovative than the average European level, in the MB area early RJV members did not exhibit high levels of patenting prior to entry. And, while size was positively related with patenting activity in the ICT field, no such clear relationship emerged in the MB field.

- Put differently, such evidence indicates Framework Programme RJVs may have reinforced existing leaders and networks in Information and Communication Technologies, a relatively more "mature" field, where a "network of excellence" has already emerged and hierarchy of innovators is rather stable. In contrast, Framework Programme RJVs seem to have favoured the exploitation of the innovative potential of new actors in Medical Technologies and Biotechnology, a more fluid, emerging field.

- The benefits from cooperative R&D are positively related to the firm's in-house technical capabilities, especially the ability to undertake R&D. Cooperation seems to complement, rather than substitute for, internal technical capabilities. In order to benefit from R&D cooperation, a firm must keep upgrading its knowledge base and technical capabilities. The nature of the relationship may, however, depend to some extent on the nature of the industry and the technological field. More work is needed in this regard.

- In all five sectors surveyed for KNOW, over 63% of product/service innovations are developed in-house, between 9% and 13% are bought in, and around 20% are developed via collaboration. Empirical results show that the share of innovations developed in-house has a positive and statistically significant effect on the innovative sales share of surveyed firms, contrary to the share of innovations developed via collaboration that has no statistically significant effect. This result raises some questions regarding the advantages of excessive collaboration, even though the analysis shows that some collaboration is beneficial. More work is needed in this regard.

- With the exception of the chemical sector, most firms in the KNOW survey cited secrecy and lead time as more important protection methods than patents, with the exception of the chemical sector. The value of patents appeared particularly low in the two ICT service sectors and for smaller firms. Three-quarters of the most important innovations had not been patented. The probability of patenting the most important innovation was found to rise with:

(a) specialization in chemicals and telecom equipment;
(b) product innovations;
(c) R&D intensity of the firm;
(d) share of R&D spending on external sources;
(e) firm size;
(f) the receipt of government subsidies.

- Pioneering recent work in Europe and the United States has pointed out geographical clustering features of knowledge-related activities. Technological knowledge and spillovers seem to be geographically localized. The KNOW programme produced preliminary evidence of regional clusters of organizations participating pair wise in Framework Programme RJVs. Such clusters seem to involve neighbouring European countries. One such cluster seems to involve Nordic countries. Others seem to involve France, Belgium and the Netherlands. Several other examples have also been indicated. More work is also needed in this regard.

- PACE, a survey of Europe's 615 largest industrial firms in the early 1990s, shows that a quarter of respondents gave their highest score to PRIs as an important source of innovation-related knowledge. The value of PRIs was particularly marked among high technology firms, with 37% of these firms giving their highest score to PRIs. These findings contrast sharply with those of CIS 1 and CIS 2 and of the KNOW survey which find that PRIs are a comparatively unimportant knowledge source for most firms. The main explanation of the discrepancy is that PACE is limited to the largest firms, more likely to use knowledge obtained from PRIs. The findings from the other surveys largely measure the importance of PRIs to smaller and/or less innovative firms, which make up the majority of respondents.

- Essential questions for innovation policy are (a) if proximity matters to knowledge flows and (b) if yes, how do these flows occur and what are the conditions for their success. Answers to these questions are of relevance to an assessment of a range of government policies to support close linkages between firms and between firms and universities and PRIs. Weighted data for Europe's largest firms (PACE) indicate that sourcing of technical knowledge from PRIs is subject to localisation effects: almost half of the interviewees rated domestic public research as more important than foreign sources; a very small proportion rated national and foreign PROs in reverse order. Geographical proximity effects increase with the quality and availability of outputs from PRIs in the firm's domestic country. They decline with rising R&D expenditures, with increased importance attached to basic research results in scientific publications, and with experience in the North American market. New technologies that increase the amount of codified knowledge produced by PRIs and decrease the time between discovery and codification could decrease the proximity effect.

- Within a single country the geographical distribution of a sector like ICT would be expected to depend on:

(i) A "metropolis" effect – because many of the ICT service activities typically are concentrated in cities, such as publishing, advertising, broadcasting, computer software development and services, telecom services.
(ii) The supply of skilled labour, such as engineers, computer scientist, business economists, etc., which again is expected to be a function of location of universities and business schools, often determined by government decisions.
(iii) A "random" location of manufacturing firms due to person al preferences among the original founders.

- Such a pattern is indeed verified in the case of a small Nordic country. The strong "metropolis" effect on regional ICT specialization is counterbalanced at the more detailed industry the rather decentralised na ture of the public education system. On the whole, there is a rather close correlation between the distributions of basically government financed R&D and higher education institutions in ICT and the regional distribution of private employment. Engineers an d computer scientists typically choose jobs close to these institutions. More specialised small -scale clusters usually emerge around these.

1.5. POLICY IMPLICATIONS

1. The channels and mechanisms of knowledge flows define the links that make up production and innovation systems. As such, they relate directly or indirectly to all policies that affect such systems. At a minimum, they relate to the entirety of the spectrum of science, technology and innovation policy, being particularly akin to policies that provide incentives to access and disseminate knowledge and policies affecting learning processes. Knowledge flows are also directly related to intellectual property protection policies and competition policies that create the infrastructure supporting various forms of formal interaction among economic agents in production and innovation systems.

2. The importance of policies concentrating on national channels of knowledge flows remains high. International channels are, however, developing fast and will increasingly attract policy attention. Coordinating the two will become inevitable soon, especially in closely nit country groupings like the European Union.

3. Policies to enhance the absorptive capabilities of firms remain key. They are probably more important now than ever before.

4. SME innovation is strongly affected by their most important customers / suppliers.

5. The Internet has neither replaced traditional channels of knowledge flows nor is it expected to do so any time in the foreseeable future. In contrast, the Internet has added another very important channel for communication and knowledge exchange. Firms have embraced it enthusiastically. Policy can broaden access and methods of utilization.

6. Despite the contemporary climate for stronger IPR protection, European SMEs neither search patent databases for creative ideas nor strive to apply for patents.

7. The implementation of policies to promote cooperative R&D during the past couple of decades has resulted in the formation of formidable knowledge communication networks across Europe. The thrust should be maintained.

8. A relatively small number of organizations, including primarily large companies, universities and a few PRIs, have emerged as core players in European cooperative R&D activities, playing a disproportionately important role in maintaining channels of communication than their counterparts. It is conceivable that the same organizations will emerge as the core players in the new "networks of excellence" currently debated in the context of the 6th Framework Programme.

9. The knowledge-intensive network to which the innovative RJV participants refer and against which they benchmark has a clear European rooting.

10. Cooperative R&D programmes could have differential effects across industries and technology fields depending on the degree of maturity of the industry. Attention to sector dynamics is warranted during programme design and evaluation. For example, at the early stages of technological development and competition in an industry, policy should attempt to create networks of excellence and to open up existing networks to potential innovators by promoting R&D-intensive programmes that are strongly technology-oriented. At later stages of the life cycle, when the industry is technologically mature and networks of leading actors are well established, a more effective policy target would be to link peripheral actors to extant networks, favour a broad diffusion of knowledge, and guard against the use of collaboration for the creation of unreasonable barriers to entry.

11. Geographical proximity matters to knowledge flows and this can be a strong influence for the localization of production and innovative activity. The explanation is multi-faceted and calls for complex policy approaches to creating regional competitive advantages.

Innovation-related knowledge flows define the links that make up production and innovation systems, thus relating to all policies that affect these systems. Governments should be aware of the fact that most of their industrial, science, technology and innovation policies will impact the channels, direction, and intensity of knowledge flows affecting industry. Put differently, in order to be effective in leading a country/region to the new, knowledge-intensive, "learning" era, science, technology and innovation policy must build bridges and blend with broader economic and social policies. This requires a more synthetic policy approach than in earlier decades.
Such a message is in concert with contemporary technology/innovation policy thinking in Europe as reflected in the discussion over the European Research Area, the Sixth Framework Programme for RTD, and the Action Plan e-Europe 2002.

Section 2

BACKGROUND AND OBJECTIVES OF THE KNOW PROGRAMME

There is by now a large body of theoretical and empirical research that supports an active Science and Technology (S&T) Policy. In the case of the European Union (EU), a complex nexus of S&T policies are already in place at three levels of governance: European Union, EU member state, and local/regional. Core S&T policy concerns of the EU include raising the competitiveness of European industry, developing a European "economic space" and European "research area", narrowing the "technology gap" among EU member states, and improving the economic and social cohesion within the region. These pan-European goals require policies to enhance linkages among knowledge-intensive activities in different EU member states and regions.

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Still, few would doubt that the development and application of sophisticated S&T and related policy instruments has been subject to considerable uncertainty. A major problem is the lack of systematic empirical evidence to verify theories of the process of technological innovation, to determine the needs of the innovation system, and to test the efficacy of different policy instruments. The problem is especially acute in service industries, an embarrassing omission for service-based economies. Analysts are often forced to base their reasoning on relatively circumstantial and/or fragmented empirical evidence or on a limited range of innovation proxy indicators such as research and development (R&D) expenditures and patent counts, which frequently prove inadequate for the task at hand. In response, serious efforts are currently underway at the OECD, the European Commission, and individual countries to create better innovation indicators, to improve data coverage, and to harmonize methodology and analytical practice. These efforts have already bared fruits: a considerable amount of relevant empirical data has become available recently which has not been fully exploited. This situation underscored the KNOW research programme.

> *The goal of this programme has been to empirically appraise the diffusion of knowledge of relevance to the innovative activities of European industry, including both manufacturing and service sectors. The appraisal has focused on questions of interest to regional, national, and pan-European science, technology and innovation policy.*

To achieve this goal, we've launched a major empirical investigation of the traditional and emerging routes of innovation related knowledge dissemination in European industry. This includes knowledge flows between industrial firms as well as between firms and other sources of relevant knowledge such as universities, technical institutes, and government laboratories. Recent advances in the theory of innovation systems have guided the empirical investigation. The results have been used to evaluate the successes of implemented policies, suggest improvements to existing policies and to point out future policy options regarding the creation and transmission of new technological knowledge in the European Union.

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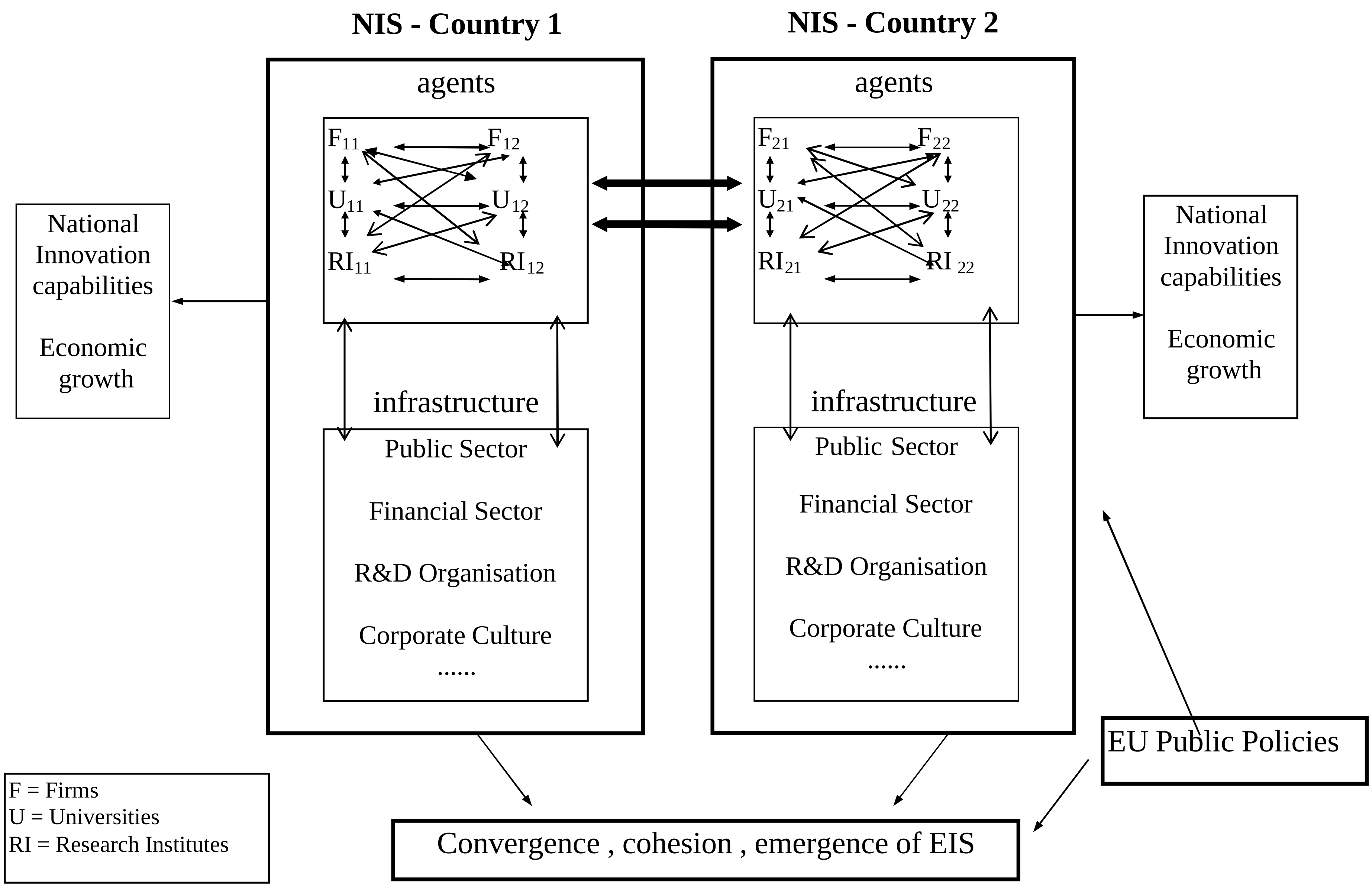
(12) Derive recommendations to guide future policy options towards facilitating the access to and the transmission of innovation-related knowledge in order to encourage innovation in European industry and sustain/create new competitive advantages.

Figure 2.1 provides a simplified schematic of innovation-related knowledge flows and innovation systems in an attempt to place the KNOW programme in perspective. For simplification reasons, the Figure shows only some important elements of the national innovation systems (NIS) of two countries, including three kinds of economic agents (firms, universities, research institutes) and some features of the infrastructure supporting the NIS. The arrows indicate linkages between the economic agents within a NIS, as well as across NIS's, which result in innovation-related knowledge flows. Linkages can be formal, such as through a joint venture, or informal, such as through patents and informal communication. In the Figure, the NIS is assumed to determine national innovative performance, which, in turn, influences the rate of economic growth of a country. The strength of the linkages and corresponding knowledge flows between the two (assumed European) NIS through time is hypothesized to indicate whether they are converging and, further, whether a European Innovation System is emerging. Europe-wide public policies facilitate the process of convergence either directly – e.g., by increasing S&T linkages among economic agents across EU member countries through the Framework Programmes on RTD – and indirectly by setting up a harmonized policy environment – e.g., competition policy, intellectual property rights policy, international S&T treaties.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National Innovation capabilities
Economic growth
National Innovation capabilities
Economic growth
EU Public Policies
Convergence , cohesion , emergence of EIS
F = Firms
U = Universities
RI = Research Institutes

In essence, the KNOW programme has been about the arrows in Figure 2.1, that is, the extent, density, and mechanisms of innovation-related knowledge flows affecting the innovative capacity of European industry and the mechanisms that support such flows. The programme has also examined the incentives to access and transmit knowledge and the determinants of knowledge transmission. *On the basis of the observed knowledge flows and of the evolution in the determinants and transmission mechanisms of such flows, the programme made inferences about the nature of the innovation systems that sustain and are influenced by such flows as well as about the tendency for these innovation systems to converge into a larger European Innovation System.*

By design, the KNOW programme has focused exclusively on disembodied knowledge flows. These utilize channels such as inter-organizational cooperation through both formal and informal partnerships; accessing the intellectual property of others through both traditional and modern means of communication (e.g., scientific journals, internet); movement of skilled personnel; scientific and community memberships; and other sources of competitive intelligence. Embodied knowledge flows, including the transfer of knowledge between buyers and sellers incorporated in products, even though very important, were determined to be out of this programme's domain.

In order to achieve the research objectives listed above, the seven members of the KNOW consortium pursued the following analytical goals:

- Review the evolution of policies within the EU that are of relevance to knowledge diffusion and the current policy context, using, among other sources, the *Green Paper on Innovation* and the *First Action Plan for Innovation in Europe*. This review of the current menu of policy options and policy concerns would assist in the identification of the types of information and data analysis that can assist policy making in this area.

- Describe the sources of innovation-related knowledge, the extent of knowledge flows and the routes of knowledge transmission for industrial innovation in both the European Union and seven member states, using four existing data sources: the European Patent Office (EPO) patent applications and citations database; the first Community Innovation Survey (CIS); the PACE survey of Europe's largest R&D performing firms; and the STEP-TO-RJVs databank of cooperative research projects (research joint ventures) established in Europe through the Framework Programmes on RTD and EUREKA.

- Supplement the information from these data sources by conducting extensive field research – focused survey of a large number of companies followed up by in-depth interviews of a select sample of them – to obtain missing information at the level of the firm and of specific events of knowledge dissemination.

- Appraise the methodological issues that arise when combining qualitative and quantitative information from diverse data sources that are not necessarily easily linked.

- Examine mechanisms of access to and dissemination of innovation-related knowledge in terms of the type of knowledge and the nature and geographic location of the agents involved. Analyze the influence of several firm, sector and national characteristics on the ability of firms to be active partners in European knowledge flows. Try to determine if there are missing links/mechanisms of transmission for some types of knowledge and the extent to which these are more pronounced in the case of regional, national, or international knowledge flows.

- Evaluate the effect of "knowledge spillovers" on the innovative performance of European industry.

- Link the results from the above analyses to the innovation policies of the EU and EU member countries in order to discuss:
  (iv) The success of S&T policies in assisting European industry to access and benefit from innovation-related knowledge flows;
  (v) Progress in NIS convergence and emergence of a European Innovation System;

(vi) Policy options to improve the flows of innovation -related knowledge across EU member countries and regions in order to enhance cohesion and ensure the long -term viability of a European Innovation System.

This is undoubtedly a very tall order. Nonetheless, the members of the consortium worked diligently for 30 months to address all research objectives and analytical goals above. They succeeded in providing very interesting, and sometimes intriguing, answers to a good number of the underlying questions, reflected in the long list of deliverables listed in section 7 of this report. These deliverables include databases, extensive methodological papers, policy papers, and close to twenty analytical papers, all of which can be found on the website of the KNOW programme http://www.know.ntua.gr

This report tries (a) to summarize the context, underlying methodology, and main analytical results of this research effort and (b) to distil relevant policy implications for European, national, and regional governments.

The contents of this report should be viewed as an attempt to synthesize the results of a very rich research programme focusing on a topic of wide ranging interest in a challenging era of fast-paced European integration, forthcoming expansion, and on -going global process of economic integration. We are certain that the explored methodologies and multiple analytical results reported herein can contribute significantly to contemporary technology/innovation policy thinking in Europe, reflected in important debates over the European Research Area, the Sixth Framework Programme for RTD, and the Action Plan e -Europe 2002.[1]

[1] See: (i) European Commission (2000) "Communication form the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions: Towards a European Research Area", Brussels, COM (2000) 6, January 18;
(ii) European Commission (2000) "Proposal for a Decision of the European Parliament and of the Council Concerning the Multiannual Framework Programme 2002 -2006 of the European Community for Research, Technological Development and Demonstration Activities Aimed at Contributing Towards the Creation of the European Research Area";
(iii) European Commission (2000) "e -Europe: An Information Society for All", Draft Action Plan, prepared by the European Commission for the European Council in Feira 19 -20 June.

Section 3

SCIENTIFIC DESCRIPTION OF METHODOLOGY AND RESULTS

This section consists of three parts. Part 1 summarizes the analytical framework that provided the context and brought together key theoretical tools and concepts underpinning the investigation of the main research questions of the K NOW programme. Part 2 illustrates the research methodology, including the research stages and the various sources of quantitative and qualitative information used in the analysis. Part 3 presents the research results of KNOW, starting with an extensive des cription of disembodied knowledge flows, then progressing to statistical and econometric outcomes, and concluding with the highlights of a large number of in -depth interviews carried out in seven European countries.

3.1. ANALYTICAL FRAMEWORK FOR KNOWLEDGE FLOWS

3.1.1. THEORETICAL FOUNDATIONS AND KEY CONCEPTS

Recent economic theorising seeks to expand the ways and methods of understanding the relationships among economic actors from simple linear models of deterministic outcomes and rational behaviors to more complex models of social, institutional, and political interactions. An increasing number of economists – particularly those endorsing the evolutionary approach to technical change – identify diversity in the ways economic agents interact as both a ca use for and an effect of the enlargement of their knowledge base and competencies leading to the creation of novelty. Diversity is thus seen as valuable information that is intentionally generated and preserved. The reasoning is based on the assumption tha t qualitative differences in techniques, processes, and organisational forms provide opportunities for economic agents to engage in learning processes. These learning processes enlarge the knowledge base of market participants and strengthen their potentia l for creativity and adaptability in times of uncertainty and flux (Metcalfe, 1993; Saviotti, 1997; Cohendent and Llerena, 1997).

However, the mechanisms that generate and preserve diversity in economic processes cannot be considered in isolation from th e surrounding economic, political, and institutional conditions at the national and international level. In this respect, arguments that take into account the idiosyncratic ways in which learning processes unfold in distinct national contexts need to be in troduced in the discussion.

3.1.1.1. The “Systems of Innovation” Concept and its Elements

The National System of Innovation (NIS) approach is an analytical concept that situates national variations in technological and institutional development within th e wider international context. A starting point for the NSI approach is that historical, institutional, and cultural factors affect the behaviour of economic agents by influencing their ability to learn and produce new knowledge or re -combine existing know ledge in new ways (Nelson & Rosenberg, 1993). As Lundvall (1993) states, “what makes national systems of innovation important is that the organised markets of the real world may be organised differently in different national systems and that the behaviour of agents, rooted in different systems, may be governed by different rules and norms” (p.277). While several authors have employed the term “systems of innovation”, however, they do not all share the same empirical and/or analytical focus.[2] Depending on the subject and level of analysis, systems of innovation can be national, regional, sectoral, or even supra-national (ibid). The following paragraphs unbundle the NSI concept and discuss some of its key conceptual elements.

The notion of a 'system' is not new in the economics literature.[3] Recent contributions to the 'systems' approach place innovation in technologies and organisational forms of production at the centre of analysis. For example, Nelson and Rosenberg (1993) define a system as 'a set of institutions whose interactions determine the *innovative performance of national firms'* (emphasis added) (p.4). Freeman was the first to use the concept of national system of innovation in his study of the economic and technological development of the Japanese economy. He defined it as 'the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies' (Freeman, 1987, p. 1). Other authors use the terms 'national system of innovation' and 'technological system' to denote the set of distinct economic, industrial, and institutional factors which contribute to the development and diffusion of new technologies and which provide a framework within which governments form and implement policies to influence the innovation process (Metcalfe, 1993; Carlsson and Stankiewicz, 1991).

Lundvall (1992a), on the other hand, adopts a much broader view arguing that a national system of innovation includes 'all parts and aspects of the economic structure and the institutional set-up affecting learning as well as searching and exploring' (p.12). Under this approach, history, language, and cultural elements are also important determinants of national idiosyncacies in firm behaviour, inter-firm linkages, industrial structures, and public policy (Lundvall, 1992a). The problem with such a broader view of a 'system' is that it represents a level of analysis that may not be entirely reducible to its individual components. Thus, for the purposes of this programme, a narrower but equally comprehensive view of a system is adopted. Two particular characteristics of a systemic approach to innovation are particularly relevant in the context of this study. First, that co-operations and user-producer relations may be more important that the pursuit of competition, and second, that knowledge is regarded as a key resource, and that the relative economic success of individuals, firms, and organisations is dictated by their learning potential (Lundvall, 1999).

An important reason why we still don't have a firm and broadly accepted definition of NIS is the complex nature of the innovation process. Some authors have limited the

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[2] It is beyond the scope of this short review to present in detail the various systems of innovation approaches. For a comprehensive account of different innovation system conceptions see McKelvey (1991), Lundvall (1992a), and Edquist (1997a) among others.

[3] For example, Kornai's (1971) more general definition of the economic system can be considered to be a precursor to the systems of innovation approach. Input-output theory has also formally considered economic systems.

notion of innovation to technical innovation. Nelson and Rosenberg endorse a view of innovation that is restricted mainly to technological and organisational advances within firms. In contrast, Lundvall (1992a) uses a broader definition of innovation as interactive processes of 'learning, searching, and exploring, which result in new products, new techniques, new forms of organisation, and new markets' (ibid, p.8). Such processes relate to research and development (R&D) but they can also be found in other economic activities such as marketing and procurement (Edquist & Johnson, 1997). Along this line, McKelvey (1991) summarises three different meanings of the term 'innovation'. According to McKelvey, the term can denote (a) a specific stage in the process of technological change; (b) all kinds of organisational, social, and institutional novelties; and (c) the process of creating, diffusing, or using these various changes (p.118).

It becomes clear from the above that the notion of innovation extends way beyond the R&D departments. Thus, the need for direct and indirect measures of innovation activities is growing. To do so, one has to have a clearer view of what constitutes an innovation. A first step in this direction was made in the Oslo manuals published by the OECD (OECD, 1992/1997) which proposed guidelines for collecting and interpreting technological innovation data. These manuals distinguish between three types of innovation as follows:

- "A *technological new product* is a product whose technological characteristics or intended uses differ significantly from those of previously produced products. Such innovations can involve radically new technologies, can be based on combining existing technologies in new cases, or can be derived from the use of new knowledge.
- A *technologically improved product* is an existing product whose performance has been significantly enhanced or upgraded. A simple product may be improved (in terms of better performance or lower costs) through use of higher-performance components or materials, or a complex product that consists of a number of integrated technical sub-systems may be improved by partial changes to one of the sub-systems.
- A *technological process innovation* is the adoption of technologically new or significantly improved production or delivery methods. These methods may involve changes in equipment, or production organisation, or a combination of these changes, and may be derived from the uses of new knowledge. The methods may be intended to produce or deliver technologically new or improved products, which cannot be produced or delivered using conventional production methods, or

essentially to increase the production or delivery efficiency of existing products." (OECD, 1997, p. 48-49).

These definitions intend to exclude changes in products that mainly provide subjective improvements of customer satisfaction based on personal taste and aesthetic judgement, and/or derived from fashion, and/or brought about mainly by marketing. Such changes are identified under the heading 'other creative product improvements'.

In addition, the second edition of the Oslo Manual distinguishes between a *worldwide technological product or process innovation (TPP)* and a *firm-only TPP innovation*. The former applies the very first time a new or improved product or process is implemented, while the second occurs when a firm implements a new or improved product or process which is technologically novel for the unit concerned but is already implemented in other firms and industries (ibid, p.52). Similar definitions of innovations have also been used in the Community Innovation Survey II (CIS-II) where a technological innovation was originally defined as 'technologically new productions and processes and significant technological improvements in products and processes'.
Yet, concerns have been raised regarding the extent to which definitions for concepts as amorphous as technologically new products and processes can be ubiquitously developed (Hansen, 1999). These concerns are based on two grounds. First, the experience so far suggests that not only is it difficult for firms to decide what is 'new', but also it is difficult for them to make a distinction between a 'new' and an 'improved' product or process (ibid). Second, the increasing importance of the service sector in the economy and the different notion of what constitutes a 'new product' or a 'new process' in the service sector call for modifications in the foregoing definitions that were originally designed to apply to the manufacturing sector. The CIS-II has taken this point seriously and has thus incorporated a separate definition of innovation in services as follows:

A new or improved service is considered to be a technological innovation when its characteristics and ways of use are either completely new of significantly improved qualitatively or in terms of performance and technologies used. The adoption of a production or delivery method, which is characterised by significantly improved performance, is also a technological innovation. Such adoption may involve a change of equipment, organisation of production or both and may be intended to produce or deliver new or significantly improved services which cannot be produced or delivered using existing production methods or to improve the production of delivery efficiency of existing services.

The introduction of a new or significantly improved service, or production or delivery method can require the use of radically new technologies or a new combination of existing technologies or new knowledge. The technologies involved are often embedded in new or improved machinery, equipment or software. The new knowledge involved could be the result of research, acquisition or utilisation of specific skills and competencies. (CIS-II, Service sector questionnaire)

Notably, under the above definition, organisational and managerial changes in service firms are not regarded as technological innovations.

3.1.1.2. Learning, Learning Capability, and the Learning Economy

In the history of innovation system studies, the focus has gradually shifted from knowledge to learning as the central topic to understand for economic development. A short and rather broad definition of learning is "…generation, transfer and distribution of knowledge" (Lundvall, 1999).

Two qualifications should be added to this broad definition. First, learning is *interactive* and interactive learning is central in the process of innovation (Edquist, 1997, p. 5). Although almost all learning is interactive there are different kinds of learning, which involve different amounts of social interaction. (Johnson, 1992). For example, there is individual learning from isolated imprinting of immediate experiences of the memory, rote learning (learning by repetition, not necessary understanding), learning via feed-back, and finally systematic and organised searching for new knowledge in universities and R&D departments. The two latter types of learning require intense and complex forms of interactions and are assumed to be increasingly important. Second, learning is a socially embedded process. "Without a minimum of social cohesion the *capability* to learn to master new technologies and new and more flexible forms of organisation will be weak."(Lundvall, 1999, p. 20)

In modern economies, technical and organisational change has become increasingly endogenous. Learning processes have been institutionalised and learning by doing (and learning by using) have been more important. That is the background for the emergence of the concept of "the learning economy".

In a learning economy the organisational modes of firms are increasingly chosen in order to enhance learning capabilities. Networking with other firms, horizontal communications patterns and frequent movements of people between different posts and departments are becoming more and more important. The firms of the learning economy are to a large extent "learning organisations" (Lundvall and Johnson, 1994). Learning organisations facilitate the learning activities of its members in search of a process of continuous transformation. From a policy point of view, governments have an important role to play in providing the means to learn, the incentive to learn, enhancing the capabilities of public and private organisations to learn, and facilitating access to relevant knowledge bases. However, the exact ways and methods for government action in this area remain a matter for consideration.

3.1.1.3. Knowledge and Knowledge Flows

The importance of learning in innovation points to the significance of knowledge and knowledge flows within innovation systems. Mainstream economic theory considers knowledge as a uniformly available public good that can be transferred and learnt at little cost. The normative approach to the creation of technological knowledge suggests a linear process in which firms endogenously seek out and apply knowledge inputs in the form of R&D to generate innovative output.

Yet, this view is being increasingly criticised on both the oretical and empirical grounds by recent developments of the evolutionary approach in economics. This approach draws a distinction between information and knowledge in that the former refers to 'knowledge that has been reduced and converted into messages t hat can be easily communicated among decision agents', while the latter is considered as the 'conceptual and factual contexts that enable agents to interpret and give meaning to 'information'' (David and Foray, 1995). Furthermore, this approach attributes idiosyncratic properties to knowledge creation since it views knowledge as the outcome of context -specific learning processes experienced by individual agents who, in turn give their 'personal touch' in the process by bringing in their pre-existing knowled ge, competencies, and experience. The evolutionary approach also identifies the *linkages* and *interactions* among the economic agents who produce, diffuse and adopt this knowledge as crucial for the translation of knowledge inputs into innovative outputs. For example, at the micro -economic level of the firm, Audretsch and Stephan (1999) found that the appropriation of economic returns of new knowledge in emerging technologies, such as biotechnology, is not always made by the same firms who produce this knowledge as the normative approach would suggest. Rather, it is often the case that the appropriation of returns is made by newly established firms who receive knowledge spillovers and inflows from the sources that created this knowledge (i.e. universities, research institutes, or other industrial organisations).

In addition to the foregoing characteristics of knowledge, two distinct dimensions of knowledge have been identified in the literature: the codified and the tacit. The former refers to knowledge that has been reduced to codified and transmittable form, while the latter refers to knowledge that exists subconsciously in the human mind, is acquired through experience, imitation, and observation, and can be transferred only by personal contact (David and Foray, 1995; Nonaka and Takeuchi, 1995). Examples of tacit knowledge are workers' know-how and skills which may not be recognised as such even by the individual following them. In a corporate environment, a related form of tacit knowledge has to do with the intuitive shared perceptions and beliefs that simplify communication in the workplace. Along these lines, four different components of scientific and technological knowledge have been identified and are presented schematically in Table 3.1 (Antonelli, 1999).

Table 3.1: The Four Components of Scientific and Technological Knowledge

	Tacit	***Codified***
Internal to the firm	Learning	R&D
External to the firm	Socialisation	Re-combination

Source: Antonelli (1999)

It is generally assumed that internal tacit know ledge is generated through learning -by-doing and learning-by-using at the firm level while informal links and social relations among members of scientific communities may result in the transfer of external tacit knowledge form one agent to another in the form of ideas, skills, and techniques. Similarly, internal codified knowledge is normally developed through the engagement of researchers in formal R&D activities. External codified knowledge acquisition, on the other hand, involves the transfer of knowledge in embodied (i.e. knowledge contained in artefacts and equipment or software) or disembodied form from sources external to the firm (universities, research institutes or other industrial organisations) or from formal co-operation among firms (Antonelli, 1999). It is important to note that all activities surrounding the generation and/or acquisition of new knowledge may be enhanced or confined by specific elements of the (national) institutional environment, such as the regime for intellectual property rights, the culture and norms that govern the informal relations among scientists involved in research activities, or even the policies of journals for publishing scientific papers (David and Foray, 1995).

The emphasis on access to external (to the firm) sources of knowledge and the view of knowledge as the outcome of learning processes implies the existence of ***knowledge flows***. Knowledge flows link different sources of new scientific and technological information and its potential users. They include technology transfer and the flow of know-how, knowledge, and information, including both accidental spillovers and intentional transfers. There are many alternative routes for knowledge flows to materialise. They require a *channel*, such as for example an established collaborative link between two scientists from different firms, and a *mechanism*, that is a way in which communication can be achieved through the specific channel, such as co-operative research efforts, informal discussions, or the expressed ideas of a scientist. Such flows are not limited to the exchange of information between firms or institutions. Knowledge flows within large firms that are active in several industrial sectors could also play a crucial role in the diffusion of knowledge across disciplines (Arundel, et. al. 1998).

Following the emphasis placed by the system's approach on learning processes, David and Foray (1995) argue that what characterises and determines the performance of 'different systems of learning in science and technology' is not so much their ability to produce new knowledge as their ability to disseminate it effectively and allow it to become economically valuable to third parties. Thus, the intensity and variability of knowledge flows among the constituents of a national system are critical determinants of its 'distribution power'. Along these lines, it has been suggested that policy-makers should shift their interest from steady structures and absolute measures of innovative activities (such as R&D expenditure and patents) to the different types of *interactions* among actors within and beyond the boundaries of a national system.

3.1.1.4. Modes of Interaction Embodying Knowledge Flows

Four such types of interactions have been identified in the literature as embodying knowledge flows (Smith, 1994; OECD, 1996a). The first type of interaction refers to *inter-industry interactions among individual/firms*. These are materialised through several channels such as formal and informal collaboration agreements among firms, the conduct of contract work, interactions among members of scientific communities employed in different firms, user-producer interactions, as well as interactions with external-to-the-firm sources of information (i.e. firms providing training services, external consultants, etc.) that contribute to the accumulation of competitive intelligence. Available empirical evidence suggests that these interactions entail knowledge flows that may not always have a significant impact on innovative outcomes (Arundel et. al., 1998). In the case of collaborative R&D, for example, there has been contradictory evidence regarding its impact upon innovative performance. Studies of the telecommunication and office equipment sectors found that firms participating in cooperative R&D agreements are less innovative than those that do not (Arundel et. al., 1996; Malerba et. al., 1996).

Along the same lines, there are *interactions among firms, universities and public research institutes* that represent the second type of interactions identified. These may include joint research activities and all other formal and informal linkages which aim at the acquisition by firms of generic knowledge and/or information from academic sources.

Inter-industry interactions through the purchase of machinery and equipment represent the third mode of interaction. The transactions of technology products in the form of machinery and equipment within and among sectors are regarded as contributing to intra- and inter-industry flows of knowledge embodied in these products. Such knowledge flows are, however, beyond the scope of the empirical investigation in this study.

Finally, the fourth type of interaction refers to *personnel mobility.* Inasmuch as data on the number of scientists and engineers involved in research activities are widely available in most countries, data on mobility of personnel between industry and academia are the most difficult to trace. Perhaps the most important contribution of universities to industry and research institutes is the continuous production of highly-skilled personnel, trained to think critically. In addition, a whole range of mid-career and other training programmes renew the skills of industry employees. Often, industry reciprocates academia by offering training programmes for university graduates and employees and research institute employees.

It is important to note that the types of interactions identified above may have regional, national, as well as international dimensions. As already discussed in a previous section, the approach of systems of innovation, has a strong spatial dimension. The importance of distance is due to the unique characteristics attributed to technological knowledge and learning which are regarded as being evidently shaped by the opportunities for personal contact among the parties involved. When knowledge has a large tacit component, innovative activities tend to be regionally concentrated because economic agents benefit from relevant externalities that appear either in the form of involuntary spillovers or as intentional information flows.

Nevertheless, the existence of strong knowledge-intensive linkages with actors outside the agglomeration has also been well appreciated by relevant studies on the success of some regional industrial agglomeration. Furthermore, the increasing globalisation of economic activity through the internationalisation of trade and investment has increased the opportunities for trans-national interactions among economic agents and the subsequent flows of knowledge beyond national boundaries. To this end, tracing the intensity and impact of interactions within and across industries at the European level is one way to examine the convergence of national innovation systems and the possible emergence of a European System of Innovation. For example, it has been suggested that if domestic sources of information are considered as more important than foreign sources then national systems of innovation are likely to maintain their standing. Alternatively, there will be ground to argue that national systems are losing out to intra-regional or to a pan-European system (Arundel, et. al., 1998).

3.1.1.5. The Institutional Dimension

Yet, the process of identifying and measuring interactions among actors in a national system should not be seen in isolation from the broader institutional environment within which these actors operate. Traditional economic and other regulations, such as competition and intellectual property rights protection, taxation, financing, education, national policies, EU-level policies and so forth can ease or block agents' interaction and subsequently the innovation-related knowledge flows. This is particularly important when exploring the question of the emergence of the European Research Area and a European system of innovation since there are important differences in the ways public sector institutions and research facilities supporting industrial innovation have been set up and operate in each country. Likewise, even within national borders it may also be the case that public institutions are organised differently and thus differ in their ability to support and promote innovative activities across industrial sectors (Nelson and Rosenberg, 1993; David and Foray, 1995). In this respect, some institutions may be more important for the organisation of linkages and the flow of knowledge in particular industries than in others.

The range of institutions that are regarded as particularly relevant in shaping public and corporate strategies towards science and technology and thus in influencing the 'distribution power' of a national system varies according to the perspective adopted. For example, when considering best policy practices for the diffusion and adoption of new knowledge throughout an economy the OECD (1996a) calls for 'actions which go beyond innovation and technology diffusion defined in a narrow sense, encompassing only those government actions and regulations that are directly technology-related, and whose main instruments are managed by ministries and public agencies with technological development or diffusion as their main mission'. It argues for an extension of the boundaries of technology policy 'to include all measures targeting innovation and technology diffusion, irrespective of institutional arrangements and division of labor within government (for example, an R&D tax incentive is included even when managed by the Ministry of Finance), as well as related policies with a different primary goal (e.g. education or training)' (p.11). Thus, training and education policies, the finance structure, and the broader macroeconomic and industrial context are inserted into the discussion as critical factors in influencing knowledge flows. Furthermore, the availability of modern communication infrastructure in a national system has been regarded as particularly influential in establishing linkages among scientists and in allowing access to scientific processed information, electronic publishing in science, and science education and training (OECD, 1998)

Yet, from a more narrow perspective, one may choose to focus on those institutions at the public and private sphere which are directly science and technology related and are regarded as 'critical' for the distribution of knowledge. From that point of view, Smith (1994) has identified the following types of institutions:

a) *Public sector institutions* refer to all formal establishments that may have a direct or indirect effect upon the generation and diffusion of knowledge in a national system.

Such institutions include universities, public research institutes and other private and non-profit research organisations, research councils, standard setting organisations, patent offices, and libraries.

b) *Public sector instruments* refer to legal and regulatory measures and policy-related initiatives explicitly oriented towards the diffusion of knowledge. These include R&D collaborative programmes funded by national of other foreign sources, technology-related legal and administrative regulations, such as mechanisms for protecting intellectual property rights, subsidies towards new scientific structures and equipment, such investments in communication infrastructure, and public procurement policy.
c) The last category refers to the *technology infrastructure institutions,* which include 'soft' measures, such as industry associations and conferences, training centres, trade and scientific publications, agencies and organisations supporting information exchange, etc.

The formal and informal institutions identified above differ from country to country and even from region to region. Their role and contribution in facilitating knowledge flows is expected to vary accordingly.

3.1.1.6. Firm-level Dimension

At the corporate level, the intensity and effectiveness of inter- and intra-industry interactions is determined to a large extent by the firms' own commitment in learning activities and the ability of firms to recognise and appreciate the value of new information. Cohen and Levinthal (1990) have labelled the latter as the *absorptive capacity* of the firm. The term refers to the firm's ability to recognise the value of new, external information, ranging from generic science to new production equipment, assimilate it, and exploit its economic potential through commercialisation. A firm's absorptive capacity largely depends on the level of prior related knowledge owned by the firm. Given that learning is a highly localised and history-dependent process, the current set of skills and expertise owned by a firm are critical for the nature and direction of learning processes that aim to enhance the knowledge base of the firm in the future. Thus, lack of tangible or intangible investment (in the form of human capital) in an area of expertise early on may inhibit the development of technological knowledge by the firm in that area at a later stage. Along this argument, the ability of a firm to use the results of research efforts made by other firms or other public and/or private research establishments depends on its ability to understand them and to assess their economic potential.

The second important factor that determines the intensity and effectiveness of interactions among actors, and thus affects knowledge flows, is the intensity of effort or commitment to learning undertaken by firms themselves. The latter contributes to a firm's absorptive capacity and reflects the intention of firms to internalise the results of technology or knowledge purchased from third parties. Kim (1999) describes this intensity of effort as 'the amount of energy relinquished by organisational members to solve problems'. He subsequently makes the arguments that the higher the energy consumed in solving problems within a firm, the more intensive are the interactions and knowledge flows among actors within and outside the firm, and thus the higher are likely to be the effects upon increasing its knowledge base.

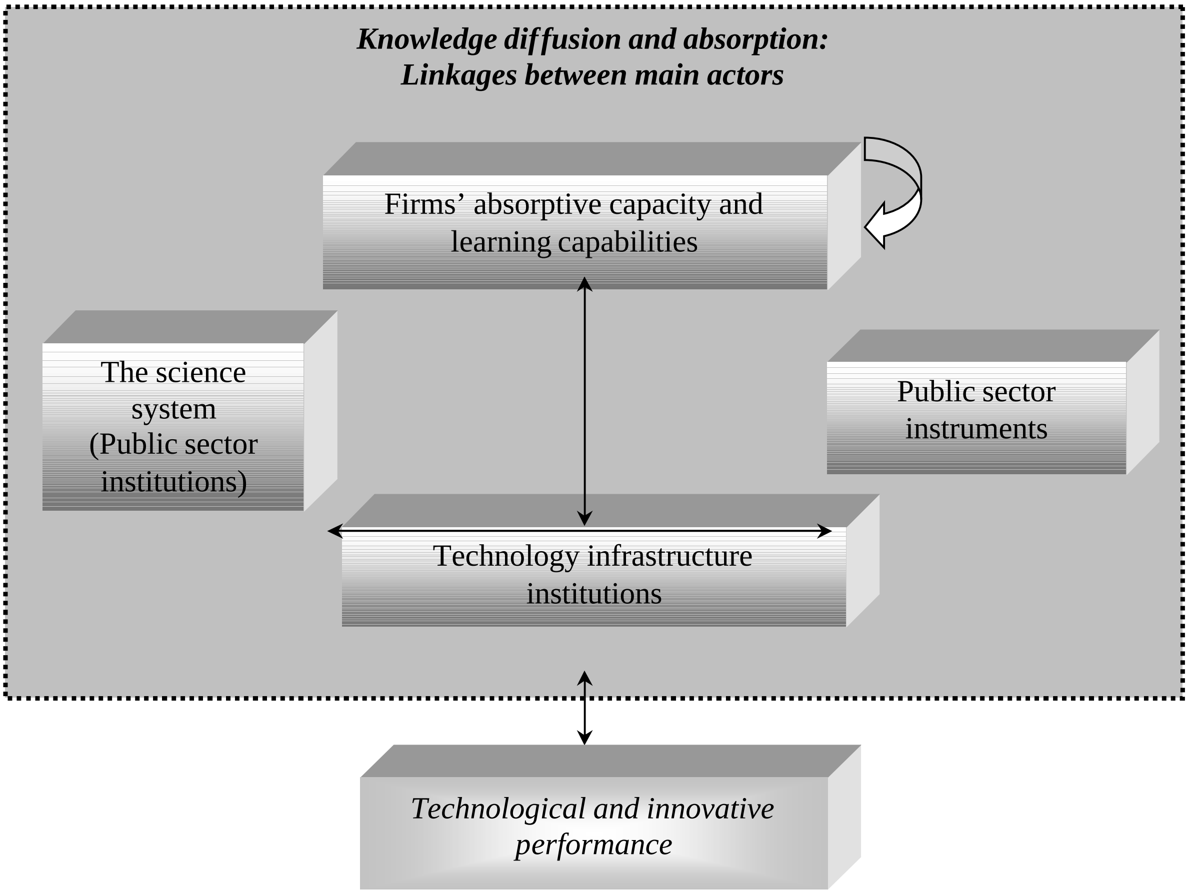
One implication of the need for firms to invest in learning in order to be able to effectively use external knowledge, even when freely available, is that large firms could have an advantage in both the production and use of new knowledge. This is because large firms are more likely to be involved in the types of activities that make it easier to absorb external technologies. In addition, it has been suggested that their employees are often better place and more 'equipped' to exploit external knowledge than those of other firms (Minne, 1996). These implications have been borne out by surveys, which show that there is a strong positive relationship between firm size and the probability that a firm conducts R&D, is involved in cooperative R&D, and uses patent disclosure as a source of technical information (Malerba *et al*, 1996).

The systems of innovation approach identifies that management practices are a significant institutional factor that influences inter-firm learning and knowledge flows, which, in turn, are relevant to firm-level economic performance (Gjerding, 1992). For example, an internal organisational structure that encourages interactions between the various departments and functions of the firm (R&D, production, sales and marketing linkages) enhances the firm's 'distribution power', that is its ability to support and improve efficient procedures for distributing and utilising knowledge. Other aspects of the internal organisation of firms, such the geographic location of sub-units, the corporate communication infrastructure and networking, and the development of a corporate culture that appreciates the importance of the human factor have also been recognised as important in influencing learning processes and inter-firm flows of knowledge (Odagiri and Goto, 1993; Mowery and Rosenberg, 1993). Human aspects, in particular, and especially those related to the properties that individuals bring to the workplace in terms of qualifications, scientific and technical knowledge have received particular merit in contemporary economic and business literature due to the current emphasis on the importance of *intangible* assets of firms or nations, that is non-material factors that contribute to their growth and performance without being included in the traditional category of fixed assets. (Commission European Community, 1999).

* * *

The foregoing analytical arguments on the role of knowledge in innovation form the conceptual framework that underpins the investigation of innovation-related knowledge flows in the present study. Figure 3.1 illustrates this framework in schematic form. The arrows represent the interactions among actors while the boxes represent the actors and their knowledge resources or their role as facilitators in knowledge transactions. The performance of such a system depends on the level of its 'distribution power' which in turn is related to the availability and intensity of knowledge flows. It is important to clarify that the links among these actors extend beyond national borders. Thus, the interactions indicated by the arrows extend the scope of a national innovation system. Firms may have linkages with other local or foreign firms, and public sector instruments and infrastructure institutions encompass both domestic and foreign (e.g. EU) initiatives and resources.

Figure 3.1: Knowledge Diffusion and Absorption in the Innovation System



3.1.2. KNOWLEDGE FLOW INDICATORS

Various empirical efforts have been made by analysts to characterise and quantify the role of the above system elements in innovative performance. These efforts attempt to map and assess system interactions and thus require indicators of knowledge flows. There are two main groups of indicators for measuring knowledge flows that are currently being in use. The first group consists of 'traditional' indicators that have been available for decades. The second group consists of newer, experimental indicators that have be en under development since the 1980s.

3.1.2.1. Conventional Indicators

Many of the traditional innovation indicators such as patents, bibliometrics, and human capital stocks capture the output of knowledge creation (patents and journal articles) or its potential creation (human capital stocks). These indicators have also been successfully used to track knowledge flows. The growing literature in this field has substantially increased our understanding of knowledge flows and spillovers. Furthermore, traditional indicators such as patents have considerable advantages for tracing knowledge flows, such as the long time series available and the consistency with which the information is collected.

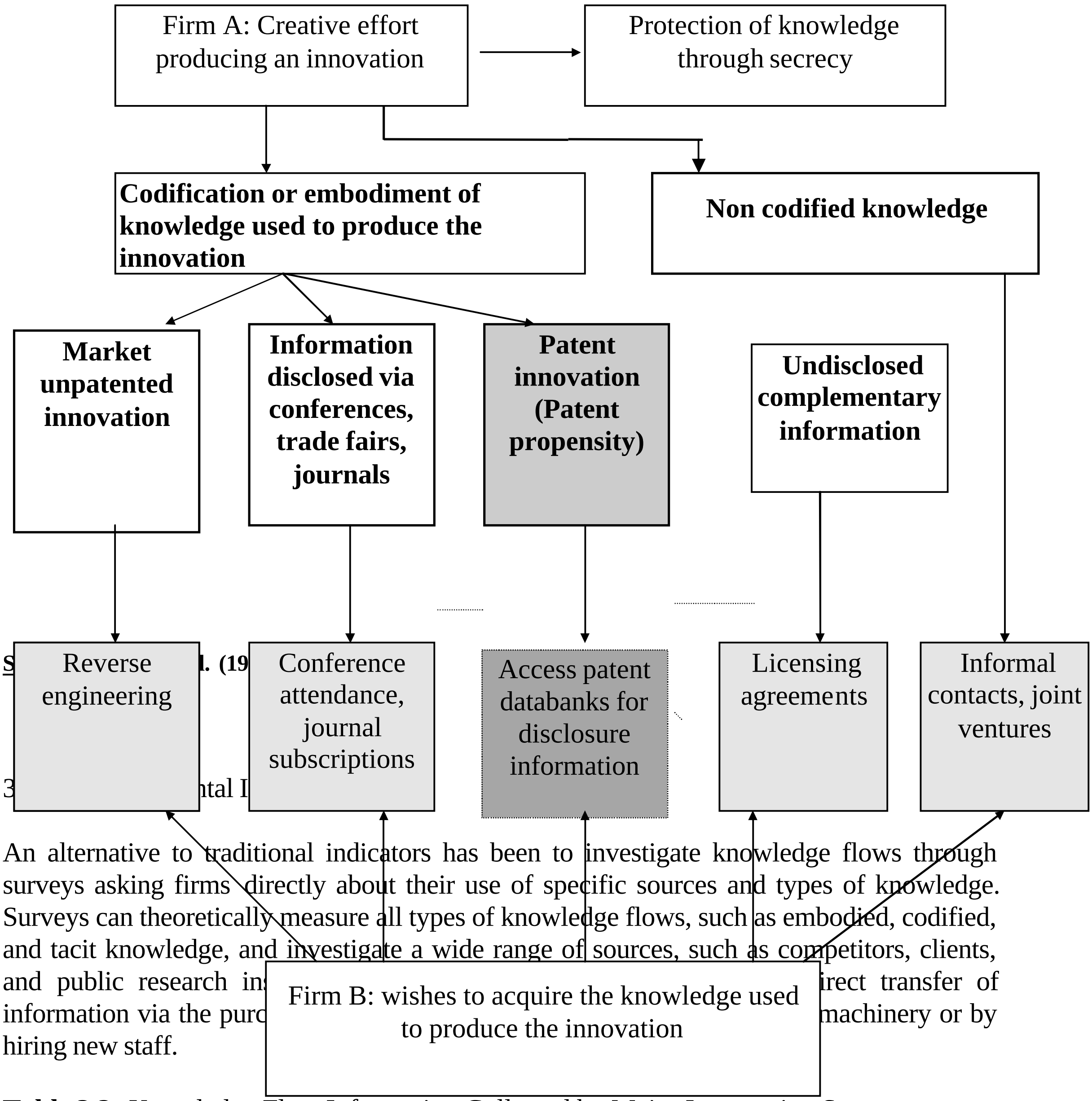
There are three main drawbacks to the use of traditional indicators to evaluate knowledge flows. The first is that traditional indicators only provide indirect measures for the flows of knowledge used in innovative activities. The use of patent citation data, for instance, is problematic because the cited data is included in the patent application by both the applicant firm and the patent examiner. This means that citation data provides the "smoking gun" but cannot guarantee this as direct evidence that the cited source of knowledge was ever used by the owner of the citing patent. Bibliometric citations probably provide a more accurate trace, but their main value is for evaluating academic uses of knowledge. They are less useful for tracking the types of information that are used by firms to innovate.

Second, traditional indicators such as patents or bibliometric citations are limited to only codified knowledge. They are more difficult to use to evaluate tacit and embodied knowledge because they cannot provide a direct measure of these sources, although a patent can indirectly point to the transfer of tacit knowledge.

The third problem with traditional indicators is that they fail to capture the complexity of knowledge flows, which can take a range of alternative paths in response to the strategic activities of different firms. This is illustrated in Figure 3.2, which shows an example of the different routes that can be used by Firm B to obtain information about an innovation developed by Firm A (Arundel et al., 1998). The specific routes available to Firm B depend on the strategic choices made by Firm A to appropriate its innovation. This includes whether or not the information is codified, although the knowledge required for most innovations is normally both codified and non-codified.

The complexity of different methods of knowledge acquisition, and the influences of the strategic decisions made by Firm A, show that using patents to trace knowledge flows can only provide one part of the entire picture. Furthermore, patents are of no value at all when firms do not patent their innovations. Although this will not be a problem in the pharmaceutical sector, where the majority of innovations are patented, it should be of concern for most other sectors, where firms patent less than half of their innovations (Arundel and Kabla 1998).

Figure 3.2: The Complexity of Knowledge Flows



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3[…]ntal I[…]

An alternative to traditional indicators has been to investigate knowledge flows through surveys asking firms directly about their use of specific sources and types of knowledge. Surveys can theoretically measure all types of knowledge flows, such as embodied, codified, and tacit knowledge, and investigate a wide range of sources, such as competitors, clients, and public research ins[…]irect transfer of information via the purc[…]machinery or by hiring new staff.

Table 3.2: Knowledge Flow Information Collected by Major Innov ation Surveys

	Europe			US	Canada		
Type of Knowledge	PACE	CIS-1	CIS-2	CMS	CIS	Bio-1-2	AMT
1. Sources of knowledge for the firm's innovative activities (not specified as to type)							
Internal information sources		*	*	***	**	**	**
External information sources	*	***	**	***	**	***	**
By geographic location	**			**			

By purpose				**	**	**	
PRO information sources	***	*	*	***	*	*	
By geographic location	**	**	**	*			
2. Codified knowledge							
Patents, publications, etc	*	**	**		***	*	*
3. Tacit knowledge							
From PROs	*			*			
From other sources				*			
4. Embodied technology							
Technology acquisition		**			*	***	***
By geographic location		***			*		
Technology transfer		**			**		
By geographic location		***			*		
Adoption of specific technology					***	***	***
5. Interactive knowledge sharing							
Cooperative R&D/Alliances	*	***	**	**	**	**	
By geographic location		***	***		***	**	
6. Channels for obtaining knowledge from:							
PROs	**			***			
Other sources		*		***			

PACE (Policies, Appropriation and Competitiveness for European Enterprises) is a 1993 survey of Europe's 500 largest manufacturing firms funded by DGXIII.
CIS-1: 1993 Community Innovation Survey of firms of all siz es in 11 EU countries plus Norway.
CIS-2: 1998 updated of CIS -1; also includes the UK.
CMS (Carnegie Mellon Survey): 1994 survey of R&D labs in the US and in Japan.
Bio:1-2: Survey of Biotechnology Use - 1996; Biotechnology Firm Survey - 1997
AMT: Survey of Advanced Technology in Canadian Manufacturing - 1998

Table 3.2 provides an overview of the types of information regarding knowledge flows that have been collected in several major surveys in Europe, the United States, and Canada. The number of stars i s a rough measure of the thoroughness with which the survey investigates knowledge flows.

Innovation surveys, like those summarised in Table 3.2, also have several drawbacks:

- The coverage of tacit knowledge is relatively poor, since this type of knowledg e is rarely separated out from other types.
- Only basic information concerning the firm's objectives for using a particular source of knowledge is collected (by the Canadian and American surveys, not the European CIS).
- The information on knowledge cannot b e readily linked to the three types of spillovers: market spillovers, knowledge spillovers, and network spillovers.
- None of the existing innovation surveys provide complete coverage of the different kinds of knowledge and knowledge sources available in a s ystem. It has proven impossible to cover all aspects of knowledge flows in a single survey, particularly if the survey is voluntary.
- Surveys in general deal with subjective rather than objective information.

The CMS survey obtained a wide range of data of relevance to the objectives of this study, but so far analyses of this data have focused on appropriability conditions (Cohen et al, 1999). Some of these results suggest that the patent system in Japan plays a strong role in disseminating knowledge, while this role is less evident in the US. These differences are due to a combination of factors, including differences in the legal structure of the two systems, which has created different patenting strategies in the two countries.

Available innovation surveys have pointed out several important regularities regarding knowledge flows. They include:

- ***Firm size.* One of the most robust results of innovation surveys is the finding that there is a consistent, positive relationship between firm size and the importance of many external sources of information, including PRIs, patent databases, and co-operative R&D (Bosworth and Stoneman, 1997; Schmidt, 1997; Arundel and Steinmueller, 1998; Auito et al, 1997; Arundel et al, 1995). Large firms tend to find more sources of external knowledge of value than small firms (Arundel et al, 1995). Small firms attribute greater importance to trade fairs as an information source and almost all firms find publications to be of great value. Most firms characterize internal information sources as very valuable (Arundel, 1998).**

- *Sector.* Innovation surveys consistently report differences by sector in the value of specific information sources (Auito et al, 1997; Arundel et al, 1995). Many of these differences appear to be related to basic concepts of low, medium, and high technology sectors. There is also a wide variation in the importance of customers and public research by sector, while there is much less variation in the case of reverse engineering as an information source.

- *Internal versus external knowledge sources.* Survey research consistently shows that innovative firms rank internal sources within the firm, such as their own R&D, more highly than external information sources (Levin *et al*, 1987). As an example, the preliminary CIS-2 results for France report that 46.6% of firms give a ‘high’ importance to ‘sources within the company’ (Francois and Favre, 1998). In comparison, the second highest rating is 31.8% for customers, while the percentage of firms that give the remaining nine sources the highest importance rating varies between 2% and 13%.

- *Locus of innovation and technological complexity.* The link between the type of technology under development and the adaptive capability of the firm is an underlying thread through many of the studies based on innovation surveys. However, very few of these studies have addressed this problem directly, although several have noted that more R&D intensive firms are more likely to participate in co-operative R&D and that large firms, which are also more likely to have high levels of absorptive capacity, are more likely than small firms to use many different external information sources.

- *Absorptive capacity*. Although the concept of absorptive capacity has received a great deal of attention, it has only been studied empirically through the use of proxy indicators. One common assumption is that the amount of effort expended on innovation, for instance the amount of R&D spending or employed scientists, is an indirect measure of absorptive capacity. This could be a reasonable assumption for large firms in R&D-intensive sectors but less so for small and medium-sized enterprises (SMEs) that do not conduct R&D.
- ***Public Research Institutes.*** **An important issue is why a specific knowledge source is used. There is increased interest for PRIs, seemingly less useful to small than larger firms. The CIS provides some evidence to show that there are differences in the objectives of innovation among firms that use or do not use public research as an information source. Firms that stress developing new products as an objective are more likely to find public research to be an important source of information than firms that innovate in order to improve their existing products (Arundel, 1997). On average, PRIs are not ranked as an important external information source. This pattern holds in most sectors.**
- ***Collaborative R&D.*** **The use of collaborative R&D as a mechanism for obtaining knowledge from external sources has received enormous attention in the past couple of decades from both innovation economists and European policy makers. So far the evidence concerning the link of cooperation and innovation outputs is mixed. On the positive side, Nas et al (1994) find that CIS-1 firms that participate in cooperative R&D have a higher share of new products in their product line than firms that do not take part in cooperative R&D. Albach et al (1996) report that R&D cooperation among CIS respondents in the chemical sector is most prevalent among the more innovative sub-sectors of this industry, such as pharmaceuticals and agrochemicals. Conversely, two studies of the CIS results for the telecom and office equipment sectors found that firms that participate in cooperative R&D are less innovative (percentage of sales from innovative products) than those that do not (Arundel and Steinmueller, 1996; Malerba et al, 1996). Caloghirou and Vonortas (2000) provide an extensive, in-depth appraisal of the subject and show how the scope of the analysis may lead to different interpretations.**

- *Knowledge flows and innovation output*. Many of the analyses using CIS data show that the more innovative firms tend to use an above average number of external knowledge sources (Bosworth and Stoneman, 1997). Similar results are reported by Autio et al (1997) for the pulp and paper sector. Arundel and Steinmueller's (1997) analysis of the CIS results for telecom firms finds that the use of PRIs is positively associated with the share of total sales due to innovative products. However, it also finds a negative association between the amount of R&D spent outside of the firm and successful innovation. Christensen et al (1997) compare the use of major information sources among German food and beverage firms that are innovative leaders and laggards. A higher percentage of the leaders than the laggards obtain information from PRIs and journals, while there is little difference in the frequency of use for most other information sources.

- *NSI and geographical proximity* . So far, it has not been possible to empirically test the role of proximity in a satisfactory manner. The typical method has been to compare the behaviour of firms in the same industry but in different countries (Calvert *et al*, 1996). Unfortunately, little confidence can be placed in the results because of the poor comparability of the CIS data across countries. Surveys have on average reported proximity effects; the strength of the effect varies with the source. Bosworth and Stoneman (1997), in an analysis of the CIS data, report that domestic partners are the most important source and destination of technology transfers. Christensen et al (1997), in an analysis of the CIS data for food and beverages firms, report that these firms engage in co-operative R&D more frequently with domestic than foreign PRIs. Preliminary results from the French CIS-2 also show that co-operative agreements are more prevalent with French partners than with foreign partners (Francois and Favre, 1998). Beise and Stahl (1999), howver, failed to show that, within Germany, proximity to a PRI increased the probability that a firm sourced a new product from the PRI. More R&D-intensive firms tend to cite distant PRIs as important to innovation more often than less R&D-intensive firms.

3.1.3. KEY CONCEPTUAL ELEMENTS OF KNOWLEDGE FLOWS

The preceding discussion points out several key elements of an appraisal of knowledge flows including the nature of knowledge, the sources of knowledge, and the various channels and mechanisms through which knowledge is transferred and communicated. In addition, the discussion pointed out internal and external factors that may influence the pace and direction of knowledge flows, such as firm characteristics, institutions, and the regulatory environment.

A) Nature of Knowledge Flows

The nature of knowledge can be distinguished along three dimensions:

- *Content*. This describes what the knowledge is about or, put differently, how the knowledge is to be used by the firm in innovating. Types of knowledge relevant to this programme are:
  - (a) *Marketing knowledge*
  - (b) *Scientific knowledge*
  - (c) *Technological knowledge*
  - (d) *Strategic knowledge*
- *Communicability.* There are two dimensions of communicability:
  - (a) *Embodied/Disembodied*
  - (b) *Tacit/Codified*
- *Technological domain(s).* Knowledge may differ across sectors in terms of the specific scientific and technological fields found at the base of innovative activities in a sector (Malerba, 1999).

B) Sources of Knowledge Flows

The sources of knowledge can be distinguished along two dimensions.

- Sources of knowledge. These may be:

(a) Agents, including:

(i) Individuals (i.e. consumers, experts, inventors)

(ii) Firms including customers, suppliers, competitors, consulting firms, collaborators

(iii) Universities/Public research institutes

(iv) Government agencies

(b) The market – providing information about prices, incomes, market size etc.

- *Proximity.* There are three dimensions of proximity:

(a) Geographic – district, region, country, neighbouring country, EU, other

(b) Language/Cultural

(c) Proximity of the knowledge base – referring to the proximity in the nature of knowledge that may underpin firms' innovative activities.

C) Internal and External Factors

The extent and intensity of knowledge flows depends on factors internal and external to the firm that may influence this activity. These are:

- *Infrastructure institutions and public sector instruments*
- *General characteristics of the firm*
  (a) Ownership status
  (b) Corporate culture and type of management
  (a) Ways of communication within the firm
  (b) Strategic orientation
  (c) Technology strategy
- *The firm's absorptive capacity*. This reflects the firm's ability to make use of knowledge acquired from external sources. Proxies of absorptive capacity can be:
  (a) Scientific personnel employed by the firm
  (b) Time and ways in which the scientific and technical personnel keeps informed of technical developments outside the firm
  (c) Investment in training programmes
  (d) In-house R&D effort to keep up with scientific and technical developments
  (e) Extent of ICT use and level of IT sophistication of the firm

D) Channels of Knowledge Flows

Channels of knowledge refer to the means by which knowledge is communicated. There are two dimensions along which these may vary:

- *The nature of the channel*

(a) Written – papers, reports, patents, letters e -mails, etc.
(b) Verbal – meetings, conferences, telephone conversations, etc.
(c) Transfer of personnel
(d) Transfer of product
(e) Joint practice

- *Channel costs*
  (a) Costs for creating the channel
  (b) Costs for using the channel
  (c) Costs for maintaining the channel

Several knowledge transmission channels can be in operation within firms, between firms, and between firms, universities and research institut es. Intra- and inter-firm channels may include:

a) collaboration
b) contract work
c) access to intellectual property/knowledge of others
d) movement of skilled personnel among and within firms
e) knowledge flow through membership is scientific communities
f) use of other sources for accumulating competitive intelligence (i.e. provision of training services to firms, external consultants, users, the internet)

Knowledge channels between firms, universities and research institutes may include:

a) collaboration
b) contract work
c) access to intellectual property/knowledge of others
d) mobility of scientists and engineers
e) membership in scientific communities
f) education and training

E) Mechanisms of Knowledge Flows

Mechanisms describe the rules of the game (regime) under which knowledge is transferred (i.e., channels materialize). These differ along a number of dimensions.

- *Authority structure*
  (a) Command structure to transmit information
  (b) Voluntary transfer structure
- *Internalised/Non-internalised*
  (a) Information flows between agents operating under a common objective
  (b) Information flows between agents pursuing independent objectives
- *Priced/Unpriced*
  (a) Information exchanged for a fee
  (b) Information exchanged for free
- *Restricted/Unrestricted access*
  (d) Information available to everyone
  (e) Information available to a limited number of agents

An indicative list of knowledge flow channels and mechanisms and of corresponding sources of proxy indicators is shown in Table 3.3. Embodied technology, although widely appreciated as a means of knowledge flows, is excluded from this list. Enumerating all knowledge flow indicators is virtually impossible. The Table lists, instead, examples of simple indicators that we tried to obtain in our data, including the large databases of research joint ventures, EPO patent applications an d citations, and PACE, plus the newly -created survey database and large number of in -depth interviews.

Table 3.3: Identifying Channels and Mechanisms of Knowledge Flows

Within and Among firms		
Channels	**Mechanisms**	**Indicators/variables (and their source)**
Collaboration	• strategic technical alliances, • funded research joint ventures, • non-funded research joint ventures	CIS(?), surveys RJV Database Surveys
Contract work	• contractual agreements for technology related tasks	Surveys
Access to intellectual property/ knowledge of others	• reverse engineering • licensing • access to and use of patents • access to blueprints, trade secrets • other forms of technology transfer?	Surveys Surveys CESPRI database Surveys
Movement of skilled personnel within and among firms (used as a measure of tacit knowledge)	• movement of personnel by skill level in and out of the firm • switch of skilled personnel to other activities within a firm	Surveys Surveys
Scientific community memberships	• Attendance of conferences, trade fairs, and exhib itions • Journal subscriptions • Firm membership in local and international scientific communities	Surveys Surveys Surveys
Use of other sources for accumulating competitive intelligence	• user-producer interactions (including interactions with suppliers and competitors and other enterprises within the group) • use of external specialists (for training, and technical problem solving) • use of the Internet	CIS, surveys CIS, Surveys Surveys

Among firms, Universities and Research Institutes

Channels	Mechanisms	Indicators/variables (and their source)
Collaboration	• formal research joint ventures, and non-funded research joint ventures • informal collaboration	RJV database and surveys Surveys
Contract work	• basic or applied research in Uni/PRIs funded by industry • development of products and processes in University laboratories	Surveys Surveys
Access to intellectual property/ knowledge of others	• access to and use of University patents by industry • spin-off companies	CESPRI Database (?) Citation analysis (?) Surveys, case studies
Mobility of scientists and engineers	• mobility of scientists and engineers between industry and academia • academics occupying high-level positions in firms	Surveys Surveys/case studies
Scientific community memberships	• attendance of conferences, trade fairs, and exhibitions	Surveys
Education and training	• provision of training services to firms • provision of consultancy services to firms over technical, legal, and regulatory matters.	CIS, surveys /case studies CIS, surveys /case studies

3.2. RESEARCH METHODOLOGY

3.2.1. RESEARCH STAGES

The KNOW programme was heavily empirical, involving the exploitation of several large databases and new information from extensive business surveys and in-depth company interviews. The programme evolved in five stages. During the first two the partners created the methodology, prepared the data, and collected new information. The last three stages supported analytical work. Although listed sequentially below, several research tasks run in parallel depending on the research needs.

Stage 1: Desk research, database preparation and preliminary descriptive analysis

Stage 1 had three main research tasks:

1.1. Literature review on innovation-related knowledge flows and on EU, national, and regional policies to facilitate such flows.

1.2. Preparation of three main databases: EPO patents and patent citations, CIS and EU-RJVs.

1.3. Preliminary descriptive analysis using the three main databases plus the PACE database.

Stage 2: Field research – survey, interviews

Stage 2 had three main research tasks:

2.1 Conduct field research (focused survey) in all seven participating countries.
2.2 Conduct a number of in-depth, semi-structured interviews in all seven countries.
2.3 Write up the main results from the survey and the interviews.

Stage 3: Comparative empirical analysis of the determinants of knowledge flows in European industry – Evaluation of the impact of knowledge flows on innovative performance

The objective of Stage 3 was to synthesize and extend the results of the analysis in Stages 1 and 2 and to make links across the different data sources. It had four main research tasks:

3.1. Comparison of the results from the three different large data sets plus PACE.
3.2. Statistical/econometric analysis of the determinants of innovation-related knowledge flows in European industry.
3.3. Analysis of the effectiveness of knowledge flows in enhancing innovative performance – identification and evaluation of transmission mechanisms.
3.4. Writing reports on the results from research tasks 3.1-3.3. Linking the quantitative analysis of this Stage with the relevant qualitative information from Stage 2.

Stage 4: Comparative empirical analysis of the spatial dimension of innovation-related knowledge flows affecting the EU industry

The objective of Stage 4 was to extend the results in Stages 1-3 by emphasizing the spatial dimension of knowledge flows. It had four main research tasks:

4.1. Comparison of the results from the three different data sets plus PACE relating to the locational characteristics of knowledge flows.
4.2. Empirical analysis of the spatial dimension of innovation-related knowledge flows in the EU combining information from the different data sets plus our survey.
4.3. Writing reports on results from tasks 4.1-4.2 addressing explicitly EU and EU member state S&T policies.
4.4. Appraisal of the extent of convergence of national innovation systems within the EU and the emergence of a European Innovation System.

Stage 5: Policy analysis and recommendations

The objective of Stage 5 was to draw lessons for future S&T policy options on the basis of the analysis undertaken in the previous four Stages.

3.2.2. DATA

The KNOW programme has used empirical information from six different databases, some of which were modified and enhanced during the course of the programme. In addition, a new database was created to record the results of an extensive survey of business firms in five manufacturing and service sectors. An additional source of information has been a large number of in-depth interviews with selected companies that also participated in the survey. This section briefly describes each source of empirical information.

3.2.2.1. EU-RJV Database

The EU-RJV database is one of the core databases in the STEP-TO-RJVS databank that was created during the TSER programme "Science and Technology Policies Towards Research

Joint Ventures" (Caloghirou and Vonortas, 2000). This database records information on transnational collaborative research projects funded by the European Framework Programmes on RTD (FWPs). The current version covers projects initiated during 1983 - 1998 by the first four FWPs.

The database includes programmes whose main focus has been the creation of new technological knowledge. All commonly known programmes (and many more) satisfied this criterion, including ESPRIT, BRITE-EURAM, JOULE, RACE, BIOMED, BIOTECH, ENV, TELEMATICS and many more (64 Programmes in all). The database records research projects that involve at least one agent from the private sector (firm). The total number of recorded projects that satisfies all selection criteria amounts to 9,335. A total number of 20,499 different organizations from 50 countries participated at least once in these projects. The sum of recorded memberships reaches 65,476.

The EU-RJV database identifies the individual participants in each and every recorded project. For a very significant number of firms that participated in projects initiated during the period 1992-1996 the database also includes longitudinal financial information (5 years) obtained from the commercially available database AMADEUS.

3.2.2.2. EUREKA-RJV Database

The EUREKA-RJV database is another core database in the STEP-TO-RJVs databank. This database records information on transnational collaborative research projects selected by the EUREKA! initiative during 1985-1996.[4]

The structure of the EUREKA-RJV database is identical to that of the EU-RJV database. The recorded RJVs amount to 1,031. These collaborative projects involve 6,233 memberships corresponding to 4,261 entities from 36 countries. From these entities, the database records longitudinal financial information for 1,250 firms originating again in AMADEUS.

3.2.2.3. PACE Database

The PACE database contains the results of an innovation survey for 604 of Europe's largest R&D performing firms. The original survey was conducted in 1993 by MERIT (Arundel et al., 1995). The PACE results on the use of public research institutes are of particular value to this programme because detailed questions were asked on the importance of different types of public research output (basic research, applied research, new instruments, prototypes), the methods used to access public research results across four geographical regions

[4] EUREKA was designed in the mid-1980s to complement the European Framework Programmes on RTD by selecting collaborative research projects focusing on the development of final products and processes. The selected projects are not funded by any central agency; individual partners seek funding from their respective national governments. In contrast to the Framework Programmes for RTD, EUREKA does not pre-specify technology areas for competition.

(the specific country, other Europe , the US, and Japan), and the importance of ten different fields of public research.

3.2.2.4. RJV-EPO Database

The RJV-EPO dataset was produced cooperatively by three partners to combine information from the EU -RJV database (LIEE), the EPO -CESPRI database (CESPRI), and the EPO -MERIT database (MERIT). The merging of the three databases was carried out at the level of the firm, resulting in a large set of companies for which one can pull together RJV participations, European patent applications, and patent citations.

The EPO-CESPRI database is based upon the BULLETIN database produced by the European Patent Office (EPO). The data base provides information about all patents applied for and granted by the European Patent Office (1978-1998). CESPRI has standardised information on the names of patenting organisations and has organised the dataset at the level of individual patenting organisation (firm, university, etc.). The typical record of the database contains information about the publication number of the patent, applicant name, applicant code, applicant address, main and supplementary technological classes of the patent. Overall, the EPO-CESPRI database contains information on about 190,000 patenting organisations and 854,916 patents.

The EPO-MERIT database is based upon the EPO's REFI dataset which provides information on patent and non-patent literature cited in patent documents. MERIT has standardised information on citing and cited patent documents for the period 1978 -1999. The typical record of the database consists of two variables: the publication number of citing patent document and publication number of cited patent document. The EPO -MERIT database contains 894,103 records, corresponding to 482,687 citing patents and 388,986 cited patents.

3.2.2.5. The Community Innovation Survey (CIS) Database

The first CIS was carried out during 1992 -1993 in thirteen European countries, including twelve members of the European Community.[5] The first CIS contains information on the innovative activities of approximately 40,000 European firms. A second CIS, which differs substantially from the first, has been completed in the late 1990s with no publicly available comparative analytical results at the time of this writing.

The first CIS provided a unique set of data. Many of the questions were directly relevant to a study of knowledge flows and innovation systems, such as:

- The importance of different sources of technical information, including internal sources, market -based sources, public research institutions, and generally available information.
- The methods used to acquire and transfer new technologies including R&D outsourcing, purchases of other firms, purchases of equipment, hring skilled personnel, informal contacts with other organizations, cooperative research projects, etc.
- The geographical origin of the technological information, differentiating between six regions in total, three of which are in Europe (national, EU, non -EU) and three outside of Europe (US, Japan, other).
- The barriers to innovation, including economic factors, enterprize factors, other reasons.

3.2.2.6. KNOW Survey Database

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[5] See Arundel and Garrelfs (1998) and Archibugi et al. (1994) for detailed descriptions of the data and available research results.

A new, focused survey of firms in selected industries has been undertaken during the course of the KNOW programme to gather supplementary information on the specific internal and external mechanisms and institutions that support innovation-related knowledge flows and of the procedures that facilitate learning. While CIS 1 and CIS 2 gathered related data on a large scale, the resulting information is not accessible at the firm level. Moreover, additional detail than provided in these two pan-European surveys was considered necessary for KNOW.

The KNOW survey has several advantages over CIS, including:

- Ø The KNOW survey obtains information on the percentage of each firm's new or improved product innovations that were developed in-house, through buying in, or via collaboration with other divisions of the same firm or with independent firms or PRIs. In contrast, CIS only asks if the firm cooperated, on a yes or no basis, and then obtains information on the types of cooperation partners. It does not collect any information on whether or not cooperation led to innovations or the share of innovations developed through cooperation.
- Ø The KNOW survey obtains information on each firm's use of three appropriation methods, secrecy, patents, and lead-times, and asks which method was the most important to the firm for protecting its innovations.
- Ø The KNOW survey obtains data on the distribution of research spending by location: in-house, other divisions of the firm, and external to firm.
- Ø The KNOW survey asks for the number of employees with an academic degree in science or engineering. This provides an alternative to R&D spending as a measure of the firm's innovative capacity.

On the other hand, CIS is broader than the KNOW survey in terms of geographical, sectoral, and firm size coverage.

The KNOW survey covered seven EU countries: Denmark, France, Germany, Greece, Italy, the Netherlands, and the United Kingdom. Five business sectors were considered:

- food and beverages (NACE 15)
- chemicals excluding pharmaceuticals (NACE 24 excluding 24.4)
- communication equipment (NACE 32)
- telecommunication services (NACE 64.2)
- computer-related services (NACE 72)

To ensure comparability among countries it was initially determined to include firms with 10-1,000 employees. Two size classes were used: one for small firms with 10-250 employees and one for firms with 251-1000 employees. The information was collected by Computer Aided Telephone Interviews (CATI). Table 3.4 summarizes the effort and the achieved response rates by country.

Table 3.4: KNOW Survey – Response Rates

Country	Number contacted	Responses	Response Rate (%)	Innovators
Greece	260	110	42.3	100
Italy	278	97	34.9	80
Denmark	170	130	76.5	98
UK	1003	96	9.6	46
France	613	79	12.9	76
Germany	470	101	22.0	94
Netherlands	331	151	45.6	138
Total	**3017**	**764**	**25.3**	**632**

Although the design of the questionnaire allowed the collection of data from non -innovators as well, their share in the returned responses turned out disproportionately low. These companies were consequently excluded from subsequent analysis. Responses from firms that ex post proved to belong to non-target sectors were also excluded. Finally, a significant number of firms proved to fall out of the size range than had initially been set. In order to increase the total sample for our empirical analysis it was decided to increase the upper limit by 25%, including thus firms with up to 1250 employees. A total of 558 respondent firms were found to meet the criteria of an innovator and to belong to the selected sectors and size class. Table 3.5 shows the country and sectoral distribution of the final sample, both unweighted and weighted in terms of employment.

Table 3.5: KNOW Survey - Country and Sector Distribution of Sample

Country	**Sectors**						**%**	***Weighted %***
	15	**24**	**32**	**64**	**72**	**Total**		
Germany	18	16	21	4	20	79	14,2%	36,0
France	13	12	14	13	13	65	11,6%	21,2
Italy	19	20	13	2	24	78	14,0%	24,9
Netherlands	35	33	13	4	29	114	20,4%	3,3
UK	6	19	6	4	9	44	7,9%	5,8
Denmark	20	11	15	11	21	78	14,0%	6,9
Greece	21	21	19	10	29	100	17,9%	2,0
Total	132	132	101	48	145	**558**	100,0%	
%	23,7%	23,7%	18,1%	8,6%	26,0%	23,7%		
Weighted %	48,2	17,9	8,0	2,0	23,9	100,0%		

The final set of responding firms above were classified as innovative, i.e., firms that had introduced one or more innovations the last three years. More than half (55%) of the set corresponds to rather small firms (<50 employees) and another 40% corresponds to middle sized and larger firms (>250 employees). More than a quarter (27%) reported R&D intensity 10%-25%; about a quarter reported R&D intensity 1%-5%. More than 40% have never cooperated with a partner outside the private sector (universities, PROs); about a third have cooperated three or more times with such a partner. About 9% of these firms do not employ scientists; scientific personnel outweighs low skilled personnel in about 16% of them.

3.2.2.7. In-depth Interviews

The results of the survey were greatly enriched by insights from in-depth interviews with 71 out of the 558 companies. The set of firms to interview was not drawn randomly from the population of respondents. Instead, the partners aimed at an equal representation of all examined sectors (five) and countries (seven). Thus, interviews were allocated as two per sector per country.[6] The in-depth interviews expanded the available information from the survey on the following subjects:

§ Use of patents to obtain ideas for innovation. Also, use of patents as a means for protecting proprietary information.
§ Use of the internet in search of scientific and technological information, information regarding market dynamic and consumer behaviour, and for communication with suppliers, customers, collaborators.
§ Collaboration with universities and benefits from it.
§ The ways in which the most important source of information (as indicated in the survey) interacted with the firm in question regarding the specific innovation.
§ Evaluation of internal versus external sources of information.
§ Research cooperation: types of partnerships, types of partners, perceived returns, problems in managing the partnership(s).

Copies of the questionnaire used for the KNOW survey and of the in-depth interview guidelines can be found in Annex I and Annex II respectively.

[6] Nine interviews were carried out in the UK. This was compensated by twelve interviews carried out in France.

3.3. RESEARCH RESULTS

The KNOW program produced a wealth of quantitative and qualitative results on knowledge flows affecting European industry. Quantitative results (descriptive and statistical/econometric) are based on the analysis of the large data sets described in the previous section. Qualitative results are based on the in-depth interviews.

3.3.1. DESCRIPTIVE ANALYSIS OF KNOWLEDGE FLOWS

All available databases were used extensively for describing external relationships and knowledge flows that affect European industry. CIS 1 was used to present a more aggregate picture across all sectors at the country level. [7] The KNOW survey was used for a much more disaggregated investigation of such flows in the examined five sectors in seven EU member countries. Finally, the EPO-RJV database was used for a detailed analysis of networks among the identified organizations participating in cooperative Framework RTD Programmes and in EUREKA.

3.3.1.1. CIS 1

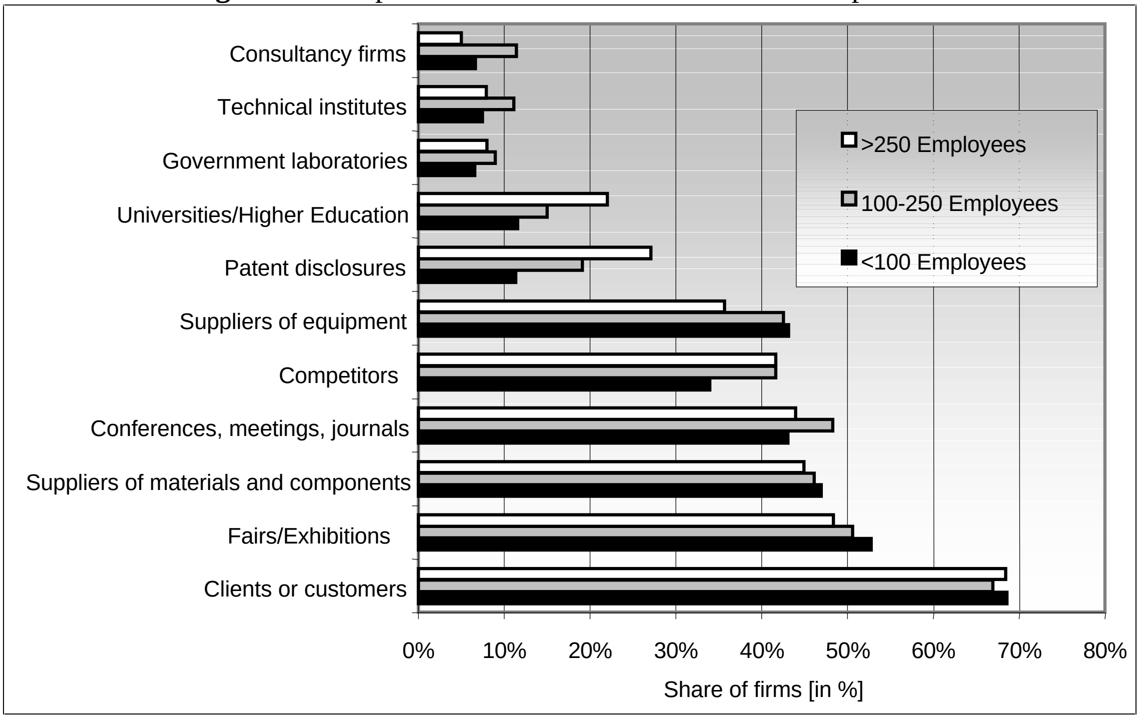
In the CIS questionnaire the firms indicated the importance of the different internal or external sources of knowledge on a Likert scale, rating importance from 1 to 5. Figure 3.3 below shows the overall importance of external sources of information. A source is regarded as important if the firm regards it as “very significant (4)” or “crucial (5)”.

Customers are of the highest significance as external sources of information, followed by suppliers and competitors. Fairs and exhibitions and conferences, meetings and journals are very important mechanisms of external knowledge transfer. Demand pull seems to be far more important than the technology push, both for small and large companies. Research institutes and consultancy firms fall behind universities and patent disclosure as important channels of knowledge dissemination.

Companies were questioned on R&D cooperation. Figure 3.4 illustrates the frequency with which different partners are integrated in R&D co-operation. The surveyed innovative companies tend to cooperate above all with suppliers and clients in vertical relationships. Cooperation among organizations in the same country is dominant. The probability to co-operate in R&D rises with company size (Figure 3.5). Larger enterprises cooperate more with universities, followed by suppliers and clients. The significance of these three partners stands in reversed order for SMEs: clients are the most common co-operation partners, followed by suppliers and universities.

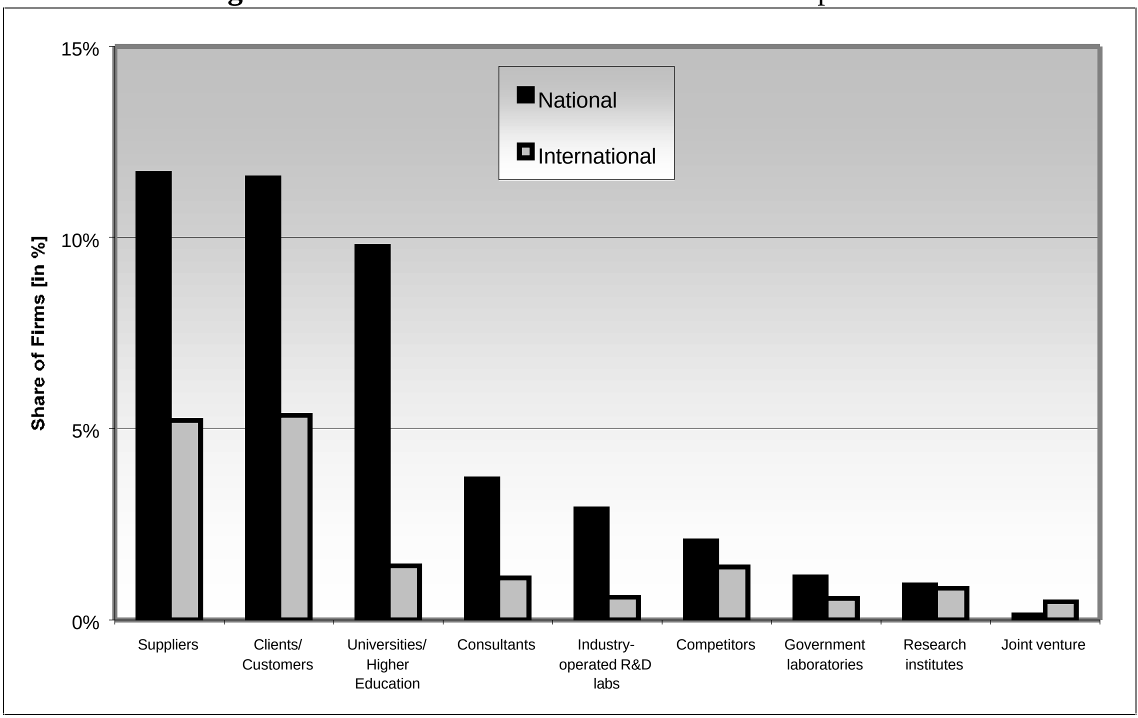
[7] The KNOW consortium originally planned to utilize CIS 2 data for this analysis. This proved impossible due to lack of access to the necessary data due to EUROSTAT regulations.

Figure 3.3: Important Sources of Innovation for Companies



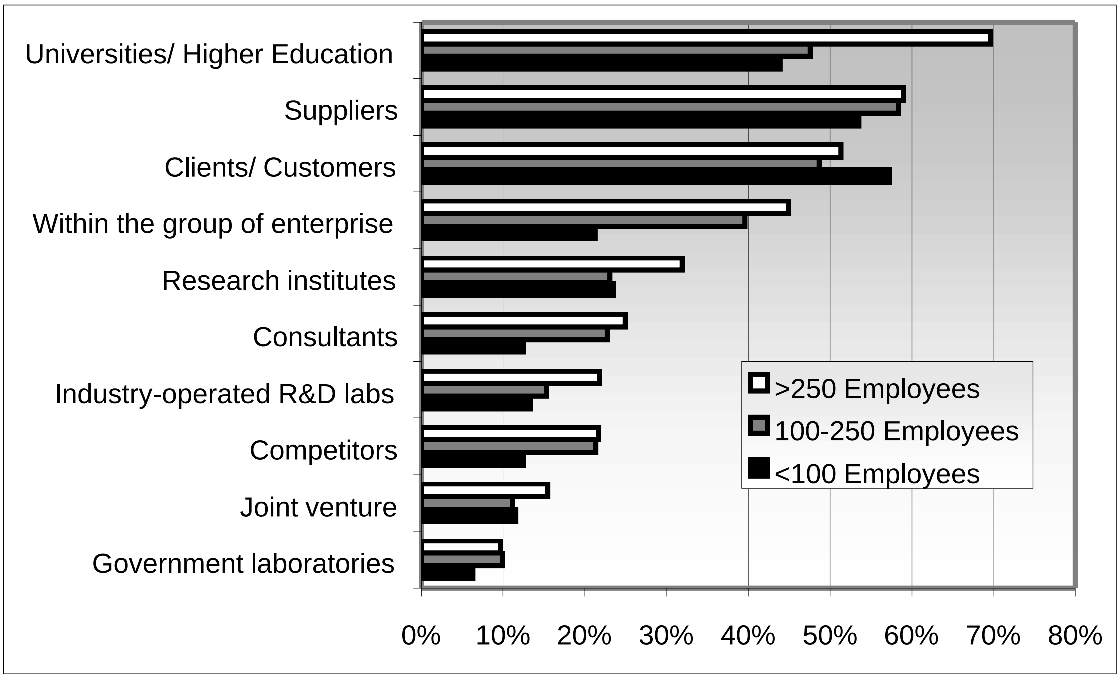
Note: Details weighted according to the number of innovative companies
Source: First Community Innovation Survey

Figure 3.4: Share of Innovative Firms' R&D Cooperation



Note: Details weighted according to the number of innovative companies
Source: First Community Innovation Survey

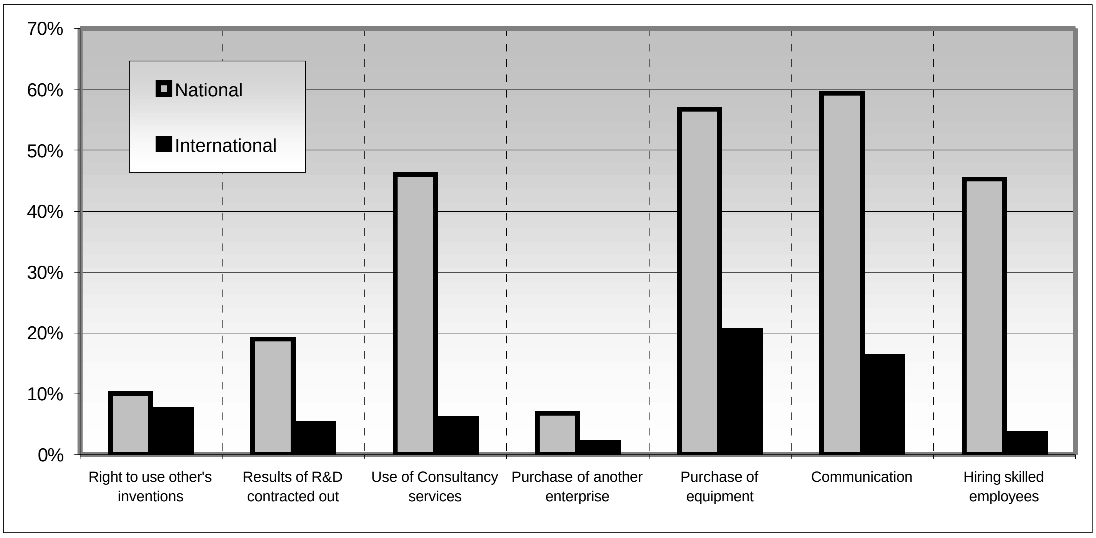
Figure 1.5: Share of Innovative Firms' R&D Co -operation



Note: Details weighted according to the number of innovative companies with R&D-Co-operation
Source: First Community Innovation Survey

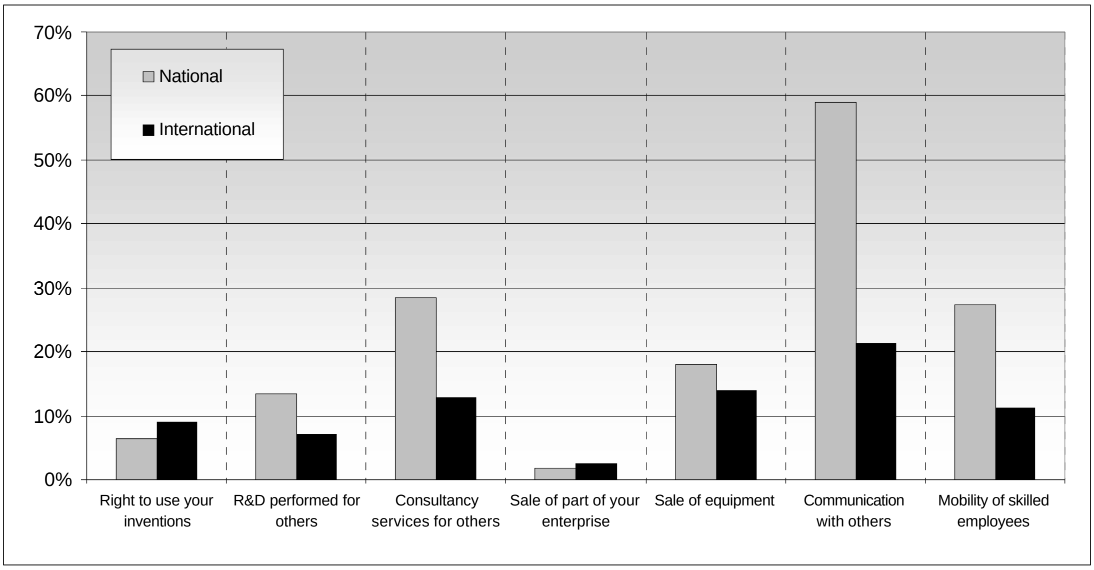
Figures 3.6 and 3.7 show the percentage of innovative companies' inflows and outflows of knowledge respectively. National channels of knowledge flows are clearly used more often than international channels. While the frequencies of the individual knowledge - outflows are comparable to those of the knowledge -inflow, they do differ in one fundamental respect: the outflow of knowledge is dominated by disembodied and informal (tacit) knowledge, especially by "communication with specialist from other enterprises". Almost 30% of the firms transfer knowledge nationally by the mobility of skilled employees.

Figure 3.6: Knowledge Acquisition from National and International Donors in 1992



Note: Details weighted according to the number of innovative companies
Source: First Community Innovation Survey

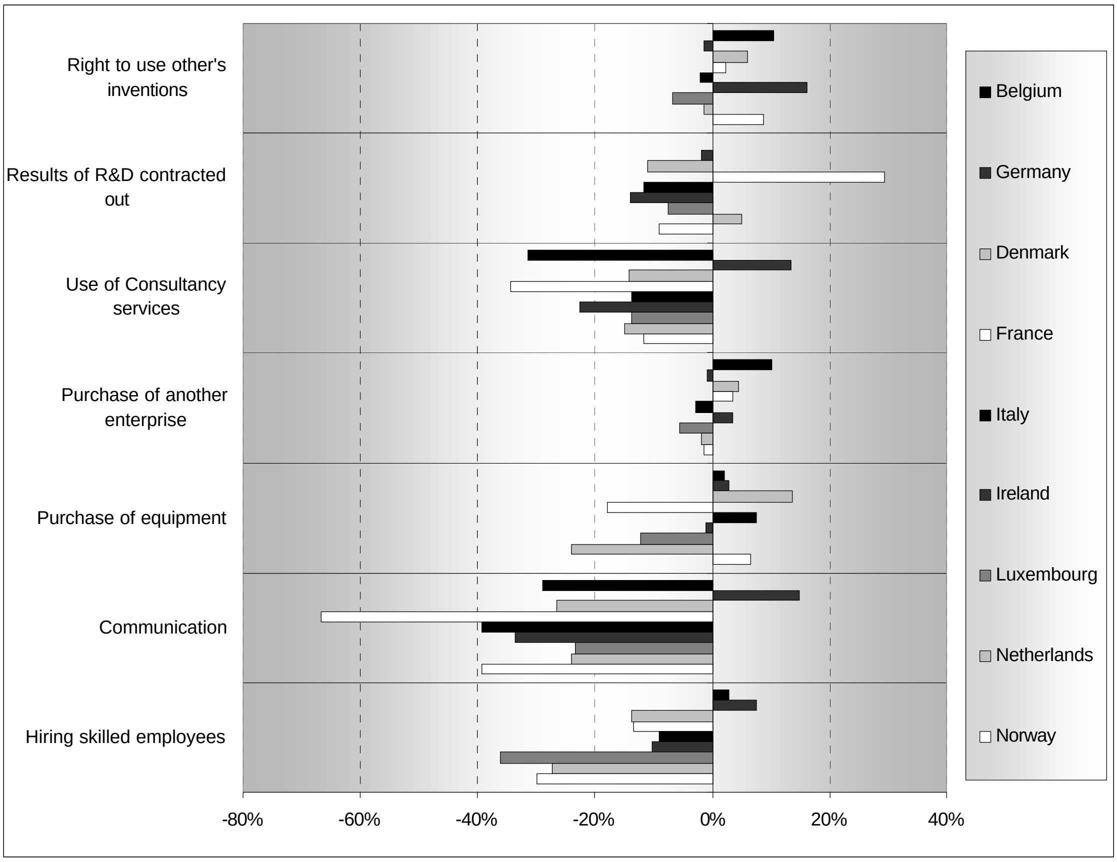
Figure 3.7: Knowledge Outflow to National and International Recipients in 1992



Note: Details weighted according to the number of innovative companies
Source: First Community Innovation Survey

Only the significance of different channels of knowledge has been presented so far. Figure 3.8 describes the importance of the different forms of knowledge -inflow by country. The values of the particular frequencies are centered around the over -all mean of the respective item. Note that the larger the country (in numbers of innovators) the larger its weight for the calculation of the mean; Germany is the primary case in point.

Figure 3.8: Knowledge Acquisition in Different Countries

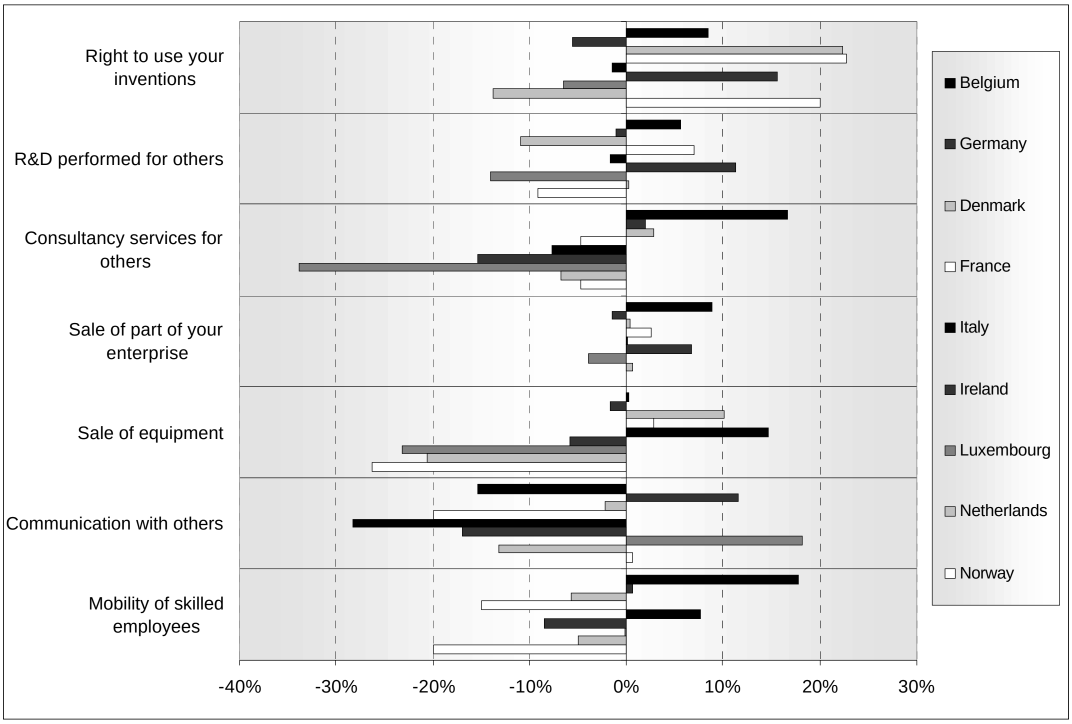


Note: Details weighted according to the number of innovative companies and centred around the mean of each item
Source: First Community Innovation Survey

Countries are shown to be very heterogeneous in this respect. For example, companies in Belgium and Denmark use embodied forms of knowledge flow more often than the average in contrast to companies in the Netherlands and Luxembourg. French firms acquire knowledge more often than the average through disembodied and formal channels whereas firms from Italy, Germany and Luxembourg comparatively avoid this form of channel. German firms prefer the disembodied and informal way of acquiring knowledge. Heterogeneity between countries is also present in knowledge outflows (Figure 3.9).

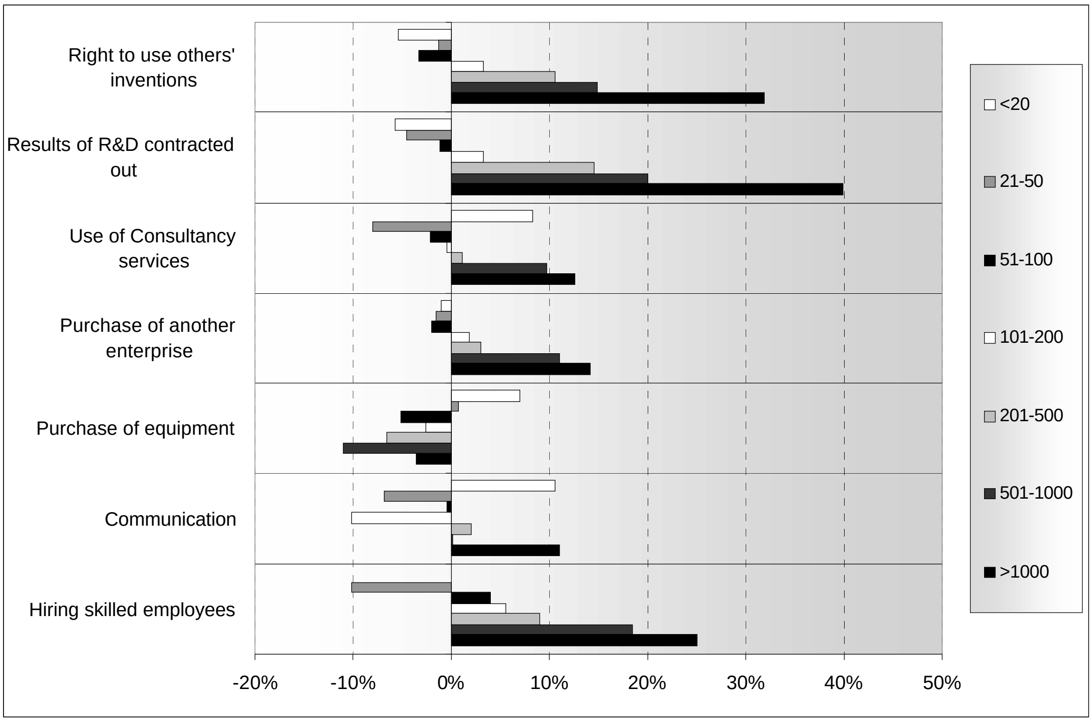
Figures 3.10 and 3.11 capture the effect of size differences of firms. A clear positive relationship between firm size and both the probability of acquiring and transferring knowledge is observed. Only one channel of acquisition and three channels of transfer do not systematically shift over the size classes. The strong connection between firm size and knowledge inflow and knowledge outflow has also been shown with bivariate analysis.

Figure 3.9: Knowledge Transfer in Different Countries



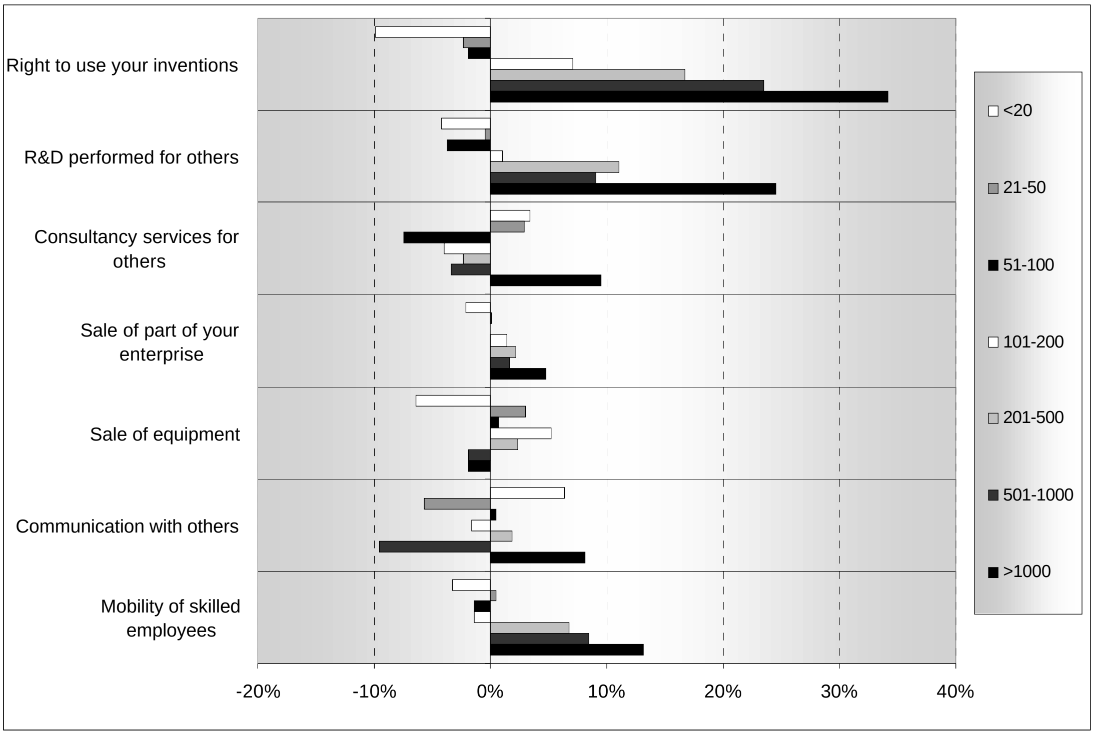
Note: Details weighted according to the number of innovative companies and centred around the mean of each item
Source: First Community Innovation Survey

Figure 3.10: Knowledge Acquisition by Firm Size



Note: Details weighted according to the number of innovative companies and centred around the mean of each size class
Source: First Community Innovation Survey

Figure 3.11: Knowledge Transfer by Firm Size



Note: Details weighted according to the number of innovative companies and centred around the mean of each size class
Source: First Community Innovation Survey

3.3.1.2. KNOW Survey

Five hundred and fifty-eight firms were surveyed in the Spring 2000 regarding their experience with knowledge flows first with respect to their general innovation activities and second with respect to their economically most important innovation of the last three years. The surveyed firms ranged between 10 and 1250 employees and were based in seven European countries: Denmark, France, Germany, Greece, Italy, the Netherlands and the United Kingdom. They operated in five selected sectors: food and beverages (NACE 15), chemicals excluding pharmaceuticals (NACE 24 excluding 24.4), manufacturing communication equipment (NACE 32), telecommunication services (NACE 64.2), and computer-related services (NACE 72).[8] For the purpose of this presentation, the latter two sectors have been merged to one called ICT services.

[8] The sample of firms was appropriately stratified by size – small and medium-sized companies, 10-249 employees and 250-1000 employees respectively – by sector, and by country. The sample was drawn randomly from the appropriate company cohorts in national registries.

Figure 3.12: R&D Activities

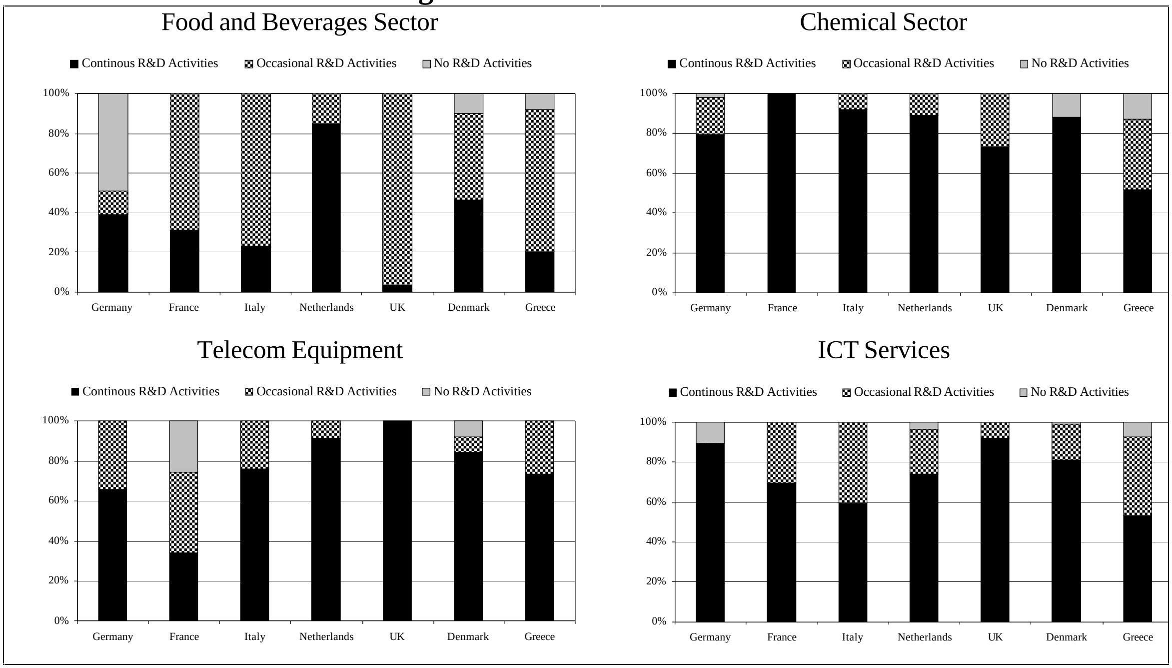
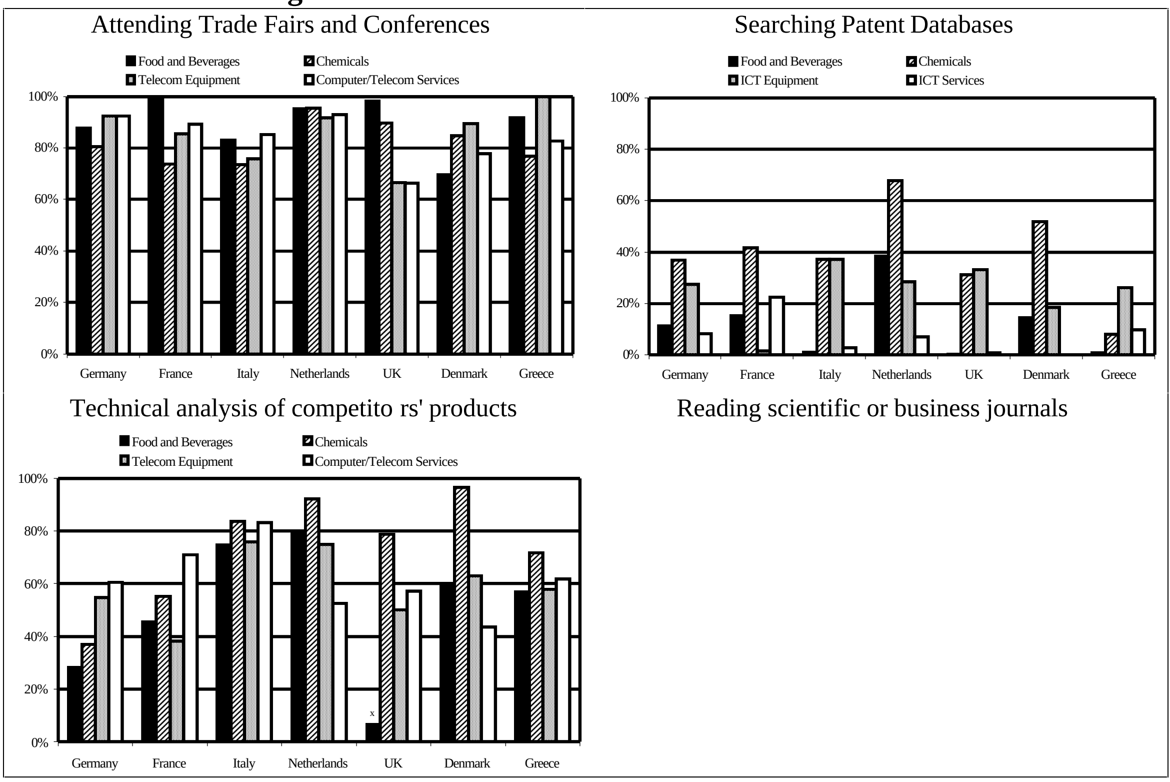


Figure 3.13: Sources of New Ideas for Innovation

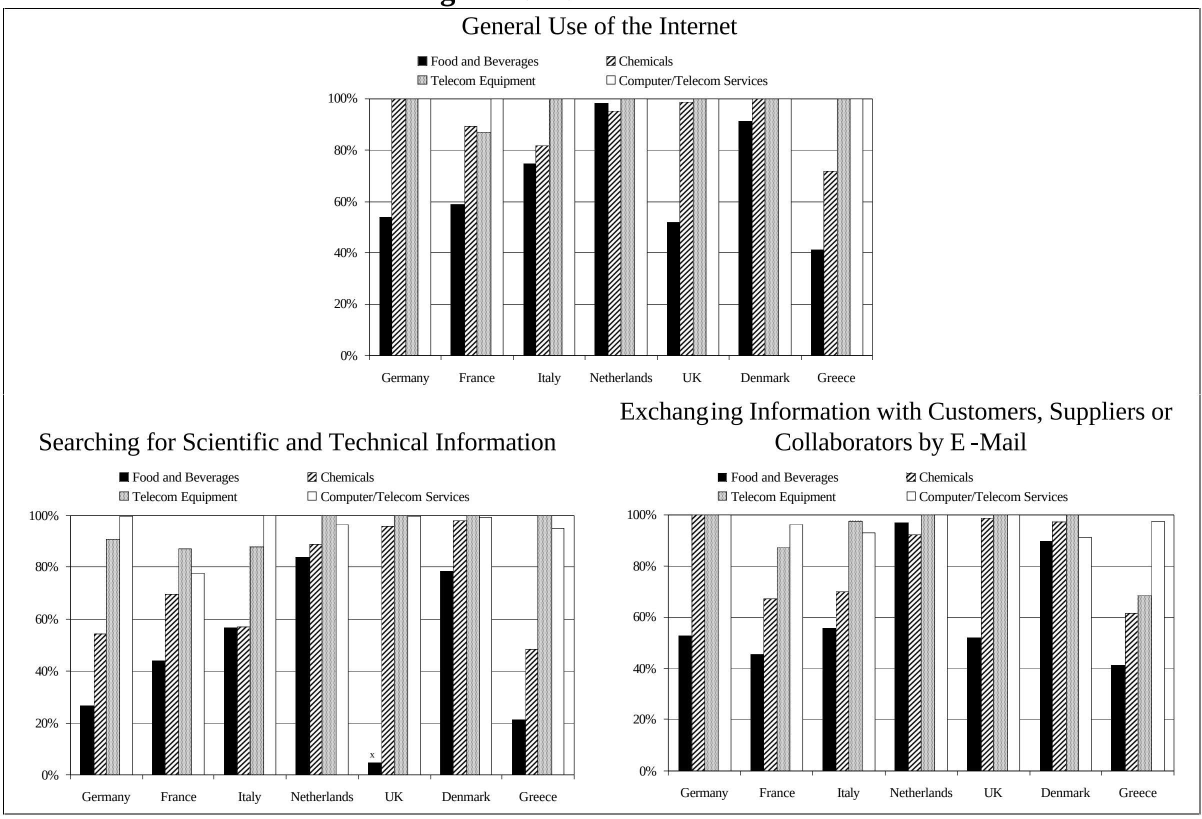


Notes: "x" indicates that the value for the corresponding stratum is based on a low number of observations, "M" indicates a missing value.

Figure 3.12 shows there are significant differences between sectors across all countries and between countries across sectors in terms of R&D orientation of the surveyed firms. According to Figure 3.13, attending trade fairs and conferences as well as scientific and business journals are the most important source of new ideas for innovation in the examined countries.

About half the innovating firms perform technical analyses of competitors' products (reverse engineering) to gain new concepts for own innovations. Danish and Dutch chemical companies report this most often. With the exception of Germany and France, reverse engineering is most important for the chemical firms. In Germany and France the telecom and computer services (ICT services) indicate the practice of reverse engineering most favourably. Searching patent databases for creative ideas is not very popular. Firms often find it too time-consuming and not sufficiently rewarding to search patent data for ideas. Only firms located in the Netherlands seem to use this information more frequently: more than one third of firms reported searching patent databases regularly, especially in the chemical sector where about 70% of innovators do it.

Figure 3.14: Internet Use

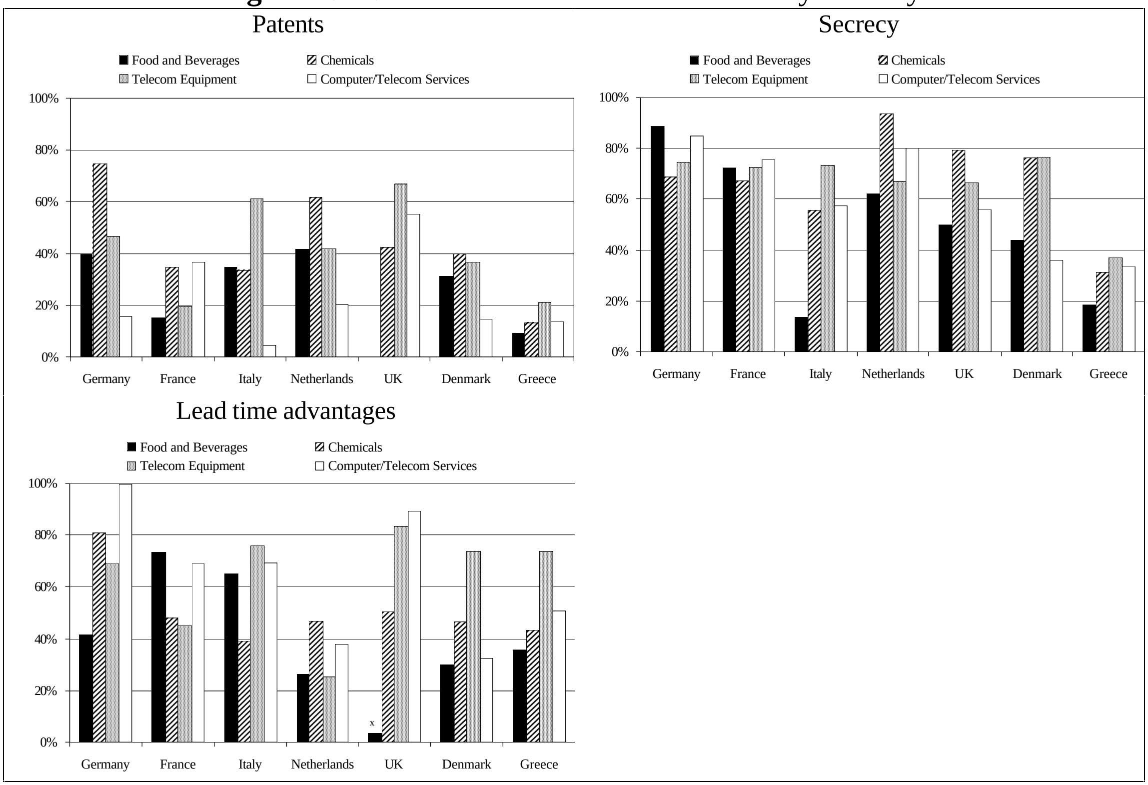


Notes: "x" indicates that the value for the corresponding stratum is based on a low number of observations, "M" indicates a missing value.

Overall, about 80% of firms use the Internet regularly in every-day business. Only in the food and beverages sector the dissemination of the Internet technology is still poor: this sector has the lowest penetration with ICT in each of the seven countries (Figure 3.14). Most firms use the Internet for both searching for scientific and technical information as well as for communication with other companies. However, the possibility of communication via the Internet seems to be the first step into the virtual world. In most firms, e-mail communication has already replaced classical communication channels like regular mail of fax. In Greece, the Internet is used only by 58% of firms, which is the lowest dissemination of this technology in the investigated countries. In the Netherlands and Denmark nearly 100% of firms use the Internet.

In most countries, secrecy is the preferred strategy of protection (Figure 3.15). More than 80% of German innovators favour this strategy. In Italy and Greece lead-time advantages are most important; patenting is less frequently used. While in the Netherlands four out of ten firms apply for patents when innovating, in Greece only one in ten does so. In the German and Dutch chemical sector patents are of high importance. British and Italian manufacturers of communication equipment as well as French and British ICT service firms use patents frequently. Dutch firms count on lead-time advantages less than firms of other countries. Secrecy is the favoured knowledge protection strategy in the Netherlands.

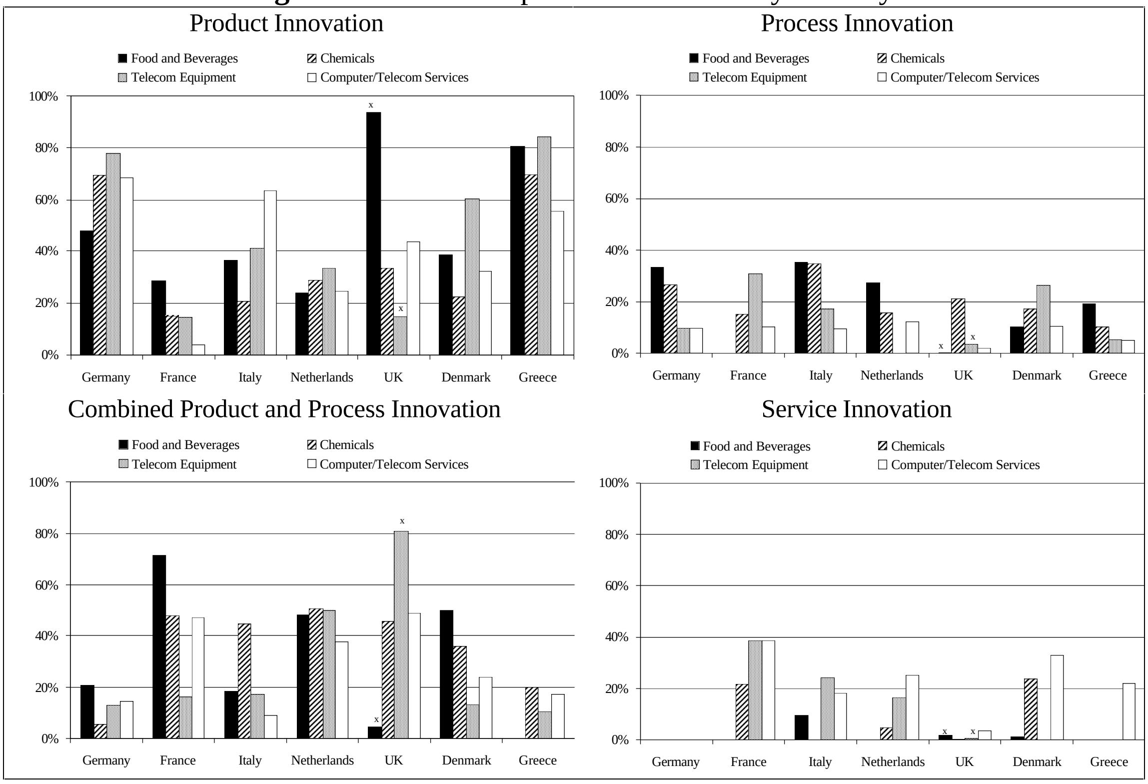
Figure 3.15: Methods to Protect Innovations by Country



Notes: "x" indicates that the value for the corresponding stratum is based on a low number of observations, "M" indicates a missing value.

Economically most important innovations are usually new products or the combination of new products and processes (Figure 3.16). Mere process or service innovations are less frequently mentioned as economically most important for firms. In Italy 25% of firms regard a new process as most valuable, while only 5% of French firms consider this.

Figure 3.16: Most Important Innovation by Country

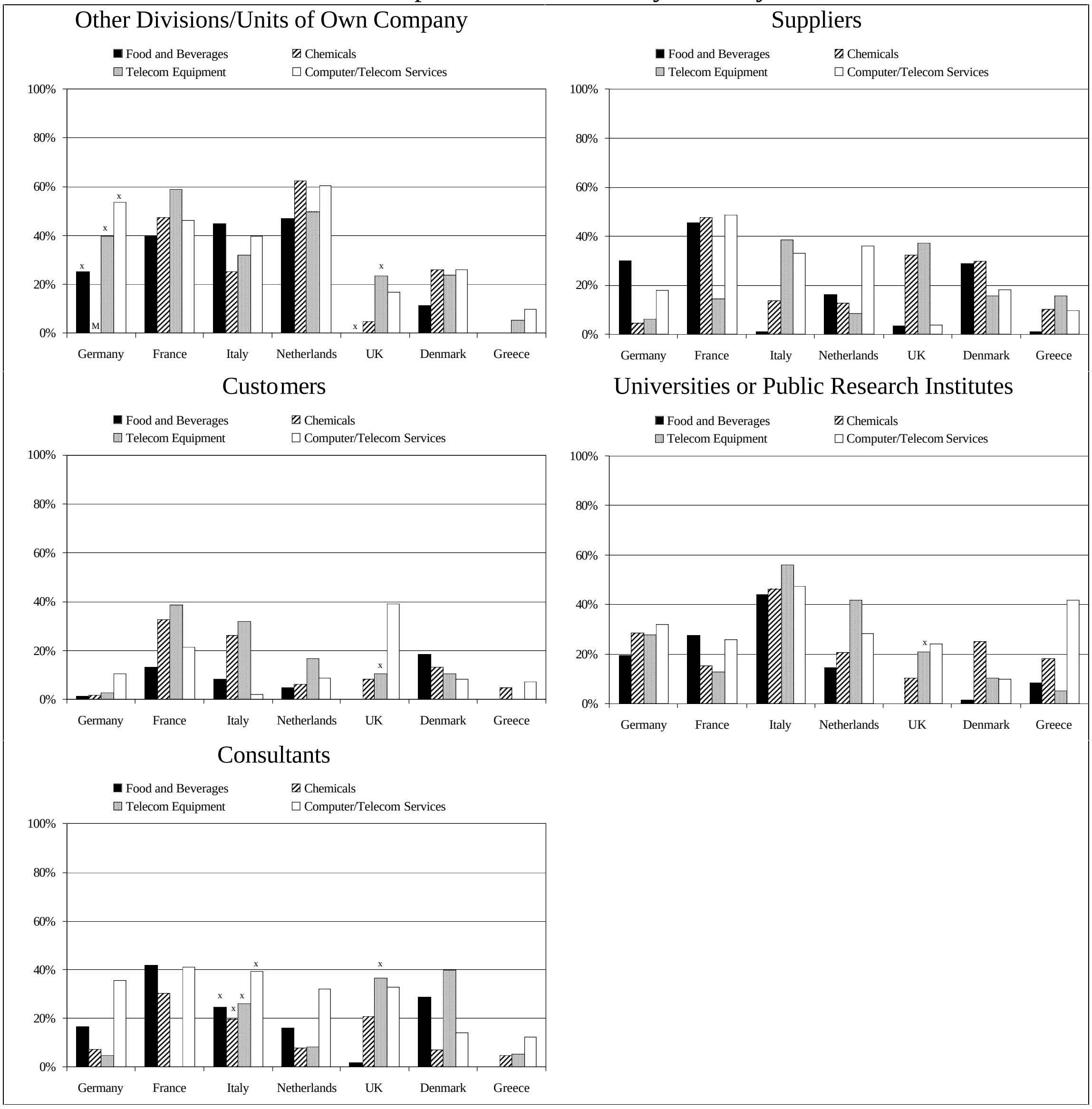


Notes: "x" indicates that the value for the corresponding stratum is based on a low number of observations, "M" indicates a missing value.

Figure 3.17 shows the sources for hiring new scientists by countries and industries. About 50% of firms in France and the Netherlands hired high skilled personnel from other divisions or units of their own companies. In France, suppliers and customers are more frequently used as a source for qualified persons than in other countries: more than 40% of French innovators hired personnel from their suppliers, and 20% from their customers. Universities or public research institutes (PRIs) are most utilised in Italy with a proportion of 46%. In the UK, Denmark and Greece only every tenth firm hired personnel of universities or PRIs to work on the most important innovation. Italy is the leading country for acquiring new personnel directly from universities or public research institutes.

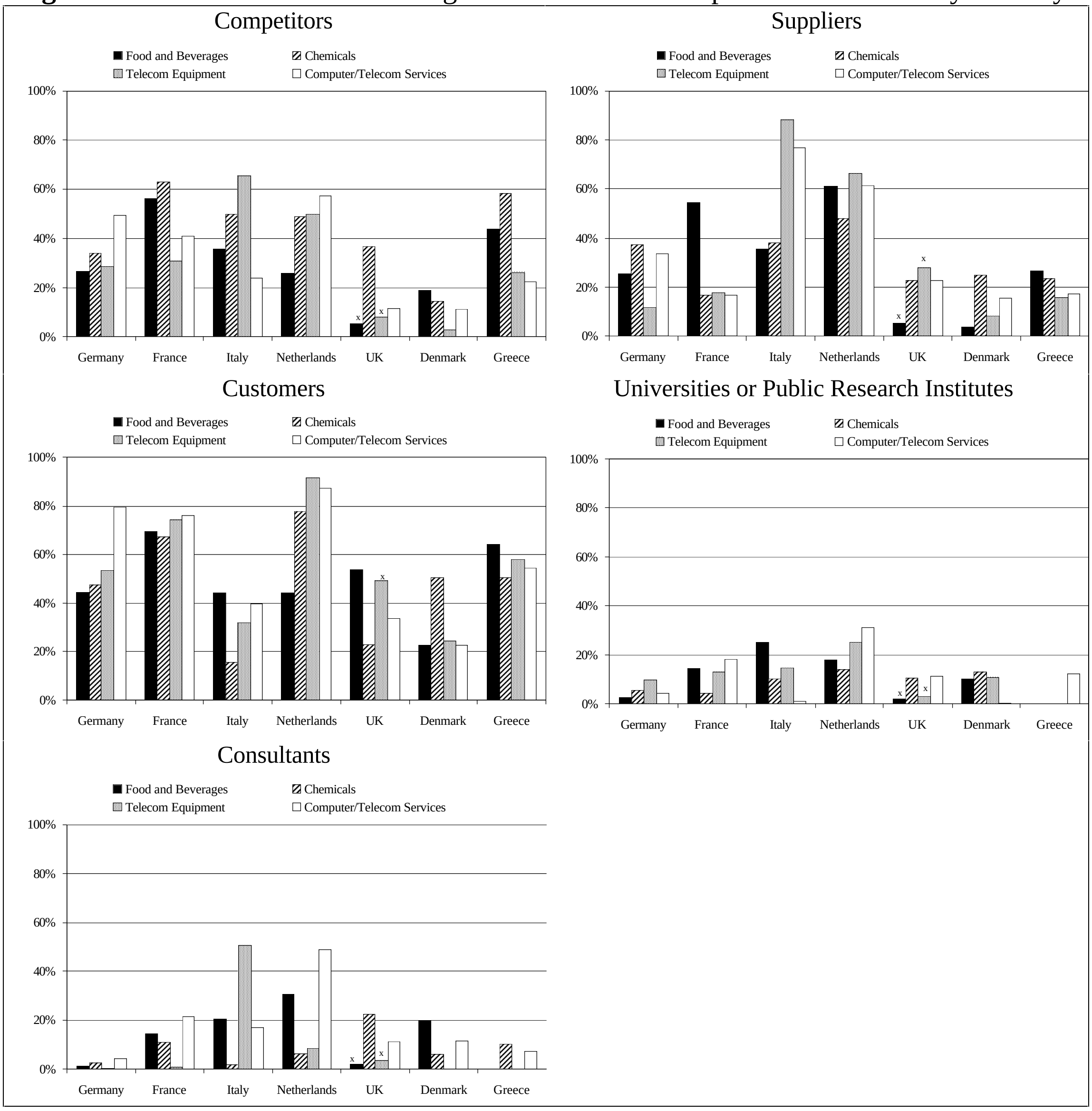
Figures 3.18 and 3.19 clearly show that the economically most valuable innovations are pulled by demand: customers are the dominating sources for the original ideas of innovations. This result is verified by the in-depth interviews (reported later), where many firms mentioned that they implement the lead-user concept in their innovation projects. Only Italian firms report that suppliers and competitors are more important than customers. Nevertheless, competitors seem to be a reasonable source of innovation in all countries, which is also supported by the importance of reverse engineering mentioned above. Suppliers are relatively mo re important in the Netherlands. The same is true for universities or PRIs and consultancies.

Figure 3.17: Source of New Scientists/Engineers Hired to Work on Most Important Innovation by Country



Notes: “x” indicates that the value for the corresponding stratum is based on a low number of observations, “M” indicates a missing value.

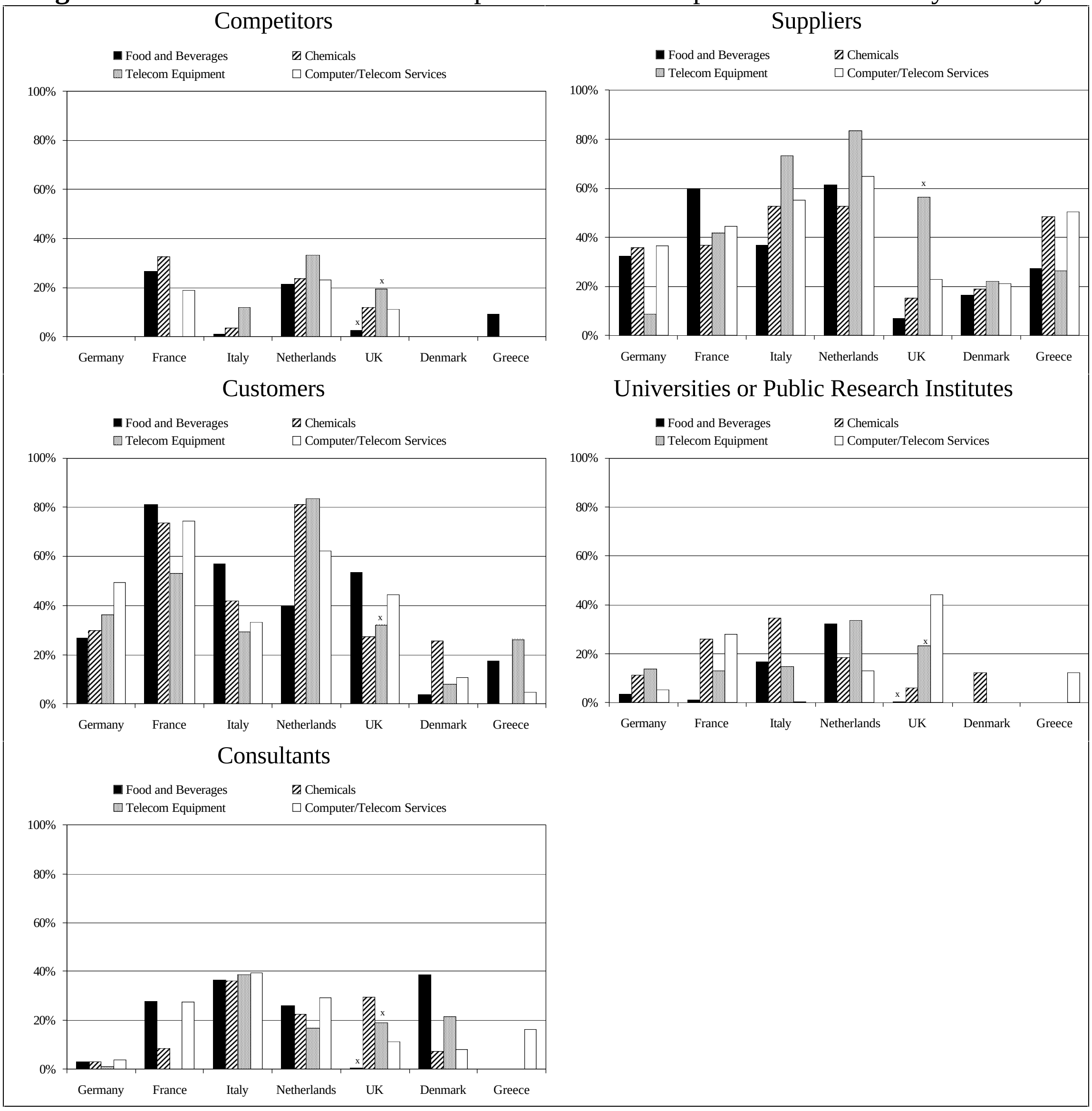
Figure 3.18: Contributors to the Original I dea for Most Important Innovation by Country



Notes: “x” indicates that the value for the corresponding stratum is based on a low number of observations, “M” indicates a missing value.

In addition to serving as frequent sources of the original idea, customers and suppliers are most frequently mentioned as the important contributors to the completion of the innovation (Figure 3.19). Dutch firms use custom ers or suppliers for a very large percentage of completion of innovation projects. They are followed by French and Italian firms.

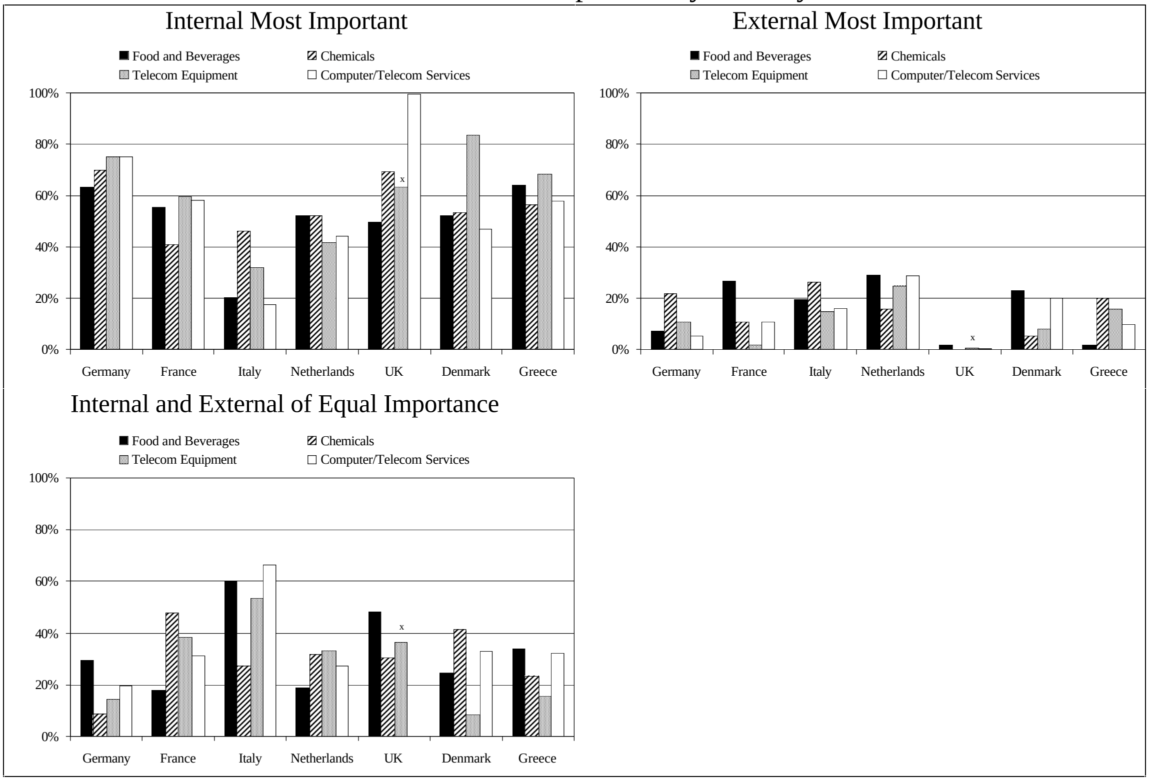
Figure 3.19: Contributors to the Completion of Most Important Innovation by Country



Notes: "x" indicates that the value for the corresponding stratum is based on a low number of observations, "M" indicates a missing value.

Internal knowledge is highly valued as a contributor to innovation in all countries, especially by German and British firms (Figure 3.20). Italy is at the bottom of this league; Italian firms seem to have the most balanced approach to internal versus external source of information. Dutch firms seem to be more open to external sources of innovation than their European counterparts. They also seem more open to inter-continental sources of knowledge (see below).

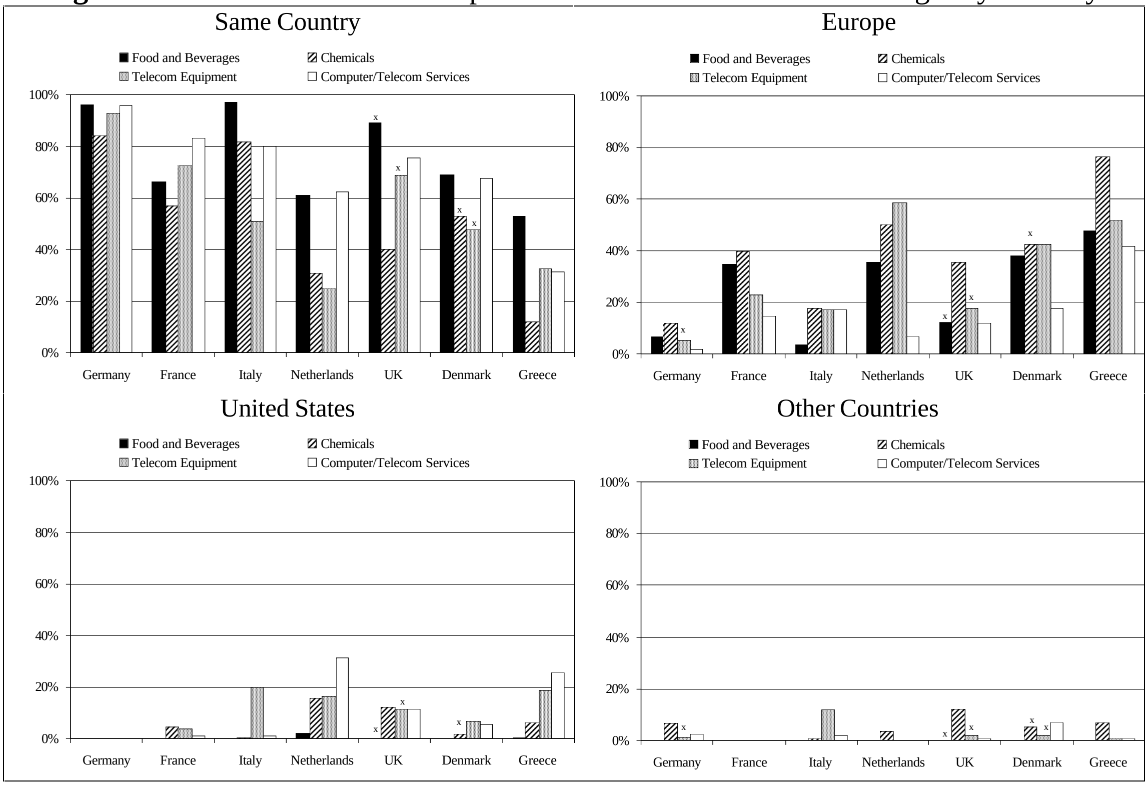
Figure 3.20: Importance of Internal Versus External Knowledge Sources for Successful Completion by Country



Notes: "x" indicates that the value for the corresponding stratum is based on a low number of observations, "M" indicates a missing value.

Globalization has been a favoured topic of business analysts and policy makers for many years. This is not, however, supported by evidence on the location of important external sources of innovation-related knowledge: national sources still dominate (Figure 3.21). While this is striking, one must be aware of potential influence of size here: by and large, our sample is made up of small and medium-sized companies. Firms of smaller countries like Greece, Denmark and the Netherlands tend to be more internationally orientated than those located in the large countries. Greek chemical firms, for example, mention companies of other European countries as most important innovation source. From the large countries, French enterprises report relatively important sources in other European countries (about 30%), followed by British firms. The United States is mentioned by about 15% of Dutch firms as a very important source of innovation-related knowledge.

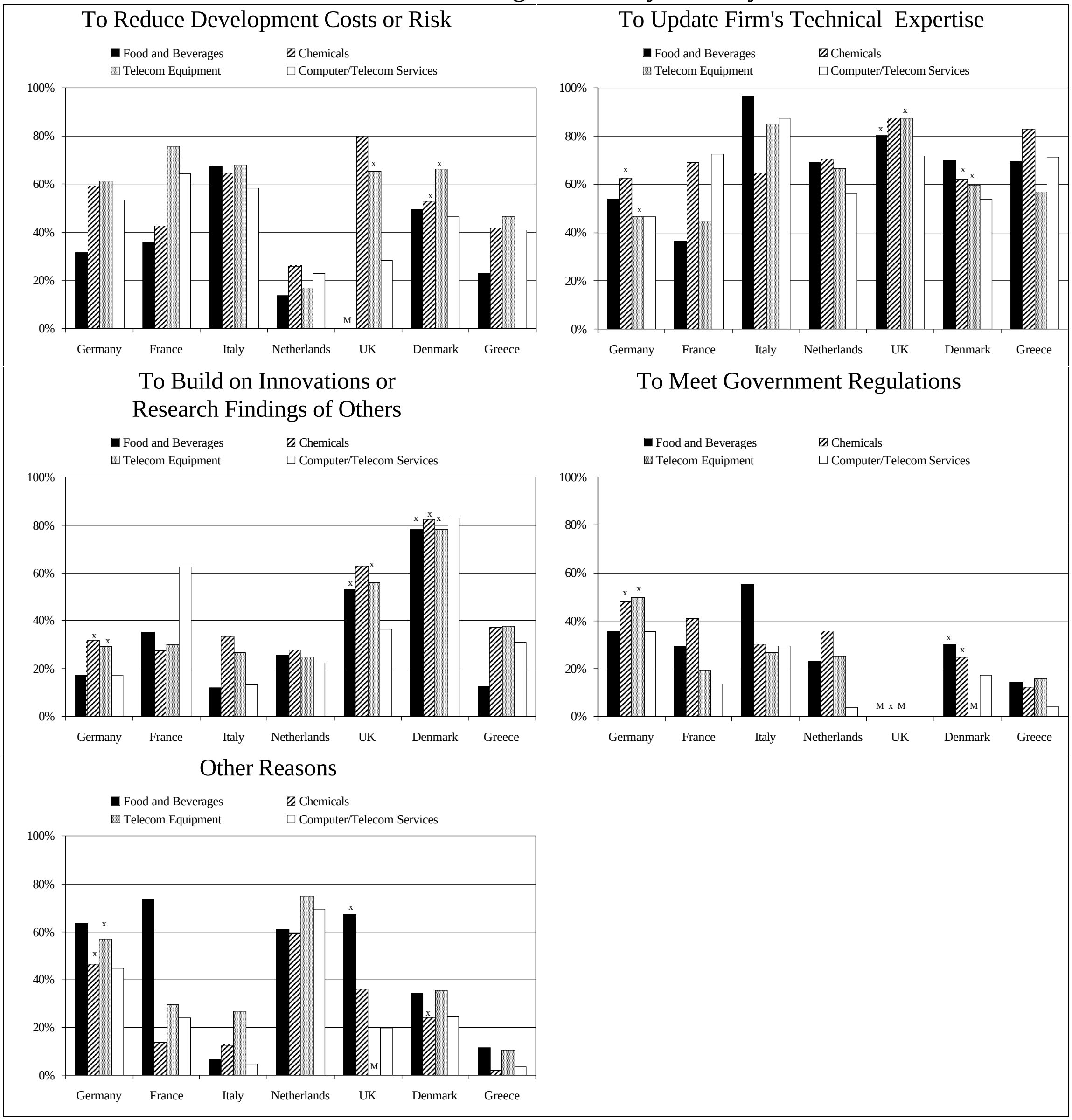
Figure 3.21: Location of Most Important External Source of Knowledg e by Country



Notes: "x" indicates that the value for the corresponding stratum is based on a low number of observations, "M" indicates a missing value.

A great variety of reasons for obtaini ng knowledge from the most important external source were reported (Figure 3.22). The dominant reasons are to reduce development costs and risks, to increase the technical expertise of the firm, and to build on the research findings of others. German, Dutc h, French and British firms report a host of other reasons as well.

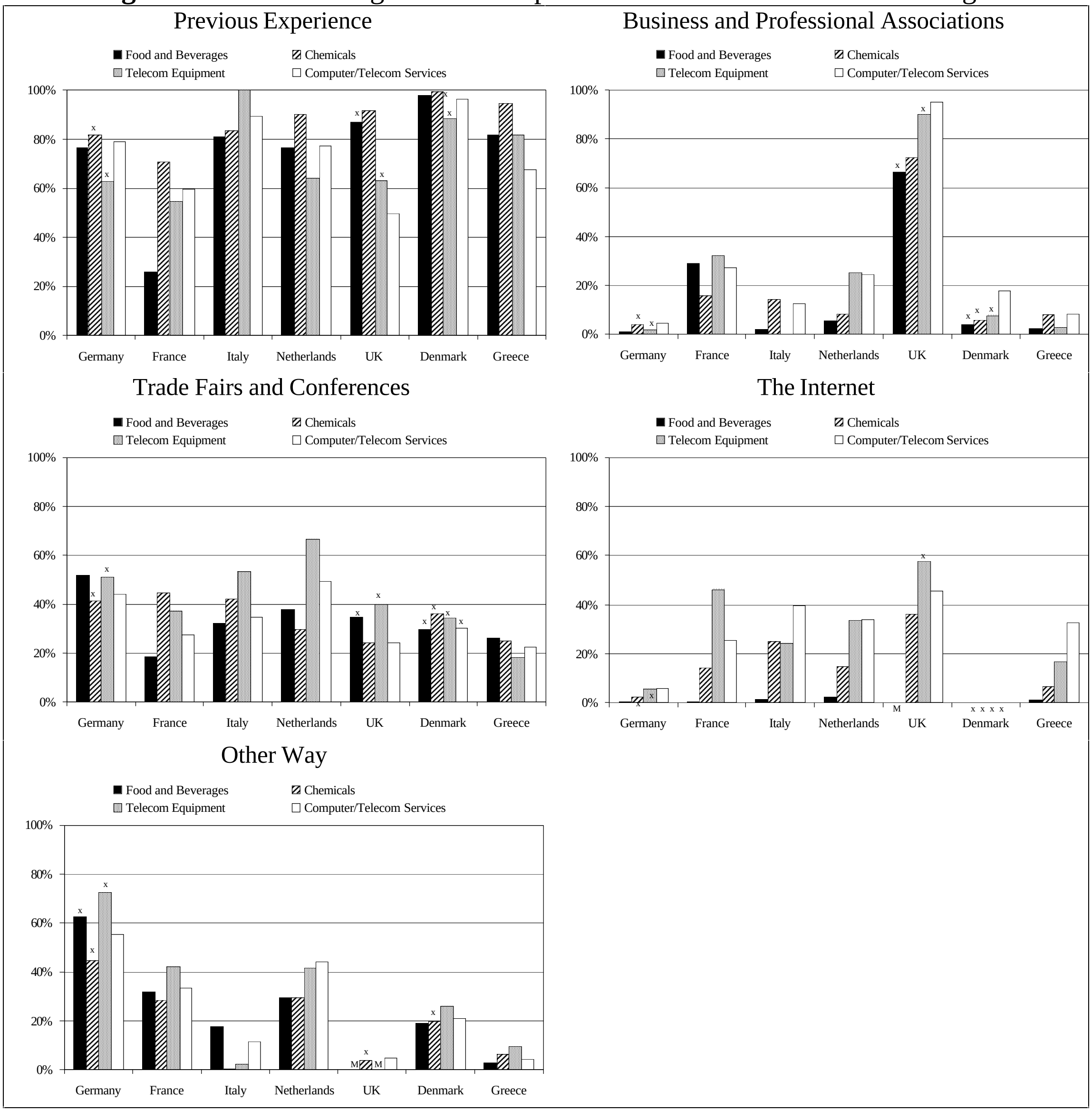
Figure 3.22: Underlying Reason for Decision to Obtain Knowledge from Most Important External Knowledge Source by Country



Notes: “x” indicates that the value for the corresponding stratum is based on a low number of observations, “M” indicates a missing value.

Previous experience is by far the most effective way of getting in contact with the most important external source of knowledge, followed by participation in trade fairs and conferences (Figure 3.23). Business and professional associations s eem to play a quite distinct role in that respect in the United Kingdom. British first, and then French, Dutch and Italian firms also use the Internet for that purpose. German firms seem to behave differently.

Figure 3.23: Contacting the Most Important Ex ternal Source of Knowledge



Notes: "x" indicates that the value for the corresponding stratum is based on a low number of observations, "M" indicates a missing value.

Scientific and technical information is the dominant type of knowledge obtained from the most important external source, followed by knowledge relevant to market introduction (Figure 3.24). By far, the most frequent method of communication with external source of knowledge is informal personal contacts, followed by research cooperation (Figure 3.25). Exchange of personnel and other methods are also used in some countries (e.g., France, Netherlands) more than in others .

Figure 3.24: Type of Knowledge Received from Most Important External Source

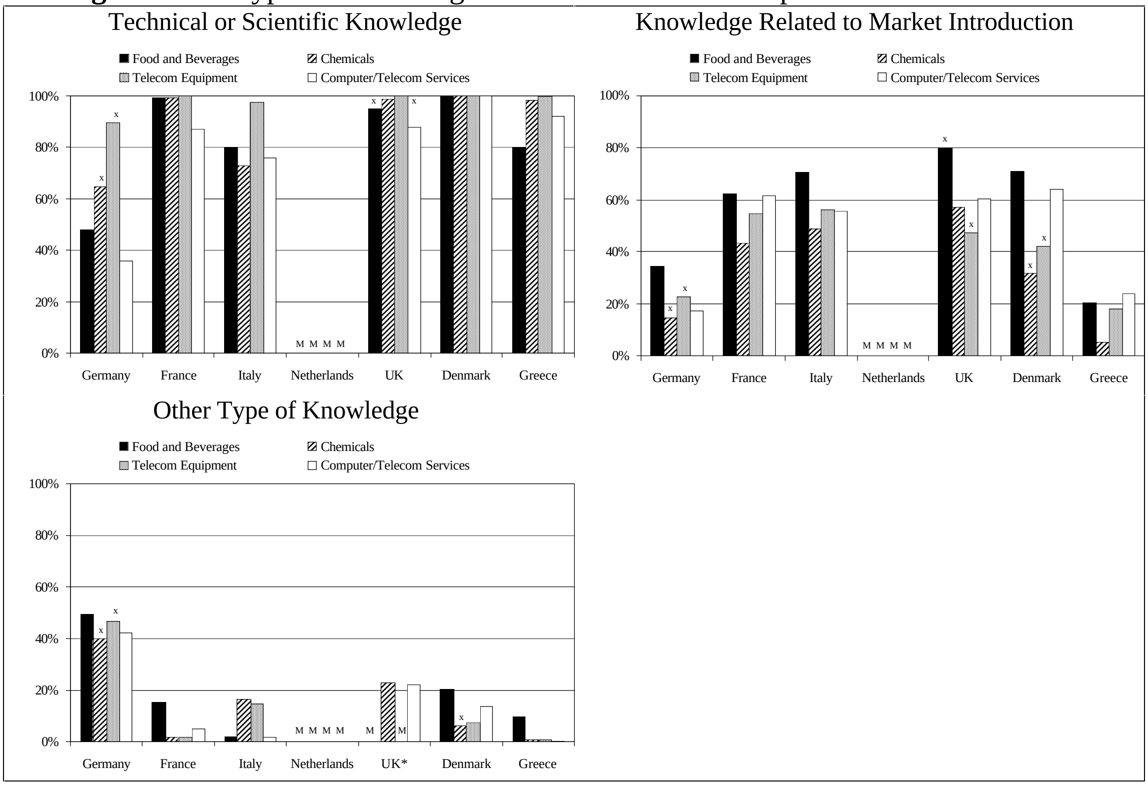
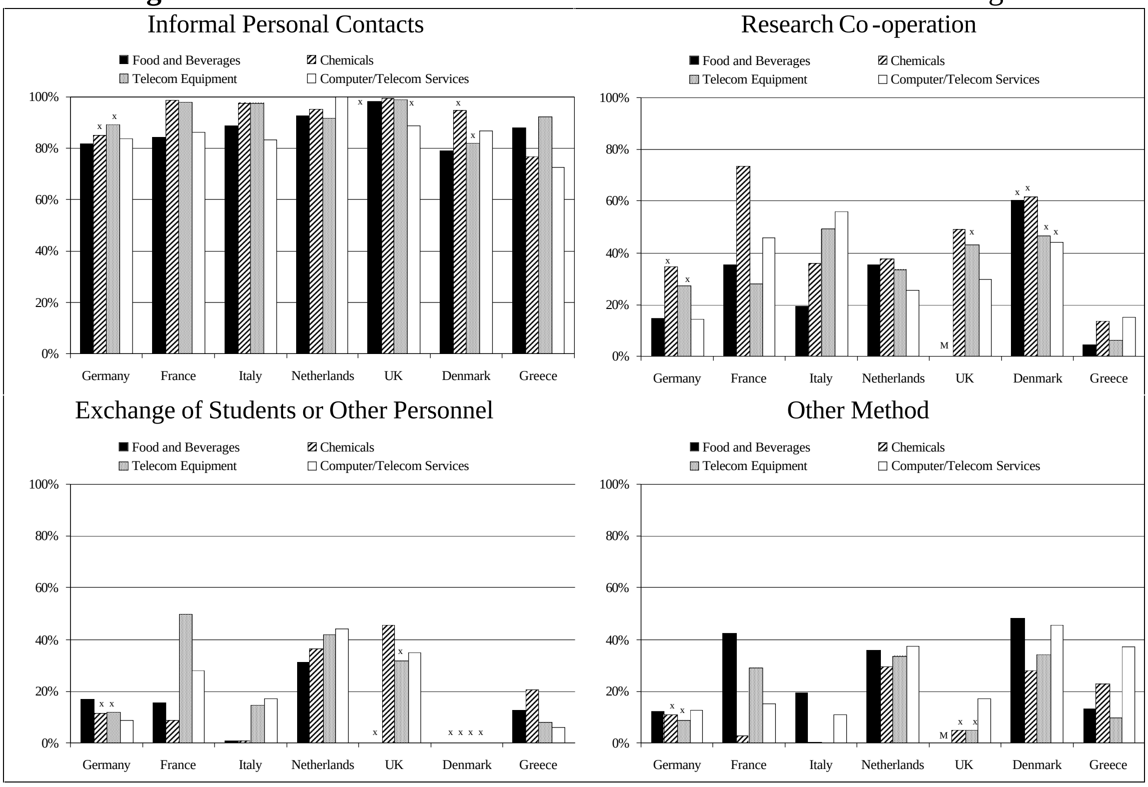


Figure 3.25: Methods of Communication to Obtain External Knowledge



Notes: "x" indicates that the value for the corresponding stratum is based on a low number of observations, "M" indicates a missing value.

3.3.1.3. RJV-EPO Dataset

The promotion of cooperative R&D has become one of the pillars of S&T policy in Europe and in the United States during the past couple of decades (Caloghirou and Vonortas, 2000). It is also considered one of the main formal mechanisms for knowledge communication among different agents in the economy. This Section illustrates important network aspects of cooperative R&D projects funded by the European Framework Programmes in RTD concentrating on the characteristics of participating organisations, degree of innovativeness, and patent citation flows. The Section draws on Breschi and Cusumano (2001) who have used the RJV-EPO dataset with 9,816 entities involved in 3,874 research joint ventures (RJVs), initiated during 1992-1996. The RJVs in question were part of 30 RTD Programmes in the 3rd and 4th Framework Programmes that included most of the well known BIOMED, BIOTECH, BRITE.EURAM, ENV, ESPRIT, JOULE, RACE, TELEMATICS and so forth. Of these 9,816 entities, 1,433 have applied for European patents in the period 1978-1998, accounting for a total of 109,457 patent applications over that period. Of these patents, 58,214 cited other patents (including self citations) and 49,240 were cited by other patents (including self citations).

The analysed network of Framework Programme RJVs is shown in Figure 3.26. Table 3.6 shows the distribution of the 9,816 RJV members by type of organizations.

Table 3.6: Distribution of all RJV Members by Type of Organisation

Type of organisation	#	%
Consultancy	67	1,06
Education	695	11,01
Industry	4028	63,83
Non Commercial	529	8,38
Research	680	10,77
Other	312	4,95
Total	6311	100,00

Missing 3505

Using graph (network) theoretical concepts, Breschi and Cusumano (2001) demonstrate a host of very interesting observations, briefly summarized below:

A. Network of RJV Projects and Programmes

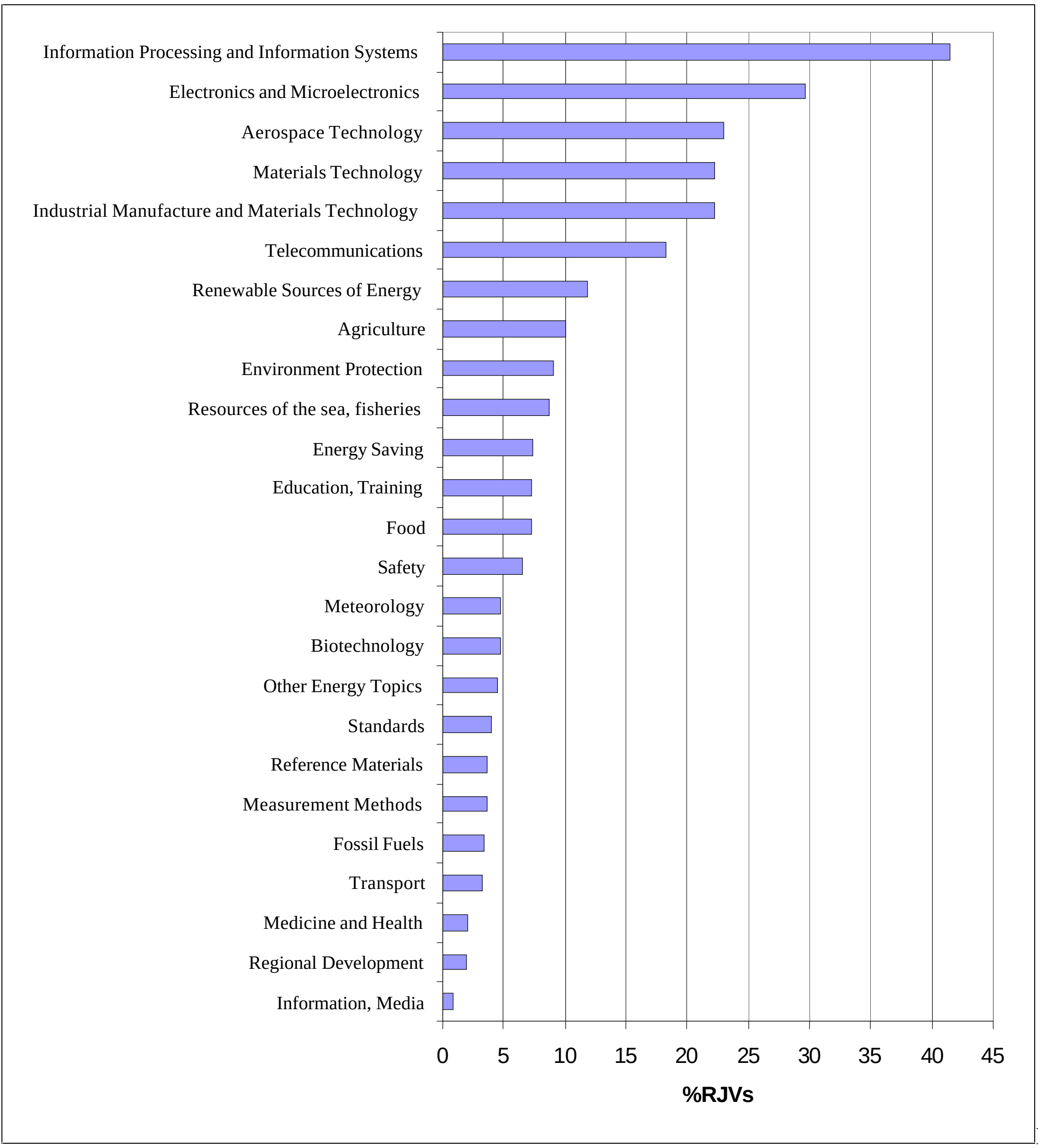
- *FWP Programmes overlap significantly in terms of participating organisations.* On average, each pair of RJV Programmes shares 50.3 organizations, which reduces to 9.26 if we consider only firms. This indicates that organizations other than firms (universities, education, consultants, etc.) play a very important role in establishing links among RJV programmes. Moverover, it indicates that the network formed by RJV Progr ammes is highly connected.

- *The network is very dense .*

- *Most entities have been infrequent participants:* 68% have only joined one RJV during the examined time period (Figure 3.27).

Figure 3.26: **Framework Programme RJVs by Technological Area**

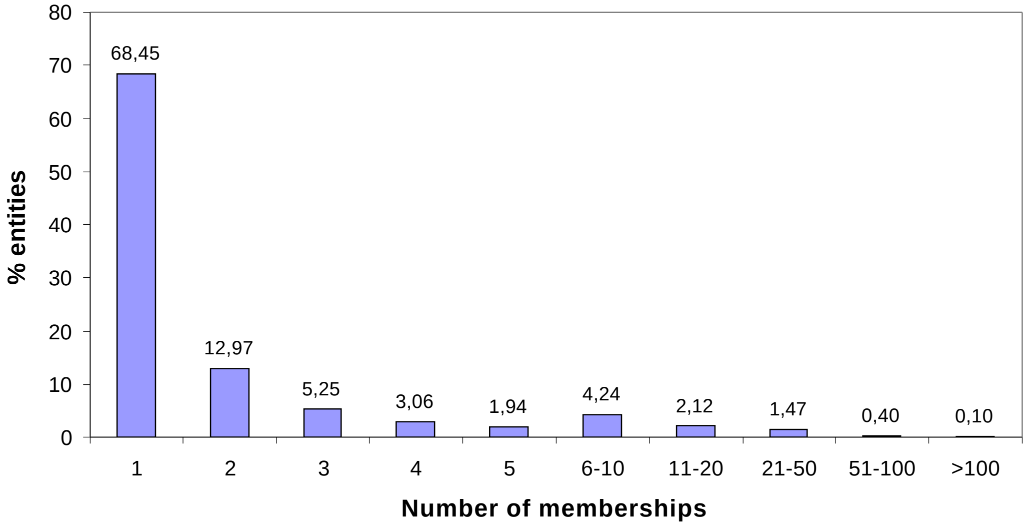
3874 RJVs (at l east one participant from the private sector), 1992 -1996



No

Note: Technological areas do not sum to 100. Most RJVs refer to two or three technical areas, thus are counted more than once

Figure 3.27: **Membership Frequency in Framework Programmes**



- *Prime contractors have, on average, participated in a much higher number of RJVs compared to Partners*.[9] Almost 80% of all Partners have participated in only one RJV, while the corresponding percentage drops to 40% in the case of Prime contractors. Moreover, about 15% all Prime contractors have participated in more than 10 RJVs.

- *Most networking activity in this RJV network occurs mainly among Prime contractors*. About 46% (963) of Prime contractors have been Primes in three or more RJV projects. In addition, about 57% of all Prime contractors have participated as Partners in RJV projects led by other Prime contractors. 85% (1778) of all Prime contractors had at least one partnership with another Prime contractor. Moreover, 29% (612) of them had 5 or more partnerships with other Prime contractors.

- *The propensity to change partners seems to be much lower in the case of Partners*. Of all Partners that have participated in 2 RJVs, 91% have remained with the same Prime contractor. Even for partners that have participated in more than 5 projects, the percentage that have remained with the same Prime contractor is surprisingly high (48%). Moreover, no partner, among those that have participated in more than 5 projects, changed more than 4 Prime contractors.

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[9] The dataset has 2,094 Prime contractors (entities that served as Prime contractors at least once) and 7,722 Partners (entities that have never served as Prime contractors).

- *The distribution of Prime contractors across organizational type is similar to the distribution of all entities (Table 3.6) with greater representation of education organizations* (rising to 15.23%).

- *There is significant concentration among industrial participants*. Many identified firms are controlled by large industrial groups, especially those related to the ICT and transport industries. British, German and French groups together account for 45% of all commercial entities owned by large groups.

B. Network of RJV Members

The analysis here assumes that within a specific RJV project Partners are directly linked only to the Prime contractor – that is, the path between any pair of Partners within a specific RJV project has length 2, whereas the path between the Prime contractor and each Partner has length 1 (the graph looks like a "star").

- *The network is quite dense*.

- *The expansion of the network during the examined time period appears to have occurred through the addition of more "peripheral" and less central actors*, while affecting relatively less the most efficient communication paths among pairs of actors.

- *A large majority of the most central actors in the network are either universities or large research organizations*. For example, only 5 among the 20 most central actors in the network are firms.

- *Prime contractors are in general much more central actors in the network than Partners*. Almost 78% of Partners have degree centrality 1, and only 53 of them have degree equal to or greater than 10. On the other hand, only 4% of all Prime contractors have degree centrality 1, while 856 of them (41%) have degree equal to or greater than 10. Whereas no partner has degree higher than 43, there are 151 prime contractors with a value of degree centrality higher than 43.

- *The emerging picture of the network is one where a very large number of peripheral agents, each with one or few connections, coexists with a relatively small number of players that have large numbers of connections and play an extremely important role in making communication among distant nodes possible and efficient.*

C. Innovative Activity of RJV Participants

- *There is a highly skewed distribution of innovative output on the basis of the patenting activity of RJV participants*. Of the 9,816 entities in the RJV-EPO dataset, only 1,433 (14.6%) had applied for patents at the EPO over this period. Of these, 929 (65%) had applied for 10 or fewer patents, whereas the number of highly innovative agents, with more than 100 applications, amounted to 144, i.e. 1,5% of all participants and 10% of the innovators' subgroup. The degree of concentration of patenting activity is remarkable: the four most innovative agents accounted for one -third (34%) of all patent applications by RJV entities, while the 15 most innovative agents accounted for half (51%) of all patent applications by RJV entities.

- *Marginal participants, i.e. entities taking part in one consortium only, appear to be on average the least innovative ones*. Hence, the innovative degree of RJV members slightly increases when dropping out of the dataset these "marginal" actors. Still, even when considering only institutions for which the joint R&D investment has not been occasional, the great majority (78% or 2,418) had not applied for a patent in the examined time period.

- *The degree of innovativeness is higher within the group of Prime Contractors (2,094 entities) than within the group of Partners (7,722 entities*), in terms both the share of innovative agents and the intensity of innovative activity (patent applications) by the most technologically dynamic entities.

- *Firms account for 76% of all innovative entities and for 84% of all patents by RJV entities* (Table 3.7). *The frequency of innovators is higher in the case of firms than in the case of research and education institutions*. Of all research institutions identified in the RJV-EPO dataset, slightly more than 85% do not register any patent, compared to 79% for firms. Moreover, only 6 research institutions (0,4%) registered more than 100 patents, compared to 111 (3%) in the case of firms. Not surprisingly, firms are much more visible relative to other organisations in terms of patent applications than in terms of RJV participation.

Table 3.7: Distribution of Patent Applications and Entity Type

Organisational type	**# of patents**	**%**	**# of entities**	**%**
Education	677	0,70	134	12,08
Industry	81508	83,95	844	76,10
Non Commercial	500	0,52	57	5,14
Other	9345	9,63	4	0,36
Research	5057	5,21	70	6,31
Missing	12370	-	324	-
Total	109457	100,00	1433	100,00

D. <u>Patent Citation Flows</u>

- *The flows of citations are rather dense within the broadly defined RJV network:* 59% of the 1,208 citing RJV members cite other participants in European RJVs (not necessarily in the same project), and 59% of the 998 cited innovative members are cited by other participants.

- *The knowledge-intensive network to which the innovative RJV participants refer has a clear European rooting*. If one defines a broad European framework by merging intra-network and intra-European citations, RJV participants' inward and outward flows appear very similar. About half of RJV participants' citations are directed to European organisations and about half of the citations received by RJV members originate from patents of European organisations. The remaining 50% of inward and outward citations concerns firstly US organisations and secondly Japanese innovators.

- *The most central (to the network) entities receive most in-network patent citations*. On the other hand, highly cited entities are not necessarily highly citing entities.

- *A very small number of entities (mostly large firms) with "central" position in the RJV network are associated with very high values of indegree and, to a less extent, outdegree patent citation centrality. Apart from these agents, there is no clearly detectable relationship between actor centrality in the RJV network and actor centrality in the citation network.*

- *There are significant differences between firms, on the one hand, and research and education organisations, on the other with respect to their centrality in the RJV network and the citation network.* Regarding firms, relatively high values of outdegree and indegree centrality are often associated with relatively low values of degree centrality in the RJV network. Regarding the research and education organizations, most occupy a relatively more "central" position in the network of RJV participants compared to firms, while the degree of centrality in the RJV network is unrelated with the degree of centrality in the citation network.

3.3.2. ECONOMETRIC ANALYSIS OF KNOWLEDGE FLOWS

In addition to describing observed innovation-related knowledge flows, the KNOW partners used the large databases to empirically appraise a number of important questions springing up from the analytical framework (Section 3.1). In particular, this effort moved on seven axes:

1. Facilitation of knowledge communication through the formation of efficient inter-organizational networks through European cooperative RTD projects.
2. Impact of EU-sponsored cooperative RTD on the innovative performance of the private sector.
3. Factors affecting the absorptive capacity of firms and, more generally, their ability to benefit from knowledge produced outside the organization. Relative importance of external versus internal sources of innovation.
4. Knowledge appropriation methods.
5. Spatial dimension of knowledge flows.
6. Internet as a mechanism for accessing knowledge.

3.3.2.1. Inter-organizational Networks

In a theoretical-cum-empirical paper, Verspagen (2001) dealt with the characteristics of research networks formed through the European Framework Programmes for RTD and EUREKA. The specific question was whether these networks, seen as a whole, are judged to be efficient for the communication of knowledge.

Research partnerships can be viewed as a network of agents that are directly or indirectly connected to each other. A direct connection results from participation in the same partnership. Indirect connections result when information or knowledge exchanged in one partnership is also (implicitly) entered in other partnerships. It is assumed that one can make inferences about the efficiency of partnership networks to communicate knowledge by examining the structure of the networks and the position of agents in them.

Management theory has followed two aggregate perspectives on networks. The first is the "social capital" perspective. Social capital can be defined as "the sum of the resources, actual or virtual, that accrue to an individual or a group by virtue of possessing a durable network of more or less institutionalized relationships of mutual acquaintance and recognition" (Bourdieu and Wacquant, 1992). Walker et al. (1997) then argue that firms occupying positions embedded in regions rich in relationships have access to high levels of social capital. In contrast, the second perspective on networks ("structural holes") argues that a firm interested in using networks as a source of information should choose partners strategically that have direct links to agents with whom the firm in questions does not yet have links. In other words, the primary strategic goal of forming partnerships is to form "bridges" between relatively unconnected parts of the network (Burt, 1992). Of interest to us here is that "social capital" networks are seemingly characterized by high local clustering and relative inefficiency in terms of overall speed of transmission of knowledge flows. "Structural holes" networks are the reverse: local clustering is low but the speed of transmission is high.

One might think that the best network structure should be found in between, achieving high levels of local clustering to benefit from high social capital and higher speeds of knowledge transmission. Drawing on recent literature, Verspagen argues that there is indeed such an intermediary type of network, a "small world". He embarks on an empirical investigation juxtaposing "small world" characteristics to those of three aggregate research networks including:

(a) the network of European cooperative R&D projects from the EU-RJV database;
(b) the network of cooperative R&D projects from the EUREKA-RJV database; and
(c) the (virtual) network defined by the patent citations of the identified firms participating in the previous two types of collaborative projects.

Results are striking: European research networks indeed show "small worlds" properties. The first network, consisting of cooperative R&D projects sponsored by the European Framework Programmes, comes closest to the theoretical model. The remaining two networks – the network of EUREKA projects and the more informal network of patent citations – also resemble small worlds. In these cases, however, the theoretical model fits less well, implying that factors not accounted by the received theory need to be included to explain the exact properties of the graph.

Hence, it is concluded that the analyzed European research networks, and particularly the network of Framework Programme RJVs, are relative efficient means of knowledge transfer.

3.3.2.2. Impact of EU-sponsored Cooperative R&D on Innovative Performance

Cusumano (2001) has undertaken an extensive analysis of the relationship between participation to European RJVs (Framework Programmes) and patenting activity with the help of the RJV-EPO data set. The assessment exercise focuses on cooperative R&D projects in two strategic high tech areas: Information and Communication Technology (ICT) and Medical and Biotechnology (MB).

For both samples of RJVs, initial descriptive statistics reveal a high degree of heterogeneity between RJV participants and non-participants: firms joining the RJVs are on average bigger and more innovative than non-participants. This first-level analysis points to the need for addressing the issue of *self-selectivity of RJV members*. That is, the positive correlation between patenting activity and participation may reflect the higher propensity of more innovative agents to participate, rather than the success of these RJVs to raise the innovativeness of participating companies. [10]

Preliminary statistical analysis pointed in the same direction: the participants' higher average level of innovativeness (propensity to patent) is mainly explained by a high innovative activity prior to the entry. However, there also appears to be a significant contribution of entry into the first RJV in increasing the differential. The overall finding is consistent with the self-selection hypothesis, but the evidence is less clear when distinguishing between technological areas. Self-selection becomes more difficult to detect in different size classes.

Subsequent formal econometric analysis pointed out a number of interesting results:

- Cumulated knowledge is the most relevant explanatory factor of current innovative activity. Technological change shows to be a *cumulative* process: firms which have patented most in the past are most likely to patent today, even when taking knowledge obsolescence into account.

The result is robust across the two technological areas even though, in general, a greater effect in the ICT field was detected. This finding may be related to the different stages of the life cycle of the ICT and MB technologies and to the structure and dynamics of

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[10] This is, of course, directly related to the classic problem of causality that has also plagued analyses of cooperative R&D.

European industry. European research in ICT has mostly involved large industrial groups, having significant experience with both generic technologies and applied research. The hierarchy of innovators in this field appears to be relatively stable (Malerba and Orsenigo, 1995, 1997). European programmes have attracted firms that were already remarkably more dynamic that the average European level. On the contrary, the development of biotechnologies has induced a greater “instability” of innovators’ hierarchy, so that the effect of the cumulated number of patents, which is nevertheless remarkably important, is generally smaller.

- RJV participants tend to be more innovative than non-members. In the ICT area, the most important waves of European programs have attracted highly research-intensive firms that were already remarkably more innovative than the average European level. In contrast, in the MB area, except for a peak in 1989, early RJV members did not exhibit high levels of patenting prior to entry.

This finding is also related to the structure and dynamics of the European industry. In this respect, the target and nature of the European consortia appear to be a relevant explanatory factor. ICT projects have seemingly been oriented towards more generic, pre-competitive research, with the aim of providing a common technological basis for ICT applications and support for the development of a European market for information services. All the major telecommunication operators and key European equipment manufacturers have participated in these projects. In the MB field, a high share of consortia has apparently dealt with more applied projects and has attracted, together with a few major players, a large number of firms that are not endowed with a significant “innovative platform” (as expressed by patents).

- Size is positively related with patenting activity in the ICT field. In the MB field, there is no clear evidence of largest firms being more innovative.

- European RJVs seem to have positively affected the patenting level of firm participating to MB projects.

The evidence supporting this result is robust to the use of alternative statistical models and to alternative specifications of the lag between RJV affiliation and patent applications. Indeed, the magnitude of the effects appears greater the longer the utilized time lag. The result partly reflects the large number of barely innovative firms that entered the “innovation track” only after the first entry into a EU-supported RJV in the MB field. Hence, the positive effect might be related to the role of RJVs in opening up innovative networks to new members. It, however, also relates to other factors, particularly the nature of R&D in these consortia and the evolution of the technological field, including:

- the relatively larger market-orientation of cooperative projects in this field; and
- the dynamics of the field during the time the examined RJVs were established (1992-1996), so that patent applications during or following the completion of the project mirror the developments of fast-emerging areas of research.

Nevertheless, RJV participation is considered a major contributor. To the extent that this is true, it can be argued that European MB consortia have attracted firms with a high "innovative potential", which has been developed and expressed in patent output in the course or immediately after these projects.

- There is no clear and robust evidence of a positive correlation between patenting activity and RJV affiliation in the ICT area, even when focussing on sectors which exhibit a relatively high propensity to innovate such as Computers and Office Equipment, Communication Equipment, and Professional -Scientific Equipment.

In ICT, cooperative R&D projects are more oriented towards pre -competitive research and development of generic technologies. When combining this typology of research with the description of participants' characteristics, it appears that the examined consortia may have attracted the major leaders in the area, reinforcing their role, rather than opening up innovative networks to new members with a high, but still unexpressed, innovative potential.

- Several policy-related insights emerge from the analysis of RJV impact by size class:

Ø Small firms do not appear to benefit from RJV participation in terms of increase in patent applications. Rather, RJV affiliation seems to reduce their patent output.

Ø In the ICT area, RJV participation seems to positively affect medium -size firms patenting, although statistical significance of this finding is sensitive to alternative definitions of the medium-size class. RJV participation does not affect the patenting behaviour of large firms.

Ø In the MB area, there is no evidence of medium -size firms reaping most benefits from RJV affiliation. Rather, the overall significant results further improve when dropping small firms from the sample. The patent activity of medium and large firms appears to get significant impulse from RJV participation. Hence, even if size itself does not appear to explain patenting behaviour significantly in this field, size seems to affect the ability to benefit from co-operative R&D (as if a minimum amount of resources and extension of productive activities was required to be able to exploit joint investments and the externalities generated in the course of the interaction). However, this is also likely to be a case in which the patent measure mostly under -estimates innovative ability, given the low propensity to patent of small firms.

Concerning policy implications, empirical results must be interpreted taking into account that ICT and MB industries are at different stages of their life cycle. On one hand, co-operative policies seem to have reinforced existing leaders and networks in the more "mature" of the two industries (ICT), where a "network of excellence" has already emerged and hierarchy of innovators is rather stable. On the other, cooperative policies seem to have favoured the exploitation of innovative potential by new actors in the case of emerging technologies (MB). This finding suggests the need for additional attention to sector dynamics at the stage of policy design and in the evaluation process of policy targets and results. At the early stages of technological development and competition, the policy should attempt to create networks of excellence, and to open up existing networks to potential innovators, by promoting cooperative R&D -intensive programmes. In later stages of the life cycle, when the industry is technologically "mature" and networks of leading actors are well established, a more effective policy target would be that of linking peripheral actors to existing networks and to favour a broad diffusion of knowledge.

3.3.2.3. Relative Importance of Internal and External Sources of Innovation

3.3.2.3.1. Absorptive Capacity

Since the work of Cohen and Levinthal (1989, 1990), the concept of absorptive capacity has gained immense importance and has spread widely across the research community. Praest et al. (2001) explore the present empirical research frontier and take stock of our ability to understand and measure absorptive capacity. An important finding is that available indicators do not proxy absorptive capacity, but access to external knowledge, which leaves the process of absorptive capacity building a black box. This problem is addressed here by introducing the dichotomy of access and utilisation of knowledge as the two faces of absorptive capacity building. It is argued that access can be measured empirically, whereas the utilisation of knowledge is largely uncovered territory.

The paper surveys the preconditions for access: openness towards knowledge sharing, the role of trained employees, and the characteristics of the knowledge to be absorbed. For this purpose it uses data from the KNOW survey of innovative enterprises. Results show that active participation in strategic alliances along with high R&D intensities are important preconditions for knowledge access. Furthermore, a high share of R&D personnel combined with a high share of academics to the total number of employees are important for innovative performance.

3.3.2.3.2. European RJVs and Knowledge Creation

In a related paper, Kastelli et al. (2001) use the survey database from the STEP TO RJVs project to explore the processes of knowledge creation and capability creation in the context of cooperative R&D. More specifically, the paper studies the links between company in-house capabilities and the benefits from their involvement in cooperative R&D. It is hypothesized that, in order to build successfully on knowledge and information that may be transferred in the context of an R&D partnership, a firm must possess skills and capabilities that facilitate knowledge absorption and conversion to new forms. This absorptive capacity seems to be a critical condition for the building-up of existing internal resources and capabilities of the firm in the context of cooperation.

A broad notion of absorptive capacity is used, consisting of three main composite factors: the internal capability of undertaking R&D, managerial capabilities that improve information and knowledge exploitation (organizational capabilities), and the capability to establish relationships for acquiring and/or creating knowledge (interacting capability). Evidence is presented that the benefits from cooperative R&D are positively related to the firm's in-house technical capabilities, particularly the ability to undertake R&D and to develop relationships with other organizations. It is argued that, rather than substituting for the lack of internal capabilities, cooperation complements internal technical capabilities. In order to gain from R&D cooperation, a firm must keep upgrading its knowledge base and technical capabilities.

3.3.2.3.3. Internal Capabilities, External Knowledge Sources, Innovative Performance

Caloghirou et al. (2001a) take another step towards the investigation of the interaction of internal firm capabilities and external knowledge sources and the effect of this interaction on the innovativeness of the firm. They draw on the KNOW survey database.

More R&D-intensive firms with high skilled personnel and firms that join R&D partnerships tend to innovate more. No strong relationship could be established between human resource training and the extent of innovation. As for methods that firms are using regularly for locating new ideas for innovation, scientific or business journals always proved positively related to innovativeness. Thus, both internal R&D capabilities as described by the intensity of R&D efforts and the high-qualified personnel and the ability to interact and access external sources of knowledge seem to boost innovative performance.

3.3.2.3.4. In-house Capabilities or Cooperation?

Widespread support within the European Union for cooperative R&D and for innovation networks between firms is founded on the belief that these mechanisms of knowledge flows improve innovation outputs. Available survey work has tended to indicate that more innovative firms use external knowledge sources above industry average (e.g., Bosworth and Stoneman, 1997). On the other hand, the same surveys provide seemingly conflicting evidence that firms rate the contribution to their innovative activities of their internal knowledge sources more highly than external sources (see earlier sections of this report). Most of available studies have not empirically evaluated measures of relative importance of in-house research versus the use of external information sources, particularly via collaboration.

Arundel and Bordoy (2001a) used the KNOW survey for a closer look at these issues. They focused on the effect of the share of product innovations developed in-house and via collaboration on the share of innovative products or services in the firm's total sales (innovative sales share). The supporting hypothesis was that if the benefits of cooperation outweigh the disadvantages, one would expect collaboration to influence innovation outcomes: more cooperation should lead either to more innovations and/or to more economically valuable innovations.

For a set of 507 responding firms, the authors tabulate the following:

§ The most commonly used innovation method is in-house development, followed by buying-in (Table 3.8).

Table 3.8: Percentage of Firms Utilizing Different Innovation Methods

	Products/services	**Processes**	**Either products or processes**
In-house	91.2	84.8	97.6
Buying-in	51.5	47.8	72.0
Collaboration	34.4	36.6	46.1

Notes: Employment weighted.

§ In all five surveyed sectors, over 63% of product/service innovations are developed in-house, between 9% and 13% are bought in, and around 20% are developed via collaboration. The highest rate of collaboration is in the telecom equ ipment sector (24.1%) while the lowest rate is in computer services (13.7%) (Table 3.9).

Table 3.9: Percentage of Innovations Developed by Each Innovation Method

	N	**In-house**	**Buying-in**	**Collaboration**	
Food & beverages	133	68.3	11.0	20.7	100%
Chemicals	130	68.2	12.7	19.1	100%
Telecom equipment	101	63.4	12.5	24.1	100%
Computer services	143	76.7	9.6	13.7	100%
Total	*507*	*70.8*	*11.1*	*18.1*	*100%*

Notes: Employment weighted.

§ The mean innovative sales share varies by country, from a low of 27% in Greece to a high of 44% in Germany. This is partly due to differences in the industrial distribution in each country and the average firm size.

§ The innovative sales share is higher among small compared to mid -size telecom equipment firms while the reverse is true for comp uter service firms. Firm size differences are negligible in food and beverages and in chemicals. The innovative sales share is highest in telecom equipment and computer services (Table 3.10).

Table 3.10: Innovative Sales Shares by Sector and Firm Size

	Small (< 250 emps)	**Mid-size (250 – 1,250)**
Food & beverages	21.6%	20.2%
Chemicals	29.5%	26.0%
Telecom equipment	55.5%	43.5%
Computer services	52.4%	72.6%
Total	*39.2%*	*44.4%*

Notes: Employment weighted within each size class.

The alternatives to collaboration are to develop products in-house or via buying-in. Buying-in accounts for only 11% of all innovations developed by the sample firms. This means that the alternative to collaboration, for most firms, is to develop innovations in-house, which accounts for 71% of all innovations.

The regression results show that the share of innovations developed in-house has a positive and statistically significant effect on the innovative sales share, while the share of innovations developed via collaboration had no effect. However, some experience with collaboration also increases the innovative sales share. Separate analyses by country show that German firms benefit more from collaboration. There was no statistically significant effect of collaboration in other countries. The results thus question the advantages of excessive collaboration, although some collaboration is beneficial.

3.3.2.3.5. Relative Value of Internal and External Innovation

Arundel and Bordoy (2001b) investigate the factors that influence firms to adopt an inward looking approach to innovation, in which they rely on knowledge sources within the firm, versus an external looking approach in which they rely on sources outside the firm. The analysis is based on responses from up to 527 surveyed firms (KNOW survey) on the importance of internal and external knowledge sources to the development of its most economically important innovation. The determining factors include appropriation conditions, technology characteristics, the firm's internal innovative capabilities, and firm boundary characteristics such as whether or not it is part of a larger firm and its size.

External information sources must play a vital role in innovation. Extant surveys consistently show that firms attach significant importance to information obtained from their customers and suppliers, from attending trade fairs and conferences, and from reading journals. Other information sources, such as patent databases or public research institutions (PRIs), are of considerably less value to most firms, although they are intensively used by specific sub-groups, as shown by the close links between pharmaceutical and biotechnology firms and universities.

Several factors could influence the relative importance of internal versus external knowledge sources: concern over leaking strategic information to competitors, the internal capabilities of the firm, technological factors, firm characteristics such as its size or boundaries, and the cost of developing the innovation.

The firm's internal capabilities should play an important role in the value attributed to external information sources. Firms with only limited in-house capabilities should be more likely to rely on external sources. However, this effect will be mediated both by the type of technology and by the firm's absorptive capacity.[11] Internal expertise could

[11] Notice difference with earlier approaches in this Section. Arundel and Bordoy (2001b) consider internal capabilities and external sources to be substitutes. Caloghirou et al. (2001), Kastelli et al. (2001), and Preast et al. (2001) consider them complements. Both

suffice for the development of well-understood technologies, while complex technologies or technologies at the technological frontier – such as biotechnology – could require firms to actively seek knowledge from external sources. However, the firm will also need a high level of internal capabilities to be able to exploit this knowledge. In this case, it is not clear if the firm will find its internal or external knowledge sources of greater importance. The value of external sources could also vary between product and process innovations. The development of process technology could require close cooperation with equipment suppliers. Often, close working relationship with important buyers is necessary for efficient product innovation.

Characteristics of the sample include the following:

- The majority of firms (71.2%) have less than 250 employees but account for only 21.7% of employment.
- Almost all the respondent firms (96%) perform R&D: 71% on a continuous basis and 25% on an occasional basis.
- The most important innovation has been patented for almost twice as many mid-size (>250 employees) as small firms.
- After employment weighing, 48.4% of firms find internal knowledge sources of greatest importance, 17.1% prefer external sources, and 34.5% found them of equal importance.
- Over 70% of firms, however, noted that external information sources (excluding other units of the same firm) contributed to both the original idea behind the innovation and to its completion. The external sources listed in the questionnaire include competitors, suppliers, customers, PRIs, and consultants.
- The lowest reliance on internal sources occurs in the computer services sector, where only 34.3% find internal sources to be more important than the alternatives, while almost half of computer service firms find both internal and external sources of equal value.
- There is very little difference between product and process innovators in the preference for internal knowledge sources, but a higher percentage of process innovators prefer external sources (26.4% versus 14.8%) while more product innovators find both sources of equal value (36.7% versus 26.0%).
- A significantly higher percentage of firms that did not bring in new scientists and engineers find their internal sources to be of greatest importance (64% versus 35.6%) while firms that bring in new expertise are more likely to find both internal and external sources of equal importance.
- Finally, 58% of firms that are part of a group cite internal sources, compared to 38.5% of independent firms.

Three different regression models explored the effect of several factors on the relative importance of these three categories of knowledge sources. Firms active in the high technology telecom equipment sector are more likely than the reference category of the food sector to find internal sources of greater value than external sources. Firm size and R&D intensity have no effect on preferences, while independent firms are less likely to

hypotheses could be true and coexist.

prefer internal knowledge sources. The analyses for the Netherlands show that the cost of the firm's most important innovation *reduces* the probability of finding internal sources of greater value than external sources, thus indicating that firms are occasio nally compelled to seek out external sources for their more expensive innovations. In general the results provide significant support for the role of external sources in the innovative activities of firms.

3.3.2.4. Knowledge Appropriation Methods

There is on-going debate in academic, business and policy circles over the need for stronger patent protection. However, patents are only one of several methods that are available to firms for protecting their investment in innovation. Two other important methods are secrecy and lead time advantages. The importance of patents to innovation depends on the usefulness of patents compared to these alternatives. Survey research consistently shows that, with some important exceptions of the sectors of chemicals and pharm aceuticals, most firms find secrecy and lead times to be more valuable than patenting (Arundel, 2001; Cohen et al., 2000; Levin et al., 1987). [12]

Arundel and Bordoy (2001c) address this issue by using two sets of questions in the KNOW survey. The first ques tion concerns all innovations of the firm: it asks whether respondents use patents, secrecy or lead times to protect their innovations and which of these methods is the most valuable. The second asks the same for the most economically important innovation of the firm.

Table 3.11 provides the distribution of the most important protection method by sector. The results are weighted by employment on the assumption that there is a positive correlation between firm size and innovative output within each sector. [13] With the exception of the chemical sector, more firms cite secrecy and lead time advantages than patents. The value of patents is particularly low in the two service sectors, although this is partly because software is usually not patentable in Europe. Mo re mid-sized firms (above 250, below 1250 employees) compared to smaller firms cite patents (15% versus 11%) while smaller firms are more likely to cite secrecy (30% versus 21%). There is no difference by firm size in the percentages citing lead -times.

Table 3.11: Most Important Protection Method for Innovative European Firms with <1250 Employees (employment weighted – numbers in %)

	All Firms	Food	Chemicals[1]	Telecom Equipment	Telecom Services	Computer Services
Patents	14	11	40	17	3	1
Secrecy	23	25	23	24	43	19
Lead tiles	34	38	27	47	39	31
Other	29	26	10	12	15	49
Total	100	100	100	100	100	100

[12] See also the KNOW survey and in -depth interviews.
[13] Unweighted results differ little.

[1] Chemicals excludes pharmaceuticals

In an econometric model, the authors examine several factors that may influence the propensity of firms to patent including firm size, sector, innovative capabilities (measured by R&D employees, continuity of R&D effort, share of R&D spent externally), innovation subsidies, firm independence, number of competitors, and utilized knowledge sources (collaboration, scientific and business journals, trade fairs and conferences, competitors' projects). It is found that R&D intensity and firm size have no effect on patent preference. R&D continuity positively influences the use of patents over secrecy. In contrast, f irms that use collaboration to develop some of their innovations are more likely to prefer secrecy to lead-time advantages, but there is no difference in the preference of patents. Finally, firms with many competitors are more likely to prefer secrecy, lea d-time advantages and other methods over patents.

Turning to the economically most important innovations of the surveyed firms, the KNOW survey shows that three quarters of them had not been patented. The remaining, 15% had been patented by the respondent firm, 7% by a different organization, and 3% by both the firm and another organization. The highest rates of patenting by the respondent firm are in chemicals and telecom equipment (24% and 21% respectively). Patent rates increase with firm size. A full 80% of the product innovations by small firms (<250 employees) were not patented compared to 54% of product innovations by larger firms.

Econometric analysis shows that the probability of patenting the most important innovation rises:
(g) for chemicals and telecom equipment firms;
(h) for innovations with a product component;
(i) with the firm's R&D intensity;
(j) with the firm's share of R&D spending on external sources;
(k) with firm size; and
(l) with the receipt of government subsidies.

Specifically for the Netherlands the authors found some evidence that high cost and firm R&D intensity contribute to higher propensity to patent the most important innovation.

3.3.2.5. Spatial Dimension of Knowledge Flows

3.3.2.5.1. Inter-country Technological Linkages

The effects of spatial proximity on the creation and diffusion of new knowledge have become an important topic of investigation since the early 1990s. In the US, pioneering work by Jaffe (1989) and Henderson *et. al*. (1993) investigated the extent to which knowledge-related activities cluster spatially. The authors showed that patents are more likely to come from firms or other institutions that are geographically close to public or private research institutes, whereas citations to domestic patents are not likely to be found beyond the borders of the state of the cited patent. In other words, technological knowledge is geographically localised.

In Europe, researchers have embarked on similar lines of research seeking to examine the extent to which innovative activity is spatially concentrated (Caniëls, 1997; Verspagen, 1997). Their findings generally confirm the proximity effect on technological spillovers across European regions. For example, recent work by Verspagen *et.al*. (2000) demonstrates that invention is a process strongly rooted in space as it tends to localise in small geographical distances. From a theoretical point of view, the underlying assumption supporting such findings is that knowledge required for invention can be of tacit and codified nature and that codified knowledge itself is capable of transmitting only a partial amount of information (Faulkner and Senker, 1995). Trust, and its local development, has also been proposed as a reason for localization for collaboration. Finally, a third factor for localization is arguably the existence of industry-specific competencies of different regions.

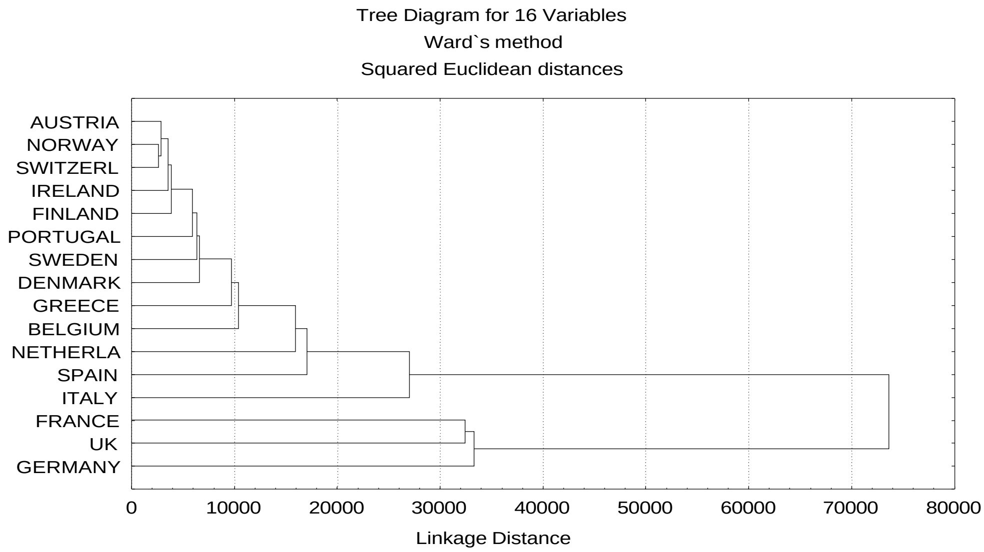
Caloghirou et al. (2000) investigate this topic at the national level within the European Union. The paper uses the EU-RJV database in an effort to unveil the factors that determine the propensity of firms and private or public research organizations from one country to form collaborative research agreements with counterparts from another. Table 3.11 presents the proportion of the involvement by each country's organizations in the examined collaborative research projects.

Table 3.12: Involvement in Framework Programmes by Country

Country	**RJVs**	**%**
AUSTRIA	648	6,9%
BELGIUM	2196	23,5%
DENMARK	1584	17,0%
FINLAND	820	8,8%
FRANCE	5151	55,2%
GERMANY	5458	58,5%
GREECE	1799	19,3%
IRELAND	1083	11,6%
ITALY	3786	40,6%
NETHERLANDS	2912	31,2%
NORWAY	552	5,9%
PORTUGAL	1288	13,8%
SPAIN	2739	29,3%
SWEDEN	1434	15,4%
SWITZERLAND	699	7,5%
UNITED KINGDOM	5472	58,6%

Cluster analysis on the basis of frequency of each country's participation in the examined RJVs positions the largest three countries (France, Germany, UK) in one cluster and the remaining 13 countries in another (Figure 3.28). The problem with this clustering, however, is that it is based only on RJV participation freque ncies, thus confirming the difference between the three large EU economies and everybody else (Table 3.11) but doing little else.

Figure 3.28: Country Clusters on the Basis of RJV Participation



The paper takes a further step in studying the propensity of organizations from different countries to join Framework Programme RJVs in pairs. It finds traces of such behaviour. Nordic countries seem to form a cluster with strong relationships: the presence of entities from Denmark, Finland, Norway and Sweden in a collaborative research project appears to be strongly influenced by the presence of the entities from other Nordic countries. Entities from France, Belgium and the Netherlands also tended to participate together. They have also collaborated more closely with entities from neighbouring countries: France with Switzerland and Italy, Belgium and the Netherlands with Switzerland. Spain and Portugal, the UK and Ireland, Germany, Austria and Switzerland also form clusters of countries with a tendency for the presence of one in RJVs to positively influence the presence of the other. Another group appears in the European periphery where entities from Greece, Portugal, and Ireland, seem to have established strong collaborative linkages. T hese results are interpreted in the paper to indicate the existence of strong collaborative linkages among neighbouring countries, throughout the four Framework Programmes. The authors also underscore indications that linkages among neighbouring countries apparently intensified as the Framework Programmes progressed through time.

3.3.2.5.2. Proximity and Knowledge Transfer from Public Research Institutes

Essential questions for innovation policy are (a) if proximity matters to knowledge flows and (b) if yes, how do these flows occur and what are the conditions for their success. Answers to these questions are of relevance to an assessment of a range of government policies, particularly in Europe, to support close linkages between firms and between firms and public research institutes (PRIs). These policies include subsidies to encourage the regional development of clusters of innovative firms, subsidies for firms to collaborate with

PRIs (universities and other public research institutes), and the establishment of science parks close to universities.

Theories of Innovation Systems are built upon the assumption that proximity matters to innovation. Yet several factors, such as the rapid growth of the internet and email, suggest that the role of proximity could be breaking down, particularly among large firms with the financial resources to seek out relevant knowledge anywhere in the world. Conversely, the need to access tacit knowledge in rapidly evolving science-based technologies could counter the centrifugal features of modern communication technologies.

Arundel and Geuna (2001) use the results of the 1993 PACE survey of Europe's 615 largest industrial firms to empirically determine if proximity matters to the flow of technical knowledge from a range of external sources to innovative firms. The study examines the effect of proximity on the sourcing of knowledge by firms from suppliers, customers, joint ventures, competitors (via reverse engineering) and publicly-funded PRIs.[14]

Descriptive results show that 24.2% of the R&D weighted firms give their highest score to PRIs, with all other sources cited less frequently. The value of PRIs is particularly marked among high technology firms, with 37% of these firms giving their highest score to PRIs. Surprisingly, 30% of low technology firms give their highest score to PRIs. Public research is of less importance to firms in medium technology sectors -all other external information sources, except joint ventures, account for a larger share of these firms' highest scores.

These results contrast sharply with those of the European CIS 1 and CIS 2 surveys, which find that PRIs are a comparatively unimportant knowledge source for most firms. There are two main explanations for the difference. First, PACE is limited to Europe's largest firms, more likely than smaller firms to use knowledge obtained from PRIs. Second, the published results from the CIS are not weighted by a proxy for innovation outputs, which means that the results largely measure the importance of PRIs to smaller and less innovative firms, which make up the majority of CIS respondent firms. For comparable, weighted samples the CIS also shows high company reliance on PRIs.

The sourcing of technical knowledge from PRIs is significantly affected by the localisation of the knowledge source: 47% of the firms rate domestic public research as

[14] In a short diversion from their main theme, but in line with the interests of the KNOW programme, the authors also evaluated the importance of external information sources to the innovative activity of firms according to their R&D expenditures (<2.5m, 2.5 - 10m, 10-40m, > 40m) and R&D intensity (< 1%, 1 - 3%, 3 - 7%, > 7%). Firms in the highest R&D expenditures class rank public research in first place (25.2%) followed by affiliated firms (21.7%). For all other R&D classes, suppliers and technical analysis are in first and second place, with public research in fourth place. Public research is in second place for the most R&D intensive firms, following very closely behind joint ventures (24.1% versus 24.3%). It is also in second place for the least R&D intensive firms, at 21.6%, after technical analysis at 24.1%. For the medium R&D intensity groups, it is in 4th and 5th place.

more important than foreign sources, while only 5% find domestic public research to be less important that foreign research. The most important output of PRIs is “specialised or applied knowledge”, given the highest score by 44.8% of the firms, followed by “general knowledge obtained from basic research” (25.5%), “new instrumentation and techniques” (20.4%), and lastly “early versions of prototypes of new product designs” (9.3%)[15].

The factors that influence the importance of proximity to the use of information from PRIs was explored through an ordered logit model. The dependent variable is the relative importance of domestic PRIs to foreign PRIs. The independent variables include firm size, activity in foreign markets, R&D intensity, a proxy for codified knowledge, and two proxies for the quantity and quality of the scientific base of a country. The ordered logit model results show that proximity effects decline with an increase in R&D expenditures, with an increase in the importance attached to basic research results in publications and for experience in the North American market, but increase with the quality and availability of outputs from PRIs in the firm’s domestic country.

The most frequently cited explanation for proximity effects is the need to gain tacit knowledge, or at least knowledge that is not yet codified. Firms use a variety of methods to acquire different types of knowledge from PRIs, including methods that provide access to codified knowledge, such as reading publications or attending conferences, and methods that provide the opportunity to access non-codified knowledge, such as informal personal contacts, joint research, and hiring trained scientists and engineers. In general, firms prefer methods that provide the opportunity for accessing non-codified knowledge, although we do not know if methods such as informal contacts are used for this purpose. However, exploratory econometric analyses did not find that the relative importance of methods that provide access to codified versus non-codified knowledge had any impact on the proximity effect. In part, this is due to the complexity of the methods available to firms for accessing non-codified research. Firms can use one method for foreign PRIs and a separate method for domestic PRIs. The role of proximity declines when useful knowledge is available in a codified form. This suggests that new technologies that increase the amount of codified knowledge produced by PRIs and decrease the time between discovery and codification could decrease the proximity effect.

3.3.2.5.3. ICT Clustering in Denmark

A rather different analytical approach is followed by Dahl and Dalum (2001) in their appraisal of knowledge flows affecting industry: they examine the case of ICTs in Denmark, featuring the “paradox” of a small but rather sophisticated domestic ICT market and weak supply. The authors use the cluster approach in analyzing this business sector, keeping a close eye on interactions that may not be captured by traditional industrial classification schemes.

In a small country like Denmark the ICT services part of the sector is by far the largest in

[15] R&D weighted results, although the unweighted results are very similar.

terms of both employment and exports. More generally, the Danish ICT sector has grown substantially. It is dominated by small R&D oriented firms with low patent propensity. The country may be characterized as a development "hub" of especially terminals for mobile communications and cordless phones. These may be typically be developed in R&D units of large multinationals, which may result in patents taken out by their headquarters outside Denmark. Or the innovations may come from rather small firms hired on contract by large multinationals, a process that does not typically result in patent applications.

Concerning the geographical distribution of the ICT sector it should be expected that among the major location factors are:

(iv) A "metropolis" effect. Simply because many of the ICT service activities typically are concentrated in cities, such as publishing, advertising, broadcasting, computer software development and services, telecom services.

(v) The supply of skilled labour, such as engineers, computer scientist, business economists, etc., which again is expected to be a function of location of universities and business schools, often determined by government decisions.

(vi) A "random" location of manufacturing firms due to personal preferences among the original founders.

The authors show a strong "metropolis" effect prevalent in the regional specialisation pattern of ICT activities in Denmark. At the more detailed industry level there is, however, a certain degree of geographical diversification, which may be somehow related to the rather decentralised nature of the public education system. On the whole, there is a rather close correlation between the distributions of basically government financed R&D and higher education institutions in ICT and the regional distribution of private employment. Engineers and computer scientist typically choose jobs close to these institutions. More specialised small-scale clusters usually emerge around these.

This pattern has major implications for policy. To further encourage the development of ICT activities a co-ordinated policy approach to such fields as higher research and education, specialised venture and seed capital and regional development of the necessary infrastructure facilities (science parks, telecommunications networks, general transport facilities, etc.) are of significant importance. Recent examples of such policies are the "lighthouse" projects with the objective to stimulate the formation of ICT -businesses in connection to knowledge and education institutions. The two Danish ICT -lighthouses have been located in North Jutland and the Copenhagen Oerestad region. The presence of the small-scale cluster in wireless communications in North Jutland has been the main reason for location of one of the projects. For the other, the major concentration of ICT activities in the Oeresund region and the deliberate, and high profiled, efforts to let this region become much more visible at the international scene, has been decisive.

3.3.2.6. Internet as a Mechanism for Accessing Knowledge

In recent years, several research efforts have dealt with the use of Internet by SMEs and have identified the barriers to and the benefits from its use by the firms. For example, Walcszuch et al. (2000) identified the following benefits:

- Ø Obtain know-how through discussion with others on the Internet
- Ø Benchmark competitor's performance
- Ø Create new business opportunities
- Ø Speedy and timely access to information from Websites
- Ø Gather information effectively

Such benefits are not perceived by firms to be equally important. The benefits that were identified as least important in a survey on American SMEs are (a) competitor's performance benchmarking, (b) inter-office document exchange, and (c) access to government and trade organisation data (Poon and Strom, 1997). In this sense, the benefits of the Internet for SMEs seem to be relatively marginal in terms of using the Internet as an information medium that can facilitate access to new know-how and relate mainly to its use as a low cost communication medium with their customers and suppliers. On the contrary, in another survey by Abell and Limm (1996) in New Zealand it was found that most benefits for SMEs are obtained by using the Web as a communication and information medium, which is most common among SMEs. Therefore, they concluded that speedy and timely access to information from websites represents the largest benefit for SMEs. In Europe, similar surveys have been underway usually by consultancy firms focusing on a particular country or on a cross-European basis (see for example Gallup, 2001). In most cases, the aim has been to investigate the diffusion of the Internet among European SMEs and to assess the status of e-business development in various national contexts. It is clear in existing work that the use of Internet as a communication and information medium differs across countries, necessitating country-specific elements to be identified and taken into account.

Constantelou and Tsakanikas (2001) use the KNOW survey results to investigate the factors that influence a firm to use the Internet either as a source of scientific and technical information or as a tool for communicating between customers, suppliers and collaborators. In addition, the paper delves into the relation between the use of Internet and the innovative performance of the firm.

Ninety three percent of the firms responding to the KNOW survey use the Internet. Firms in the computer services sector lead in Internet usage. They are followed by firms in the chemical sector (excluding pharmaceuticals). Eighty three percent of firms reported that they use the Internet to get scientific and technical information. Again the computer services sector appears to be the leader. Slightly more firms (88%) reported that they use the Internet as a communications tool (to communicate with their suppliers, customers, and collaborators).

Preliminary econometric results concerning the use of Internet in general reveal the following:

- § The use of Internet is positively affected by the level of scientific personnel of the firm and by its R&D intensity.
- § Size matters – it appears that the larger the firm, the higher the probability to use the Internet.

- § The level of innovativeness and the extent of collaboration with external partners do not seem to be related with the use of the Internet.
- § Both internal and external knowledge sources for innovation also turn out insignificant, indicating no relationship between reliance on these sources and the use of Internet in general.

Concerning the two specific uses of Internet – (a) to search for scientific and technical information and (b) to communicate with customers, suppliers, and collaborators – the following results were obtained:

- § Collaboration with external partners, either in production processes or products, is positively related only with the second use of Internet, that is the exchange of information with customers, suppliers and collaborators by e-mail.
- § The number of scientific personnel is highly and positively related to both uses of the Internet.
- § Firm size is positively related to both uses of Internet.
- § R&D intensity is positively related with both uses of Internet.
- § The level of innovativeness of the firm (measured by the extent to which it has introduced significantly changed products or services in the last 3 years) seem to have only a marginal effect on Internet usage for searching scientific and technical information.
- § Internal knowledge sources seem to have only a marginal effect on using Internet for exchanging information with suppliers, customers and collaborators whereas it has no effect on the use of Internet for searching for scientific and technical information. Reliance on external knowledge sources has no significant effect on both uses of Internet.

The authors argue that the findings indicate that European firms still regard the Internet more as an information tool than as a knowledge source that can contribute to innovation – an impression also confirmed by the KNOW in-depth interviews. Companies continue to rely more on traditional knowledge sources for innovation.

3.3.3. IN-DEPTH INTERVIEWS

In-depth interviews expanded the available information from the survey on several subjects. This section summarizes responses per subject. [16]

§ *Use of patents to obtain ideas for innovation*

The majority of firms do not use patent databases to obtain ideas for innovation. No interviewed firm in Germany and the Netherlands does. Reported reasons include:

- The technological profile of the firm does not fit the type of information that can be found in patents.
- Respondent is not R&D intensive.

[16] This summary does not contain the results of the nine interviews conducted in Denmark.

- The firm is not aware of such databases.
- There is sufficient know-how in-house.
- The available information in patents is often of marginal importance to the firm.
- Small firm cannot maintain the required human capital to utilize these databases.
- Firm obtains information through informal contacts.
- Firm relies on the parent company for patent search.
- The search for innovating ideas is done through scientific journals, trade fairs and exhibitions, reverse engineering and the Internet.
- Firm obtains the necessary information from suppliers.

The minority of firms that search patent databases mentioned the following reasons:
- Explore market trends and novelties.
- Assist technicians to access the state of the art in each scientific topic.
- Identify similar products in the market and, more generally, study what has been done in a specific area.
- Identify innovative companies and then try to reverse engineer their products.
- Identify the patent owner who will provide the technical solution.
- Take ideas for developing new applications.

§ *Use of patents to protect innovation-related knowledge*

The vast majority of interviewed firms do not use patents to protect inventions. [17] The few that do reported the following reasons:
- Patents represent the most effective method for protecting intellectual property.
- Patents preferred for products with long expected life cycle.

The reported reasons for avoiding patents include:
- Lead time and secrecy more effective methods for protecting intellectual property.
- Company does not introduce new products.
- Patent cost, including application and administration, too high.
- Unbalanced cost and degree of protection from infringement.
- Significant delays introduced when applying for patents.
- Too much information is disclosed when applying for patent.
- Increasing difficulty to patent due to invention overlap.
- Patents are not customary in the specific activity (software).
- Patents are applied for centrally from company headquarters.
- The specific national patent system considered insufficient for protecting against closely related spin-offs of the original idea.

§ *Internet utilisation*

The majority of interviewed firms use the Internet. [18] A significant number of them have developed their own

[17] Italy did not report results on patenting as a means of protecting intellectual property.
[18] All interviewed French firms reported using the Internet; nine in ten have their own website.

website. They reported using the Internet for the following reasons:
- Communicate with customers, suppliers and collaborators.
- Search for technical characteristics of competing and new products.
- Contact overseas customers.
- Get information about patents and about training programs.
- Save time, decrease costs.
- Access technical information.
- B-2-B and other e-business considered a good opportunity to reduce distribution cost and to facilitate market access without intermediate channels.
- Obtain competitive intelligence on prospective collaborators.
- Obtain ideas on new potential services to market.
- Search for new suppliers.
- Search literature on-line.
- Maintain databases of customer profiles or technological information.

Reported reasons for not using the Internet or for limiting its use include:
- Need for filtering information.
- Perceived problem with updating information on the Internet.
- Not useful.
- Firm does not know how to use it.

§ *Collaboration with universities and public research institutes*

The majority of interviewed firms in Italy, the Netherlands, and the United Kingdom had collaborated at least once with universities and PRIs. The opposite was true in France, Germany, and Greece. The reported incentives for R&D collaboration with these institutions include:
- Obtain EU funding.
- Access state-of-the-art scientific knowledge.
- Access students, well-trained human capital.
- Access specialized instruments and facilities.
- Cost effectiveness.
- The firm's main clients view positively collaboration with universities and PRIs.
- Obtain more reliable results than those from consultants.

Many interviewees also expressed significant reservations about collaborating with universities and PRIs, even those that have had such experience. Reservations were based of the following arguments:
- Firm is too small to attract the interest of the university.
- Firm did not have the chance to develop such collaboration.
- Firm does not do basic or applied work; it does development which does not require academic input.
- The applicability of the research results is questionable; universities too theoretical for industrial needs.
- Firm lacks the necessary financial resources.
- Firm believes in internal development of innovations.
- Firm prefers informal relationships with academics based on personal relationship.
- Service industry finds such collaboration less useful.
- Universities often sluggish and inactive in cooperative research.
- Firm fears loss of secrets; culture differences with universities.
- Universities often lag behind industry; graduates unaware of latest developments.
- Other divisions of the company have the necessary capabilities in basic research.
- Firm prefers to collaborate with technical centres and consultants; their competencies are perceived to be closer to the needs of industry.

§ *Cooperation with other private sector firms*

The majority of interviewed firms in the Italy, the Netherlands, and the United Kingdom have developed research partnerships with other companies. The reverse is true in Greece and Germany. French cases were divided in the middle. The reported reasons for participating in firm-to-firm partnerships include:

- Access the accumulated knowledge and experience of partners.
- Achieve synergies.
- Access information about new market trends.
- Increase own capabilities.
- Access markets and technologies.
- Collaboration with platform providers brings useful information for developing applications.
- Collaborate in anticipation of national safety regulations.
- Share costs of innovation.
- Supplier-customer collaboration strengthens lead-user concept.
- Collaborate in non-core technical activities.
- Collaborate only when the technology is mature, mainly to lower the cost of technological improvement.
- Handle increasing technological complexity and provide integrated solutions.
- Firm focuses on hybrid activities that make collaboration necessary.
- Stay abreast of technological frontier. Often, market size too small to justify the necessary investment.
- Acquire competencies that do not exist in the company and create radically new domains of activity.

On the contrary, the reported reasons for not collaborating in R&D with other companies include:

- The type of products and the sectoral characteristics do not encourage cooperation.
- Lack of appropriate organisational structure, information about suitable partners, and ways of contact.
- Lack of appropriate financial and human resources.
- Inward looking strategy.
- Risk of losing vital information to competitors.
- Market not big enough for more than one company.
- Cooperation is time consuming and costly.
- Parent company engages in partnerships; unnecessary for interviewed company.
- Never cooperate with other companies in core business.
- Cultural differences with prospective partners increase costs of cooperation.

§ *The most important source of knowledge contributing to the most economically important innovation*

Answers varied considerably in this respect. [19] A minority of firms replied that the most important source of knowledge was internal to the firm. Regarding external sources, firms mentioned suppliers, customers, competitors, universities, PRIs, and consultants. Suppliers were important for:

- Collaborating with the interviewed firm; provide necessary assets that innovating firm lacks.
- Giving technical information and suggesting ways to use the provided materials.
- Helping implement new pieces of machinery.

Customers were important for:

- Offering new ideas.
- Bringing forward their preferences and informing the interviewed firm about the success of similar products by competitors.
- Providing the very specialized information necessary for the successful completion of the innovation.
- Operating as lead users; testing prototypes.
- Exchanging personnel with interviewed company.

Competitors were important for:

- Collaborating to reduce cost and risk of innovation.
- Introducing similar products serving as benchmarks and a source of ideas.

[19] The Netherlands did not report results on this item.

Universities and PRIs were important for:
- Providing ideas (e.g., through research undertaken by students) and new solutions.
- Providing technical support.

Consultants were important for:
- Providing information for new market trends and consumer needs.
- Assisting in the completion of the innovation.
- Providing technical support.

§ *Relative importance of internal and external sources of information*

In line with received survey information, there was a clear preference for a greater importance of internal sources of information as most important for innovation. This was particularly so for the implementation of the innovation. A much smaller number of interviewees considered the two of equal importance or considered external sources of information as more important. The importance of internal sources of information was the result of:
- Familiarity and experience of company employees with the business.
- Importance of firm-specific and industry-specific information for innovation.
- Greater reliability.
- Difficulty to find the appropriate expertise in external sources.
- Specifications given by the parent company; development undertaken internally.

External sources of information were important for:
- Providing technical expertise and helping to build on the research of others.
- Helping to internalise external knowledge.
- Offering the original idea.
- Obtaining specialized know-how.
- Acquiring new competencies and opening up new commercial opportunities.
- Cooperation with other organizations crucial for keeping up with rapid changes in the technological trajectories.
- Assisting with quality management standards and complex production processes.
- The output obtained from the external source assists the firm explore different aspects of the same innovation.
- Sharing risks and costs.
- Collaborating to offer more complex solutions to satisfy customer needs.

Section 4

CONCLUSIONS AND POLICY IMPLICATIONS

The KNOW programme set to appraise the extent and mechanisms of dissemination of innovation-related knowledge flows affecting European industry. We were particularly interested in disembodied flows of knowledge between firms, universities, and other education and research institutes. Embodied knowledge flows – occurring through the use of inputs and intermediate goods in production – have attracted the attention of economists who have typically used input-output techniques to approximate them (e.g., OECD). In contrast, disembodied knowledge flows had, until recently, been subject to much less systematic empirical analysis. This partly reflected received economic theory that had been concerned with the transfer of technology embodied in products for a long time but had neglected other kinds of knowledge flows. It also reflected the lack of appropriate data. During the past couple of decades, very significant developments in mainstream economic theory dealing with knowledge spillovers, in evolutionary economics dealing with the process of technological advance, and in the study of innovation systems, to mention the most visible, have created the necessary preconditions for exploiting newly available sources of empirical information. The KNOW programme has followed in this tradition.

The main research *objectives* of KNOW were:

- Examine the extent, magnitude, and type of innovation-related knowledge flows affecting the European industry.
- Evaluate the effectiveness of knowledge transmission mechanisms in raising the ability of European industry to innovate and create economic value.
- Evaluate the effect of the nature of economic agents, of the nature of market competition, and of the nature of the technology on the mechanisms and frequency of knowledge flows.
- Determine the spatial dimension of national, regional, and transnational innovation-related knowledge flows. Specifically, determine whether these flows are largely limited to national or regional systems of innovation or whether they are increasingly becoming pan-European or global.
- Appraise the degree of convergence of national innovation systems in Europe, to the extent that such convergence may be indicated by knowledge flows between agents.
- Derive recommendations to guide future policy options towards facilitating the access to and the transmission of knowledge in order to encourage innovation in European industry and sustain/create new competitive advantages.

The wealth of accumulated and newly created empirical information of both quantitative and qualitative nature allowed the partners to address all these issues to some extent. Even though the study was explorative, we believe we've made important steps in understanding disembodied knowledge flows across Europe. This Section summarizes major findings and distills policy implications.

The Section is divided into three parts. The first provides a brief overview of public policies in EU member states that are of relevance to the KNOW programme. The overview should serve as a point of reference later in this Section. The second part summarizes the major analytical findings of the KNOW programme. The third part concludes with a synthesis of policy recommendations and suggestions for future work.

4.1. OVERVIEW OF INNOVATION POLICY IN EU MEMBER STATES

In Europe, public policies affecting the production and dissemination of innovation - related knowledge are instituted at various levels of governance: supranational (European Union), national (member states), and local. Supranational policies have been especially useful for establishing dense science and technology intensive networks across the continent. Primary policy tools serving that purpose have been the international cooperative research programmes such as those organized through the Framework Programmes on RTD and EUREKA. [20] The Framework Programmes have paid attention to all kinds of organizations involved in innovation -related knowledge flows, including large and small firms, universities and all other kind s of public research institutes (PRIs). Special emphasis has been placed on SMEs, universities and PRIs considered key for innovation and yet facing particular problems with regards to their efficient integration in the European technical enterprise. Struc tural funds allocated to member states and regions also have significant components relating to the introduction of innovations.

Member states have, however, been the traditional implementers of policies affecting knowledge flows and the ability of firms to benefit from them. These policies are briefly reviewed below. [21] They concern 1) the absorption and use of externally developed knowledge, 2) the commercialization of the results of publicly -funded R&D, and 3) the financing of innovation by private firms.

4.1.1. ABSORPTION OF NEW TECHNOLOGY

The capacity of a firm to absorb new technology has two components that match the two definitions of what it means to innovate:

- First, firms can innovate by adopting and modifying technologies developed by other firms or institutions. This is often seen as an issue of diffusion, or the transfer of technology from one organization to another. An example is the purchase of new computer-controlled manufacturing equipment. The ability of a firm to introduce this equipment into its production depends on its understanding of the advantages and disadvantages of the new technology for its own needs and strategies.

- Second, firms can innovate by undertaking creative activities to develop new or improved products and processes. Much of this work can benefit from discoveries made by other firms, universities, and other PRIs. The capacity of a firm to use these discoveries depends on its ability to understand them and to assess their commercial

[20] See Caloghirou and Vonortas (2000) and Peterson and Sharp (1998) for extensive discussions of cooperative R&D in Europe.

[21] Coverage is necessa rily selective due to space limitations. See Diederen et al. (1999) for more extensive coverage of individual member states.

applications. Any activity that a firm undertakes to deepen and widen its scientific and technological skills will also improve its capacity to absorb knowledge from external sources.

Two main kinds of policies are used by member states to improve the absorptive capacity of firms. The first consists of programmes to promote education and learning in order to improve the ability of a firm to innovate. The second consists of programmes to support technology transfer.

4.1.1.1. Education and Learning

Many member states provide educational programmes to improve the ability of firms to learn about new technologies and how to manage the entire process of innovation. Most, but not all, of these policies are directed specifically to SMEs. There are two basic approaches: general programmes to supply information of value to a wide range of firms and customized assistance to help individual firms identify and solve their own problems.

The general education programmes include demonstration projects, courses on innovation management, and visits to successful innovative firms.

1. *Demonstration centres* provide information on and demonstrations of the use of specific technologies. The goal is to reduce the risk of their adoption by helping the firm make an informed decision. These centres are usually located at research institutes with the relevant expertise.

2. *Management advice:* Successful innovation often requires many changes to a firm's organisation and improvements to its management expertise. Support in this area includes both seminars and workshops on general management and programmes that focus specifically on how to manage innovation.

3. *Best practice visits:* Several countries run programmes where SME staff visit successful innovative firms in order to learn about best practice in their industry.

Customised assistance programmes include evaluations of a firm's general management, technology audits, technology feasibility studies, and subsidies to hire recent scientific and technical graduates. Several of these programmes involve visits by a consultant to the firm. A fixed number of days of consultancy are usually provided for free, while the cost of additional days has to be partly paid for by the firm.

Individual consultancy is usually provided by expert consultants who assess the firm's technical problems and evaluate how innovation fits in with the firm's management and business plans. An example of the latter is the MINT programme, where consultants evaluate the firm's strengths and weaknesses, look for technical problems, and propose solutions. This requires between 3 and 10 days work with the firm.

1. *Technology audits* focus specifically on technical problems within the firm and make recommendations on how to solve the problem. Several of these programmes are linked to expertise at a PRI. For example, the TEFT technology audit programme in Norway is focused on finding problems that can be solved by a PRO. The technology audit is followed by a second phase where the PRI is given a subsidy to develop solutions to the identified problem.

2. *Technology feasibility programmes*, such as SMART in the UK subsidise the cost of evaluating the feasibility of adopting or developing an innovative technology. By reducing risk, they provide an incentive for SMEs that innovate very little to innovate or an incentive to innovative SMEs to move into new areas. In addition to evaluating the technology, most programmes require the firm to develop a business plan for the use of the technology.

3. *Hiring subsidies for scientists, engineers, and technicians:* A common programme to improve the absorption capacity of firms is a hiring subsidy for technical staff. Most programmes are limited to SMEs and pay up to 50% of wage costs, for between one and three years, to hire a recent university graduate to assist the firm to innovate. In some countries the subsidy is available to firms of all sizes. Several countries also design the subsidy so that the new employee provides a direct link between their university or technical institute and the firm. In Denmark, the subsidy pays 50% of the cost of hiring a PhD student, who works on a doctoral problem of interest to the firm. The student's university also receives state funding. The Teaching Company Scheme in the UK has gone the farthest in this direction. It subsidises higher education institutions to place graduates in firms to transfer technology during a two-year project. Supervision is provided jointly by the firm and the education institute.

4.1.1.2. Technology Transfer

Three types of programmes are used to support the transfer of technology to firms: government support for a technology transfer infrastructure, programmes to encourage or subsidise collaboration between firms and between firms, universities and PRIs, and subsidies for the purchase of new technology.

1. *Technology transfer infrastructures* are maintained in most EU member states. There are two main types: regional centres that provide advice on a wide range of different technologies to all firms in a geographic region and institutions that focus on specific technologies. For example, the Netherlands supports both a network of regional innovation centres and a network of technology centres, each of which is focusing on a specific industry. In many countries, the infrastructure that provides technology transfer also provides other services, such as business advice and assistance with applying for EU research funds. In Finland, the technology transfer infrastructure is closely linked to PROs and is designed to transfer technology from PROs to firms.

2. *Collaboration programmes* support the transfer of technology by either encouraging or subsidising technical collaboration and networking between firms or between

firms, universities and PRIs. Various countries (e.g., Belgium, Germany, Sweden) have programmes to create networks between firms on either a geographic or sector basis. Most countries offer subsidies for collaborative research between firms, universities and PRIs, but these programmes are discussed below under *translating public investment in RTD into innovations*. Many of these programmes subsidise collaborative research in basic or pre-competitive research that will require additional work by a firm to develop a commercially viable product or process. [The Community Framework Programmes for RTD also fall in this category.]

3. *Technology transfer subsidies*: A few countries offer subsidies to firms to adopt innovative technology. For example, France provides soft loans to firms that adopt targeted technologies, consisting of electronic components, new materials, and computer integrated manufacturing equipment.

4.1.2. COMMERCIALIZING PUBLICLY-FUNDED RESEARCH

Two main types of policies are used to encourage the commercialisation of publicly-funded research. The first consists of incentives for universities and PRIs to conduct research of value to the private sector. These incentives are often designed to influence the activities of universities or institutions where the research agenda has traditionally been determined by academic criteria, rather than by the needs of government or industry. The goal of many of these incentives is to encourage universities and PRIs to conduct research of relevance to business. The second consists of financial support for publicly-funded institutions with a mandate to conduct research of value to firms.

4.1.2.1. Incentives to Universities and PRIs

Programmes to encourage universities and PRIs to conduct research of relevance to business divide into two groups: subsidies for firms to contract out research to universities and PRIs and incentives for these organizations to direct their research into areas of commercial interest. The latter group includes both programmes that actively direct research into business relevant research and passive programmes that establish the potential for contacts between academic researchers and firms. In addition, several countries offer entrepreneurial assistance to academics who would like to commercialise an invention.

Subsidies for contract research: Most countries subsidise firms to contract out research to universities and PRIs. These are often described as collaborative or cooperative research programmes. A subsidy to the firm can be justified by the need to overcome some of the disadvantages of contracting out research to universities and PRIs. These include concerns over confidentiality, higher risks for the basic and pre-competitive research where many PRIs have their expertise, and a preference for firms to keep more applied and commercial research in-house. In addition to producing research output of value to industry, these programmes can assist in developing expertise within universities and PRIs on problems of importance to industry.

Targeted research funds: A few member states have introduced mechanisms to deliberately target academic research funds towards areas of value to industry. The research councils in the UK are responsible for distributing funds for academic research. They use two mechanisms to target research towards areas of value to industry. First, they include representatives from industry who take part in the funding decisions and second, they use the results of the Technology Foresight reports to identify promising technologies with potentially large markets. In the Netherlands, universities and PRIs can receive extra funds for projects that are partly funded by a private firm. Over time, PRIs are required to fund a percentage of their research from private sources.

Passive incentives for universities: Some countries provide passive incentives for academics to work on problems of value to industry. These often consist of mechanisms to increase the opportunity for contacts between industry researchers and academics, such as the establishment of science parks adjacent to universities, or the establishment of liaison offices.

Entrepreneurial assistance: Some universities and PRIs provide assistance for the commercial development of good academic ideas or technical discoveries. This can include help to apply for a patent, to find a buyer for the technology, or to set up a firm to exploit the technology.

4.1.2.2. Business Relevant Research Infrastructure

Many member states support institutions with a specific mandate to conduct research of value to industry. The classic example is the Fraunhofer Institutes in Germany. Many of these institutions are under pressure to increase the commercial relevance of their work, the efficiency with which technology is transferred to firms, and the percentage of their operating costs that is funded by contract research. There are two main types of institutes: specific, purpose-built institutes and "virtual" research institutes. The former most commonly conduct applied research but a few also perform basic and pre-competitive research in strategic areas. The virtual institutes are more likely to be involved in basic research. They are presented here as a separate category because most new institutes appear to follow a virtual structure.

1. *Applied research institutes:* These institutions focus on specific industries and have a long history. Many of the applied institutes are in low or medium technology sectors such as agriculture or machinery with many SMEs. These firms often lack the financial resources or expertise to solve technical problems in-house. The applied research institutes offer SMEs basic technical services for free or for a low fee. Basic and pre-competitive research institutes are usually established in strategic technologies such as biotechnology or micro-electronics where commercial applications are fed by scientific advances.

2. *Virtual research institutes*: In the past, applied or basic research institutes were usually established in new buildings with their own offices and research laboratories. The current trend is to establish "virtual" institutes that link researchers at several universities and other PRIs and sometimes within firms. This results in considerable savings and is expected to increase the efficiency of existing expertise by improving knowledge flows and cooperation. They can also encompass both basic and applied research, since there is no existing "research culture" that must be overcome.

4.1.3. FINANCING INNOVATION BY FIRMS

Policies to finance innovation by private firms is a supply side measure that does not directly concern knowledge flows. However, it is difficult to separate these measures from policies to encourage firms to build up their absorptive capacity, which *is* of relevance to KNOW. Another major policy concern is based on a perceived lack in Europe of new high technology firms and small high technology firms with rapid growth rates, at least in comparison with the United States. Part of the problem is due to a poorly developed European equity market for venture capital. This has led to a range of policies to provide seed and high-risk venture capital to help the establishment and growth of high technology firms. Policies to create new firms are not directly relevant to KNOW and are therefore only discussed in passing below.

4.1.3.1. In-house Innovation

There are three main forms of government support for in-house innovation: direct grants, soft loans, and tax incentives. All three are sometimes targeted to specific technologies or types of firms (such as SMEs) that the government wants to encourage to innovate.

1. *Direct grants* are cash expenditures to fund part of the costs of an innovation project. They are usually limited to 50% or less of the costs, with the firm required to finance the remaining. The major concern with direct grants is that firms may use them to replace private funds for research that they would conduct anyway. For this reason, direct grants are often targeted to areas where firms are less likely to finance innovative projects. For example, Belgium only makes direct grants available for basic research. Several countries, including Belgium, have more liberal funding policies for SMEs, which could find it difficult to obtain other sources of finance. France only provides direct grants to SMEs.

2. *Soft loans* cover several methods that reduce the true cost of a loan to a firm. These include government guarantees for commercial loans, zero or reduced interest loans, and forgivable loans in the event that a funded project fails. In most EU member states, a soft loan is provided for only part of the cost of an innovation project, while Austria will provide a soft loan to an SME for up to 100% of the cost of a project. Several countries, including France, Germany, the Netherlands, and the UK, only offer soft loans to SMEs. Other countries provide soft loans to firms of all sizes but give better conditions to SMEs. For example, Finland provides soft loans to a maximum of 50% of the cost of a project in a large firm, but up to 60% for SMEs.

3. *Tax incentives*: some countries (e.g., Belgium, France, the Netherlands) report tax incentives for in-house R&D. The Netherlands reduces payroll taxes for R&D personnel while France offers research tax credits to firms that conduct R&D. Belgium offers higher tax rebates for research projects in environmental technology. Tax incentives are simple for firms to use but can be costly for governments in terms of lost revenue.

Over the last decade, there has been a decline in the number of national programmes that provide direct grants to support in-house innovation by firms, partly because of concerns that direct grants crowd out private funds, rather than increasing the total amount of private investment in R&D. The approach taken by Germany, Denmark, Finland and the UK, for example, is to limit direct subsidies and to focus on the development of a favourable business environment for innovation. One result is that government support for in-house R&D has shifted in many countries from direct grants towards soft loans. This process has gone the farthest in the UK, which provides no direct grants and only gives soft loans to SMEs.

There are a few exceptions to the trend of moving away from direct grants for R&D:

1. Countries in the EU periphery, such as Greece and Ireland, continue to provide direct grants for in-house R&D, although Ireland is trying to replace direct grants with equity investment.
2. Direct grants are in use in several countries to support R&D in strategic technologies. For example, France provides substantial direct grants for R&D in strategic areas such as aerospace and electronics.
3. Direct R&D grants continue to be widely available for collaborative R&D projects or to support R&D by SMEs. The former is justified by the belief that firms would not finance collaborative R&D without incentives and because collaborative R&D is thought to have strong benefits, in the form of establishing contacts that could create spillovers and more efficient investment in the future.

4.1.3.2. Seed and Venture Capital

There is a general consensus, with the exception of the UK, that there is a lack of private equity funding for start-ups and SMEs. The response of most member states is to provide temporary incentives to encourage the development of private sources of venture capital. These temporary measures are intended to help establish private venture capital firms and give them time to develop the expertise required for successful high-risk investment. It is not clear how successful these programmes have been, with critical evaluations of programmes in countries like Austria, Denmark and Spain. The concern is that government incentives have not had a significant impact on the supply of risk capital, with most investment going to projects of limited risk. One possibility is that the main bottleneck is a lack of good projects in which to invest.

Four approaches are in common use: programmes to provide seed finance, public equity investment, subsidies for private venture capital, and initiatives to establish new stock markets that are similar to NASDAQ in the United States. In addition, France, the Netherlands and Germany have supported small projects to develop technology assessment techniques that can be used by banks and venture capital firms to assess the market opportunities for a technology.

4.1.4. POLICY REVIEW CONCLUSIONS

The policy review highlights a shift in European innovation policies. These shifts have been motivated by the following three factors:

- A reduction in subsidies to firms for both budgetary reasons and to meet European competition policy.
- The adoption of evolutionary innovation theories and system views of the innovation process.
- A search for policies that can improve the ability of the European innovation system to translate research into innovative products.

The shift in policy has produced at least five major trends in innovation policy that are of relevance to KNOW:

1. Universities and other PRIs such as government laboratories are being encouraged, or required, to direct their research efforts to areas that are of interest to private firms.

2. Direct research subsidies to large, individual firms for in-house R&D have been substantially cut-back or eliminated in most EU countries, with the notable exception of France and smaller EU countries such as Ireland and Greece that pay for these programmes largely with EU structural funds. In most other countries, direct subsidies are limited to targeted programmes to support SMEs or for collaborative research projects.

3. Targeted research subsidies for private R&D for strategic technologies such as micro-electronics or biotechnology have been reduced in favour of general policies. Targeted funding still dominates the EU Framework Programme for RTD.

4. Greater emphasis is placed on the diffusion of technology. In addition to the maintenance of a technology transfer infrastructure, many countries have introduced programmes to improve the absorptive capacity of SMEs. These include basic educational courses on innovation management and technology audits, which identify technical problems in the firm and suggest innovative solutions.

5. The increasing sophistication in S&T policy decision-making in Europe has led to a gradual refocusing of the overall policy target from technology to innovation. Given that innovation is a much broader concept than technology also depending on more general economic factors, policy makers are adopting a more balanced approach reflecting both supply-side and demand-side factors.

4.2. OVERVIEW OF RESEARCH RESULTS IN "KNOW"

The KNOW programme supported extensive empirical research, both quantitative and qualitative. Key research findings are listed below.

Descriptive Analysis

4. *CIS 1 (Firms of all sizes; manufacturing sectors)*

- Customers are of the highest significance as external sources of information, followed by suppliers and competitors. Unweighted tallies of firms may, however, bias the results by over representing the prefe rences of SMEs. For example, larger companies reportedly prefer to cooperate in R&D with universities and other public research institutes (PRIs)much more frequently than their smaller counterparts.

- Traditional mechanisms of external knowledge transfer su ch as fairs and exhibitions, conferences and other meetings, and journals remain very important sources of innovation.

- Innovative companies tend to cooperate above all with suppliers and clients in vertical relationships.

- The probability of knowledge inf lows and outflows and the probability of cooperating in R&D rise with firm size.

- National channels of knowledge communication are still used more often than international channels.

5. *KNOW Survey (heavily SMEs; three manufacturing, two service sectors)*

    - Traditional activities such as attending trade fairs and conferences, and reading scientific and business journals are reportedly the most important source of new ideas for innovation in the examined seven countries. Reverse engineering has lost none of its lustre.

- European SMEs do not search patent databases for creative ideas.

- In most countries, secrecy is the preferred strategy of intellectual property protection. Developing lead-time advantages is also very important. With the exception of chemicals, pa tenting is way down the list in terms of frequency of use. The value of patents is particularly low in the two ICT service sectors.

- Firm size seems partly related to the reported low priority of patents as a mechanism of intellectual property protection. A larger share of mid -sized firms (above 250, below

1250 employees) than smaller firms cite patents while smaller firms are more likely to cite secrecy as more important. Almost twice as many mid-size companies as small firms have patented their economically most important innovation. Other factors apparently relate to the nature of the technology (chemicals patent more), industrial structure (firms with many competitors prefer secrecy), and the innovatory activity in the firm (R&D continuity positively influences the propensity to patent). The tendency to patent also varies across countries.

- Customers, suppliers, and competitors are very important sources of information for innovation in the surveyed SMEs. This agrees with the picture emerging from the extensive CIS 1 and CIS 2 pan-European surveys.

    - The economically most valuable innovations are pulled by demand: customers are the dominating sources for the original ideas of innovations. On average, suppliers and competitors also seem to be important sources of knowledge for innovation. Significant differences between countries exist.

    - In addition to serving as frequent sources of the original idea, customers and suppliers are most frequently mentioned as the important contributors to the completion of the innovation.

    - Internal knowledge is highly valued as a contributor to innovation in all countries, especially in Germany and Britain. Italian firms seem to have the most balanced approach to internal versus external source of information. Dutch firms seem to be more open to external sources of innovation than their European counterparts.

    - National sources continue to dominate as the important external sources of innovation-related knowledge, at least as far as the surveyed SMEs are concerned. Firms of smaller countries like Greece, Denmark and the Netherlands tend to be more internationally orientated than those located in the large countries.

    - The dominant reasons for obtaining knowledge from the most important external source reportedly include reducing development costs and risks, increasing the technical expertise of the firm, and building on the research findings of others.

    - Previous experience is by far the most effective way of getting in contact with the most important external source of knowledge, followed by participation in trade fairs and conferences. Business and professional associations seem to play a quite distinct role in that respect in the United Kingdom. British first, and then French, Dutch and Italian firms also use the Internet for that purpose. German firms seem to behave differently.

    - Scientific and technical information is the dominant type of knowledge obtained from the most important external source, followed by knowledge relevant to market introduction. By far, the most frequent method of communication with external source of knowledge is informal personal contacts, followed by research cooperation. Exchange of personnel and other methods are also used in some countries (e.g., France, Netherlands) more than in others.

- The large majority of surveyed firms use the Internet regularly in every-day business. Firms in the computer services sector lead in Internet use, followed by firms in the chemical sector. Dissemination of the Internet technology is still poor only in the food and beverages sector. The lowest use of the Internet was reported in Greece. Almost all users reported using the Internet to access scientific and technical information and to communicate with their suppliers, customers, and collaborators. Internet use is found positively related to the level of scientific personnel, the R&D intensity of the firm, and to the size of the firm.

6. RJV-EPO Database (Firms of all sizes; all sectors)

- The RJV network of projects initiated through Framework Programmes during 1992-1996 is quite dense. The network is also highly heterogeneous: a few agents with many ties coexist with a much larger number of agents with few ties placed in more peripheral position in the network.

- A relatively small number of agents have played a very important role as co-ordinators of cooperative projects. These agents are, on average, more innovative and they occupy more central positions in the RJV network.

- Universities and other large research organizations have played a disproportionately larger role than private sector firms as core actors the RJV network during the examined time period. In contrast, large companies have been much more central than universities and research organizations in the European patent network.

- Only a small fraction (less than 15%) of all participating entities in the examined RJVs had registered patent applications at the European Patent Office in the period 1978-98.

- Apart from very large innovative firms, there is no clearly detectable relationship between RJV participation and the position in the RJV network, on the one hand, and between the extent of innovative activity and the position in the citation flow network, on the other.

- The knowledge-intensive network to which the RJV participants refer in their patent citations has a clear European rooting. About half of all citations are directed to European organizations of all kinds, with the remaining directed primarily to organizations in the United States and in Japan.

Statistical Analysis *(All databases except CIS)*

- European research networks show "small world" properties, an ideal form of network featuring high levels of local clustering and higher speeds of knowledge transmission. The network of Framework Programme sponsored RJVs comes closest to the "small world" model. The network of EUREKA RJVs and the more informal network of European patent citations also resemble small worlds. The theoretical model fits less well the latter two cases. Overall, the analysed European research networks, and particularly the network of Framework Programme RJVs, are relatively efficient means of knowledge transfer.

- There is a need to address more aggressively in the future the issue of *self-selectivity of RJV members* in European Framework Programme RJVs. That is, the identified positive correlation between patenting activity and participation may reflect the higher propensity of more innovative agents to participate, rather than the success of these RJVs to raise the innovativeness of participating companies.

- The evidence of self-selection blurs when distinguishing between different technological areas and becomes more difficult to detect in different size classes. A comparison between the field of information and communication technology (ICT) and medical and biotechnology (MB) is stark. The examined set of RJV participants tend to be more innovative than non-members in both cases. However, while in the ICT area European programmes have attracted highly R&D-intensive firms that were already remarkably more innovative than the average European level, in the MB area early RJV members did not exhibit high levels of patenting prior to entry. And, while size was positively related with patenting activity in the ICT field, no such clear relationship emerged in the MB field.

- Put differently, such evidence indicates Framework Programme RJVs may have reinforced existing leaders and networks in Information and Communication Technologies, a relatively more "mature" field, where a "network of excellence" has already emerged and hierarchy of innovators is rather stable. In contrast, Framework Programme RJVs seem to have favoured the exploitation of the innovative potential of new actors in Medical Technologies and Biotechnology, a more fluid, emerging field.

- The benefits from cooperative R&D are positively related to the firm's in-house technical capabilities, especially the ability to undertake R&D. Cooperation seems to complement, rather than substitute for, internal technical capabilities. In order to benefit from R&D cooperation, a firm must keep upgrading its knowledge base and technical capabilities. The nature of the relationship may, however, depend to some extent on the nature of the industry and the technological field. More work is needed in this regard.

- In all five sectors surveyed for KNOW, over 63% of product/service innovations are developed in-house, between 9% and 13% are bought in, and around 20% are developed via collaboration. Empirical results show that the share of innovations developed in-house has a positive and statistically significant effect on the innovative sales share of surveyed firms, contrary to the share of innovations developed via collaboration that has no statistically significant effect. This result raises some questions regarding the advantages of excessive collaboration, even though the analysis shows that some collaboration is beneficial. More work is needed in this regard.

- With the exception of the chemical sector, most firms in the KNOW survey cited secrecy and lead time as more important protection methods than patents, with the exception of the chemical sector. The value of patents appeared particularly low in the two ICT service sectors and for smaller firms. Three-quarters of the most important innovations had not been patented. The probability of patenting the most important innovation was found to rise with:

(m) specialization in chemicals and telecom equipment;
(n) product innovations;
(o) R&D intensity of the firm;
(p) share of R&D spending on external sources;
(q) firm size;
(r) the receipt of government subsidies.

- Pioneering recent work in Europe and the United States has pointed out geographical clustering features of knowledge-related activities. Technological knowledge and spillovers seem to be geographically localized. The KNOW programme produced preliminary evidence of regional clusters of organizations participating pair wise in Framework Programme RJVs. Such clusters seem to involve neighbouring European countries. One such cluster seems to involve Nordic countries. Others seem to involve France, Belgium and the Netherlands. Several other examples have also been indicated. More work is also needed in this regard.

  - PACE, a survey of Europe's 615 largest industrial firms in the early 1990s, shows that a quarter of respondents gave their highest score to PRIs as an important source of innovation-related knowledge. The value of PRIs was particularly marked among high technology firms, with 37% of these firms giving their highest score to PRIs. These findings contrast sharply with those of CIS 1 and CIS 2 and of the KNOW survey which find that PRIs are a comparatively unimportant knowledge source for most firms. The main explanation of the discrepancy is that PACE is limited to the largest firms, more likely to use knowledge obtained from PRIs. The findings from the other surveys largely measure the importance of PRIs to smaller and/or less innovative firms, which make up the majority of respondents.

- Essential questions for innovation policy are (a) if proximity matters to knowledge flows and (b) if yes, how do these flows occur and what are the conditions for their success. Answers to these questions are of relevance to an assessment of a range of government policies to support close linkages between firms and between firms and universities and PRIs. Weighted data for Europe's largest firms (PACE) indicate that sourcing of technical knowledge from PRIs is subject to localisation effects: almost half of the interviewees rated domestic public research as more important than foreign sources; a very small proportion rated national and fo reign PROs in reverse order. Geographical proximity effects increase with the quality and availability of outputs from PRIs in the firm's domestic country. They decline with rising R&D expenditures, with increased importance attached to basic research resu lts in scientific publications, and with experience in the North American market. New technologies that increase the amount of codified knowledge produced by PRIs and decrease the time between discovery and codification could decrease the proximity effect.

- Within a single country the geographical distribution of a sector like ICT would be expected to depend on:

(vii) A "metropolis" effect – because many of the ICT service activities typically are concentrated in cities, such as publishing, advertising, broadcast ing, computer software development and services, telecom services.

(viii) The supply of skilled labour, such as engineers, computer scientist, business economists, etc., which again is expected to be a function of location of universities and business schools, often determined by government decisions.

(ix) A "random" location of manufacturing firms due to personal preferences among the original founders.

- Such a pattern is indeed verified in the case of a small Nordic country. The strong "metropolis" effect on regional ICT specialization is counterbalanced at the more detailed industry the rather decentralised nature of the public ed ucation system. On the whole, there is a rather close correlation between the distributions of basically government financed R&D and higher education institutions in ICT and the regional distribution of private employment. Engineers and computer scientists typically choose jobs close to these institutions. More specialised small -scale clusters usually emerge around these.

4.3. POLICY IMPLICATIONS

12. The channels and mechanisms of knowledge flows define the links that make up production and innovation systems. As such, they relate directly or indirectly to all policies that affect such systems. At a minimum, they relate to the entirety of the spectrum of science, technology and innovation policy, being particularly akin to policies that provide incentives to access and disseminate knowledge and policies affecting learning processes. Knowledge flows are also directly related to intellectual property protection policies and competition policies that create the infrastructure supporting various forms of formal interaction among economic agents in production and innovation systems.

This Section briefly summarized member state policies affecting inno vation-related knowledge flows. To achieve closure, the overview only referred to technology and innovation, ranging from policies directed to the enhancement of the absorptive capabilities of firms, to commercializing public research, to methods of R&D and innovation funding. One could obviously expand coverage way beyond this range to address all policies of relevance to the "knowledge" or "learning" economy (Lundvall and Borras, 1999; OECD, 2000). Governments should be aware of the fact that most of their industrial, S&T and innovation policies will impact the channels, direction, and intensity of knowledge flows affecting industry.

13. *The importance of policies concentrating on national channels of knowledge flows remains high. International channels are, however, developing fast and will increasingly attract policy attention. Coordinating the two will become inevitable soon, especially in closely nit country groupings like the European Union.*

National channels of knowledge flows remain more important than international channels. A long series of surveys, also including the KNOW survey and in-depth interviews, have underlined the continuing dominance of national over international channels. Results should be interpreted with care, however, as they may often over-represent the importance of national channels to SMEs. While national channels remain most important even when one weighs the results by firm size and innovativeness, the difference narrows significantly. Results may also be sensitive to the sector. Globalization is pushing for increasing international links, which tend to be exploited first by more innovative and/or larger firms.[22] Most importantly, long streams of European R&D programmes – both those that are implemented by the EU such as the Framework Programmes on RTD and those that aren't like EUREKA – have also created very strong networks among economic agents across Europe. In this respect, the current debate on the European Research Area calling for more extensive coordination of supranational (European) and national/regional S&T and innovation programmes and policies seems right on the mark.

14. *Policies to enhance the absorptive capabilities of firms remain key. They are probably more important now than ever before.*

Available survey work indicates that, on average, firms rate the contribution of internal knowledge sources to their innovative activities more highly than the contribution of external sources. While empirically correct, this statement also needs to be qualified in terms of (a) firm size and sector – larger firms and those operating in certain sectors tend to be more open to external sources of innovation and (b) degree of innovativeness – more innovative firms tend to use external knowledge sources above industry average.[23]

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[22] This becomes more important when considered in conjunction with the observation below that customers and suppliers are the most important source of information for new technologies and products for SMEs. If major customers or suppliers look abroad, small firms that supply them or buy from them will do too, even if indirectly.

[23] The qualifications for internal-external knowledge sources resemble those for national-international linkages. Although still largely a matter of anecdotal evidence and

The degree of openness notwithstanding, what needs to be stressed is the relationship between internal and external sources of knowledge. Rather than substitutive, it is now clearly understood that the two are complementary. A firm needs to be competent internally in order to tap into and benefit from external knowledge flows. For example, the benefits from cooperative R&D are positively related to the firm's internal capabilities, particularly with respect to conducting R&D and developing relationships with other organizations. In order to gain from R&D cooperation, a firm must keep upgrading its existing knowledge base and capabilities.

Hence, all sorts of policies that enhance industry's absorptive capacity – using the broad sense of the term incorporating the ability to both access and to utilize knowledge – necessarily enhance industry's benefit from a given level of knowledge flows.

15. *SME innovation is strongly affected by their large, most important customers and suppliers.*

The lifeblood and advantage of SMEs is quick response to demand requirements. Ensuring strong demand for advanced SME products by their large industrial customers and strengthening the links with sophisticated suppliers will work wonders in terms of providing incentives for innovation to SMEs. SMEs consistently report that the most important sources of information and innovation ideas for these companies are customers, suppliers, and competitors. With the exception of certain industries like biotechnology, large companies use, on average, universities and PRIs much more often than their smaller counterparts.

16. *The Internet has neither replaced traditional channels of knowledge flows nor is it expected to do so any time in the foreseeable future. In contrast, the Internet has added another very important channel for communication and knowledge exchange. Firms have embraced it enthusiastically. Policy can broaden access and methods of utilization.*

The majority of surveyed firms note that external information sources contribute to both the original idea behind the economically most important innovation and to its completion. They access these sources of information mainly through traditional mechanisms of knowledge communication and transfer such as trade fairs, conferences, scientific and business journals, and reverse engineering. Nevertheless, the vast majority of surveyed SMEs in KNOW use the Internet regularly in every-day business, particularly to get scientific and technical information and to communicate with their suppliers, customers, and collaborators. Other benefits with respect to Internet use by SMEs include benchmark competitor's performance, create new business opportunities, and access information rapidly. Government policy may assist in turning the Internet from an information medium into an integrated strategy tool.

17. *Despite the contemporary climate for stronger IPR protection, European SMEs neither search patent databases for creative ideas nor strive to apply for patents.*

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case study work, it is apparent that conditions leading to more open strategies for external sources of knowledge will also lead to more international linkages, especially in a continuing environment of globalization.

In most countries, secrecy is the preferred strategy of intellectual property protection. Developing lead-time advantages is also very important. With the exception of the chemicals and pharmaceuticals constellation of sectors, patenting is way down the list in terms of frequency of use in industry. The value of patents is particularly low in services, as also shown by the ICT service sectors surveyed for KNOW. Firm size is partly related to the reported low priority of patents. Smaller firms tend to work with patents less than larger ones. Other contributing factors seem to be the nature of the technology (chemicals patent more), industrial structure (large numbers of competitors induce preference for secrecy), and the innovatory activity in the firm (R&D continuity positively influences the propensity to patent). It is still a matter of expert debate whether regimes of stronger intellectual property protection are preferable across the board.

18. *The implementation of policies to promote cooperative R&D during the past couple of decades has resulted in the formation of formidable knowledge communication networks across Europe. The thrust should be maintained.*

R&D collaboration involving firms, universities and other PRIs has become an important source of knowledge flows. More specifically, there are strong indications that the European Framework Programmes for RTD have created highly connected and dense networks with efficient structures for knowledge communication. Programmes were found interconnected in terms of overlapping participants. Organizations other than firms (universities, consultants, etc.) have played a very important role in establishing links among RJV programmes. While most organizations have participated in these programmes infrequently, there is a cadre of technology and innovation leaders who have weaved a tight core in these networks.

19. *A relatively small number of organizations, including primarily large companies, universities and a few PRIs, have emerged as core players in European cooperative R&D activities, playing a disproportionately important role in maintaining channels of communication than their counterparts. It is conceivable that the same organizations will emerge as the core players in the new "networks of excellence" currently debated in the context of the 6th Framework Programme.*

The Framework Programme RJV network is characterized by a very large number of peripheral agents, with one or few (formal) connections, coexisting with a relatively small number of central players with large numbers of connections that play an extremely important role in maintaining communication among distant nodes. Prime contractors have participated, on average, to a much higher number of RJVs compared to Partners. Most networking activity in this RJV network occurs mainly among Prime contractors who are apparently the central actors in the network. The frequency distribution of Prime contractors in the set of participants is biased towards universities and large industrial groups. In addition, the distribution of innovative output on the basis of the patenting activity of RJV participants is highly skewed in favor of Prime contractors, especially companies. Marginal participants are, on average, the least innovative ones.

It would not be unreasonable to expect that the same, or similar, organizations will emerge as the core players in the new "networks of excellence" currently debated in the context of the 6th Framework Programme. There are well-known positive and negative aspects of this. The positive is that these organizations possess the capabilities to play leading roles. The negative aspect is the potential for limited entry of newcomers in the inner circle of the network. Policy should ensure that there are no unreasonable barriers to entry.[24]

20. *The knowledge-intensive network to which the innovative RJV participants refer and against which they benchmark has a clear European rooting.*

Intra-network patent citations in Framework Programme cooperative R&D projects have tended to go to European patent holders. The most central actors (mainly to be found among Prime contractors and especially large firms) receive most in-network patent applications. This encouraging result runs counter the more pessimistic arguments concerning the ability of European industry to be at the forefront in state-of-the-art technologies relative to their counterparts from the United States and Japan.

21. *Cooperative R&D programmes could have differential effects across industries and technology fields depending on the degree of maturity of the industry. Attention to sector dynamics is warranted during programme design and evaluation.*

Evidence rests on Framework programmes with concentration on information and communication technology (ICT) and medical and biotechnology (MB). On one hand, in the ICT area European programmes have largely attracted highly R&D-intensive firms that were already remarkably more innovative than the average European level (self-selection problem) whereas in the MB area early RJV members did not exhibit high levels of patenting prior to entry. One the other hand, while there is no clear and robust evidence of a positive correlation between patenting activity and RJV participation in the ICT field, such evidence exists for the MB field. The interpretation could well be related to the life cycles of the respective industries. Cooperative policies seem to have reinforced existing leaders and networks in the more "mature" of the two industries, where a "network of excellence" has already emerged and hierarchy of innovators is rather stable. In contrast, cooperative policies seem to have favoured the exploitation of innovative potential by new actors in the

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[24] This notion is not entirely new. In principle, demands are similar to those in competition policy. The big difference, of course, is that competition policy (antritrust) has traditionally dealt with existing markets whereas here we are dealing with knowledge and the markets of the future. During the past couple of decades, however, significant developments in economic understanding of technological advance have led to the incorporation of "technology market" and "innovation market" concepts and network concepts in competition policy. It may be that this policy area can provide some input to ways of handling efficiently the potential of entry barriers to the "networks of excellence".

case of emerging technologies.

If so, at the early stages of technological development and competition in an industry, policy should attempt to create networks of excellence and to open up existing networks to potential innovators by promoting R&D-intensive programmes that are strongly technology-oriented. In later stages of the life cycle, when the industry is technologically mature and networks of leading actors are well established, a more effective policy target would be to link peripheral actors to extant networks, favour a broad diffusion of knowledge, and guard against the use of collaboration for the creation of unreasonable barriers to entry.

22. *Geographical proximity matters to knowledge flows and this can be a strong influence for the localization of production and innovative activity. The explanation is multi-faceted and calls for complex policy approaches to creating regional competitive advantages.*

Pioneering recent work in Europe (including KNOW) and the United States has pointed out geographical clustering features in knowledge-related activities. Technological knowledge and spillovers seem to be geographically localized. Weighted data for Europe's largest firms indicate that sourcing of technical knowledge from universities and other PRIs is subject to localisation effects: domestic public research is typically rated as more important than foreign sources. There are also preliminary indications of clustering among organizations in neighboring countries for participating in Framework Programme cooperative R&D ventures.

The preconditions of dynamic knowledge-related clusters are not, however, easy to achieve. For example, it was shown that the geographical distribution of a sector like ICT can be reasonably expected to depend on:

(x) A "metropolis" effect, the result of the fact that many of the ICT service activities typically are concentrated in cities.

(xi) The supply of skilled labour, which is expected to be a function of location of universities and business schools, often determined by government decisions.

(xii) A "random" location of manufacturing firms due to personal preferences among the original founders.

Such a pattern was observed in Denmark where the strong "metropolis" effect on regional ICT specialization is counterbalanced by the rather decentralised nature of the public education system. On the whole, close correlation was observed between the distributions of government financed R&D and higher education institutions in ICT and the regional distribution of private employment. Engineers and computer scientists typically choose jobs close to these institutions. More specialized small-scale clusters usually emerge around these.

The upshot is that creating local competitive advantages requires complex policy solutions.

We started this Section arguing that innovation-related knowledge flows define the links that make up production and innovation systems.[25] As such, they relate directly or indirectly to

[25] See Figure 2.1 for an illustration.

all policies that affect production and innovation systems. Governments should be aware of the fact that most of their industrial, science, technology and innovation policies will impact the channels, direction, and intensity of knowledge flows affecting industry.

Put differently, in order to be effective in leading a country/region to the new, knowledge-intensive, "learning" era, science, technology and innovation policy must build bridges and blend with broader economic and social policies. This requires a more synthetic policy approach than in earlier decades.

Such a message is supported by both the mainstream and evolutionary economics approaches and is in full agreement with the debate over the knowledge-based economy. The message is also in concert with contemporary technology/innovation policy thinking in Europe as reflected in the discussion over the European Research Area, the Sixth Framework Programme for RTD, and the Action Plan e-Europe 2002.[26]

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[26] See:

(i) European Commission (2000) "Communication form the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions: Towards a European Research Area", Brussels, COM (2000) 6, January 18;

(ii) (ii) European Commission (2000) "Proposal for a Decision of the European Parliament and of the Council Concerning the Multiannual Framework Programme 2002-2006 of the European Community for Research, Technological Development and Demonstration Activities Aimed at Contributing Towards the Creation of the European Research Area"; and,

(iii) European Commission (2000) "e-Europe: An Information Society for All", Draft Action Plan, prepared by the European Commission for the European Co8uncil in Feira 19-20 June.

Section 5

DISSEMINATION AND EXPLOITATION OF RESULTS

The coordinating team and all participants committed to the widest dissemination of the results of this project. A long list of working papers has been produced (see Annex) and has been presented in Conferences and at the final workshop in Athens, on May 2001. These working papers will be available on the web site http://www-liee.chemeng.ntua.gr . Other ways of dissemination have also been used (workshops, participation in conferences and publications).

In the following section we present in detail all efforts undertaken by the KNOW research teams.

1) Presentation to conferences:

- Two papers have been submitted by the Greek team for presentation to the EAEPE conference:
    - In Berlin in November 2000: "Inter-country technological linkages through European Collaborative Research Programmes: Does geography (still) matter?" Y. Caloghirou, A. Constantelou A. Tsakanikas and
    - In Sienna in November 2001: "Influential factors in the innovative performance of firms: Some empirical insights", Y. Caloghirou, I. Kastelli, A. Tsakanikas
- One paper has been presented by IKE at the Nelson and Winter Conference organized by DRUID in Aalborg in June 2001: "Two faces of Absorptive Capacity Creation: Access and Utilisation of Knowledge", M. Praest, B. Dalum, G. Villumsen.
- At the same Conference in Aalborg, Lucia Cusmano from CESPRI presented the paper "European Research Joint-Ventures and Innovation: a microeconometric analysis of RJV impact on firms' patenting activity".
- Aldo Geuna (as member of the BETA team) and Anthony Arundel (MERIT) presented a paper entitled "Does proximity matter for the transfer of knowledge among Public Institutions, Universities and firms?" at the 8th Schumpeter Conference "Change, Development and Transformation", in June 1999.

2) Workshops:

The KNOW FOR INNOVATION workshop was organized in Athens in May 2001 by the coordinating team with a view to present the project results. Fourteen working papers were presented to academics and policy makers.
A working paper has been presented to the MESIAS workshop on "The upgrading of Absorptive Capacities of Domestic Firms and Institutions" held in Budapest in March 2001: "Cooperative R&D as a means for knowledge creation".

3) Papers from the project will be published in the Discussion Papers of the Athens University of Economics and Business and the University College London. The paper "Firm Leadership and Innovative Performance: Evidence from 7 EU Countries" by D. Czarnitzki and Kornelius Kraft is published as ZEW Discussion Paper 01-35. Moreover, this paper is submitted to "Small Business Economics" in "ZEW Documentation" series,

4) A report with the descriptive analysis on the results of the KNOW survey, was circulated to the Greek firms that responded t he questionnaire and the same is planned by the German team in order to announce the results to the German firms that responded.

5) Working papers from the project have been presented at Seminars at the Athens University of Economics and Business, the Univer sity College London, the National Technical University of Athens and in Milan during the last two years. A seminar was also presented by L. Cusmano from CESPRI on the topic "European Technology Policy and Co-operative R&D: an empirical analysis of European Research Joint Ventures", at the Faculty of Economics, University of Malaya, Kuala Lumpur, Malaysia.

6) Publications to journals:

- IKE plans a publication on "New Organisational Forms in R&D" based on the interviews in Denmark. The publication is expected i n Spring 2002.
- MERIT is planning to submit three papers for publication:
  - ü "The relative value of internal and external information sources to innovation": submitted to the 'XXVI Simposio de Analisis Economico' to be held in Alicante, Spain, in December 200 1.
  - ü "In-house capabilities or cooperation? The effect of innovation methods on innovation outputs"
  - ü "Innovation strategies and appropriation methods"

The authors of all three papers are Anthony Arundel and Catalina Bordoy.

- A paper produced by SIRN entitled " The Economics of RJVs" will be published in the volume "Essays in Honour of E. Drandakis" by Elgar in 2002.

7) All working papers that have been presented in the "KNOW FOR INNOVATION" workshop in June 2001 are revised for publication.

8) The coordinating team ha s created a website hosted by LIEE/NTUA for the needs of the project where working papers and material related to the project is or is planned to be posted. The website can be found at the address:
http://www-liee.chemeng.ntua.gr .

9) The consortium will discuss the publication of a book containing all the main findings of the project. Additionally, all working papers already presented to conferences or seminars are planned to be submitted for publication.

Exploitation efforts and plans

Title	**Partner(s)**	**Exploitation**
"Inter-country technological linkages through European Collaborative Research Programmes: Does geography (still) matter?"	NTUA/LIEE	EAEPE Conference & KNOW FOR INNOVATION workshop
"Influential factors in the innovative performance of firms: Some empirical insights"	NTUA/LIEE	EAEPE Conference &

		KNOW FOR INNOVATION workshop
Cooperative R&D as a means for knowledge creation	NTUA/LIEE	EAEPE Conference & MESIAS workshop
"Two faces of Absorptive Capacity Creation: Access and Utilisation of Knowledge"	IKE	DRUID Conference & KNOW FOR INNOVATION workshop
"European Research Joint-Ventures and Innovation: a microeconometric analysis of RJV impact on firms' patenting activity"	CESPRI	KNOW FOR INNOVATION workshop, DRUID Conference, seminar
"Does proximity matter for the transfer of knowledge among Public Institutions, Universities and firms?"	MERIT, BETA	Schumpeter Conference & KNOW FOR INNOVATION workshop
KNOW FOR INNOVATION workshop	All partners	Open workshop
"Firm Leadership and Innovative Performance: Evidence from 7 EU Countries"	ZEW	KNOW FOR INNOVATION WORKSHOP, Discussion paper & in "Small Business Economics"
Descriptive analysis on the results of the KNOW survey	ZEW, NTUA	Report
"The relative value of internal and external information sources to innovation", July 2001.	MERIT	KNOW FOR INNOVATION workshop & submission to journal
"In-house capabilities or cooperation? The effect of innovation methods on innovation outputs" July 2001.	MERIT	KNOW FOR INNOVATION workshop & submission to journal
"Innovation strategies and appropriation methods", June 2001.	MERIT	KNOW FOR INNOVATION workshop &

		submission to journal
“The Internet as a mechanism for information acquisition and transfer: Evidence from survey analysis”.	NTUA/LIEE	KNOW FOR INNOVATION workshop
“The Economics of Research Joint Ventures”, July 2001.	SIRN	chapter in a book
“Small Worlds and Technology Networks: The Case of European Research Collaboration”, May 2001.	MERIT	KNOW FOR INNOVATION workshop
“Factors affecting firm’s Innovative Behaviour”, May 2001.	SIRN	KNOW FOR INNOVATION workshop
“Is there Such a Thing as University -Industry Relationships?”, July 2001.	BETA	KNOW FOR INNOVATION workshop
"European Technology Policy and Co -operative R&D: an empirical analysis of European Research Joint Ventures"	CESPRI	Seminar
“New Organisational Forms in R&D”	IKE	Intended publication

Section 6

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Section 7

ANNEXES

ANNEX 1:

KNOW QUESTIONNAIRE -FINAL

Name of the firm:____
Address:____
____
Phone: ____________________ Fax: ____________________________
Main Activity (NACE Rev.1, 2 -digit code) ____________________________

General introduction to the aim of the study: This questionnaire is part of an EU-funded research project on how firms acquire new knowledge from sources outside the firm, and the role this knowledge plays in the introduction of new or improved products, processes, or services. The project involves research teams in 7 EU countries, and the questionnaire procedure is conducted in parallel in these countries for 5 selected industries. The unit to be asked is called a 'firm'. This 'firm' is the **physical site** or **establishment** where you work. The 'firm' can thus be a division or subsidiary of a large company or a subsidiary of a multinational , but you are asked to answer only on behalf of the site where you actually work. In most questions, you are asked to answer with a Yes, No, or Don't Know (Dk).

A. GENERAL INFORMATION ABOUT THE FIRM

A1 Is your firm part of a geographically spread multi-establishment company [Yes/No/Dk]

Which of the following **best** describes your area of responsibility (one option only):

1.1 A division of your company [division]
1.2 A regional or national subsidiary [subsidiary]
1.3 The head quarters [company]

[By 'division' we refer to a business line for particular products or services under the respondent's responsibility]
[By 'subsidiary' we refer to a company that is owned by another company by at least 51%]

If 1.1 or 1.2 is 'Yes' :
In which country is the head quarter located: ___________[write in - Dk]

If Yes in A1 and (A1.1 or A1.2) is 'Yes' : Please answer all questions for your [**division/subsidiary**] only. **Do not** give answers for the entire company.
If No in A1 or A1.3 is 'Yes' : Please answer all questions for your **entire company**.

[*Note to partners: All brackets in the questionnaire state 'firm'. These will be substituted by 'division', 'subsidiary', or 'company' depending on the answer to the above questions*].

A2 What is your [firm]'s main business?
____[write in - Dk]

A3 How many competitors does your [firm] have in the main business?___[write in - Dk]
[*By competitors we mean those that the firm itself currently perceives as being competitors. We are not looking for the competitors in a specific geographical area*]

A4 During the most recent three years has your [firm]: [Yes/No/Dk in each case]
1. Increased output of already existing products or services?
2. Introduced new product or service lines to the market?
3. Acquired other firms?
4. Joined strategic alliances?

[By 'diversification into new product or service lines' we mean introduction of new products, processes or services in related or unrelated areas to the [firm] main business activity]

The next questions focus on how firms may introduce new or improved activities to the market. We have three categories:

First, **buy in** new activities through purchase, licensing, or contracting out development work.

Second, develop new activities mainly **in-house**.

Third, develop new activities in **collaboration** with external partners

[*Note that by external we refer to all activities outside the [firm] like other divisions, universities, public research institutes and firms, whereas in-house is restricted to the site of the firm, division or subsidiary*].

In the following two questions we would like you to distribute the activities according to these three categories so that the sum adds up to 100%.

A5 Has your [firm] in the most recent three years introduced new or improved **production processes**? [Yes/No/Dk]
If No/Dk go to question A6, If Yes:

A5.1 *What percentage of your [firm's] new or improved production processes were introduced using any of the following methods? The percentages should add up to 100%*

1. Buying in	*__________%*	*Dk*
2. In-house development	__________%	Dk
3. Collaboration with external partners	__________%	Dk
	100%	

If A5.1.3 > 0% then:
From which countries did your **main** collaboration partner(s) come from?________________ [Write in - Dk]

[Note to the respondents: by 'main' we mean the most important to the firm either in terms of financial benefits or knowledge they contributed to the firm]

A6 Has your [firm] in the most recent three years introduced new or improved **products**? [Yes/No/Dk]
[By products we mean both manufacturing products and services]
If No/Dk go to filter, If Yes:

A6.1 *What percentage of your [firm's] new or improved products were introduced using any of the following methods? The percentages should add up to 100%*

1. Buying in	*_________%*	*Dk*
2. In-house development	_________%	Dk
3. Collaboration with external partners	_________%	Dk
	100%	

If A6.1.3 > 0% then:
From which countries did your **main** collaboration partner(s) come from? ______________[Write in - Dk]
[Note to the respondents: by 'main' we mean the most important to the firm either in terms of financial benefits or knowledge they contributed to the firm]

If no or DK to Questions A5 and A6 inclusive, go to E6, otherwise go to A7.

A7 *In the* ***most recent fiscal year,*** *what percentage of your [firm]'s sales can be attributed to products or services that were?*

1. Unchanged or slightly modified over the last three years ______% Dk
2. Significantly improved or new to your [firm] in the last three years ______% Dk

[The percentages should add up to 100%] 100%

B. INNOVATIVE BEHAVIOUR

I am now going to ask you a few questions about how your [firm] in general seeks to get ideas for new products/processes/or services and what methods it uses to protect them.

B1 Does your [firm] **regularly** seek to obtain **ideas** for innovation by? [Yes/No/Dk in each case]

1. Searching patent databases
2. Reading scientific or business journals
3. Attending trade fairs and conferences
4. Technical analysis of competitors' products *[reverse engineering]*

[Note to respondents: Ideas are general concepts on what might be technically or economically feasible].

B2 Does your [firm] use the Internet? (Yes/No/Dk)

If No/Dk go to B3, if Yes :

Does your [firm] use the Internet for: [Yes/No/Dk in each case]

1. **Searching the world wide web for scientific and technical information?**
2. Exchanging information with customers, suppliers or collaborators by e -mail?

B3 Universities and research institutes are often regarded as major sources of knowledge for firms. In the last three years, in how many research and development projects has your [firm] been engaged with Universities and public research institutes?_________[Write in - Dk]

[Public research institutes include both domestic and foreign research institutes]

B4 Does your [firm] use any of the following methods to protect innovations? [Yes/No/Dk in each case].

1. Patents
2. Secrecy
3. Lead time advantages

If Yes to more than one option:

B4.1 Which of these [list options that were given in B4] is the most important to your firm?_________[Write in - Dk]

C. MOST IMPORTANT INNOVATION DURING RECENT 3 YEARS

I would now like to ask you about the realised most economically important innovation introduced by your firm in the most recent three years. This innovation can be a product, a process, or a service. *[Note to the respondents: By 'economically important' we refer to the innovation with the highest realised or expected profits or sales].*

C1 Would you briefly describe this innovation?

____ ________________ [write in]

C2 Is this innovation - seen from your [firm] – a?

1. Product innovation? [Yes/No] [*market*]
2. Process innovation? [Yes/No] [*production line*]
3. Combined product and process innovation? [Yes/No] [*market*]
4. Service innovation? [Yes/No] [*market*]

C3 When was this innovation introduced for the first time? Year_____ Month [if given]____

[If market then:]

C4 What percentage of your [firm's] **total sales** in the most recent fiscal year was due to this innovation? _____% [write in - Dk]

[If production line then:]

C4 Did this innovation reduce your **total variable manufacturing costs** in the most recent fiscal year? (Yes/No/Dk)

If Yes, by what percentage did this innovation reduce your manufacturing costs _____% [write in - Dk]
[Note to the respondents: Variable manufacturing costs include all costs other than fixed equipment: i.e. labour, materials, energy, set -up time, etc.]

C5 Did your [firm] receive subsidies from regional, national or EU authorities that contributed to the development of this innovation? [Yes/No/Dk]

C6 Did your [firm] hire or bring in new scientists or engineers to work on this innovation from any of the following? [Yes/No/Dk in each case]

1. **If [division/subsidiary]:** [Other divisions/units of your company]
2. Suppliers
3. Customers
4. Universities or public research institutes
5. Consultants

[This includes both permanent and temporary hiring or job transfers]

If No or Dk to all options in C6 go to C8, otherwise go to C7

C7 Did the new staff contribute in one of the following ways: [Yes/No/Dk in each case]

1. Shorten development time?
2. Provide **new** knowledge in areas where your [firm] **already** had expertise?
3. Provide knowledge in areas where your [firm] **lacked** expertise?

If Yes in C7.2 or C7.3, then go to C7.1.1. ?therwise go to C8

C7.1.1 What type of knowledge did the staff bring in? [Yes/No/Dk in each case]

1. Technical or scientific knowledge
2. Knowledge related to market introduction
3. Other type of knowledge [write in] ____ _______________

C8 Did any of the following contribute to the **original idea** behind this innovation? [Yes/No/Dk in each case] *[Note to the respondents: Ideas are general concepts on what <u>might</u> be technically or economically feasible].*

1. Competitors
2. Suppliers
3. Customers
4. Universities or public research institutes
5. Consultants

If Yes to more than one options in C8:

C8.1 Which was the most important? : [read out again all that received a 'yes'] _______ [write in - Dk]

[If the respondent answers 'competitor', 'cus tomer', or 'supplier' in C8.1]:
C8.2 In which industry is this [firm from C8.1] operating? ________

C9 Similarly, did any of the following contribute to the completion of this innovation? [Yes/No/Dk in each case]

1. Competitors
2. Suppliers
3. Customers
4. Universities or public research institutes
5. Consultants

[Note to interviewers: By 'completion' we mean the time period during which an innovation is being developed until finalisation]

If Yes to more than one options in C9:
C9.1 Which was the most important? [read out all that received a ‘yes’] ______ [write in - Dk]
[If the respondent answers 'competitor', 'customer', or 'supplier' in C9.1]:
C9.2 In which industry is this [firm from C9.1] operating? ________

C10 Overall, how important to the successful completio n of this innovation were **internal** knowledge sources as compared to **external**? [one option only Yes/Dk]

1. Internal most important
2. External most important
3. Internal and external of equal importance

[Note to respondents: Note that by external we refer to all activities outside the [firm] like [other divisions], universities, public research institutes and other firms, whereas in -house is restricted to the site of the division or subsidiary]

C11 Has your firm applied for or been granted one or more pa tents for this innovation? (Yes/No/Dk)

Has any other firm or organisation applied for or been granted one or more patents for this innovation? (Yes/No/Dk)

If No or Dk in C9.1 go to E1, otherwise go to Section D

D. MOST IMPORTANT EXTERNAL SOURCE FOR THE SP ECIFIC INNOVATION.

I would now like to ask you some questions about the [most important external source identified in C9.1], which you identified in the previous section as the most important external source for the completion of the innovation **. In case the [most important external source identified in C9.1] is more than one firm please select one**

of these and answer the following questions for this firm alone [*Note to the interviewers: we let the respondent select one firm according to his/her judgement*].

D1 Where is [most important external source identified in C9.1] located? [one option only Yes - Dk]

1. Elsewhere in [your country]
2. Elsewhere in Europe
3. United States
4. Other country

D2 **Why** did you **originally** decide to obtain knowledge from [most important external source identified in C9.1]? [Yes/No/Dk in each case]

1. To reduce development costs or risk
2. To update your technical expertise
3. To build on innovations or research findings of others
4. To meet government regulations
5. Other [write in] ________________

If Yes to more than one options:
D2.1 Which of these reasons [list options given above] was the most important? ________ [write in - Dk]

D3 **How** did you get in contact with [most important external source identified in C9.1]? [Yes/No/Dk in each case]

1. Previous experience
2. Business and professional associations
3. Trade fairs and conferences
4. The Internet
5. Other way [please specify] ___________

If Yes to more than one options:
D3.1 Which of these methods [list options given above] was the most important? ________ [write in - Dk]

D4 To obtain this knowledge did your [firm] use some of the following **methods of communication**? [Yes/No/Dk in each case]

1. Informal personal contacts
2. Research co-operation
3. Exchange of students or other personnel
4. Other method [please specify] _____________________________

If Yes to more than one options:
D4.1 Which of these methods [list options given above] provided the most useful information? ________ [write in - Dk]

D5 Eventually, **what type** of knowledge did your [firm] get from the [most important external source identified in C9.1] [Yes/No/Dk in each case]

1. Technical or scientific knowledge
2. Knowledge related to market introduction
3. Other type of knowledge [please specify] ___________________

E. ADDITIONAL QUESTIONS ABOUT THE FIRM

E1 Does your [firm] perform research and development activities: [Yes/No/Dk in each case]

1. Continuously?
2. Occasionally?

[*Note to respondents: please note that research and development activities also include adaptation and development type of activities. The same applies to all subsequent questions*].

E2 How much was spent on research and development in the most recent fiscal year? [local currency - Dk] ________

[Note that R&D expenditures include internal as well as collaborative research activities]

E3 How many persons are employed to do research and development activities? ______ [write in - Dk]

E4 *How was research and development expenditures distributed in the most recent fiscal year between:*

1. In-house expenditures	_______%	Dk
If [division/subsidiary]		
[2. External expenditures in other parts of your firm	_______%	Dk]
3. External expenditure in independent organisations	_______%	Dk
[The percentages should add up to 100%]	100%	

[Note to interviews: Note that option 2 should come up only if the respondent is responsible for a division/subsidiary].

[Note to respondents: By 'external' we refer to all activities outside the [firm/division/subsidiary] like [other divisions], universities, public research institutes and firms, whereas in-house is restricted to the site of the division or subsidiary].

E5 During the most recent three years has your [firm] received any public subsidies from regional, national or EU authorities for research and development activities? (Yes/No/Dk]

If No/Dk go to E6, otherwise go to E5.1

E5.1 What percentage of your [firm's] total budget for research and development during the most recent three years was from such public subsidies? _____ [write in-Dk]

E6 How many employees on average were working at your [firm] in the most recent fiscal year?_______ [write in - Dk]

E6.1 During the most recent three years, what percentage of your employees has participated in training programs either inside or outside your firm? __________% [write in - Dk]

If E6.1 is >0% then:

E6.1.1 What was the aim of these training programmes? [Yes/No/Dk in each case]

1. To upgrade technical skills
2. To upgrade computing skills
3. Other [please specify]___________________[Write in]

[By 'upgrading technical skills' we refer to case where production line workers have special training on new equipment, or engineers attend conferences and specially designed technical courses].

[In 'upgrading computing skills' we include secretarial training course on software].

[In case of managerial training specify the type of training in A5.1.1.3].

E7 How many employees have an **academic degree** in a scientific or engineering field? _______ [write in - Dk]

E8 Is your [firm] managed by the owners or members of the owner's family? [Yes/No/Dk]

E9 What were the total sales of your [firm] in the most recent fiscal year [local currency - Dk]?

This brings us to the end of this survey. I would like to thank you for your participation.
Would you please confirm your job title and mailing address?
Job title:
Street:
Postal Code:
City:

Would you like to receive a copy of the results? [Yes/No]

END OF INTERVIEW

ANNEX 2:

Sample design and Survey Protocol for *'KNOW FOR INNOVATION'*

Sample design

A lot of correspondence has already taken place among members of the group regarding sample design. Below, there is a summary of main points raised so far as well as comments to some critical questions.

1. *How many firms shall we draw from the population?*
   A rough estimate of the gross sample size for each country might be about 500 firms. As we have 5 sectors and two size classes 10 -249 and 250-999 employees (10 Strata), we do a stratified sampling. This yields about 50 firms to be randomly selected in each stratum. If some countries have less than 50 firms in a stratum we suggest to sample all firms available and to distribute the difference to 50 equally over the other strata.

2. *How do we draw the gross sample?*
   We suggest drawing an initial sample (10 strata with 50 firms each) and a reserve sample (of same size) simultaneously from the population using the simple random sampling technique. This secures the same sampling probability for every firm. You may consider asking the Statistical Agency of your country to prepare sample and a reserve sample for you from the total population in your country based on the employment criteria we have set for the selected sectors.
   Then we call **all** firms (randomly) from the initial sample in each stratum. If we don't have enough respondents from this initial sample, we use the reserve sample. This is done by a new randomly selected sub-sample of the reserve sample, i.e. if you need two more interviews in one stratum you draw a small sub-sample of this stratum from the reserve, e.g. 20 firms of your reserve sample and call all those 20 firms. If we don't receive the desired number interviews the procedure has to be repeated until we have completed the desired number of interviews.

Questions

(a) *What do we do if a questionnaire is incomplete?*
Our suggestion is that purposely-incomplete questionnaires will not be considered in the analysis. Ideally, they should not be considered in the number of completed questionnaires either. However, this should depend on the time and budget constraints of each respondent.

(b) *If we get 80 answers before having called all firms in the sample, should we stop or continue?*

We consider approaching firms sector by sector according to the number of questionnaires we wish to collect in each sector. Then, if in a sector we have reached the required number of completed questionnaires without having called all firms in that sector, we can stop as long as all calls to firms have been made in a random order.

(c) *If we cannot collect the required number of completed questionnaires in a sector, what do we do?*
If after using the reserve sample we still cannot achieve the required number and we run out of firms in a given sector, we distribute the difference equally over the other sectors by increasing the number of completed questionnaires in each of them. At the same time, we look in other partners' distribution of completed questionnaires over the sectors in order to make sure that no sector is under-represented.

After we complete the survey, we weight the results using the methodology proposed by ZEW.

Pilot survey

We recommend that each partner make own arrangements for a pilot survey of 4 to 5 interviews per country to test the questionnaire. These should preferably be face-to-face interviews where the interviewer will read out the CATI format and ask the respondent to provide in-depth responses and comments to the questions (i.e did you easily understand this question, was anything ambiguous, were important options left out, would it be preferably if we had included options for questions on sales & R&D, etc.)

There are two important issues we have to be clear from the outset: (a) whether we will eventually include the pilot questionnaires in the survey, and (b) how to select the firms for the pilot survey. With regard to the first point, and after consultation with some of the partners, we propose not to include them in the final number of completed questionnaires. Regarding the selection of firms for the pilot, we suggest that this should be made randomly from the sample. When each of you completes this pilot round we expect you to come back with a short report indicating the points we may need to reconsider, modify, etc. and the specific problems you experienced during the pilot.

The deadline for completion of the pilot survey is 30 November 1999.

The process that each group can use to reach the respondents during the pilot and the proper survey is described next:

For the needs of the survey, the coordinator has already asked the Commission to provide the group with a formal letter announcing the scope and aims of the study. Each partner is going to get an originally signed copy of this letter sent out by the co-ordinator.

Survey guidelines

1. Establish the contact. Call the firm and try to identify the appropriate person normally responsible for Research and Development activities in the firm [R&D Director], [Research Director], [Technical Director], [Owner/General Manager for SMEs].'
2. **If the person is not available**, call again (maximum 4 times until we get connected to the person of interest). Assuming we wish to conduct the survey within 4 weeks, the maximum time step for the next call should be 1 week. After 4 unsuccessful attempts and after knowing the right person, we may send out the formal letter along with the questionnaire by post to the Director of the respective Department. If we still don't get a response we call the firm for the 5th time and ask for this person. If he/she is available continue with step 3. If still not available, ask for a senior colleague of this person and continue with step 3.
3. **If the person is available**: Introduce yourself and explain briefly the purpose of your call, the goals of the study, why it is of interest to the firm, and also the fact that the survey is being funded by the European Commission. Then, ask him/her if he/she is willing to participate in this survey?
    - (i) (**If Yes**) *Could you now spare some of your time to reply to a few questions I am going to ask you over the phone?* Proceed with Section A of the questionnaire
    - (ii) (**If not able to answer immediately**) *When would it be a more appropriate time to call you?* (arrange for a new time to do the interview)
    - (iii) (**If refusing to arrange a new time**), Propose to send the formal letter along with the questionnaire (preferably by fax/e-mail) with the request to call again either the same day or the next.
    - (iv) (**If he/she says explicitly he wants to see the questionnaire first**) Arrange to send the formal letter along with the questionnaire (preferably by fax/e-mail) with the request to call again either the same day or the next.
    - (v) (**If refusing to participate in the survey**), Go to section for <u>non-response analysis</u> (Section E to be supplied).