HIGHER EDUCATION SYSTEMS AND INDUSTRIAL INNOVATION

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Abstract

The objective of the research was to gather empirical evidence about efficient ways of organising the linkages and interfaces between higher education institutions (including research units) and private-sector firms in order to spur industrial innovation. One of the project’s principal aims was to combine two dimensions which are often considered separately: firstly, the construction of the competences and the professionalities of the actors involved in innovation, and, secondly, transfers of knowledge from higher education to firms and *vice versa*. Five European countries (Austria, France, Germany, Portugal, UK) were selected in order to provide, at least by way of an initial hypothesis, national systems that were sufficiently disparate from the point of view of the resources "offered" to companies, be it in terms of institutions, organisations or actors. It was essential to include the United States. Indeed, the relations between higher education and companies which have evolved in that country are undoubtedly an international point of reference Three sectors were chosen in each country as being representative of the new challenges emerging for the relationship between higher education and industry in key sectors where generic technologies are tending to develop, albeit in different ways. The investigations within more than 40 firms form the empirical basis of this project.

The main results could be summarized as follows :
1.The type of skills and competence profiles required of R&D workers are now more demanding in multiple dimensions, particularly in the combination of technical disciplinary expertise with a broad range of business, management and social skills. Emerging evidence suggests that firms are developing 'extended internal labour markets' (EILMs) through closer links with key universities. The social networks embedded in such EILMs facilitate training and rapid transmission of evolving (uncodified) knowledge. 2. The sample of multinational firms we have selected enables us to take stock of the moves towards industrial rationalization taken by firms seeking to develop their technological globalization strategies by exploiting a diversity of cognitive resources. Preparation for the recruitment and integration of young graduates play crucial roles in the absorption of knowledge. 3. We found six coherent types of science industry relations that we describe precisely. These results further confirm the criticality of research agendas compatibility, favouring two different ways of collaborating associating an industrial partner and an academic one. 4. The analysis identifies four main types of intermediate actors : those actors who are the medium for an economic relationship between the firm and the HERS; the "gatekeepers", who work for a firm or a HERS ; the hybrid actors have been through the process of aligning the practices, rules and values of their "home" system (industry or academia) with those of their partner ; those who are involved in the trilateral network but are independent or on the road to being independent of the partners. 5. Labour-market entry of graduates is one of the factors which allows us to introduce all the signalling/human capital/network problematics and relate it to the emergence of an new form of labour market which combines the mechanisms of the internal and external markets. In spite of this diversity of practices, however, we maintain the hypothesis that it is possible to identify dominant forms of these relations which differ from one country to another. 6. Nevertheless the report insists on the increasing human capital mobility in high tech sectors and supply some evidence of an emerging European innovation systems. 7. Considering a US-Germany comparison, we infer that in IPR matters, German public research institutes – representative of the European continental situation - are facing a dilemma: they need to provide more pre-development type services for industry, involving stricter IPR claims from corporate partners and they also need to retain IPR in core areas of expertise in order to prevent a "bleeding out" and remain a partner for industry in the future.

Finally the report provides different policy formulations and recommendations. We underline that for firms, the main objective is to resolve the problems posed by the transition from knowledge to competences. With an OLM of PhD level, the firms, especially very small ones, enable to have easier access to a suitably trained workforce. By promoting the circulation of knowledge, these markets help to reduce the previous conceptual gaps and to promote the creation of greater absorptive capacities at firms, as well as sustaining the spirit of mutual trust and reciprocity in which these networks were founded.

At the national level, the lessons learned by public policy makers will be dealt with them in the general following order:

- The United Kingdom, where the policies and regulations are typically market oriented is undergoing a process of specialization.
- In France and Germany, where the relations between Science and Industry are facing fairly similar challenges, the scenario tends to alternated between radical change and a process of accommodation.
- Austria and Portugal, which have rather different technological and industrial structures, but are both facing the special challenge of adapting the small-scale national systems of innovation to the European Union and world-wide competition in general.

1.Executive summary

1.1. General objectives

The SESI project tackles the question of how higher education institutions influence the innovation activities of private-sector firms, which provide the basis for economic competitiveness and societal wealth generation.

The objective of the research was to gather empirical evidence about efficient ways of organising the linkages and interfaces between higher education institutions (including research units) and private-sector firms in order to optimise the flow of knowledge and information between them and thereby spur industrial innovation.

In this respect, the SESI project aims to answer three main questions:

- What are the components and configurations of the knowledge transfer between higher education institutions and industrial innovation activities?

- Under what conditions does the knowledge transfer between higher education institutions and firms benefit innovation capacity and performance?

- How do different national higher education systems perform in supporting industrial innovation capacity?

The answers to this series of questions should enable those engaged in the project to make (public) policy recommendations.

General approach: the Innovation Space as an "interactive" and "embedded" approach to innovation

Innovation is self-evidently multidimensional and goes hand in hand with changes in the organisations and institutions in which the actors' strategies unfold. This is why any partial approach to innovation, focusing, for example, on the strategy pursued by any one of the actors involved, remains partial when it comes to drawing conclusions, since very little in the way of general lessons can be derived from it. At the same time, however, holistic approaches to innovation do little to make good this deficiency. Such approaches frequently lead to the definition of an institutional environment that guides the decisions taken by any of the actors, who are reduced in consequence to mere agents; as a result, they plot only a fraction of the coordinates of an actor seeking to solve problems and redefine his system of constraints before eventually managing, more or less convincingly, to reconstruct his action system, which remains immersed in an environment made up of organisations and institutions.

The definition of innovation adopted in this project derives from the evolutionary and societal analysis approach. Innovation is regarded as the outcome of a twofold process whereby resources are created and also appropriated by firms, which construct an innovation space integrated into local, national and international institutions. Picking up on famous Lundval's work in this field[1], the main point here is no longer the process of calculation and decision-making but the process of learning and creating complex bodies of knowledge within innovation systems. These include not only firms' internal processes but also the interaction between firms and public R&D organisations as well as education and training establishments.

Innovation encompasses a number of processes - technical, organisational, institutional and cognitive - all contributing to technology design and development, but it also has two additional defining characteristics.

Firstly, innovation constitutes a firm's specific capacity to construct its stocks of knowledge and competences, its relationship with technology and the practices it adopts in its cooperation with its industrial and academic environment. The outcome of these processes, particularly in multinational firms, is a truly distinctive capacity for generating technological and organisational resources in a bid for global competitiveness.

Secondly, a firm constructs its innovation space by interacting with its industrial and institutional environment[2]. To innovate, it must acquire and hence choose the resources which it lacks and deems necessary. In order to appropriate these resources and utilise them effectively for its own development, it will specify them according to its particular needs, in order possibly to convert them into innovative routines (see the evolutionary theory of the firm and in particular Nelson[3]) that cannot be purchased in the market.

Thus firms are faced with a permanent tension between, on the one hand, the preservation of routines that construct, order and maintain knowledge and know-how as a coherent whole and, on the other, the search for new routines that might produce renewal. In other words, firms are not only structures for the management and accumulation of specific knowledge but also entities endowed with rules governing their functioning, which embody the collective lessons learnt in the course of their history, and with rules governing their development, through which new knowledge can be acquired.

Depending on the capacities they have built up over time and their ability to evolve, research and higher education establishments enable firms to explore more or less rapidly the opportunities offered by the emergence of new technological and scientific fields. This is what is meant by the "embeddedness" of the strategies of the various actors operating within an economic area, the limits of which need to be defined. This question of the limits of contingency is especially pertinent to this project: to what extent can a firm's strategy be related to a particular innovation system? Can innovation systems still be defined on a national basis? What impact do the strategies of multinational companies - and for that matter those of "research universities" - have on national innovation systems?

The links between higher education and innovation reveal that industrial firms are key actors not only in the circulation but also in the production of knowledge. After all, if they are to innovate successfully, firms must of necessity be part of the general process of constructing scientific and technical knowledge. This process has always

[1] Lundvall B-A. (1992) "*National Systems of Innovation, Toward a Theory of Innovation and Interactive Learning*", Pinter Publishers, London.

[2] In the perspective of the "Societal Effect Theory", see : Lanciano-Morandat C., Maurice M., Nohara H. and Silvestre J-J. (eds.) (1998), "*Les acteurs de l'innovation*", Editions L'Harmattan, Paris and Maurice M, Sorge A (ed). *Embedding organizations : societal analysis of actor, organizations and socio-economic context.* Amsterdam : John Benjamins publishing company, 2000. (Advances in organizations studies; 4)

[3] Nelson R. (1988), Institutions supporting technical change in U.S., in Dosi G. et alii, *Technical Change and Economic Theory*, Pinter Publishers, London.

existed, of course, and R&D activities have always had a strong international dimension, but nowadays it takes the form of an all-out race to produce academic knowledge and for this to be absorbed by firms.

It is here that the main focus of our project lies, the object of investigation being the relations between actors from two different worlds - higher education and firms - which have separate and not necessarily convergent goals. It was decided to focus on firms' behaviour in the organisation of R&D activities and on the links between that aspect of their behaviour and the practices they adopt in cooperating with higher education. One of the consequences of this was that two major social phenomena had to be investigated.

- The first is the dynamic of the linkage between the global and local dimensions: to what extent do firms' strategies affect scientific and technological organisation and policies, both nationally and locally ? Similarly, what opportunities do national institutional infrastructures provide for companies and their practices, particularly multinationals?

The second is technological innovation, regarded as a process that unfolds within the dynamics of particular industries or sectors. Taking Pavitt's well-known typology as its point of departure[4], the project set out to analyse the consequences of the emergence of new technological systems, the emblematic examples being biotechnology and the convergence of information technology and telecommunications.

1.2. Methodology

The method was designed to reflect the problem areas and interpretative models at three distinct levels:

- Countries and sectors
- Firms and their relations with higher education
- Societal dynamics or the global/local interaction.

In particular, the aim was to take account of the interactions and interdependencies between the micro-economic level and that of the sectors and countries included in the project.

1.2.1. Six countries and three sectors

Five European countries were selected in order to provide, at least by way of an initial hypothesis, national systems that were sufficiently disparate from the point of view of the resources "offered" to companies, be it in terms of institutions, organisations or actors. Higher education and innovation systems do in fact differ significantly from one European country to another. By way of illustration, it was noted in the initial statements explaining the choice of these five countries that:

- The United Kingdom has an education system which is elitist but undergoing radical change and there is a relatively low level of public funding for research.
- France has a dual system of higher education - universities and the *grandes écoles* - which has had a considerable influence on the "innovation space" of French companies, and its research system is heavily subsidised by the public purse.

[4] Pavitt K. (1984), "Sectoral Patterns of Technical Change: Towards an Taxonomy and a Theory", *Research Policy*, 13, 343-373.

- Germany and Austria have "intermediate" systems of education and R&D, bearing all the hallmarks of involvement by trade unions and employers' associations.
- Portugal has links between higher education and companies which are both more direct and more recent.

However, the aim was not to study the institutional specificities in themselves but rather to link them to sectoral dynamics. Three sectors were chosen in each country as being representative of the new challenges emerging for the relationship between higher education and industry in key sectors where generic technologies are tending to develop, albeit in different ways. The information technology sector, whose growth has been very rapid, is of interest because it brings together, in ways specific to individual countries, industrial production activities and customer service activities. The telecommunications sector, which has undergone a huge amount of technological and organisational innovation, was seeing its links with the public sector being challenged by deregulation in various EU countries just as the project was being launched. The pharmaceutical sector, whose links with higher education and research date back further, was facing the biotechnology revolution.

It was discovered straightaway that a sizeable body of literature on innovation and the circulation of knowledge in these various countries and sectors had been produced in recent years. The first phase of the project, then, consisted in gathering together and analysing the corpus of existing studies and surveys, at both national and sectoral level. At sectoral level, the aim was to highlight the strategic orientations and the most important technological and organisational issues. At national level, it was a matter of determining the exact institutional context of industry-science relations and of understanding how the different countries' education systems and technology policies are structured.

1.2.2. Selection of companies and examination of their links with companies

Constructing the sample of firms

Three companies per sector and per country (two each in Portugal and Austria) were studied, making a total of 48. The initial idea was to take one "foreign" multinational, one large "national" company and one SME for each sector, in an attempt to have a comparable sub-sample for at least two countries.

One of our objectives was to question these firms about the qualities of the different national systems (their "strengths and weaknesses"). In practice, a multinational creates a network of different national systems by incorporating them into its own organisational space. Thus it was relevant to investigate to what degree these firms, through their subsidiaries, attempt to pick up and "import" institutional and organisational attributes which they have identified outside of their country of origin or, conversely, to "export" their own original attributes.

Data collection

The investigation of each company took place over a one-year period. Once the project had been presented, a confidentiality agreement was signed with each firm. A research protocol was drawn up in such a way as to ensure that both the project's initial intentions and the interviewees' arrangements were respected. This protocol made provision for an average number of interviews (at least 10 to 15, often around 20, each lasting 2 to 3 hours), for factual and/or public data to be supplied by the company and for the findings to be handed back in the form of a case study and validated by the interviewees. The interviewees were selected partly from within the company and partly from within the universities and laboratories cooperating with the firm.

On the company side, these were R&D managers, project managers, researchers and engineers, HR managers and those responsible for related fields such as alliances and patents. Among their academic partners, interviews were conducted with heads of laboratories, departments and projects, sometimes with researchers. Semi-directed interviewing techniques were used with both types of partner, based on a standardised interview guide devised for all firms in the various countries. Before the interviews were held, the various organisations' strategies and structures were studied: this was done on the basis of documents supplied by management in the different organisations and supplemented where necessary by press reviews. For the firms, this enabled us to become familiar with the situation of the group or SME: competitive position, international development, technological trends, role of R&D, number of employees. For the universities, engineering colleges and public laboratories, the same documentary work was carried out in order to situate the organisation in its public context and in respect of cooperation with industry in general.

Finally, the interviews were conducted in such a way as to reveal.

- each firm's strategy (that of both the multinational and its local subsidiary),
- its general organisation and more specifically the role of the R&D unit,
- development of technology policy in conjunction with marketing policy,
- its practices relating to technological alliances,
- human resource management practices in general and for R&D in particular,
- the evolution of innovation coordination at national level,
- knowledge management practices,
- policies pursued in terms of intellectual property,
- the evolution of attitudes to cooperation with "academia",
- the funds committed to this effect.

The interviews conducted at universities and public laboratories were designed to explore in depth two major cases of collaboration, looking at them in terms of their organisation, funding and evaluation. Here we needed to highlight two methods of knowledge transfer: R&D cooperation and joint training for graduate students (including arrangements for job placements).

1.3. Main results of research

1.3.1. Changing R&D Organisation and Innovation: Knowledge Sourcing and Competence Building

The emergence of the knowledge-based economy has profound effects on the organisation of R&D activities, and the types of skills and knowledge required for productive and innovation activities. This paper argues that, at the top end, knowledge is now moving too rapidly to be encoded and institutionalised into a stable set of occupations, and hence new mechanisms are necessary to facilitate the effective generation and transmission of knowledge between higher education institutions and firms. The growing importance of 'Mode 2' knowledge (Gibbons et al 1994) in technological innovation calls for a reassessment of the institutional arrangements underpinning the 'professional model' of knowledge formation. Emerging evidence suggests that firms are responding by developing 'extended internal labour markets' (EILMs) through closer links with key universities. The social networks embedded in such EILMs facilitate training and rapid transmission of evolving (uncodified) knowledge. The study is based on case studies carried out in large multinational high-technology firms in Britain. The paper draws out the common trends and issues in the different sectors and discusses the implications of the changes for the education and training of the next generation of R&D knowledge workers.

First the type of skills and competence profiles required of R&D workers are now more demanding in multiple dimensions, particularly in the combination of technical disciplinary expertise with a broad range of business, management and social skills. The effectiveness of R&D workers depends on their ability to apply scientific and technological expertise in shifting problem contexts, to operate in inter-disciplinary and trans-disciplinary environments and to sharpen their project management skills. Then there is a growing need for new or combined disciplines in the rapidly evolving innovation environment. Many of them are highly specific to certain industrial situations and problems, and cannot be easily defined in an academic context. This suggests that the creation of new disciplines and competences will have to be embedded in the problem solving process. Evidence from our case studies suggests that the reverse flow of knowledge from industry to academia through personal networks and research collaboration plays a crucial role in the creation and generation of new disciplines.

1.3.2. The organisation of R&D and the management of cooperation: controlling a diversity of knowledge sources"

The focus of interest here is the construction of knowledge in firms viewed in the context of their approach to academic collaboration and against the background of transnational activities that bring into play local infrastructures for the diffusion of technologies.

The sample of multinational firms we have selected enables us to take stock of the moves towards industrial rationalisation taken by firms seeking to develop their technological globalisation strategies by exploiting a diversity of cognitive resources. Such an evaluation can readily be extended to include an examination of the structures of R&D organisation and of the processes of resource construction. We begin this examination by outlining its objectives and establishing the value of taking account of knowledge and competences in the management of innovation. We analyse the role of the structures of R&D organisation in the globalisation of technology strategies. We deal jointly with the internal organisation of activities (role of innovation projects, human resource management) and with the external organisation of academic collaboration. We underline that the management of knowledge and individual expertise constitute an autonomous framework for the construction of resources in the various R&D units.

Through its structures and processes, the management of knowledge represents an attempt not only to take advantage of opportunities but also to resolve organisational problems. The low level of mobility between subsidiaries and between research laboratories and business units does not aid the circulation of knowledge. The diversity of occupational profiles sought by multinationals can also lead to cognitive compartmentalisation. Finally, the introduction of project-based management makes it possible to organise R&D activities more efficiently while at the same time reducing the opportunities for knowledge accumulation. The practices put in place in order to overcome these difficulties show that several different paths can be taken. At the same time, they illustrate the changes firms are undergoing as technological globalisation advances. The various modes of knowledge management attach equal importance to the production and to the absorption of knowledge. Preparation for the recruitment and integration of young graduates and the forging of lasting relations between firms and their academic partners play crucial roles in the absorption of knowledge. As a result, they encourage the observer to examine very closely the institutional aspect of the multiplicity of environments within which the subsidiaries of the same multinational operate.

1.3.3. Research Agendas and Science Industry Relations

We attempt to highlight the crucial importance of research agendas in both understanding the underlying logic of research collaborations settling between academic research units and firms, and in understanding the feedback effects of science industry relations on the pace of scientific knowledge production. The empirical data are original ones collected within the SESI project network. It is made of interview based monographs of 50 science industry relations. These data were collected in six countries (A, F, G, P, UK, US), interviewing firms of the IT and Pharma/Biotech sectors and their academic partners. Our main empirical result is that we found six coherent types of science industry relations that we describe precisely. These results further confirm the criticality of research agendas compatibility, favoring two different ways of collaborating associating an industrial and an academic partner. We finally argue that this two different forms of collaborating are leading to two different models of science industry relations (A and B) presenting different but both socially valuable emergent outcomes. The following table summarizes these models.

**The robust strategies of the academic and industrial players
and the two models of science industry relations**

		Strategies of the Academic players	
		Increasing their volume of research by pooling informa-tion on needs and codifying solutions of industrial partners	Deepening their knowledge in a specific area of excellence by collaborating only within this field
Strategies of the **Industrial players**	Benefiting from research at a relatively low cost in an integrated, systematic and less risky way	**Model A** lower risk lower expected reward stronger ties dense networks Cumulativeness and social demand	
	Entering a research field by contributing to its emergence so as to benefit from an important advance on its competitors even if he has to bear greater risks		**Model B** higher risk higher expected reward weaker ties bilateral relations Creativity and social demand

1.3.4. Firms, higher education and research systems and public action: the principles animating the relationships between actors in the innovation process

The purpose is here to apprehend, by adopting an actor-based approach, the diversity of interactions between innovation systems in firms and higher education and research systems (HERS).Based on societal analysis of innovation and Triple Helix, this analysis identifies four main types of intermediate actors:

- those actors who are the medium for an economic relationship between the firm and the HERS;
- the "gatekeepers", who work for a firm or a HERS and whose function is to coordinate the two systems;
- the hybrid actors who, by virtue of having worked in both the firm and the HERS, have been through the process of aligning the practices, rules and values of their "home" system (industry or academia) with those of their partner;
- those actors who are involved in the trilateral network but are independent or on the road to being independent of the partners.

Various sets of relational principles are constructed around these actors. Each set of principles tends to privilege one type of actor rather than another. Similarly, a trilateral relationship between a firm and a HERS unit may possibly, though not necessarily, fall within the scope of several different sets of principles. A distinction has to be made between those relational principles that are mediated mainly by relationships that fluctuate between the formal and the informal and those that are organised around relationships that are formalised in programmes of strategic co-operation. In the first case, three principles are identified, the "symbolic" principle, the "dormant" network, the creation of a new intermediate actor. In the second case, three other principles are valorised, the actors as a portfolio of resources, the embedded principle, the use of a constituted intermediate. The interactions between these different actors and these different relational principles characterised various intermediate spaces of innovation.

This raises the question of which factors linked to the partnerships or the macro-economic context within which those partnerships function influence this typology of relational principles and intermediate actors mode of classification.

1.3.5. Co-production of Competences between Academia and Industry: an emergent Bridging Institution

In classic innovation literature, the Higher Education and Research System (HERS) and industry are held to be two autonomous, independent spaces for the production of knowledge and competences. Such a conceptual separation is increasingly remote from reality, if it has in fact ever reflected relations between the HERS and industry. On the contrary, the interaction between the HERS and the companies, notably where the production of human resources is concerned, creates recurring movements through which the different actors are to a greater or lesser extent channelled in the shaping of their competences and the development of their career paths. Labour-market entry of graduates is one of the factors which allows us to introduce all the signalling/human capital/network problematics and relate it to the emergence of an new form of labour market which combines the mechanisms of the internal and external markets.

In this text, we focus our analysis on the different dimensions of this interaction between the HERS and the companies for the joint construction of competences and strategies for using the various mechanisms of collaboration (internship, hiring, selection, industry fellowships, temporary use of post-docs, contract research etc.). The institutional arrangements governing these relations and the practices resulting from them may be quite different depending on the sectors, the diploma levels of graduates or the individual companies, whose R&D strategy may differ even within a single sector. In other words, the building of networks or the signalling mechanism remain subject to extremely varied local contexts. In spite of this diversity of practices, however, we maintain the hypothesis that it is possible to identify dominant forms of these relations which differ from one country to another.

This hypothesis could be sustained, for example, by the fact that socio-occupational categories such as 'engineer', 'researcher' or 'technician' do not reflect a 'natural' order but rather, are social constructs, as we showed it in previous researches. In this sense, what we attempt to do in this text is to show 1) how the construction of the most significant actors in innovation, notably engineers and researchers, are embedded in the societal contexts specific to each country, 2) to what extent these professional figures can be considered as bearers of particular cognitive resources - because they correspond to the crystallisation of certain institutional, scientific and professional rationales- and 3) the way that such configuration of actors works as one of the major elements structuring the collaborative ties between the HERS and industry.

1.3.6. National Innovation Systems and Industry Science Relationships in Europe

Globalisation means radical changes in foreign affairs and consequently in tariffs. Domestic markets are no longer sanctuaries for big firms which are more and more multinational in their ownership, governance, scope and aims.

All these evolutions challenge the relevance of the "national" innovation system concept whereas American authors doubt if the American innovation system will be able to maintain its high level of performance as all of the central components of the innovation system now are undergoing change.

Structural changes in the national systems of innovation system, are not occurring in isolation and may well result in some "convergence" in structure which would imply that the raison d'être of the NIS analysis could disappear. The European integration sets up another challenge to the NIS analysis. What will come out from the old national innovation systems whereas there are currently three institutional settings to take into account to deal with industry science relationship ?

After reviewing some threats against the NIS, we show that a great deal of globalisation is actually Europeanisation even if the European law framework is still very sketchy and analyses the possible emerging European innovation system. It insists on the increasing human capital mobility in high tech sectors and supply some evidence of a an emerging European innovation systems. The small country case is also analysed with its variants as it appears when looking at Portugal and Austria. Simultaneously if the project driven ISR seems obsolete, innovation policies will more and more relying on the financing of basic research as well as on local, national, and European infrastructure. In the European case, it seems also important to improve the links between the higher education system and the SMEs.

In this perspective, it seems that proximity to the University has facilitated the development of human resource links through student placement and recruitment, but not necessarily formal collaborative links. Given the characteristics of SMEs, students and graduate recruitment probably provide one of the most important mechanisms through which they absorb academic knowledge and new skills. SMEs often face recruitment difficulties and the shortages of qualified technical staff can inhibit growth and innovation. Proximity to universities provides a recruitment advantage for them. For many SMEs, the importance of universities lies in their contribution to the formation of internal capabilities, and not necessarily in formal knowledge transfer through research links. Knowledge transfer is a social process which requires social and organisational proximity.

1.3.7. Industry-Science Relationships in High-tech Sectors: Comparison of Germany and the United States

We seek here to develop a "transatlantic" approach by comparing the NIS of two countries, the United States – the inescapable reference point in matters of innovation – and Germany – whose institutional arrangements, currently undergoing profound change, can be seen as representative of the countries of Continental Europe. Based on a hundred interviews with actors involved in innovation in both firms and academic organisations, this approach uncovers both the similarities and the differences in science-industry relations between the two countries. On the one hand, these relations contain mechanisms that pit the world of science and that of industry against each other in terms of objectives, time horizons and incentive systems. The gulf between the two worlds gives rise to the same type of problems, difficulties and dilemmas, that is "transfer gaps" that have to be bridged in one way or another. On the other hand, over the course of its history, each country has constructed a set of institutions, of legal and regulatory arrangements and organisations that are supposed to help bridge such transfer gaps.

Nevertheless, for various reasons, problems linked to intellectual property rights have emerged recently as core issues for science-industry relations in the two countries. Against the background of the increasing tensions between the existing rules and the changes being instigated by certain actors, they would seem to be emerging as the key element in these relations. The future evolution of NIS could depend on the way in which the protagonists in science-industry relations in each country succeed in negotiating solutions and putting in place new arrangements that strike a balance between public and private interests.

For instance in Germany, political moves are intended to weaken the professors' "free inventor" status in favour of universities as their employer. Because of reduced public funding there are increasing pressures on public research institutes to raise more external funding from industry contracts. Currently, universities still have a very lax attitude towards and a lack of expertise in IPR matters. But the IPR regime governing industry-university-relations is seen as moving closer towards the U.S. model. In IPR matters German public research institutes are facing a dilemma: They need to provide more pre-development type services for industry, involving stricter IPR claims from corporate partners and they also need to retain IPR in core areas of expertise in order to prevent a "bleeding out" and remain a partner for industry in the future. Similarly, universities face the problem of becoming a low-cost R&D provider for companies compromising their primary mission, i.e. the advancement of knowledge.

1.3.8. Co-ordination of actors and micro-economic incentives: high skills and knowledge transfers

In the first instance, the lessons and recommendations focus on the micro-economic aspects of these relations examined in the first part of the report. What forms does the coordination among the actors take ? What institutional and organisational arrangements encourage effective relations ? What are the consequences for each partner's internal organisations? What labour market regulations are, in principle at least, best suited to the current and future modes of these relations and will ensure that the protagonists have at their disposal the knowledge and competences they require?

A number of lessons can be learnt from the examples of successes and failures recorded in the case studies produced during the various phases of the SESI project. These lessons are located at the following three strategic levels:

- that of the factors of risk and uncertainty,
- that of the processes whereby interests converge and, finally,
- that of the interfacing institutions, agencies and "bodies".

Cooperation cannot in itself provide solutions to the various challenges faced by each of the categories of partners (firms and higher education institutions) unless the form it takes coheres with the partners' internal organisational choices. If there is a number of challenges specific to the different actors, effective joint responses are possible. For firms, the main objective is to resolve the problems posed by the transition from knowledge to competences, whereas for the university involved, the major challenge revolves around the emergence of new disciplines and academic entrepreneurship.

With an OLM of PhD level, the firms, especially very small ones, enable to have easier access to a suitably trained workforce. By promoting the circulation of knowledge, these markets help to reduce the previous conceptual gaps and to promote the creation of greater absorptive capacities at firms, as well as sustaining the spirit of mutual trust and reciprocity in which these networks were founded. From the individual point of view, doctoral candidates stand to obtain advantages like highly specialised technical know-how and the social skills which can be acquired via exposure to the complex multi-disciplinary and multi-functional patterns of organisation generated by the management by projects approach.

IV Policy Formulation

In the previous part, it was attempted to describe the characteristics of a general model for the relations between firms and academia which might serve to improve the efficiency of the exchanges between these institutions. The aim of this model, which was mainly based on the results of the monographs drawn up on individual firms in the framework of the present project, was to identify goals and modes of action. What should the priorities be for the public policy-makers responsible for building and circulating knowledge (tacit and codified, as well as generic and applied knowledge) and the competences and skills embodied in persons.

On the whole, this approach is in line with the triple helix model (Etzkowitz 2000)[5] for the interactions between science/industry/public authorities. In addition to being extremely general, one of the great advantages the latter approach is that it gives the public authorities a leading role in the relations between Science and Industry in terms of both the analyses and the standards they are required to produce. Public incitements are bound to influence the decisions and attitudes of individual actors in one way or another, and can have either positive or negative effects from the point of view of economic and social welfare.

Looking at the problem in question in terms of the production of standards and analyses seems to be a promising approach, all the more so as the Triple Helix model was not designed just to analyse the interactions between the three categories of protagonists. It also takes into consideration the internal transformations which each of the protagonists undergoes as the result of their relations being redefined. Here there is a shift of emphasis towards the increasing tendency for overlaps to occur between the three types of partner, and more importantly, for hybrid structures to emerge, as exemplified by the "entrepreneurial universities" , which are having direct effects at the regional and local levels. Three-part initiatives classically involve agreements which can take various institutional forms, but which in addition, tend to generate common structures, such as the spin-offs which are frequently being given as an example these days.

Apart from these general considerations, it is proposed to deal in the present chapter with the institutional specificities of the countries studied, with a view to drawing up some recommendations without losing sight of the specific national contexts. These recommendations are mainly based on the monographs in which firms were re-analysed with a view to drawing some initial conclusions which might be of use to public authorities. Taking as a starting-point the idea that relations between firms and universities are rooted in configurations of actors and the rules of the game, many of which are dictated by the given national context, it is proposed to deal with each country separately in turn. This does not mean that the effects of globalisation and/or Europeanisation are held to be negligible or secondary. The contrary is the case, since our country-by-country approach also makes it necessary to look at the overall tendencies from three different angles.

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[5] Etzkowitz, H., Webster, A., Gebhardt, C., and Cantisano Terra, B.R. (2000) "The future of the university and the university of the future: evolution of ivory tower to entrepreneurial paradigm", *Research Policy*, 29, 313-330.

- To what extent are the overall policy statements, such as those produced by the OECD (OECD 2000)[6] in the form of regular recommendations strongly inspired by the American model, adopted and implemented in the various countries?
- How do public and private actors adapt their national systems of innovation to converge with other countries, or on the contrary, to accentuate the differences?
- Is the national level still that to which the coherence of the systems of innovation is built first and foremost?

It is not within the scope of this chapter on recommendations to public actors to attempt to answer these three questions in detail. For a closer analysis, readers are referred to the reports, especialoly the nationl ones, in which all these aspects have been covered[7]. Here the same national reports will be used as a basis to define possible orientations and suggestions for public policy-makers, focusing in particular on the high tech, ICT and pharmaceutical sectors (in the latter case, especially as far as biotechnology issues are concerned).

In the case of each country, our analysis will therefore focus on the combined effects of the three-fold instances mentioned above :

- What lessons can be learned from the reforms introduced during the last few years with a view to making the relations between Science and Industry and R&D policies in general more efficient? To determine what the general sources of inspiration have been, it is worth consulting the recommendations on research, development and technology (RDT) policies made by the OECD. These recommendations recently served as a reference frame for adopting the reforms recommended by the OECD experts (OECD 2000) in the various countries. They can be summarized as follows:

- the modes and possibilities for developing the national institutional framework . These are "path dependent ". Casper (1999)[8] has suggested that there exist three basic scenarios which can be used to interpret patterns of institutional reform:

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[6] OECD (2000) *OECD Science, Technology and Industry Outlook 2000*. Paris: Organisation for Economic Co-operation and Development.

[7]CRIS International, 2001, Biotechnology : Industry-Science Relationships in Germany, WP 2.2., SESI PROJECT CONTRACT N° SOE1 - CT97-1054 Project n° 1297.
CRIS International, 2001, Information and Communication Technology: Industry-Science Relationships in Germany, WP 2.2., SESI PROJECT CONTRACT N° SOE1 - CT97-1054 Project n° 1297.
Lam Alice and Nicolaides Andy, 2001, UK Policy Reforms on Academic-Industry Relationships: Challenges for Knowledge Transfer and Competencies Building, WP 6, SESI PROJECT CONTRACT N° SOE1 - CT97-1054 Project n° 1297.
Mayer Kurt, 2001, Sector report: Industry-Science relationships in the Austrian ICT Industry, WP 6, SESI PROJECT CONTRACT N° SOE1 - CT97-1054, Project n° 1297.
Unger Martin, The Pharmaceutical Industry, Sectoral Monograph, WP6, SESI PROJECT CONTRACT N° SOE1 - CT97-1054 Project n° 1297
Verdier Eric, 2001, The French higher education and research system in the perspective of innovation: a political turning point ?, WP6, SESI PROJECT CONTRACT N° SOE1 - CT97-1054 Project n° 1297
We used here many sentences and analysis of these different national reports. But The author of this chapter is responsible for the proposals and recommendations and of course for any misunderstanding.

[8] Casper, Steven (1999). National Institutional Frameworks and High-Technology Innovation in Germany. The Case of Biotechnology. Berlin: Wissenschaftszentrum Berlin für Sozialforschung

. a process of *convergence* towards an American oriented Framework, which means making radical structural transformations in R&D policies of the European mainland countries such as Germany and France;

. a process of *specialisation,* which means reinforcing the specific national frameworks and approaches to the globalisation of Research, Development and Technology;

. a process of *adjustment* of the present institutional frameworks in France and Germany, for example, to make room for at least minimal forms of entrepreneurial science-based innovation without undermining the country's particular achievements in the field of Innovation.

- the development of infra-national initiatives liable to yield increasingly diverse sets of local innovations and relationships between Science and Industry in particular. The national institutional frameworks should not indeed be viewed simply as constraints weighing on the decisions of the micro-economic actors, but rather as examples of decisions in which such and such an economic or technological factor was given priority. The National Institutional Framework can influence these strategies by determining the relative cost of building the organisational competences they require; for example "a company management faced with international competition can survey the spectrum of possible organisational arrangements prevalent within their [national] industry, and attempt to shape a coherent strategy" (Casper, ibid, 6). Public policies may influence the conclusions of this "survey", and hence the choice of strategy made by the firms and individuals, but only within certain limits.

This non-deterministic approach, which nevertheless takes the path determinants (dependency) into account, is all the more useful as the dynamism of innovation systems is resulting increasingly from the emergence of innovation networks within which tacit forms of knowledge are circulating, and which involve various institutional arrangements, from clusters of technological districts to more widespread innovative milieus (cf. the previous chapter). This is in fact what public policy-makers have been striving to achieve by encouraging local initiatives on these lines (Lundvall and Borras, 1997)[9].

Based on the systems of classification proposed Amable, Barré and Boyer (1997)[10] and by Casper (ibid.), the lessons learned by public policy makers will be dealt with her in the following order:

- the United Kingdom, where the policies and regulations are typically market oriented and the orientation adopted as far as science,

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[9] Lundvall, B-A., Borras, S., 1997, "The globalising learning economy: Implications for innovation policy, Report based on the preliminary conclusions from several projects under the TSER Programme, DG XII, Commission of the European Union, Draft Paper.

[10] Amable, B., Barré, R. & Boyer, R. *Les systèmes d'innovation à l'ère de la globalisation*, Economica Paris, 1997..

technology and innovation are concerned is undergoing a process of specialisation.

- France and Germany, where the relations between Science and Industry are facing fairly similar challenges, especially in comparison with those being met on the other side of the Channel, and where the scenario tends to alternated between radical change and a process of accommodation.
- Austria and Portugal, which have rather different technological and industrial structures, but are both facing the special challenge of adapting the small-scale national systems of innovation to the European Union and world-wide competition in general.

The main recommendations could be summarized as follows :

The main recommendations at the national level
(see the complete final report for a detailed presentation)

The UK: maintaining specialisation in a context of academic excellence

Preventing both public and private sectors from under-investing in R&D
Avoiding too much focusing of financings in the "top universities"
Optimising technology transfer and networking policies
Pursuing promising reforms designed to fill the "skills gap"
Encouraging the entrepreneurial university

The French and German cases: between accommodation and bifurcation

The French higher education and research system in the perspective of innovation: a political turning point ?

. Handling the shift from a mission oriented policy to a diffusion oriented policy
. Simplifying public interventions designed for SMEs to make them more efficient
. Reaching a temporary compromise between mission and diffusion oriented policies
. Higher education and the production of skills : consolidating what has been achieved by the reforms
- <u>Ensuring that the numbers of science graduates continue to increase</u>
- <u>How to make the private sector recognize the value of doctoral training (the PhD)</u>
. Overcoming the problems involved in producing skills in some key sectors
. Improving the running of the public higher education and research system

Main stakes in the German ICT and Bio-technology industries

. ICT: higher educational reforms to remove the barriers to innovation
- <u>Coping with a shortage of qualifications</u>
- <u>Reducing the academism of university training courses</u>
- <u>Developing the spirit of enterprise at university in order to make better use of the scientific potential</u>
- <u>Favouring the development of clusters in the field of ICT</u>
. Biotechnology: marching on from strength to strength
- <u>Ensuring that an appropriate supply of skills is available</u>
- <u>Promoting the emergence of new disciplines</u>
- <u>Sustaining the dynamism of local innovation networks</u>

Austria and Portugal: the lessons taught by smaller members the European Union

Austria: from industrial dynamics based on incremental l innovation towards a knowledge based society

. Confirming the relevance of network and consortia policies to stimulate innovative SMEs

. Stimulating the formation of the appropriate skills for a knowledge based economy

. Reforming the science base: how compatible would this be with the roots of the Austrian system of innovation ?

***Portuguese paradoxes*.**

. Limited scope for the high tech industries.

. The weakness of the intermediate institutions: can they be relied on ?

. Entrepreunarial universities: the main challenges

2.background and objectives of the project

General objectives

The SESI project tackles the question of how higher education institutions influence the innovation activities of private-sector firms, which provide the basis for economic competitiveness and societal wealth generation.

The objective of the research was to gather empirical evidence about efficient ways of organising the linkages and interfaces between higher education institutions (including research units) and private-sector firms in order to optimise the flow of knowledge and information between them and thereby spur industrial innovation.

In this respect, the SESI project aims to answer three main questions:

- What are the components and configurations of the knowledge transfer between higher education institutions and industrial innovation activities?

- Under what conditions does the knowledge transfer between higher education institutions and firms benefit innovation capacity and performance?

- How do different national higher education systems perform in supporting industrial innovation capacity?

The answers to this series of questions should enable those engaged in the project to make (public) policy recommendations.

General approach: the innovation space as an "interactive" and "embedded" approach to innovation

Innovation is self-evidently multidimensional and goes hand in hand with changes in the organisations and institutions in which the actors' strategies unfold. This is why any partial approach to innovation, focusing, for example, on the strategy pursued by any one of the actors involved, remains partial when it comes to drawing conclusions, since very little in the way of general lessons can be derived from it. At the same time, however, holistic approaches to innovation do little to make good this deficiency. Such approaches frequently lead to the definition of an institutional environment that guides the decisions taken by any of the actors, who are reduced in consequence to mere agents; as a result, they plot only a fraction of the coordinates of an actor seeking to solve problems and redefine his system of constraints before eventually managing, more or less convincingly, to reconstruct his action system, which remains immersed in an environment made up of organisations and institutions.

The definition of innovation adopted in this project derives from the evolutionary and societal analysis approach. Innovation is regarded as the outcome of a twofold process whereby resources are created and also appropriated by firms, which construct an innovation space integrated into local, national and international institutions. Picking up on famous Lundval's work in this field[11], the main point here is no longer the process of calculation and decision-making but the process of learning and creating complex bodies of knowledge within innovation systems. These include not only firms' internal processes but also the interaction between firms and public R&D organisations as well as education and training establishments.

Innovation encompasses a number of processes - technical, organisational, institutional and cognitive - all contributing to technology design and development, but it also has two additional defining characteristics.

Firstly, innovation constitutes a firm's specific capacity to construct its stocks of knowledge and competences, its relationship with technology and the practices it adopts in its cooperation with its industrial and academic environment. The outcome of these processes, particularly in multinational firms, is a truly distinctive capacity for generating technological and organisational resources in a bid for global competitiveness.

Secondly, a firm constructs its innovation space by interacting with its industrial and institutional environment[12]. To innovate, it must acquire and hence choose the resources which it lacks and deems necessary. In order to appropriate these resources and utilise them effectively for its own development, it will specify them according to its particular needs, in order possibly to convert them into innovative routines (see the evolutionary theory of the firm and in particular Nelson[13]) that cannot be purchased in the market.

Thus firms are faced with a permanent tension between, on the one hand, the preservation of routines that construct, order and maintain knowledge and know-how as a coherent whole and, on the other, the search for new routines that might produce renewal. In other words, firms are not only structures for the management and accumulation of specific knowledge but also entities endowed with rules governing their functioning, which embody the collective lessons learnt in the course of their history, and with rules governing their development, through which new knowledge can be acquired.

Depending on the capacities they have built up over time and their ability to evolve, research and higher education establishments enable firms to explore more or less rapidly the opportunities offered by the emergence of new technological and scientific fields. This is what is meant by the "embeddedness" of the strategies of the various actors operating within an economic area, the limits of which need to be defined. This question of the limits of contingency is especially pertinent to this project: to what extent can a firm's strategy be related to a particular innovation system? Can innovation systems still be defined on a national basis? What impact do the strategies of multinational companies - and for that matter those of "research universities" - have on national innovation systems?

The links between higher education and innovation reveal that industrial firms are key actors not only in the circulation but also in the production of knowledge. After all, if they are to innovate successfully, firms must of necessity be part of the general process of constructing scientific and technical knowledge. This process has always

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[11] Lundvall B-A. (1992) "*National Systems of Innovation, Toward a Theory of Innovation and Interactice Learning*", Pinter Publishers, London.

[12] In the perspective of the "Societal Effect Theory", see Lanciano-Morandat C., Maurice M., Nohara H. and Silvestre J-J. (eds.) (1998), "*Les acteurs de l'innovation*", Editions L'Harmattan, Paris.

[13] Nelson R. (1988), Institutions supporting technical change in U.S., in Dosi G. et alii, *Technical Change and Economic Theory*, Pinter Publishers, London.

existed, of course, and R&D activities have always had a strong international dimension, but nowadays it takes the form of an all-out race to produce academic knowledge and for this to be absorbed by firms.

It is here that the main focus of our project lies, the object of investigation being the relations between actors from two different worlds - higher education and firms - which have separate and not necessarily convergent goals. It was decided to focus on firms' behaviour in the organisation of R&D activities and on the links between that aspect of their behaviour and the practices they adopt in cooperating with higher education. One of the consequences of this was that two major social phenomena had to be investigated.

- The first is the dynamic of the linkage between the global and local dimensions: to what extent do firms' strategies affect scientific and technological organisation and policies, both nationally and locally? Similarly, what opportunities do national institutional infrastructures provide for companies and their practices, particularly multinationals?
- The second is technological innovation, regarded as a process that unfolds within the dynamics of particular industries or sectors. Taking Pavitt's well-known typology as its point of departure[14], the project set out to analyse the consequences of the emergence of new technological systems, the emblematic examples being biotechnology and the convergence of information technology and telecommunications.

An interpretative "framework" of local and national differences in industry-science relations

The project started from the hypothesis that "societal" differences in respect of innovations - whether "incremental" or "radical", to use the standard terminology – are linked to the nature and quality of links between higher education establishments and firms. One of the project's principal aims was to combine two dimensions which are often considered separately: firstly, the construction of the competences and the professionalities of the actors involved in innovation, and, secondly, transfers of knowledge from higher education to firms and *vice versa*.

Three variables were deemed particularly crucial and singled out for special attention: the acquisition of "professionality" by the engineers, researchers and managers involved in the innovation process, the organisation of innovation activities in firms and the positioning and roles of the various institutions involved in the relationship between higher education and company innovation.

The competences of the actors involved in innovation

At issue, then, is the circulation of the knowledge and competences produced (in particular) by higher education and embodied in individuals. This professionality itself comprises several dimensions:

- the construction of curricula and of competences in the context of education/training processes (to what extent should occupational profiles be specialised or interdisciplinary?);

[14] Pavitt K. (1984), "Sectoral Patterns of Technical Change: Towards an Taxonomy and a Theory", *Research Policy*, 13, 343-373.

- the linkage between theoretical gains and the application of knowledge to firms' industrial and commercial problems;

- the processes of mobility which, through transitions from education to the labour market or in mid-career, may (or may not) forge links between academic research and the actual development of new products and processes.

Thus earlier studies by the project teams focused on the impact of societal differences between French and British engineers, on the one hand, and their Japanese counterparts, on the other[15]. The method of "producing" lecturers and researchers likewise contributes significantly to the way a country positions itself relative to any given innovation profile (see Hollingsworth's study of the German case).

The organisation of innovation activities in firms and, more broadly, modes of corporate organisation

This dimension brings into play the relations between firms' various internal functions, the degree to which the organisation is hierarchised (its cohesion) and the firm's capacity to open up to its environment in order to tap into and disseminate knowledge and know-how. Thus an earlier comparison between France and Japan (see namely the studies by researchers of the SESI network) compared the compartmentalisation of functions that "traditionally" characterises French companies, the relative isolation of research and development from the other functional components of the company - the production unit in particular – to the point where the latter might even be driven to establish its own capacity for developing new products or processes. Conversely, R&D in Japanese companies gained its legitimacy from a strong capacity to appropriate basic knowledge and incorporate it into the internal innovation process.

In similar vein, the more closely intermeshed the material and service dimensions of products are, the more crucial the ability to learn lessons about innovation from relations with customers (producers/users) becomes. Indeed, product reliability (maintenance) and adaptability to customer requirements are so dependent on this that they are key factors in competitiveness. The knowledge acquired from these links with customers circulates all the more effectively if it is underpinned by appropriate occupational profiles or methods of work organisation.

The lessons learnt, like those resulting from a cognitive relationship between producers and users, will foster the emergence of incremental innovations. This reveals the extent to which the construction of professionality, firms' internal organisation and the capacity to engender a particular type of innovation are linked. Moreover, it is this linkage that lends legitimacy to the concept of a (national) innovation system, particularly from Lundvall's perspective, when he describes innovation as a "socially embedded process" within a specific institutional setting. Besides, this is absolutely explicit in the final variable taken into consideration here.

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[15] On the France/Japan comparison, see Lanciano-Morandat C., Nohara H., Maurice M.. (1992) "Innovation: acteurs et organisations; les ingénieurs et la dynamique de l'entreprise, comparaison France-Japon", LEST, Aix en Provence; on the United Kingdom/Japan comparison, see Lam A.**.** (1994) *The utilisation of human resources : a comparative study of British and Japanese engineers in the electronics industries*, Human Resource Management Journal, vol. 4, n° 3, 22-40
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Actors and institutions involved in the relationship between higher education and company innovation

The nature of this relationship depends to a not insignificant degree on the manner in which knowledge and competencies are diffused through the occupational mobility and modes of organisation discussed above. A good illustration of this phenomenon is the relative propensity of university researchers in one country or another to engage in mobility with a view to founding companies ("spin-offs") in order to bring innovative products to market. As we have seen, such initiatives receive greater encouragement in the United States than in Europe, as a result of the different societal modes of constructing researchers, the influence of which is compounded by the impact of funding structures (see Soskice's work for an explanation of the genesis of different "varieties" of present-day capitalism[16]) and, above all, the ability to attract capital for high-risk ventures. The same sort of approach could be applied to the question of mobility among engineers and managers in large firms with a view to starting up their own businesses to develop new products. More specifically, we need to examine the effects of the different incentive structures, whether they relate to funding, mid-career access to training or marketing advice.

The likelihood of spin-offs from universities and their research centres, or even from large firms, depends partly on the existence of interface institutions and, more broadly, those offering support to small firms. Such bodies may take an innovative form, for example technical centres at industry or regional level.

More generally, it is the whole range of institutional relationships between higher education establishments and companies that are at issue in this project, provided that they entail some degree of innovation. For instance, do they take the form of a standard commercial contract (where a company places an "order" with a university) or are they more akin to consortia, in which competition and cooperation mix and mingle? Are they based on more individualised relationships resulting in particular from the direct involvement of company employees in the construction of graduates' individual competences, either by teaching on university courses or acting as tutors for students on work placements?

It is not sufficient to be concerned solely with the establishment of institutional relationship between higher education and companies; we must in addition examine the cognitive and symbolic dimensions of these same relations in order to understand their scope and economic effectiveness. Thus, in the case of France, it is habitually pointed out that the country's success in certain fields (aeronautical and space industry, telecommunications, high-speed trains (TGV), nuclear industry, etc.) has its roots in the existence of a "body" of engineers educated at the most prestigious *grandes écoles* (the elite engineering and business schools). Since these "engineers" are employed as managers in large companies, in specialist research centres (National Space Research Centre, Atomic Energy Commission, National Telecommunications Research Centre, etc.), in the higher echelons of the civil service and (to a certain extent) in the financial sector, they are in effect the vehicles for institutional, cognitive and symbolic coordination across the nation.

[16] Soskice, D. (1999) "Divergent Production Regimes: Coordinated and Uncoordinated Market Economies in the 1990s" in Herbert Kitschelt et al., eds., *Continuity and Change in Contemporary Capitalism* NY: Cambridge University Press.

Developing a dynamic approach to links between higher education and firms

The three aspects discussed above were brought together in an effort to reveal the various ways in which the networks underpinning industry-science relations are constituted with a view to achieving innovation. Over and above this structural representation, it was important to develop a dynamic approach, since every national or local system has attempted to a greater or lesser degree to gain new competitive advantages. France for example has sought to move away from a policy almost exclusively geared towards large companies and, what is more, ones involved in large-scale industrial and technological programmes, in order to develop incentive structures for SMEs. However, this example surely suggests that merely decreeing into existence bodies to interface between scientific research and SMEs is not enough to ensure that such firms will manage to tap into new sources of knowledge and expertise and, better still, to appropriate them.

It was therefore necessary to develop a dynamic approach to these relations between higher education and firms, in order to examine the coherence and relevance of these reforms in the three spheres mentioned: institutional (resources, contractual arrangements, etc.), cognitive (what collective learning dynamics?) and symbolic (what cohesiveness, what sense of belonging to an "innovative community"?).

3.Scientific description of the project results

This part of report aims at presenting both the research methods we had used for different surveys and the most significant scientific results we can draw from this SESI project. Especially, this part should underline the wealth of empirical material (more than forty company case studies) and the way that we exploited it.

After the description of the methodology, we will present the main points in two different ways.

The first one (3.2.) is more theme-orientated. The approach is structured around two levels of analysis. The first involves analysis of the conditions under which firms incorporate the new challenges of the knowledge and learning economy into their strategies. In particular, focus is put on the organisation of R&D and human resource management and seek to locate the links between higher education and firms in this new competitive and cognitive context. The second level deals with the collaborative ventures between firms and higher education that were one of the two key aspects of the company case studies. The conditions under which they were set up, their objectives and the underlying principles animating the protagonists' behaviour are essential to any understanding of the strategic significance of these relations.

Although located themselves at the microeconomic level, these two approaches seek in their different ways to relocate their findings within a macroeconomic and/or societal framework in order to shed light on the challenges facing public policymakers.

The second one (3.3.) relies on the "national system of innovation approach" which favours the "national coherence" of various institutional setting-ups. We will focus our arguments on some characteristic features of each European countries studied in this report, in considering that each of these countries will have to make compromises between divergent if not contradictory pathways for organising and regulating their national research and innovation structures. The future competitiveness of each institutional system will in fact probably depend on the quality of these compromises.

3.1. Methodology used by SESI project

The method was designed to reflect the problem areas and interpretative models at three distinct levels:

-Countries and sectors
-Firms and their relations with higher education
-Societal dynamics or the global/local interaction.

In particular, the aim was to take account of the interactions and interdependencies between the micro-economic level and that of the sectors and countries included in the project.

3.1.1. Six countries and three sectors

Five European countries were selected in order to provide, at least by way of an initial hypothesis, national systems that were sufficiently disparate from the point of view of the resources "offered" to companies, be it in terms of institutions, organisations or actors. Higher education and innovation systems do in fact differ significantly from one European country to another. By way of illustration, it was noted in the initial statements explaining the choice of these five countries that:

-The United Kingdom has an education system which is elitist but undergoing radical change and there is a relatively low level of public funding for research.
-France has a dual system of higher education - universities and the g*randes écoles* - which has had a considerable influence on the "innovation space" of French companies, and its research system is heavily subsidised by the public purse.
-Germany and Austria have "intermediate" systems of education and R&D, bearing all the hallmarks of involvement by trade unions and employers' associations.
-Portugal has links between higher education and companies which are both more direct and more recent.

However, the aim was not to study the institutional specificities in themselves but rather to link them to sectoral dynamics. Three sectors were chosen in each country as being representative of the new challenges emerging for the relationship between higher education and industry in key sectors where generic technologies are tending to develop, albeit in different ways. The information technology sector, whose growth has been very rapid, is of interest because it brings together, in ways specific to individual countries, industrial production activities and customer service activities. The telecommunications sector, which has undergone a huge amount of technological and organisational innovation, was seeing its links with the public sector being challenged by deregulation in various EU countries just as the project was being launched. The pharmaceutical sector, whose links with higher education and research date back further, was facing the biotechnology revolution.

It was essential to include the United States. Indeed, the relations between higher education and companies which have evolved in that country are undoubtedly an international point of reference, especially in terms of the universities' responsiveness to changes in their environment and to the demands of firms as well as particularly effective spin-off processes. It appeared, furthermore, that, far more than in other countries, large US universities with strong research capabilities have over the past two decades been the catalysts for the emergence of new industries (e.g. micro-computers). It therefore seemed appropriate to examine the funding, organisation and "governance" of these institutions, with a view to reflecting on the ways and means of creating an efficient European model of innovation. By the same token, but without any field work having been done, the case of Japan has been used as a point of reference in this project, above all because of the recognised expertise of two members of the network running the project.

It was discovered straightaway that a sizeable body of literature on innovation and the circulation of knowledge in these various countries and sectors had been produced in recent years. The first phase of the project, then, consisted in gathering together and analysing the corpus of existing studies and surveys, at both national and sectoral level. At sectoral level, the aim was to highlight the strategic orientations and the most important technological and organisational issues. At national level, it was a matter of determining the exact institutional context of industry-science relations and of understanding how the different countries' education systems and technology policies are structured. The second stage was to compare the various "societal" spaces studied. The aim was to gauge the significance of these sectors in the different economies (see appendix 4) and, above all, to compare the institutional vehicles for cooperation between firms and academic establishments. Special attention was devoted here to different types of policy on technology diffusion ("mission-oriented" or "diffusion-oriented" policies). The final step was to design relevant questions for the company surveys on the basis of these "assessments".

3.1.2 Selection of companies and examination of their links with companies

The investigations within firms form the empirical basis of this project

Constructing the sample of firms

Three companies per sector and per country (two each in Portugal and Austria) were studied, making a total of 48 (see list in appendix 2). The initial idea was to take one "foreign" multinational, one large "national" company and one SME for each sector, in an attempt to have a comparable sub-sample for at least two countries.

One of our objectives was to question these firms about the qualities of the different national systems (their "strengths and weaknesses"). In practice, a multinational creates a network of different national systems by incorporating them into its own organisational space. Thus it was relevant to investigate to what degree these firms, through their subsidiaries, attempt to pick up and "import" institutional and organisational attributes which they have identified outside of their country of origin or, conversely, to "export" their own original attributes.

As a result of mergers and take-overs, the differences linked to a company's "nationality" proved to be far less relevant than predicted. Such restructuring processes affecting production and finance had a decidedly adverse effect on our field work in companies, which took longer to complete than planned, for many reasons. First of all, it is necessary to stress the impact of the context in which the investigations in firms took place. We were operating during a difficult period of enhanced competition due to an accelerating globalisation of markets which leads firms continuously to re-examine their "area":

- In the pharmaceutical field, this process has led, notably, to a headlong rush into mergers. For example, two firms studied in this project, themselves already created from earlier mergers, became, for a while, the largest international pharmaceutical company. Relations with managers became appreciably more complex because they were not only asked to participate in the new internal restructuring, but at the same time they felt extremely insecure about their own future in a process for which the main motivation was a rationalisation of R&D.

- In the computer and telecom area, the (not insignificant) mergers have not taken place on the same scale as in the pharmaceutical industry. Nevertheless there is continuous internal restructuring; for example, the break-up of a major global firm into two parts, both of them studied in the SESI project. This reorganisation goes a long way to explaining why, in France, after responding positively for one whole year, this firm finally refused to participate in the SESI project.

As a consequence, interviews for the company surveys were more difficult than anticipated. The discussions took more time than planned, or less, and validation processes – an important feature of the methodology - were more complex due, for instance, to the replacement of our original contacts.

Data collection

The investigation of each company took place over a one-year period. Once the project had been presented, a confidentiality agreement was signed with each firm. A research protocol was drawn up in such a way as to ensure that both the project's initial intentions and the interviewees' arrangements were respected. This protocol made provision for an average number of interviews (at least 10 to 15, often around 20, each lasting 2 to 3 hours), for factual and/or public data to be supplied by the company and for the findings to be handed back in the form of a case study and validated by the interviewees. The interviewees were selected partly from within the company and partly from within the universities and laboratories cooperating with the firm.

On the company side, these were R&D managers, project managers, researchers and engineers, HR managers and those responsible for related fields such as alliances and patents. Among their academic partners, interviews were conducted with heads of laboratories, departments and projects, sometimes with researchers. Semi-directed interviewing techniques were used with both types of partner, based on a standardised interview guide devised for all firms in the various countries. Before the interviews were held, the various organisations' strategies and structures were studied: this was done on the basis of documents supplied by management in the different organisations and supplemented where necessary by press reviews. For the firms, this enabled us to become familiar with the situation of the group or SME: competitive position, international development, technological trends, role of R&D, number of employees. For the universities, engineering colleges and public laboratories, the same documentary work was carried out in order to situate the organisation in its public context and in respect of cooperation with industry in general.

Finally, the interviews were conducted in such a way as to reveal :

- each firm's strategy (that of both the multinational and its local subsidiary),
- its general organisation and more specifically the role of the R&D unit,
- development of technology policy in conjunction with marketing policy,
- its practices relating to technological alliances,
- human resource management practices in general and for R&D in particular,
- the evolution of innovation coordination at national level,
- knowledge management practices,
- policies pursued in terms of intellectual property,
- the evolution of attitudes to cooperation with "academia",
- the funds committed to this effect.

The interviews conducted at universities and public laboratories were designed to explore in depth two major cases of collaboration, looking at them in terms of their organisation, funding and evaluation. Here we needed to highlight two methods of knowledge transfer: R&D cooperation and joint training for graduate students (including arrangements for job placements).

Data analysis

In accordance with the approach adopted for the SESI project, each case study is divided into two parts. The first deals with the firm's trajectory and strategy in respect of innovation, competences and knowledge. The second is given over to a presentation of some actual cases of collaboration between the firm and the higher education system in the two fields of research and training (competences).

Typical structure of a firm monograph

Core of the SESI, these monographs aim to analyse the relationships between its innovative dynamics and the Higher Education and Research System (It isn't matter of reconstructing the whole coherence of the firm). In the SESI perspective, the monograph is made up of two parts. The first one concerns the trajectory and the strategy of the firm concerning innovation, competencies and knowledge. The second one systematically presents some precise cases of collaboration between firm and higher education system in the both fields, research and training (competencies).

Taking into account the sectoral context (technology, competitiveness and markets - or products), the first part is made up of three stages :

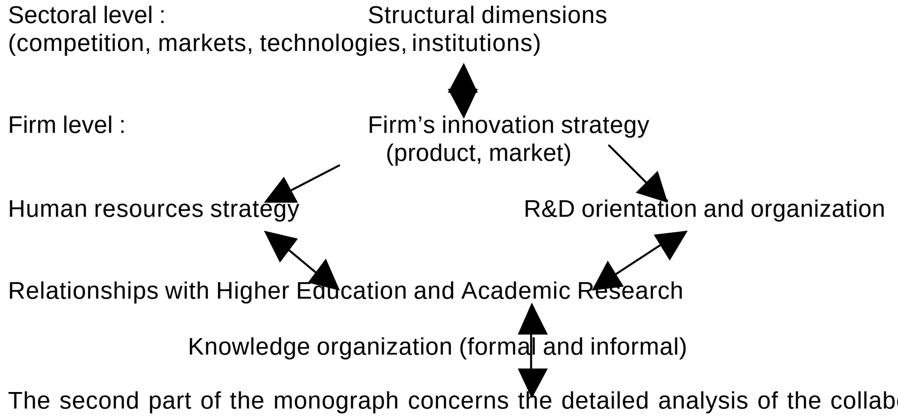
- The first one aims to identify the technological strategy of the firm : particularly, it's necessary to integrate the evolution of its position in term of products-market and its organization (these both dimensions are often strictly linked)

-The second one interprets these orientations in three crucial fields for the SESI project : the human resources strategy, the orientations and the organization of the R&D, the relationships with the Higher Education and Research System. The first and the second ones strongly interact with the third one : for example, a partial externalisation of the internal R&D would involve a fast increase of the relationships with the academic research or some intermediary research institutions .

-As a conclusion of this first part, it would be useful to identify the firm's dynamics in terms of competencies and knowledge. One shall distinguish the explicit strategy with an effective "knowledge management" and the results of routines which constitute endogenous innovative capabilities.

The following graph summarises this first part of the monograph.

How the firm builds its innovative capability



The second part of the monograph concerns the detailed analysis of the collaboration cases between HES and the firm.

As far as the sectoral context is concerned (technology, competitiveness and markets – or products), the first part is divided into three sections.

- The first aims to identify the firm's technological strategy and in particular to outline the evolution of its product/market position, on the one hand, and of its organisation, on the other (the two dimensions being closely linked in many cases).

- The second interprets applies these findings to three fields of crucial importance to the SESI project: human resources strategy, the orientation and organisation of R&D and relationships with the higher education and research system.

The first and second of these interact strongly with the third: for example, the partial externalisation of internal R&D functions would entail a rapid increase in relationships with academic research or some intermediary research institutions.

- By way of a conclusion to this first part, it would be useful to identify the firm's dynamics in terms of competences and knowledge. A distinction will be made between explicit "knowledge management" strategies and the results of routines that make up firms' endogenous capacities for innovation.

The diagram produced above summarises the first part of the case study.

The second part of the case study comprises a detailed analysis of instances of collaboration between HES and the firm in question.

In order to ensure the relevance of the results, the content of each case study was discussed with the managers of the firms and institutions concerned. Indeed, this debate was an opportunity to test the coherence of the researcher's interpretations. In certain cases, this exercise led to a substantial revision of the case study.

3.1.3. The broader perspective: from micro-economic foundations to "societal" comparisons

Our cross-cutting analysis of these case studies began at the microeconomic level, with a dual perspective being adopted.

- In the first, the focus was on the organisational development of R&D processes, with an attempt being made to link the issues of competences and knowledge, in keeping with the initial intentions of this project. Two points of view - knowledge sourcing and project management – were pursued by analysing the effect of cooperation with higher education on processes inside and outside of firms.
- In the second, the focus was on industry-science relations, with the instances of collaboration studied in the firms forming the basis for the analysis. Particular attention was paid to two aspects: a typology of relations with regard to their aims, resources and evaluation and an analysis of the modes of intermediation between the two "worlds" - firm and "academia", with particular emphasis on interface institutions.

The case studies, combined with the results of the previous phases, served as a basis for drawing up sector and national reports for each country. The idea here was to examine the main challenges encountered by national industries and institutional environments, in particular those linked to the global strategies of firms in these hi-tech sectors.

This stage prompted a more general question about the evolution of national innovation systems: are we witnessing a convergence of the institutional processes involved in cooperation between firms and higher education? Can we speak of the Europeanisation of national research and innovation systems? What lessons can be learnt from a comparison between Europe and the United States (with Germany serving in this instance as a "control country") ?

3.2. Thematic Approach of Science/Industry Co-operation

This second part attempts to take advantage of the wealth of empirical material - more than forty company case studies - gathered in the course of this research project. The approach is structured around three fields of analysis.

The first subsection involves analysis of the conditions under which firms incorporate the new challenges of the knowledge and learning economy[17] into their strategies. The focus is put on the organisation of R&D and human resource management and it seeks to locate the links between higher education and firms in the new competitive and cognitive context.

The second subsection focuses on the collaborative ventures between firms and higher education that were one of the two key aspects of the company case studies. The conditions under which they were set up, their objectives and the underlying principles animating the protagonists' behaviour are essential to any understanding of the strategic significance of these relations.

The third subsection deals with recent changes in the joint production (co-production) of competences and high-level skills by academia and industry by comparing the recent evolution of the higher education and research system (HERS) in five countries.

Although located themselves at the microeconomic level, these three subsections seek in their different ways to relocate their findings within a macroeconomic and/or societal framework.

3.2.1. <u>**Changing R/D organisation and new management of knowledge**</u> (for a detailed analysis, see the chapter of Alice Lam in final report of July 2001)

The first part of this subsection defines the new environment in which knowledge is produced and circulated and in which firms operate[18]. Knowledge is being renewed at ever increasing rates, and this has a profound affect on the organisation of R&D by firms. In consequence, the nature of R&D work in firms is changing considerably and is giving rise to new "research worker" profiles that sharpen the tensions between the partners in industry-science relations.

The second is devoted to firms' competences in the internal and external organisation of R&D. Taking as its starting point the acknowledgement that technological competitiveness is based on knowledge, it analyses the various tools developed by firms – particularly multinationals - in order to manage knowledge. The

[17] See in particular Lundvall and Borras, 1997, "The globalising learning economy: Implications for innovation policy". Report based on the preliminary conclusions from several projects under the TSER Programme, DG XII, Commission of the European Union, Draft Paper.

[18] Gibbons, M et al (eds) 1994 The new production of knowledge. London: Sage.

major challenge is how to manage the diversity that has been created to a large extent by multinationals' globalisation strategies[19].

I) Changing nature of R&D organisation and innovation

1) Towards the "third-generation R&D" organisation

All the firms examined in this study are placing increased emphasis on improving R&D productivity and effectiveness by organisational restructuring and by enhancing their capability for internal and external networking and knowledge transfer. The recent changes in the organisation and orientation of R&D activities in the case study firms can best be captured by the concept of "Third generation R&D". This concept was first developed by Roussel/Saad/Erikson (1991; cited in Reiger and Wichert-Nick1997) to denote the contemporary development in R&D organisation and the process of formulating technology strategies in large enterprises. Evidence from the case studies shows that the knowledge and skills contents, and boundary of R&D work in the "third generation model" differ greatly from those in the traditional models of R&D organisation.

The "first generation R&D" was the dominant model (1950-70) at a time when R&D management was shaped by the technology-pull view. R&D was assumed to be the main driving force behind innovation and decisions about the technology that would be used by the enterprise. The main characteristic of this first generation R&D management is the pre-eminence of the professional ideology which stresses specialisation and autonomy of the R&D professionals. These professional specialists are regarded as the key "knowledge agents" whose formal training and qualifications give them a source of authority and a repertoire of knowledge they are ready to apply to technical problems within their disciplinary expertise. Innovation activities in the "first generation model" take place behind a screen of impenetrable science and are isolated from business problems and the rest of corporate activities. In other words, "science" and "commerce" are treated as two separate domains.

The "second generation R&D management" (1970 -late 1980s) is a transition stage towards the third generation. It began in the early 1970s when the technology-push view was overruled by the market-pull view. The most distinctive feature is the corporate focus on forging a strong link between business and R&D management. This is achieved through de-centralisation of R&D to business units, and the formation of a market relationship between R&D (as suppliers) and business divisions (as customers). This is a model dominated by managerialism and commercialism where academic specialists give way to generalists, and short-term R&D reduces the organisation's ability to cope with technological changes.

Most of the companies looked at in this study are undergoing a paradigm shift from the "first" and "second generation R&D" towards the "third generation R&D". This is characterised by an attempt to create long-term visions and to balance the R&D portfolio strategically across the whole corporation. It seeks to combine the benefits of market-driven, decentralised R&D with the technology-push benefits from a long-term orientated, fundamental R&D (Coombs and Richard, 1994). Unlike in the "first generation R&D", innovation is not an autonomous activity occurring within the domain of "science" and driven primarily by the R&D experts. The "third generation R&D" requires the integration of R&D into the business and organisational context. Yet in contrast to the market-driven "second generation R&D", it seeks to maintain the ability to generate new knowledge beyond the existing core competence. Innovation in "third generation R&D" is generated in the context of application and networks of interaction

[19] Whitley R., 1992 , "*European Business Systems"*. London : Sage,.

within and external to the enterprise. It is a de-centralised, network form of R&D organisation. The ability to access knowledge from a wide variety of contexts and sources is critical for sustaining its capability to generate radical innovation. This new approach to R&D calls for a redefinition of the nature of R&D work and the type of knowledge and skills required for innovation.

2) Changing nature of R&D work

Cross-functionality and transdisciplinarity

In the "third generation" model, R&D work is increasingly organised on a multi-disciplinary basis. Innovation takes place in mixed project teams involving experts with a diverse range of scientific expertise as well as non-R&D groups. Flexible specialisation and "inter-dependent professionalism" are the characteristic features in "third-generation R&D". For example in the ICT firms, there have been efforts to recruit staff with a diverse range of expertise outside the traditional disciplines of computer science and electronics engineering. The importance of having "mixed skills" in the R&D labs is emphasised by many of the managers and researchers interviewed.

Tensions between the "line" and the "team" are symptomatic of all matrix organisations. However, in industries where innovation is increasingly problem-oriented and transdisciplinary in nature, the core of their activities tends still to be underpinned by specialist scientific knowledge. The difficulty in striking a balance between the two is much greater than in older industries.

External networking and collaboration

One of the fundamental features of the "third generation R&D", in contrast to the short-term oriented, business-driven "second generation", is to recognize the need to maintain long-term vision and a capability to create new knowledge beyond its existing core competence. The ability to exploit a wide spectrum of external knowledge resources and collaborate with external organisations is regarded critical for creating new knowledge. All the firms examined in the study are engaged in an increasing range of external collaborative activities such as alliances, joint ventures and R&D collaborations with other firms and academic institutions. For many of these firms, R&D activities now involve a complex arrangement of alliances and networked activities. Th R&D lab is increasingly seen as "the integrating centre for a network of relationships outside". Such external networking and knowledge sourcing activities are particularly intense in the pharmaceutical sector where the scale of investment required for drug research and the need to integrate knowledge from many different domains are beyond the reach of internal R&D programmes. The locus of innovation is increasingly found in networks of collaboration. This means that the ability of R&D workers to collaborate and negotiate with external agents, and to exploit external knowledge is becoming a necessary part of their competence profiles. "Networking skills" and ability to "access and understand a much bigger data base" were frequently mentioned by many of the managers as something they look for amongst their R&D staff.

In many organisations, there has been a growing demand for R&D staff capable of performing a gate-keeping or boundary-spanning function. These are specialist roles responsible for internal and external coordination and transfer of knowledge across functional and organisational boundaries. These roles are usually performed by highly qualified scientists with managerial and business experiences, and also additional training in IPR matters. The type of knowledge and experience required is usually highly specific to the firm.

3)The new R&D knowledge worker

Re-definition of competence in innovation

The above evidence suggests that the contents and boundary of R&D work have become increasingly fluid, ambiguous and transient. The problems that R&D workers have to deal with are no longer contained within the boundary of individual specialisation and conventional disciplinary expertise. Standardised and "pre-packaged" professional knowledge is no longer sufficient to deal with the spectrum of activities and level of uncertainty that they have to cope with. A large part of the problem solving activities in the new R&D environment has very little to do with the application of narrow standardised expertise and more to do with the capacity to define problems and adapt to new situations. As noted by a manager in the pharmaceutical firm: "Research is about knowing what to do when *nothing is written down*. It is about learning t*o anticipate the unexpected* and deal with it". Many of the managers interviewed were concerned that graduates did not have the type of "research skills" or "problem solving abilities" that the companies required. What they are looking for, according to the HR manager in the R&D lab of an ICT firm, is "a capacity to define the problems correctly in the first place; solving the problems is no more than a last step in the chain". A common criticism is that many of the graduates regard research as a process of solving problems that have been pre-defined.

The type of knowledge and skills required for the new innovation context has a strong "tacit" component and collective dimension. The simple classification of knowledge categories developed by Lundvall and Johnson (1994) provides a useful illustration. The authors distinguish the following four different categories of knowledge:

- Know-what - refers to substantive knowledge and knowledge about facts
- Know-why - refers to understanding of basic principles, laws of nature
- Know-how - refers to human skills and competences necessary to act intelligently in a complex and changing environment
- Know-who - refers to the social capability to cooperate, to communicate and establish trust relationships.

Innovation in the high-skills sector demands the effective interface of all four categories of knowledge. However, the emerging evidence suggests that 'know-why' has become more important than 'know-what'. This is because 'know-what' knowledge can easily become obsolete in a fast changing environment. Most important of all, 'know-how' and 'know-who' knowledge are absolutely vital in the new innovation context. They are critical capabilities needed for the production of 'Mode 2' knowledge.

Growing versatility and diversity of careers

The distributed and network form of R&D activities, coupled with the rapid pace of technological advancement and discontinuity imply that the careers and work roles of R&D staff will be increasingly characterised by versatility and diversity. Evidence from our case studies suggests that an increasing number of the R&D staff will be deployed outside the traditional R&D function. In many of the companies, there are growing concerns that the low-level of turnover among their R&D staff may inhibit innovation and the capability of the laboratories to create radically new competences. Many of the companies are now re-writing the psychological contract with their R&D staff. The idea is to encourage the mobility and internal transfer of the R&D staff on a more systematic basis. A common practice is to increase the transfer of staff from the R&D laboratories to the business units. In some companies, policies are being developed to enhance the two-way flow of staff between the corporate labs and business units. These policies are aimed at career development and also at the integration of technical and commercial capabilities.

Reduced strength of internal competence building

The general trend observed in many of the companies is the reduced strength of the internal competence building model. This has been caused by the need to speed up the learning process and to create new competences in an environment where the rate of change is dramatic. Hewlett Packard is a good example. As the company seeks to transform from a hardware manufacturer to an enterprise service provider and systems integrator, the internal competence building approach is proving to be too slow for adapting to the changes. The company has recently adopted a compromise strategy of allowing more openness in its career development and recruitment policies.

4)Problems for firms in skills and knowledge sourcing

The changing nature of innovation and shifts in the skills and competence requirements pose a number of challenges for firms. The first is recruitment: whether universities from which they recruit most of their R&D workers are able to supply the graduates and post-graduates with the range of skills and competence required. Formal disciplinary knowledge acquired through conventional means of specialist education is still necessary but clearly no longer sufficient. Firms increasingly look for those with the following qualities: a) a good grasp of the 'knowledge of the basics' and a higher threshold of ability to ensure the ability to adapt and learn; and b) a broad portfolio of competence and experience beyond traditional disciplinary expertise. In addition, all the companies in the study emphasise the importance of business experience. This is because of the time scale pressures in product development and the need for R&D staff to engage in customer interface. While graduate recruitment is important, many companies, especially those in the ICT sector reckon that they can no longer afford the time for the training and integration of a large number of graduates with no practical experience.

The second problem stems from the rapid evolution of knowledge and the limitations of institutional signals (e.g. occupational certification) in providing reliable information about the content and quality of skills and knowledge that graduates have. Codification is too slow a process for the transmission of rapidly evolving tacit knowledge. The assessment of quality is critical when the competitive advantage of firms depends on nonreplicable human resources. More effective mechanisms will have to be developed for the rapid transmission of knowledge between universities and firms.

The third problem facing firms is the growing intensity of labour market competition for scientific and technical talent. As competitive advantage depends increasingly on tacit competence and unique configuration of knowledge resources, firms will compete to hire the best and make sure that they have a stable supply of reliable core R&D workers. However, a fundamental dilemma facing many firms is the growing difficulty in attracting and retaining the best researchers, many of whom are reluctant to pursue a career in an industrial environment where firms can no longer provide stable research careers. Firms will have to devise new strategies to tackle the problem of 'intellectual resource immobility'.

Finally, firms also have to manage growing tension between greater openness and flexibility in skills and knowledge sourcing and the need to sustain the capability to move ahead rapidly within their core competences. The increased demand for scientific creativity and absorption of external knowledge is encouraging greater openness in firms' human resource policies. The potential danger is the weakening of their internal absorptive capacity and ability to accumulate knowledge and capitalise on learning. New mechanisms will have to be developed to promote the effective linkages of internal and external knowledge.

How are our case companies responding to these problems?

5)Towards a new approach: the "extended internal labour market model"

Building strategic partnerships with universities

A common strategy adopted by the companies in our study is to forge close institutional links with universities in order to gain early access to the best people and ideas, and to develop mechanisms through which they can influence the initial education and training of their potential recruits. In all the companies, there is an increased emphasis on "student placement" as an effective channel for graduate recruitment. Companies favour recruiting those who have spent a 6-month or one-year internship with them. The idea is that these students have already gained the business understanding and organisational knowledge during their internships, and hence are more qualified and suitable than those with a pure specialist training from their universities. The placement period also allows the company to have a long period of screening and probation. It serves both the training and recruitment functions. It amounts to a kind of "informal apprenticeship" which gives the companies an opportunity to instill the specific competence and tacit knowledge for the type of work for which they are recruiting.

Another significant development observed in all the companies is the attempt to develop a more focused and targeted approach to the ways that they relate to academic institutions. The idea is to focus their attention and concentrate resources on a small number of key institutions from where they are most likely to resource their people and knowledge. The term "strategic partnership" is often used to denote an intention to forge long-term, multi-dimensional and trusting relationships with the key institutions. The relationships between the company and academic institutions would be sustained by a range of linking mechanisms including collaboration in research, industrial inputs to curriculum development, student placements, and exchange of staff. The intention behind all these, according to a senior manager responsible for university links in one of the ICT companies, is to have "early access to the most talented people" and trusted access to the best ideas":

Towards the formation of "extended internal labour markets" (EILMs)

The above evidence suggests that firms are devising new strategies to cope with the changing nature of innovation and competition, and to compensate for the limitations of the "professional model" in Mode 2 knowledge production. The concept of the "extended internal labour market" (EILM) would seem useful to interpret the significance of the new approach adopted by the firms. The concept of EILM, in a traditional sense, is used to describe the recruitment channels most commonly used by firms for non-skilled manual workers (Manwaring 1984). It refers to the practice of recruiting through existing employees of the firm and extending its internal labour market through their social networks in the local community. It therefore describes a recruitment channel and the relationship between a firm and its community. This paper applies the concept in a new context, stressing the active role of firms in developing social networks for knowledge and skills resourcing. Unlike earlier work which has focused primarily on recruitment channels, this paper highlights the importance of EILMs, in addition, as mechanisms for knowledge and skills generation and transmission between universities and firms in the high-skills sector. The EILM concept draws attention to the critical role of careers and mobility of people in the formation and transmission of knowledge in the high-skills sector.

For firms, developing their EILMs compensates for many of the shortcomings of the "professional model" in the generation and transmission of Mode 2 knowledge. The build up of social networks through EILMs serves three important functions:

a)as a recruitment channel;

b)as an informal "apprenticeship" system;

c)as a mechanism for sustaining boundary-spanning knowledge networks.

6) Rethinking the links between innovation and systems of competence building

The analysis presented here illustrates how firms' models of R&D organisation and innovation co-evolve with their human resource policies and organisational learning capabilities. R&D is a learning process and the effectiveness of such a process is embedded in the development of human resources and systems of competence building The existing literature on innovation, however, has rarely discussed the linkages between the two. This has resulted in a gap in our understanding of how firms' innovative capabilities are related to a wider set of societal institutions beyond the R&D and technological systems. There is a close connection between firms' R&D strategies and systems of competence building. It illustrates the importance of labour market institutions, and education and training systems in supporting the different types of innovation and knowledge sourcing strategies. It also illustrates the changing role of university-industry relationships as firms move towards the third-generation R&D model of innovation.

FIGURE 1 INNOVATION AND COMPETENCEN-BUILDING: AN INTEGRATED MODEL

Model of R&D	First-generation	Second-generation	Third-generation
Innovation & Knowledge strategies	Strong corporate R&D (Centralisation) Knowledge accumulation	Divisional R&D (Decentralisation & externalisation) Knowledge acquisition	Alliances and partnerships (Decentralisation & internal/ external networking) Knowledge sharing and Creation
Organisational forms	Bureaucratic	Market-based	Network organisation
Type of knowledge workers	Mode 1 disciplinary experts---→ (problems identifiers and problem solvers)		Mode 2 transdisciplinary experts (Problem identifiers, problem solvers and strategic brokers)
Competence building	ILM Internal core competence (careers and training)	Reduced ILM Sub-contracting and externalisation	EILM Extension of 'core' to external knowledge suppliers (e.g. universities)
University-industry Relationships	Linear model ---.> Interactive model - supplier of fundamental knowledge -certified competence - pool of codified knowledge		- partner in knowledge generation - reputation-based competence - tacit knowledge embodied

II) Multinationals, technological globalisation and Knowledge management tools (for a detailed analysis, see the chapter of Claude Paraponaris in final report of July 2001)

In organising their R&D activities, multinational groups actively seek out a diversity of resources. This diversity applies to the modes of product design, of technology construction and of client relations[20]. Similarly, there is a diversity of occupational and personal profiles. Finally, it applies both at multinational level (the main thrust of multinational strategy being to incorporate diversity rather than endure it) and in local establishments: a single R&D unit usually draws on a number of different sources of knowledge (technological alliances, collaboration with universities and engineering schools that do not necessarily function institutionally in the same way).The firms studied are attempting to endow themselves with this diversity through globalisation.

i) Structures better suited to technological globalisation

In all the multinational firms studied, control of R&D is organised internationally. After several decades of experience with siting diversification, the questions of centralisation and decentralisation (or "hub" or "network" organisational forms (Boutellier, Gassman and Von Zedtwitz 1999)) are being stated differently at the beginning of the 21st century.

The majority of the firms have turned their subsidiaries into specialist units, following a decision-making process based on an assessment of local technological advantages. These now exist in sufficient concentration in the various zones of the "triad". The movement towards specialisation involves giving a particular site responsibility for the development of one or more technologies (at this level, firms tend to think in terms of technologies rather than specific products). This allocation of responsibilities has proceeded over the last decade against the background of the drive to rationalise operations.

Multinationals are globalising their technology strategies by seeking once again to extend their asset base while at the same time developing their contractual activities. Despite this, there is little long-term mobility between the various R&D sites or between the various countries in which the multinationals operate. Nevertheless, such mobility could help to bring about a certain convergence of practices in the various locations. What tends to happen, rather, is that functional managers, whose task it is to relay central management policy, spend short periods of time at the various sites. In fact, the structures of R&D activities have gone through several phases of development over the past 20 years, which explains why the current structures combine a market-driven approach with networking practices.

In more or less formal ways, firms have adopted this organisational principle, which consists of separating long-term exploratory activities from development activities. Diversity is organised on these same two levels. The functions associated with the strategic development of technologies are concentrated on the first level, where responsibility for major academic collaborations and the dissemination of knowledge within the firm also lies. The second level draws on the first but is more closely linked to the market dynamic. This division of responsibilities is very well established in IT and telecommunications companies but less well established in pharmaceutical companies, in the sense that the first level is not yet functioning fully as

[20] We are not referring here to multinationals' location strategies, which involve either producing locally or adapting products to the market profile.

a network since it is still to some extent centralised at a single site that retains overall control.

However, this new organisational structure is subject to co-ordination problems. Although the short-term secondment of functional managers makes it possible to establish consultation procedures that are very useful in advancing knowledge, each of the levels in fact develops its own preoccupations and academic contacts. The cases that best illustrate these difficulties are those of firms that have become highly specialised in service-based products.

This search for control of diversity has been accompanied by another major development in the guise of project-based management.

<u>Project-based management: a results-driven mode of organising professional interactions</u>

The new R&D structures lead to the various units becoming specialised in certain areas, while at the same laying down the principles governing the exchange of knowledge. They are also intended to lead to employees becoming specialists in specific R&D functions. As they carry out their activities, however, employees are at the heart of a multiplicity of interactions with their colleagues that contribute to the construction of effective innovation processes. Professional interactions occur at all levels at all the sites operated by multinationals; they constitute the basis of R&D personnel's creativity. The same issues around the control of diversity are raised here too: differences in the progression of R&D activities from unit to unit, differing assessments of clients and of risks and of the need for co-ordination, even within the same design team. In this case, diversity is the object of very considerable attention on the part of R&D managers. The dominant approach to rationalising R&D activities is based on the spread of project-based management. Very little research work is currently being undertaken that is not organised in this way. It has a general effect on management tools and behaviour. The reasons for the adoption of project-based management are linked to the demands of competitiveness (innovation time, R&D budget, shared understanding of "needs"), which structure a large part of the design processes, from the project specification and the drawing up of the project budget to the organisation of creativity and the evaluation of the results.

<u>Project specification and budget formulation: themergence of procedures and the need for justification</u>

Project-based organisation involves bringing together several professional specialities and competences in order to work towards the same goal. How can a diverse set of R&D employees be mobilised to achieve the same objective? Although diversity may be necessary, it nevertheless needs to be controlled. Even within the same firm, a clear distinction is frequently made between the "German" concept of the R&D function and the "British" approach, with the former remaining very strongly attached to the autonomy of the R&D function vis-a-vis business units and the latter showing itself more receptive to short-term commercial concerns; the "French" approach tends to lie somewhere in the middle.

From this point of view, the preparation for a project is very significant. It is subject to a standard validation process that applies to all the subsidiaries in a multinational group. As part of this process, the autonomous actors in the subsidiaries are called on to justify their intentions and the means to be deployed in giving concrete form to those intentions within the framework of a very explicit monitoring programme that is activated prior to and during the project. For most firms, the presence of a company of North American origin has been decisive in determining the speed at which this type of management is adopted. Projects are specified in discussions between marketing and R&D managers. The discussions focus on the value of the project in the light of the subsidiary's particular remit and of an analysis of its costs and benefits. The actors putting forward the proposal must supply a detailed breakdown of the project, dividing it into various phases that will constitute a ready-made schedule for monitoring. The project is submitted to a committee of experts made up of financial managers, technological experts and representatives of the R&D co-ordination committee at multinational group level. This committee decides on the project launch and its budget allocation. The committee's decisions are taken within a budgetary framework allocated by head office to each of the sites on the basis of its previous results. Thus the project must be prepared with its overall coherence in mind: it must both justify the value added it may create and provide proof of the availability of the resources that will be deployed, both internally and in collaboration with external partners. In this way, interaction between the different professionals is encouraged in order to ensure that proposals link the needs that emerge from knowledge of clients with the resources created from the production of scientific and technical knowledge. The encouragement must be all the greater since the actors are urged to interact on the basis of very different relationships to time and to risk. Marketing professionals consider short-term risk in terms of the image they have of users, regard the duration of a project as a time frame imposed on them and expect their colleagues to provide solutions that are ready for use. This is why they have a preference for shorter projects that are finalised on the basis of a risk assessment. For technology professionals, risk is an inherent part of exploration and of the unfolding of the project; from this point of view, it constitutes a variable linked to the competences of the researchers and engineers who make up the project team. Risk is not defined in the same way by all the actors: for technology professionals, a project represents an opportunity to construct new knowledge, while others see it as a means of attaining commercial targets. Nevertheless, we are not really dealing here with a "client-supplier" relationship, since the actors on both sides have scientific or technical competences that enable them to discuss in detail their needs and proposals. A certain degree of homogeneity in these technical competences, in some cases the fact of having taken the same course of education or training, combined with functional mobility among employees, may facilitate the discussions that lay the groundwork for a project. Thus cognitive proximity between the actors facilitates the preparatory stages of a project: they are marketing managers who usually have technical expertise and have worked in R&D departments or engineers who have experienced functional mobility and are therefore valued contributors to the discussions.

This co-ordination is based in part on the business units, which are responsible for maintaining the company's competitive position. In this case, R&D is a resource, but at the same time one whose specificities are fully recognised. On the one hand, it is R&D that provides some of the business units' jobs. On the other hand, it is R&D managers who have the task of ensuring that the internal and external resources required to conduct projects are available. As a result, the process of laying the groundwork for projects is non-linear. This is self-evident to all the firms. This process may be based on more or less structured networking practices, which will be analysed subsequently.

The organisation of creativity and evaluation

The complexity of these professional interactions is also revealed as projects unfold. It has become commonplace to make a distinction between "cosmopolitan" and "local" attitudes among the actors involved in projects (Petz and Andrews 1976). The former, which are also described as "professional", guarantee access to useful knowledge through their involvement in scientific communities, while the latter, which are also described as "organisational", are more committed to the success of projects by virtue of their greater involvement in routines. In the absence of any real certainty about the different variables affecting a project, each actor is in fact led to produce hypotheses and demands to put to his or her colleagues. Depending on the situation, a biologist will sooner or later declare himself more confident than his colleagues about an experiment's chances of success, while a computer engineer will seek his colleagues' support for his ideas for future uses of the Internet. In this respect, the project manager cannot be said to control the interactions. In fact, it is known that the composition of teams must fulfil two major conditions: the actors must complement each other and their behaviour must be compatible (Hagedoorn and Schakenraad 1994). It is at this point that the dilemma of professional interactions is defined: cognitive as well as social proximity must be privileged without impairing the necessary diversity of approaches to both the forms and content of innovation. Thus here we have the problem relocated within the framework of the actors' autonomy and management's leadership practices. When a project is being completed, the interactions occupy a different strategic dimension. The aim at this point is to define the lessons that have been learnt. What individual learning processes have the actors been through? How can a consensus be reached in order to make official what has been learnt collectively? As the accumulated experience undergoes a process of objectification, the interactions produce agreements and differences of opinion. This raises an issue of knowledge management: who is going to accumulate the knowledge that has been acquired, and by what means? These questions are important ones from the point of view of giving renewed life to the project teams. If a project finishes by achieving its objective, the experience it has produced will be durable: the successes and failures experienced by team members shape their attitudes and necessarily affect each team member's involvement.

The organisation of creativity is left to the discretion of local project managers. However, it is monitored by evaluation procedures which, at regular intervals (every quarter or every month depending on the nature and duration of each individual project), determine each project's future. The evaluation is carried out by a functional project director whose task it is to apply the rules laid down for the whole group to each of the R&D sites. The aim is to assess each project team's progress in terms of the objectives laid down at the outset : time allowed for each of the phases, adherence to the allocated budget, production of new knowledge, technical reliability and commercial relevance of the project output (prototypes, software, simulations). This type of evaluation has several further advantages for multinationals:

- the standardisation of project control despite the particularities and individual requirements of each project;
- the opportunity to compare projects (benchmarking), both within the firm and against those undertaken by competitors;
- the dissemination of an approach to evaluation to every level of the management hierarchy;
- the identification of which teams are quicker or better producers of knowledge than others.

Nevertheless, project evaluation does not eliminate diversity within firms; rather, it provide guidelines for controlling the distribution of resources (by giving management the means to halt a project in order to concentrate resources on another) and to identify to some extent the potential of individual teams.

The rationalisation of academic collaborations: justifying and sustaining multinationals' cognitive networks

Academic collaboration is subject to the same constraints as the management of the competences of R&D personnel. Developed on a local basis by taking advantage of the opportunities of the moment, academic collaboration must now be justified to central management by local managers. The objective here is to make these collaborations transparent in order to assess their relevance and to provide co-ordinated guidance for firms' actions. This seems to be a particularly ambitious goal. On the one hand, it is not difficult to understand why firms engaged in technological globalisation should seek to put in place networks of contractual and relational resources. In the sense that it constitutes a potential source of new knowledge, collaboration must be able to be of benefit to any unit that feels the need for it. On the other hand, academic collaborations tend to follow patterns of development that cannot easily be generalised. Current approaches to the creation of shared knowledge emphasise several factors: regularity of contact between the partners, the type of relations fostered when projects are being specified and the fostering of relations that allow tacit knowledge to be brought into play and common practices to be gradually developed (Doz and Shuen 1995), (Inkpen 1996). It is also known that the joint production of knowledge and the absorption of academic knowledge depend on the local infrastructures for disseminating such knowledge.

Thus even when they are standardised to some extent, collaborations retain a strong personal dimension. They tend to give rise to fairly durable links and academic research laboratories seem to be very attached to them[21]. Multinationals' attempts to rationalise their academic collaborations in Europe can be summarised by outlining three significant developments.

- The first important development was the consolidation of the globalisation of collaboration strategies. As a result of the changes they had made to their own internal structures, firms had equipped themselves with the means to apprehend their portfolio of collaboration at the international level. The first direct expression of this was the establishment of global collaboration functions whose specific task it was to co-ordinate the academic relations of the various units. This transnational mode of organisation frees subsidiaries from the local constraints on collaboration. In principle, it should enable each subsidiary to forge links with the academic partner of its choice within the multinational's network. In fact, this organisational ideal is dependent on the functioning of internal information networks: everything depends on the quality of the co-ordination between local managers in charge of collaboration and the ability of project managers to adapt their practices to different contexts in order to absorb the knowledge. This development manifested itself in different ways in different sectors. In the pharmaceutical industry, it took place in two successive phases on the American and European continents. First, many German and French firms set themselves up in the United States in order to build up very quickly the collaborative links they needed to support their specialisation in bio-engineering. These foreign ventures gave a more global dimension to their traditional portfolio of collaboration during the 1980s. In the following decade, American firms made the trip in the opposite direction, forging closer links in Europe. Changes in the regulations on intellectual property rights have made them more favourable to

[21] Going against the current of general writings on the relationships between academia and industry, several phenomena need to be highlighted. Firstly, such relationships have existed on a large scale for a long time, and in some cases they have been very intensive. Secondly, they have always been a matter of concern to industry, even in countries reckoned to be hesitant in this regard. Thirdly, it was scientific communities and not national entities that were very quick to seize on these relationships as a relevant space.

universities and have in fact encouraged multinationals to increase their investments in European scientific networks. In the IT and telecommunications industries, the globalisation of collaboration took place earlier, particularly in non-European firms, firstly because of the shorter duration of R&D projects, which made it easier to establish a greater diversity of links, and secondly because of the quality of the partners: engineering schools adapt more easily to these relations than universities.

- The second development concerns the quality of the relationships between the partners. As in the case of the internal management of knowledge, collaboration has led to the introduction of various management mechanisms and has caused firms to give detailed consideration to the needs of their academic partners. These needs seem to play a major role in the negotiation of contracts between the partners. Universities have realised that the various types of collaboration give rise to two effects that may jeopardise the development of their research activities. Firstly, the recruitment of students by firms - sometimes even before they have completed their degrees - may well lead to a shortage of candidates for publicly funded research posts. Secondly, by insisting that relations remain exclusive to some degree, firms risk segmenting the supply of academic scientific and technological knowledge. As a result, collaboration contracts are now explicitly taking greater account of the needs of academic partners, which is regarded by firms as a promise of trust. This acknowledgement of the needs of academic partners is also an attempt to respond to the aspirations of research organisations in respect of intellectual property rights, since the latter are showing themselves more demanding than in the past when it comes to the division of rights.
- A third, more recent development has seen a concentration of collaboration among a smaller number of partners and a greater insistence on exclusivity. It will be particularly interesting to observe the results of this strategy in the longer term. Multinationals are gambling on structuring scientific networks not on the basis of a collection of regional or national spaces, as has been the case hitherto, but rather at area level. The intention is clearly to secure a diversity of sources of knowledge and competences, in the European area for example, for the actors in telecommunications or life sciences. The exclusivity aspect of this strategy is not entirely consistent with the greater recognition being given to the needs of academic partners.

These developments manifest themselves in different ways depending on the technology policy being pursued.

- Those firms that have the most ambitious technological programmes and are seeking to be world leaders find themselves needing to combine several different levels of academic collaboration. On the one hand, they tend to establish long-term partnerships with a small number of research institutions operating in basic disciplines in order to maintain a supply of new research findings for their own long-term research activities. In this area, the firms tend to favour exclusive collaboration. On the other hand, they also collaborate with universities and research institutions on specific programmes geared to shorter-term technological developments, albeit also within the framework of long-term agreements. In general terms, firms in this category are seeking to consolidate and extend their technological base.

- Those firms that have positioned themselves in technological niches, those that concentrate on the "service" element of their output (we do not include the pharmaceutical industry here) and, finally, a few recently established subsidiaries of multinationals tend rather to use collaboration as a general source of technological knowledge and know-how. A division of labour seems to have emerged, with the R&D unit focusing on product design and the academic establishment providing very specific knowledge, industrial processes or technical tests, sometimes as an alternative to a commercial supplier.

Thus the nature of collaboration with academia seems to change as R&D organisations themselves evolve. However, the structures are not in themselves capable of supporting innovation projects, so the various resources have to be allowed to develop as opportunities present themselves. From this point of view, it is very interesting to analyse the co-ordination processes that are emerging in R&D units with the aim of reconciling incorporation in globalised knowledge management structures with the more localised creation of competences.

3.2.2. Science/Industry relationships and Actors of innovation

The following two subsections concur in two ideas, firstly that the modes of production and regulation of the higher education and research system, on the one hand, and those of firms, on the other, differ profoundly[22] (and, secondly, that relations between higher education and industry play a major role in the dynamics of innovation.

In the first subsection, these two systems are seen as having their origins in divergent, not to say antinomic principles, even though various areas of compatibility can be identified. In the second one, on the other hand, an "intermediate" innovation space is defined right at the outset as a set of interactions and mobility flows between the two systems. Both chapters make the point that collaboration is on the increase and agree on the need to go beyond mere acknowledgement of the heterogeneity of higher education-industry relations[23]. The view is taken that the partnership relation has to be apprehended in its totality (rather than focusing exclusively on the contractual form of the relation) in order to give meaning to the variety of possible arrangements and eventually to construct typologies.

With approaches rooted in two different disciplines, economics and sociology, these two chapters take different variables into account. Moreover, the first one confines itself to transfers of knowledge as it proceeds with the task of modelling industry-science relations, while the second is also concerned with the interactions through which the competences of the actors involved in innovation are produced.

The first analyses the relations examined in the company case studies carried out in the course of the SESI project in an attempt to ascertain whether the objectives of industrial and academic actors converge or diverge. Locating itself within the "new economics of science" approach (Dasgupta and David, op. cit.), it uses the notion of "research agenda" in order to explain the various forms of accommodation between the interests of the industrial and academic protagonists in these relations. Furthermore, this approach seeks to be a dynamic one in order to take into account the changes that have taken place in industry-science relations as the process of innovation itself has changed. Thus the relations are classified in accordance with these various objectives. The models and typologies thus produced are an attempt to define good practice in a way useful to public policymakers.

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[22] Dasgupta P., David P., 1994, "Towards a New Economiccs of Science", *Research Policy* 23 (5).

[23] Cohen W.M., Héraud J.A., Goe W.R., 1994, "University Research Centers in the United States", Canergie Mellon University.

The second subsection extends the relation to encompass public actors; in doing so, it adopts the triple helix approach (Etzkowitz and Leydesdorf 2000)[24]. It begins by identifying a number of intermediate actors and relational principles at work between the three systems, the existence of which in turn reveals a number of different intermediate innovation spaces (Lanciano et al., 1998)[25]. This chapter presents a typology of these relational principles and of the actors involved in them that incorporates their trajectories, and in particular the transition between formal and informal relations. It then goes on to investigate the variables that structure these intermediate spaces, namely the (multinational) firm effect, the innovative milieu effect, the sectoral effect and the national effect, before finally putting forward a method for analysing the relations between the various actors.

I) Research Agenda and Science Industry Relations (for a detailed analysis, see the chapter of Nicolas Carayol in final report of July 2001)

This part begins by recalling the evolution of the economic literature on Science Industry Relations. It notices that the growing importance of the phenomenon encourage numerous authors to question the consequences of this phenomenon: they have sought to identify the benefits as well as the risks and costs stemming from a large number of science-industry relations. Such relations are thus at the heart of a larger problematics posing the issue of how science and private research "fit together" which includes the question of the implications of science-industry relations on the returns from public research in both the short and long term?

It opposed two main approach of this relations:

- The first placed under the heading "new economics of science", (Dasgupta and David (1994, (David et al., 1995).). For these authors, the problem lies elsewhere: the social division of research labour, assigning basic research to science and applied research to the companies, guarantees the existence of a "dynamic balance" between open science and industry in these two worlds. Such a balance comes about naturally and it should be maintained[26]. The only relevant public policy issue thus becomes better promotion of the dissemination of scientific knowledge from science towards the companies, without calling into question the intrinsic efficiency of open science in the collective production of knowledge. Science-industry relations are justified solely because they permit better transfer of tacit knowledge.
- The second is widely known under the generic name of" Mode 2 of knowledge production". These authors stress interdisciplinarity, the co-production of research in networks of science-industry collaboration and the production of knowledge in the " context of application " (Foray and Gibbons, 1997). Their focus is radically orientated towards the distribution of knowledge and even more so towards the adaptation of the supply of public research to the companies' demand. It systematically highlights the fact that the relations between academic and corporate researchers may contribute to producing knowledge with more obvious potentiality for application.

Overall, these two approaches would seem to occupy separate and irreducible fields of analysis in numerous respects, notably in their prescriptions of public policies,

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[24] Etskowitz H. and Leydesdorff L. (2000), *The dynamics of innovation: from National Systems and "Mode 2" to a triple helix of university-industry-government relations*, Research Policy 29, pp.109-123.

[25] Lanciano-Morandat C., Maurice M., Nohara H., Silvestre JJ. (Eds) (1998*), Les acteurs de l'innovation*, Edition l'Harmattan.

[26] On this point, a heading from the article by Dasgupta and David (1994) is significant: "Policy changes: maintaining science and technology in dynamic balance" (emphasis added).

since the "new economics of science" insists on the limitation of science-industry relations while the "Mode 2" authors emphasise (implicitly at least) their systematically beneficial nature. In order to bridge this theoretical gap, it is crucial to arrive at a better understanding of the microeconomic mechanisms simultaneously called into play within science and in the course of science-industry relations. While such an enterprise goes beyond the purpose of this paper, our aim here is to propose the use of the notion of "research agenda" as the "missing" concept which would allow the oppositions between the different approaches to be reduced and to provide a more in-depth treatment of the problematics of science-industry relations. These agendas are the research objectives that the agents set for themselves. We would argue that they are crucial both in the functioning of open science (in normative and positive terms) and for the establishment of science-industry relations and the participants' returns and ultimately on the way that science and markets fit together.

The empirical evidence on which we have based our analysis comes from original data collected within the framework of the SESI project[27]. These take the form of fifty in-depth case studies of science-industry relations in six countries (Austria, Germany, France, Portugal, UK, US) with industrial partners in the sectors of information and telecommunications, pharmaceuticals or health-related biotechnologies. The variables surveyed mainly deal with knowledge, partner strategies, original organisational solutions adopted, cash flows and intellectual property agreements.

Our presentation is organised in the following manner: after examining how research agendas are at the very core of the functioning of open science, we demonstrate how they allow a better understanding of the process of establishing relationships between public and private researchers. In particular, the introduction of new variables such as the expected benefits from the exploitation of synergies with collaborative research efforts or the academic researchers opportunity cost borne by the partial diverting of their own research agendas because of the collaboration suggests that two opposing forms of relations can be distinguished in practice. On the basis of the empirical data, we propose initially a typology which brings out six coherent types of science-industry relations and then compare the data and typology to the theoretical propositions from the preceding section in order to show that they are consistent (f. . Then we shall argue that the relations generate dynamic effects which may be distinguished on the basis of the two kinds of collaborations and that they lead to two ideal-typical models of collaboration (called A and B), with distinct original properties stemming from the relationship created between open science and the markets.

i) The types of science-industry relations

We have been able to constitute six coherent types of science-industry relations, which we shall briefly summarise here.

Type 1, **The most simple version of the collaborations**. It illustrates a situation in which an academic player already has application potential, expertise or technology (because of the player's area of scientific specialisation). The marginal investment needed to develop it thus relatively slight and may be accomplished through a doctoral dissertation or even a master's thesis. The academic partner perceives the relation simultaneously in terms of a complementary development of its knowledge, an opportunity for student placement and the establishment of an industrial

[27] SESI is a TSER (Targeted Socio-Economic Research) project funded by the European Commission's DG XII (contract SOE1-1054, project 1296).

tie which can subsequently be strengthened. The industrial partner sees this relation as a means of creating ties with a potentially new academic partner and thus testing its capacities as well as an opportunity to benefit from knowledge at a relatively low cost, which it can absorb totally by purchasing the technology and/or hiring the PhD who has carried out the research.

Type 2, **A strategic bilateral relations** most often based on framework agreements extending over several years and possibly covering a large volume of research[28]. The academic partner is specialised in topics with a strong application potential; it tends to adopt a dedicated, integrated organisation in order to meet specific industry needs (respect of deadlines, responsiveness), to attract their collaboration budgets, (industrial partner clubs) and limit the costs of collaborative research. Industrial funding occupies an important share of their budget, which often compensates for difficulties in obtaining a sufficient level of supplementary public funding. By stabilising the funding from one or several major players in related sectors over several years, it thus stabilises its own funding in the future. The industrial partners offer a natural opening for their PhDs, who cannot all be absorbed by the academic labour market (which reinforces the ties even further over the long run because the PhDs become potential clients). The academic partner observes industry's needs and attempts to anticipate future demands, which allows it to select research directions which will turn out to be most fruitful in terms of science-industry relations. It also plays on synergies between lines of research and thus benefits from increasing returns.

The industrial partner outsources its research in this context mainly on the basis of a low-cost research offering (it could carry out the research itself but this would cost much more). The research is not at a very high level, entails relatively few risks and is likely to yield innovations in the short and middle term (6 months to 5 years). The industrial partner often hires the PhDs who have been directly involved in the research projects funded. As the partner has been able to observe their abilities over a relatively long period of time, there is less asymmetry of information and the work contract is generally more stable. By hiring the PhDs involved, the partner is sure of being able to absorb the knowledge produced (notably tacit knowledge) if this turns out to be useful. This permits the industrial partner to compensate for the risks of losing competences through the outsourcing of the research. The academic partner is responsive to its needs (as permitted by the establishment of considerable decentralised relations between engineers and academic researchers) and has appropriate organisational structures. In addition, the industrial partner may influence the academic research agendas and encourage specialisation in fields deemed promising in terms of its own research needs. In most instances, the industrial partner insists on maintaining the industrial property rights for the collaborative research because such research is generally rather close to development.

Type 3, **Consortia associating several research laboratories and several firms**. These are most often set up on a national basis and benefit from considerable public funding. The broad objective common to academic and industrial partners is the building of bridges between their two worlds, thus permitting both the development of the interpersonal relations which will provide the basis for subsequent bilateral agreements and the joint creation of the cognitive bases for a shared research field. The academic partners have many of the same features as those of type 2 and are in fact often involved in this kind of relations as well. The firms are interested in this kind

[28] One case of a consortium has been included in this type because the collaboration involves only one academic partner and three industrial partners, one of which has a preponderant share.

of relations mainly because of the low costs: jointly produced knowledge and major investments are shared (in part or entirely) and there is generally additional public funding. The firms are most often required to make considerable concessions on research content, however, and the periods necessary for structuring the project can be long. There may also be significant problems with IPR and the sharing of technical knowledge because of the large number of partners, who may be direct competitors (while the research projects may be exploited rather quickly).

Type 4, **Collaborations which are riskier than the preceding ones**. They do not entail large amounts of funding. The academic partner is generally at a higher level of excellence, specialised in a narrow field of competence and less inclined to let itself be swayed from its research agendas. Its research projects have less potential for direct application than the previous types. The industrial funding thus almost exclusively supports lines of research deemed likely to earn recompense within the scientific community itself. The company takes a greater risk in funding this research than in the preceding types but it nonetheless commits itself to these collaborations because they should allow it to maintain its capacity for innovation in the middle and long term and/or get beyond a recurring technological obstacle. In this context, the industrial partner is less inclined to influence the academic partners' research agendas, precisely because, in its eyes, their interest lies mainly in their originality. This kind of relationship is most often spontaneously organised and flexible. *Type 4* also includes the endowment of university chairs (2 cases), the content of which is increasingly directed towards the development of original research projects on behalf of the industrial partner.

Type 5 **Original cases of science-industry relations.** These occur within academic research funding programmes developed by European pharmaceutical companies, which use science-industry relations as leverage in the reorientation of pharmaceuticals towards biotechnologies. These programmes have allowed them to create numerous ties with academic laboratories which previously had little contact with the firms. In this situation, since the company's main objectives were to establish networks of collaboration and develop multiple learning situations, it did not seem relevant to orientate the academic partners' research topics but rather, to benefit directly from the most advance research in the scientific field. Thus, the academic partner profits from industrial funding in order advance lines of research which it had defined in accordance with its objectives for academic rewards. In this respect, this type shares many common features with *types 4* and *6*.

Type 6 Cases which are distinguished by:

- **the research content is at once of a high scientific level and risky for the firm for one thing;**
- **it implies significant funding from the firm (unlike *type 4*) for another,.**

In the firm's eyes, these two points are compensated for because the anticipated returns in case of success are extremely high. It should be noted that all these cases of collaboration imply the development of emerging research paths (bioinformatics, gene sequencing, new path in electronics, new mathematical methods of telecommunications monitoring and management). These relations thus give academic researchers (and often corporate researchers as well) opportunities for important discoveries and major recompenses as pioneers in emerging lines or fields of research. They do not consider themselves constrained in their choice of agendas; on the contrary, the relationship offers important leverage for the advancement of their lines of research, notably those which are not yet well received by the academic establishment. The organisational forms adopted are rather varied and adapt fairly easily to the objectives, with the common goal largely guaranteeing the partners' involvement. The participants are notably mixed laboratories and private research teams located in a scientific environment.

It should also be noted that nearly 70 percent of the cases concerning companies in the pharmaceutical and biotechnology sectors belong to the last three types while more than 70 percent of the cases concerning firms in the information and telecommunications sectors belong to the first three types .

Four of the spin-offs in our sample are involved with software technologies (notably for the Internet) which represented a by-product of the research activity (most often PhD theses) conducted at a specialised research institute. They have thus been classified in *Type 1*. Two biotechnology spin-offs which were the subject of specific high-level research projects have been classified in *Type 4*.

ii)Typology and compatibility of the agendas

Here we are comparing the theoretical grid and the typology derived from the empirical data. The typology clearly brings out the partners' strategic objectives in the collaboration. *Types 1, 2* and *3* describe situations where the academic partner's requirements concerning the expected rewards of the collaborative research are less significant than in *types 4, 5* and *6*. Similarly, the cases of the first three types clearly correspond to situations where the collaboration represents a less risky investment for the industrial partner than in the last three types.

We may thus conclude that the empirical data tend to confirm the theoretical grid. Certain limitations must be noted, however. First of all, the data only concern real cases of collaboration and we have not specifically studied relations which might not have been concretised, while the theoretical grid attempts to explain relations and non-relations alike. Second, measuring the scientific excellence of the research projects is also extremely difficult and partial and is not based on indisputable data. We would argue, however, that there is no irrefutable measurement system available and under the circumstances, an in-depth case analysis is always preferable.

Toward two models of science-industry relations: Compatibility of research agendas and dynamics of science-industry relations

Developing a typology and a static interpretative grid helps us to understand a complex reality at a given moment in time. The relationship itself must be seen, however, as a source of change insofar as it constitutes a resource for the partners. In order to grasp these dynamics, it must be seen that one of the consequences of establishing science-industry relations is precisely the establishment of new science-industry relations. In the context of the surveys carried out, there appear to be four main types of dynamic effects.

First of all, the creation of a science-industry relationship may lead to the creation of specific organisational mechanisms for the management and evaluation of the collaborations. Thus, the fact of having established or continuing to establish science-industry relations can reduce the costs generated by new collaborations.

Second, science-industry relations permit the creation of networks of interpersonal relations. Third, the partners arrive at a more in-depth understanding of their research practices and needs through the relations they form. The academic partner is better able to respond to the industrial partners' needs and the latter are more able to benefit from the competences of the former. These mutual learning experiences lead to the creation of knowledge which is, in various ways and to different degrees, conceived to be developed by the different partners. They thus increase their knowledge bases in the direction of greater compatibility between them. The relationship can, on the one hand, lead to greater economic relevance of the academic player's lines of research and, on the other, increase the industrial player's capacity to absorb and develop the scientific knowledge.

It should be noted that these different dynamic effects are far from "pure". For one thing, they are not independent of each other and are most often combined. For another, they can be more or less specific to the initial partner; for example, the third dynamic effect, which depends on the learning of reciprocal needs and competences, is generally more specific to the initial partner, or in other words, that it particularly increases the propensity to collaborate with the same partner. Finally, the national institutional structures may considerably influence the way in which these effects occur.

In any case, it is rather difficult to predict exactly what these dynamic effects will be and there is obviously also a random dimension. We would argue, however, that they way they come into play may be distinguished in terms of the two forms of relations and that they are generally reinforcing. Indeed, the establishment of one of the two forms of relations seems to reinforce the features which predispose the agents to collaborate according to this same form and leads them to undertake quite specific strategies. This leads to two global forms of ideal-type co-operation which we shall call Model A and Model B (and which are briefly summarised in Table 3). These models of collaboration also include a certain normative dimension in that they seem to display properties which are distinct but economically and collectively pertinent and which emerge from the interrelation of the two worlds of open science and the markets[29].

Model A: Cumulativeness and social demand

In Model A science-industry relations, the academic partner's overall strategy is to increase its volume of research, even if this means allowing itself to be distracted from its research agendas. To this end, this partner needs to adopt a specific organisation concerning science-industry relations (in order to increase its visibility and reduce its costs). It attempts to maintain relations with several industrial partners in the same sector for greater development of its research projects and to deepen existing relations with one or two strategic partners in order to stabilise funding. If the academic partner is ready to be distracted from its agendas, it must still preserve its internal thematic coherence in order to benefit from synergies between its lines of research. But this requirement is not incompatible with the relations it maintains with industrial partners; on the contrary, once it is keenly aware of the problems faced by industrial concerns in a given sector, it can benefit from specialising in the production of knowledge which is useful to them. It thus undertakes a kind of "cognitive Darwinism", selecting the lines of research which will be pertinent to industry in the future. It plays the role of pooling information on the needs of the industrial partners and codifying their technical problems in order to provide common scientific responses.

This does not mean that it detaches itself from the academic world (since public funding remains its main source of financing) but it maintains secrecy about technical data and especially the industrial partners' objectives and avoids publishing research results before patent applications have been made. In this respect, the academic partner is usually ready to sacrifice intellectual property rights on collaborative research in order to fulfil its strategy aimed at the increase in the volume of research, especially

[29] This does not mean, however, that there can be no coexistence between the two forms within a single discipline, sufficiently large research laboratories or university departments. In general, the effect of the collaboration is more apparent as the level of analysis descends from the laboratory or university department towards the research group itself. It is also possible that there is a certain interpenetration between the two forms but in our view this would be difficult.

since the industrial partner is all the more concerned with maintaining the ownership of knowledge relatively close to development.

The low cost of the research carried out by the academic partner encourages the industrial partner to outsource research that was previously carried out for the most part in-house. The cost is further reduced when the relationship takes the form of a consortium. The outsourcing does not entail a loss of know-how because the industrial partner can hire the PhDs who have carried out the collaborative research. The establishment of decentralised, long-term interpersonal relations allows the development of research projects likely to find solutions for technical problems that have been set aside. It uses the leverage effect of funding to encourage the thematic specialisation of the academic partners and thus encourage the emergence of centres of competences useful in the long term.

As a result, the bilateral and multilateral collaboration networks are fairly dense. Relations can be quite intense in the form of strategic collaborations; these strong ties are developed over the long run with a self-reinforcing dynamics, more specifically with the initial partners (who have a mutual advantage in prolonging or even intensifying relations with the same partner).

The collective effect of this dynamics is a specialisation of research laboratories in fields which conceptualise the industrial partners' technical problems while largely maintaining the dissemination of knowledge. Thus, the properties of efficiency intrinsic to open science (based on the cumulativeness of knowledge) are for the most part preserved while clearly integrating the industrial partners' needs. This idea largely overlaps that introduced by the authors of the so-called finalisation thesis (Böhme et al. 1983) who maintain that a discipline can be finalised in an "appropriate" way in its "post-paradigmatic phase" (i.e., when it reaches a certain level of maturity). In economic terms, an "appropriate" finalisation means that the orientation of the research agendas is collectively efficient. There is no longer any conflict between giving a research project applied objectives and undertaking fundamental interrogations. This idea is integrated into the notion of "basic oriented research" (developed by the finalisation thesis), which contests any systematic opposition between fundamental and applied research. This reading is consistent with the description of the engineering sciences proposed by Rosenberg and Nelson (1994) and Detrez and Grossetti (1998) or that of the transfer sciences proposed by Blume (1995) and corresponds at the level of collective efficiency to certain arguments developed by Romer (1993).

<u>Model B: creativity and social demand</u>

In Model B science-industry relations, the academic partner's main objective is to exploit the advantage offered by its scientific edge in a narrow field of excellence. Its funding sources are mainly public and its PhDs generally find career opportunities in the academic world. It only establishes relations with industrial partners when the collaborative research is likely to reinforce its own lines of research and are thus only perceived as sources of additional funding. It is little inclined to permit itself to be diverted from its research agendas; which may if need be suggest and provide information about medium- and long-term applications of its knowledge.

The industrial partner undertakes such risky collaborative research because it anticipates high returns in case of success. The partner is often quite advanced itself in the field of investigation involved, which is necessary for the absorption of the academic partner's knowledge and that produced in the course of the relationship. This relationship may allow it to expand its positions still further and gain a notable advance over its competitors in the mastery of promising fields.

The Model B relationship is thus more orientated towards increasing the excellence of the two partners' research in a narrow field. The resulting science-industry collaboration networks are less dense than those of Model A. The volume of collaborative research may be very high in certain cases but there are fewer science-industry relations and they are less stable over time.

If the collective outcomes of the Model A relations have already been explored in the literature, those of Model B are more difficult to grasp. We would suggest, however, that they play an important role in the emergence of new fields or lines of research radically influenced by the needs of industrial partners.

Indeed, the academic partners considered here are mainly seeking a form of scientific excellence which may consist in contributing to the emergence of new research fields. These path-breaking research projects are precisely the ones which industry is likely to fund because they suggest a large range of new applications. In particular, interdisciplinary research projects are of considerable interest for science-based technologies (Gibbons et al., 1994; Meyer-Krahmer, 1997). This suggestion is supported by the empirical evidence stemming from our data, notably the cases of science-industry relations corresponding to *types 4* and *6* of our typology, namely those which are closest to our Model B. Type 6 relations involve all the research projects in emerging fields (e.g., bioinformatics, gene sequencing, gene therapy, new paths in electronics, new mathematical methods). *Type 4* relations, even if they are of a lower volume, generally also concern original research projects exploring bran new paths.

Table 1: the theoretical zones of compatibility between potential partners in LL and HH

		Strategies of the **Academic players**	
		Increasing their volume of research by pooling information on needs and codifying solutions of industrial partners	Deepening their knowledge in a specific area of excellence by collaborating only within this field
Strategies of the **Industrial players**	Benefiting from research at a relatively low cost in an integrated, systematic and less risky way	**Model A** lower risk lower expected reward stronger ties dense networks Cumulativeness and social demand	
	Entering a research field by contributing to its emergence so as to benefit from an important advance on its competitors even if he has to bear greater risks		**Model B** higher risk higher expected reward weaker ties bilateral relations Creativity and social demand

II) Firms, high education and research systems and public action: the principles animating the relationships between actors in the innovation process (for a detailed analysis, see the chapter of Caroline Lanciano-Morandat in final report of July 2001)

The purpose is here to apprehend, by adopting an actor-based approach, the diversity of interactions between innovation systems in firms and higher education and research systems (HERS).

Social scientists are divided in the way they apprehend the production of scientific and technical competences and knowledge. Some stress the difficulties caused by the fraught relationships between the two contradictory worlds of business and industry, on the one hand, and academic teaching and research, on the other. Others emphasise the "well-established cooperative links" between science and industry that contribute to innovation, in particular through the professionalisation of teaching and the establishment of socio-technical networks. Yet others claim that these two positions merely represent two separate historical phases.

The contribution begin by locating this approach of the “intermediate innovation space” in the context of the literature (1). Then it proceed to identify the various actors and the different principles animating the relationships between them and to construct the various possible couplings of relational principles and actors (2) in order, finally, to seek out the variables that structure these couplings at a more general level (3).

1)The "intermediate" innovation space as a basis for constructing relations

This paper is based essentially on two types of analysis, societal analysis and triple helix theory, but it also takes account of ideas and tools developed by sociologists at the Centre de Sociologie de l'Innovation at the Ecole des Mines in Paris. It focuses on the actors in innovation, on the emergence of new actors and on the type of organising principles produced when relationships are established.

a) The societal analysis of innovation (Lanciano et al. 1997, 98) places the actors at the heart of the innovation process. They are not the agents of economic theory, nor mere individuals nor even Crozier and Friedberg's exclusively strategic actors. In societal analysis, the term *actor* "*denotes any individual or collective entity having a capacity for socialisation or structuration*" (Maurice, Sellier, Silvestre 1982). Thus it can be applied to individuals, to occupational categories, to an organisation or to an institution, depending on the level of analysis. At the microeconomic level, the interactions between actors will be primarily those between individuals or occupational categories, while at the macroeconomic level, the focus will be on the interactions between organisations and institutions. These actors have not only historical depth but also an ability to react to their environment, both of which help to shape their practices while at the same time enabling them to influence those practices in accordance with their immediate or long-term strategies. This tension between determination and autonomy is the source of both the stability of the principles animating their actions and their dynamic, that is the actors' ability to evolve. These animating principles unfurl within an institutional framework, the "innovation space".

The innovation space is, in the first instance, an occupational space (Maurice et al. 1982) and a locus of learning that is constructed in interaction with the actors who constitute it and with its environment (Lanciano et al. 1998).

This is to say that it is structured through the interactions between the construction of competences and the actors' occupational and organisation practices. In this sense, this notion draws on both the contributions of the Chicago school of sociology (Hughes) ("opportunities space" Paradeise) and on those of the sociology of organisations (Parsons). The actors/spaces dialectic has similarities in this respect with the notion of "embeddedness" (Polanyi 57, Granovetter 83, 85). Construction of the innovation space requires continuity (and hence serves to forge links) between institutional elements and occupational trajectories. These institutional elements are the policies pursued by public institutions and firms in the areas of training, occupational mobility, the hierarchisation of knowledge and know-how and organisation. Occupational trajectories (Tripier 1992), on the other hand, are the processes of socialisation undergone by individual actors within the education and training system and in firms. Thus the innovation space is not synonymous with the national innovation system (Lundval 1988, 1992, Nelson, 1993, Edquist 1997) because it is a "social construct" that emerges out of the subtlest interactions between individual actors and occupational categories, interactions which are then structured and diffused within organisations and institutions. The learning processes involved are analysed by observing the work actually done by each employee in a specific productive context (workshop, technical unit etc.) and his/her "position" (Bourdieu 197) in a social field rather than by investigating a general process at the level of the organisations in question.

The research carried out in 1997 and 1998 by researchers in societal analysis placed the firm at the heart of the new productive system and took as its starting point the assumption that innovation was an inherent part of that system: firms cannot but innovate if they want to survive and develop. Innovation is perceived as both the production of resources (not only products but competences, knowledge and know-how as well) by the firms and the endogenisation and specification (Gaffard 1989, Moati, Mouloud 1993) of the generic resources produced by the environment, that is by the educational, R&D and industrial spaces.

b) Taking transfer mechanisms as their starting point, the **triple helix theorists** (Erzkovitz, Leydesdorf 2000 a and b) extend the analysis of the innovation dynamic to embrace not only the relations between firms and the HERS but also the state. Each of the three helices represents one of the systems and has its own internal coherence, dynamic, strategy and capacity for change. Thus in recent years firms have been busy forging strategic alliances among themselves. Higher education and research systems are not only producers of qualifications and knowledge but are also economic actors, as reflected in the emergence of the "entrepreneurial university". The state is opening up itself to various public actors (various groups and institutions) (Quéré 1996, Verdier 1999) characterised more by the production of public goods at different levels (local, regional) than by their participation in acts of government. Each time these various partners establish relations, the interaction between the different modes of coherence and dynamics produces a range of non-homogeneous and non-synchronised reactions that act upon and disrupt the principles animating the partners' actions (sub-dynamic). This disruption forces each of the partners to negotiate and put in place a series of "accommodations", both internally and vis-à-vis its partners. The helices are similar to the spaces of societal analysis in highlighting the varying degrees of compatibility between different dynamics but differ from them in not constructing their systemic coherence on the basis of the interdependence between actor and space.

d) We will take these various studies into account here and place the relational principles that emerge out of the interactions between, on the one hand, firms, higher education and research systems and public action, on the one hand, and the actors involved in innovation, on the other, at the heart of current innovation systems. This coupling of relational principles and actors will be denoted by the acronym AFHEP (actors/firms, higher education and public action). A few years ago, the firm played a central role in the innovation space; today, at the beginning of the 21st century, it has moved aside in favour of the firms-HERS-public action "triad" (FHEP). This new innovation space, which will be described here as "**intermediate**", encompasses a variety of actors and relational principles.

The actors in the innovation process are no longer confined within the bounds of their respective systems and the relationships between them are mediated by "intermediate actors". The adjective "intermediate" (Callon 1991, Vinck 1999) refers only to the human actors involved. In our view, the non-human actors such as laws, technological artefacts, objects, competences and monetary incentives linked to the capacity to innovate are all elements in the process of constructing human actors identified by societal analysis. The relational principles linking the AFHEP coupling that structure this space can be distinguished from each other firstly by the degree of formalisation and secondly by the three different procedures for effecting the transition from one world to another. This first is a process of alignment (Callon 1994) among the actors themselves, the second a process of coordination among actors (Thévenot 1985) and the third involves the use of an organisation or institution to bridge the gap between the partners. Our notion of alignment process differs somewhat from that of Callon and denotes the actors' ability to draw on their previous "practical experience" in order to incorporate certain perceptions, knowledge and actions (Bourdieu 1974) into their behaviour patterns and thereby make certain adjustments to their practices. Thus irrespective of discipline and subsequent career trajectory, individuals who have completed a doctorate will have acquired the ability to work with others merely by virtue of that shared experience. They may well find it easier than others to align their different professional practices and adapt to new practices. The shared experience of having completed a doctorate makes them "compatible" actors.

However, the intermediate innovation space is also seen as a space in which actors operate amid the clashing and jostling of diverse sets of rules and values, giving rise to various tensions and conflicts. These tensions and conflicts may either represent an extension of the struggles taking place within each organisation or be a result of the relationships established between the actors or of the form those relationships take. They find expression in scientific and technological controversies and disputes arising out of social relations of domination and subordination at a more general level (Bourdieu 1976) or out of the hierarchical and professional relations within organisations that do not share the same rules and values.

The multiplicity of actors involved produces a diversity of relational principles, and vice versa. Their processes of permanent adaptation affect both the relationship itself and the helices (or spaces) that oblige the actors in the innovation process, the intermediate actors and the partners to negotiate and to jointly manage their relations. The intermediate innovation space thus delineated emerges as a tool that allows us to apprehend the actors, the relational principles and the way in which they are structured.

In the first part of this paper, we will attempt to identify and categorise the various actors in the trilateral relationship and the corresponding relational principles. In the second part, we will investigate the variables structuring the intermediate spaces.

2) The intermediate actors and the various relational principles

Analysis of the case studies reveals the existence of three types of actors involved in innovation: those in organisations, those in firms and those in HERS units.

Within this broad category, four main types of intermediate actors can be identified:

- those actors who are the medium for an economic relationship between the firm and the HERS;
- the "gatekeepers", who work for a firm or a HERS and whose function is to coordinate the two systems;
- the hybrid actors who, by virtue of having worked in both the firm and the HERS, have been through the process of aligning the practices, rules and values of their "home" system (industry or academia) with those of their partner;
- those actors who are involved in the trilateral network but are independent or on the road to being independent of the partners.

Various sets of relational principles are constructed around these actors. Each set of principles tends to privilege one type of actor rather than another. Similarly, a trilateral relationship between a firm and a HERS unit may possibly, though not necessarily, fall within the scope of several different sets of principles.

A distinction has to be made between those relational principles that are mediated mainly by relationships that fluctuate between the formal and the informal and those that are organised around relationships that are formalised in programmes of strategic cooperation.

<u>The transitions between informal relational principles and formalised relational principles and vice versa</u>

Many historical and sociological studies have shown how informal relations have led to the establishment of networks of relationships (Charpentier-Morize 1989). These relationships are frequently mediated by individual actors who have shared similar experiences during their university studies. These forms of relations are currently being brought into favour again, since they represent a particular phase in an historical process and may consequently evolve into more institutionalised relationships. They are also being taken into consideration because they remain productive when relations become subject to explicit organisation and management. In this way, informal relations may supplement relations that have been formalised in programmes of strategic cooperation. However, this type of principle is also favoured in its own right by small firms in circumstances in which there is considerable uncertainty about innovation networks (biotechnology networks) or the trajectories of firms and institutions. Despite their strategic importance, these relations are not managed and controlled by senior management in firms or the HERS but are initiated at local level by actors within the units concerned or by individual "gatekeepers" who enjoy relatively little legitimacy. Nevertheless, these relations are implicitly accepted and given indirect support by the managements of the partner organisations (Kreiner, Schultz 1993, Hippel 1987).

Three of these sets of principles were observed at work in the course of the SESI field work.

3.2.3. Co-production of competences between academia and industry : an emerging bridge institution (For a detailed analysis, see the chapter of Hiroatsu Nohara in final report of July 2001)

Our survey is based on a sample which includes a variety of companies in terms of sector, size and nationality. This variety complicates our analysis by making the situation of each company specific but we shall nonetheless privilege two entries: the national territory on which the companies operate and the sector to which they belong.

Concerning the first, the companies remain subject to the different national conditions in the production of graduates, and this is true in spite of two newly emerging phenomena: the mobility of graduates beyond national frontiers is on the rise, especially in certain segments (computer scientists, post-docs in high-tech sectors etc.); a portion of the multinationals are often innovative in their relations with local university systems where they have operations.

With regard to sectoral factors, it is possible to distinguish two technological regimes (Carlsson 1995) corresponding to the pharmaceutical sector and the information and communications technologies (ICT).

Following the Kline and Rosenberg model, the first reflects the science-based sector which is at once in direct contact with academic science (research universities and public research institutes) and associated with the co-production of competences embodied in PhDs or high-level engineers.

The second, more market-orientated, has a greater need for engineers capable of imagining technological applications adapted to the market/users. We shall attempt to address the functioning of the intermediary labour market through four aspects: co-operation between the HERS and the companies in the creation of supply capacity, the concept of practical training (student placement, internship), a typology of new graduates' recruitment and the co-production of PhD.

Interactions between companies and the HERS in the joint development of teaching programmes and the capacity for supplying new competences

The observation of our cases shows that in the United Kingdom and France alike, the national companies, representative of each sector, have contributed--and, to a lesser degree continue to do so--to the co-construction of the curriculum, certification or a given university establishment in order to develop the capacity for supplying new competences. The companies' involvement in the educational system occurs not only at formal levels but also at very informal ones, through, for example, participation in national bodies such as the Qualifications Commission which accredits engineering schools in France or the Engineer Council which supervises engineer training programmes in England, or participation in the board of directors of a certain university, or joint creation of specialised training streams, or informal participation--at very decentralised levels--in seminars, courses or mentoring of interns.

These different levels of involvement in higher education are aimed at a group of very heterogeneous objectives ranging from increasing the company's visibility in the university environment or gaining access to the cream of the student population to explicitly creating competences for that particular company, not to mention responding to a “social obligation”. For the majority of the national companies in France and the United Kingdom, these different participations, however dense and multi-dimensional they may be, do not seem to have been thought out in any systematic way or co-ordinated by an overall strategic approach.

In the English case, this lack of coherence probably stems from the fact that the business units or subsidiaries are extremely autonomous and human-resources management is decentralised if not fragmented, which makes any overall co-ordination difficult at central level.

In the French case, institutional relations have historically been constituted under State aegis between certain schools and companies held to be the “national champions” in sectors such as telecommunications, chemicals or computer science. Each major industrial programme systematically included scientific and educational sections covering the strengthening of the training capacity, improvement of the curriculum, exchanges of personnel and so on. These relations by osmosis created training programmes, particular curricula or networks for individual exchanges. But the fortunes of these results were subject to changes in political priorities and ties were sometimes frozen when the technologies, the market or the teaching programme evolved at different paces and sometimes in opposite directions. In this case, as if the companies were operating in stable cognitive environments with points of reference that were already known, their behaviour in relation to the HERS was marked by a kind of institutional automatism. Routinised over time, such automatic reflexes rigified these ties and were hardly propitious for their regeneration, which was highly necessary at a time when, as in pharmaceuticals, the fields were undergoing rapid change.

On the other hand, the multinationals observed, notably North American, manifest a strategic desire to build a systematic, overall approach relative to their different commitments to the HERS. Their two strategic aims (and the resulting practices) are clearly distinguished from those of the 'national' companies. These two aims are not always in perfect harmony but reflect the presence of strategic co-ordination at a very high level of authority within these world-wide groups.

On the one hand, there are the European ambitions which lead certain multinationals (Motorola, HP, pharma co. etc.) to place themselves immediately in the European space in order to seek out potential candidates for collaboration as broadly as possible, for example, by establishing a 'cartography of centres of excellence in Europe' or by casting a wide net over experienced engineers or researchers in the European labour market.

On the other hand, they target what are sometimes called strategic partnerships, based on a lasting relationship with certain institutions of higher education. They thus develop a long-term, all-encompassing partnership with schools or universities, often those located nearby.

What emerges, in the French case at least, is that the multinationals are not necessarily seeking to create partnerships with the “best” schools or universities but rather to set up a dense network with local schools in order to constitute a veritable reservoir of new graduates. Such a partnership leads these firms to involve themselves systematically in very broad dimensions of the management of the universities/partners in order to influence the content of the academic curriculum as well as the engineers' professional profile and ultimately to attract the students best suited to their needs.

In order to do so, some of these companies are members not only of the board of directors but also of the scientific board which determines the orientation of university research or various academic committees which define the teaching programmes. This participation in university governance is naturally accompanied by practical measures such as aid for courses, funding of facilities, organisation of internships for students and joint advising of doctoral theses or training of faculty. Beyond these classic means, which are used very systematically, they sometimes seek to influence pedagogical reform in the training of engineers by pleading in favour of teamwork and project-based learning, which make students aware of business environments.

This kind of tight interweaving of company-university relations would ultimately seem to be aimed not so much at gaining access to the 'best talents' but at a more general revamping of the engineer/researcher profile in order to make it better adapted to changing technological and market conditions. According to the assessment of certain members of management, the French-style hierarchy of schools, based on academic excellence and the capacity for theoretical abstraction, is not always relevant to industry, which is confronted with the rapidity of technological change.

Thus, the strategic partnership deployed by these multinationals may gain ground in a system which has remained relatively homogeneous and alter the national framework for the training of engineers/scientists.

The notion of internships

In nearly all the case studies published, the students' internships in the company are thought to be one of the fundamental elements cementing HERS-company relations, even if this phenomenon often has little visibility. The flows of students repeatedly crossing the borders between the two worlds each year thus constitute the main networks structuring the labour market and feeding the intermediate space of innovation. Although it is difficult to measure, the effectiveness of the internship undeniably strengthens the companies' abilities to anchor themselves in the innovative environment, which is notably true for the SMEs. Furthermore, various observations show that the players (company, university, students) are practically unanimous in stressing the usefulness of the internships. There seem to be different reasons pushing the partners to dialogue and co-operate in this area, often going beyond considerations of the short-term cost/advantage calculation.

For the companies, the organisation of the internship may permit the creation of a pool of future hiring candidates or the observation and testing of the students' individual qualities beyond the formal signalling of their academic certification, or the assignment of an intermittent technical study or the gaining of advanced information or knowledge about certain technologies through the interns. These different motivations vary from one sector to another: the ICT companies often use interns as a supplementary workforce, while in pharmaceuticals it tends to serve as a hiring filter. For the universities, the internship is one means of placing students in the labour market, gaining current information about the technological needs of a constantly changing industry and improving the quality of training or reorientating research through the resulting feedback. The graduate students, meanwhile, develop their professional ability by complementing their academic competence with practical work experiences aimed at solving concrete problems.

Beyond this general consensus over the usefulness of the internship, its status and significance differ according to the national (and sectoral) contexts of the training of engineers/scientists. Indeed, the in-company internship occupies a very different place in the programme depending on the degree of “completeness” attributed to the engineers at the end of their formal training. Three country groups may be distinguished in this respect:

- **Germany** and **France** are the two countries where training institutions are assumed to supply the world of industry with engineers in the form of “quasi-finished products”, who are immediately operational and duly certified by a title based on the legitimacy of the State (Dipl. Ing. and Ingénieur Diplômé). In this case, the training institutions necessarily integrate the internship periods into their programmes so that the students are alternately initiated to the acquisition of scientific knowledge and the learning of practical knowledge.

Engineering schools in France generally organise two months of internships during the third and fourth years and four to six months during the fifth year, which culminates in an internship report. In Germany, the *Fachhochschulen* and the technological universities both organise four to eight months of in-company internships (*Praktikum*) during the programme, not counting the periods of vocational apprenticeship (2 to 3 years in the dual system) which the majority of students carry out before entering these institutions of higher education.

Although both countries have a binary system--with institutions devoted to the training of engineers alongside more generalist universities--the practice of internships is also part of university training, which is more scientifically orientated. Local arrangements between companies and training institutions, as well as incentive systems at national level, are highly developed in order to encourage the co-ordination of internships. In spite of these similarities, given the very different profiles of the students in the two countries, the internships yield neither the same behavioural effects nor the same professional results. In particular, France is characterised by an approach based on a more multifunctional conception of the engineer's role (mixed profiles of technologist, scientist and manager) while the German approach is more orientated toward the technological profile.

- In the **United States**, the training of engineers occurs within a single university programme, in parallel with scientific training. Since the universities have neither the vocation to produce engineers nor the ability to certify them as such, they organise in-company internships only exceptionally or leave the initiative to the students themselves, through summer jobs. In neither case is the internship required within the university curriculum and engineers essentially rely on on-the-job training after graduation from the universities, on the basis of the technological competence acquired in an academic way. In terms of training at least, there is a complete break between the two worlds.

- The **United Kingdom** is an atypical case marked by the coexistence of the American-type university system where the internship is neither required nor integrated in the academic curriculum, the system of sandwich courses (one-third of recent engineering graduates), where paid--or fellowship--students alternate salaried employment and training, often in the polytechnics, and the continuing education system where a portion of those employed continue to study on a part-time basis. Two particular features of the UK case should be noted.

First, a historical antagonism between theory and practice in the training of engineers results in the fact that the sandwich course is considered as a second choice, while, with the exception of disciplines such as chemistry or biology, the practical aspects are often neglected in the more classical universities.

Second, the training institutions only grant students their academic diploma, which is separate from the title of engineer. New graduates coming from the most academic programme are thus considered “half products”, as is the case in the United States. After obtaining their diplomas (3 or 4 years of study at undergraduate level), the recent graduates have to complete at least two years in a formal training programme in the work situation and two years in a position of professional responsibility before being accredited as “Chartered Engineer”. In such a context, even if the employers request more industrial placement and recognise its utility, the internship does not quite seem to function as a mediator between the two worlds as is the case in the countries of Continental Europe.

Thus, the way internships are practised reflect both the companies' behaviours in the area of human-resources management and the conception of the engineers which the higher education institutions should to provide for the national economy. This means that they reflect as well the way the figure of the engineer is constructed in a societal context.

Practices for recruitment of new graduates

The sourcing of new graduates who are well trained and informed of the latest technological advances is one of the companies' main mechanisms for transferring knowledge and competences produced by the HERS. This kind of absorption of competences embodied in individuals is all the more necessary in view of the fact that the emerging kinds of knowledge are not easily transferable by more classical formalised means.

With regard to the recruitment practices for R&D staff, there is one constant which goes beyond the diversity observable at sectorial, national or inter-company level. Given that every act of recruitment is based on a gamble, the companies attempt to reduce the uncertainty surrounding the competence and behaviour of the person to be hired.

One way of doing so involves evaluating these individuals--and their competences--on the basis of the signals they possess, such as diplomas, final educational institution, age, experience, professional specialisations, research subjects or laboratory affiliation (Spence 1973). These signals include certain elements which are more or less objectivised (such as the diploma, which corresponds to a form of “certification” of the quality of the competence they have forged within the university system), and subjective elements which must be interpreted by the players and which yield a system of “reputation”. In general, certification and reputation constitute two major means of co-ordination which organise the matching of supply and demand on the labour market. Without minimising their “universal” contribution to the reduction of uncertainty and the lowering of costs, however, we may consider that these means of co-ordination are also embedded in national institutional mechanisms and thus diversely regulated, with extremely variable functions and significance from one country to another, notably where the labour-market entry of recent graduates is concerned. To cite only one example, certification may depend on extremely different institutional arrangements. Furthermore, these classic means are no longer entirely satisfactory for regulating matching in many segments of R&D activity or in scientific specialities where the disciplinary corpus undergoes rapid evolution. In other words, the companies can no longer limit themselves to these means of regulation in order to select the appropriate specialised competences.

They thus tend to set up, more or less explicitly, "networks" which permit them not only to contact, inform themselves about, detect and select the talents corresponding to their particular needs but also and above all to co-produce them with the HERS. The discussion of the emergence of such networks thus goes beyond the issue of informational uncertainty surrounding hiring and addresses approach the wider issue of the building of new knowledge or competences in the intermediate innovation space.

A combination of these three mechanisms, which yields different functional modes depending on the sector, region or country involved, seems to shape the form of interaction which develops between HERS and firms.

If we now consider the case studies in the United Kingdom and France, we see that the companies have recruitment practices which vary according to their size, local environment or sector but obey certain constants: the size of the company (or group), for example, shows a rather significant correlation with the local, national, European or world-wide levels of recruitment: the national companies are less focused on Europe than the multinationals; the pharmaceutical companies have a much greater demand for PhDs than those in ICT and so on. It is clear that between the various situations at hand and their specific needs, the companies develop their own sourcing strategies.

Nonetheless, the HERS institutional framework within a given country does not remain inactive; rather, it tends to introduce a certain number of specifically "national" behaviours.

Thus, the companies in France, in spite of acute local shortages, enjoy an overall situation where the supply of high-level recent graduates is relatively abundant and above all, extremely well ranked by their diplomas. In particular, the engineering schools, which attract the cream of the crop from each generation, have a very visible certification, notwithstanding their internal hierarchy of schools. The engineering diploma, supervised by the State (Qualifications Commission) and supported by group of institutional measures, considerably diminishes the uncertainty related to hiring by guaranteeing the standard of technical quality that is required of the graduates. Combined with systematic in-house internships, the companies do not seem to have any particular difficulties in choosing among the candidates.

This trust is consistent with the fact that French companies mainly employ recent graduates in R&D posts (training through research) before moving them into other functions, thus structuring the "internal market". This dominant pattern, tied to the figure of the French engineer, is above all applicable to the ICT sectors, whereas it remains relatively marginal in pharmaceuticals: since there is no engineering school for life sciences, the biologists and chemists in this sector, as well as the PhDs in pharmacy or medicine, mainly come from university programmes. But here, the majority of the new recruits are PhDs who find their place in the networks of relations between the HERS and the industry monitoring their training.

By contrast, companies in the United Kingdom are confronted not only with a shortage seen as 'generalised' but with a confusion of signals transmitted by diplomas. In other words, and unlike countries such as France and Germany, where HERS certification provides a guarantee of the standard for engineers, the English diploma neither standardises nor stabilises levels of quality. The English university system clearly functions on the basis of reputation, as is the case in the United States: the new graduates are not "qualified" as engineers but evaluated through the reputation associated with the institutions from which they come. This system, which is closer to a market mechanism, often leads to a sharp polarisation of quality levels: it tends to overrate the best graduates but does not always guarantee the minimum standard. Combined with a certain weakness in industrial internships, the hiring of recent graduates thus confronts employers with problems stemming from the non-legibility of their qualifications.[30]

In the English case, the certification procedure for chartered engineers increases this uncertainty since it there is no guarantee that the companies can hold on to the young engineers once they are certified and thus recover their investment. Such uncertainty leads the companies either to create networks of trust guaranteeing the earliest possible access to the best candidates in certain targeted universities (strategic partnership) or to opt for experienced engineers who have already acquired the necessary competence--and professional reputation--on the external market. Most companies combine these two methods, but the national ones tend to opt more for the second and the multinationals for the first.

In any case, the English situation reflects a greater use of the external market as a source of competence than is the case in France. It thus creates a form of intermediate space of innovation which is not exactly the same as that prevailing in France. The mobility of experienced engineers in the United Kingdom serves as a tool for knowledge spill-over between companies or sectors that is not simply technological but also, and above all, contextual, whereas in France the direct flows of recent graduates between the HERS and the companies tends to inject the latest scientific knowledge, thus reinforcing the technological database, but sometimes to the detriment of the accumulation of knowledge that is more tacit or oriented towards market needs.

3.2.4. New trends of innovation system in the globalisation

n the following two subsections, we will deal with two particular problems whichi are the Europeanisation of innovation system and the intellectual property rights.

I) Europeanisation of national systems of innovation (for a detailed analysis, see the chapter of Alain Alcouffe in final report of July 2001)

The threats of globalisation on national system of innovation (NSI)

As formulated by D. Mowery, the convergence of national pattern of innovation appears to take place. He remarks that NSIs have been structured around national research organisations and domestic firms at a time when the strategic interests of the different stakeholders converged easily towards national goals. Their international linkages were mainly through the scientific community that has a longstanding tradition of global networking. The situation has evolved gradually during the 1970s and 1980s with the intensification of government-sponsored international co-operation in technological development, especially within Europe. The globalisation of firms' R&D strategy and access to public research together with increased mobility of scarce highly qualified labour now lead to much more fundamental transformations:

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- The hierarchical and centralised model of NSIs governance that still prevails in a majority of countries must leave way to a contractual and decentralised one. Within public/private partnerships the source of initiatives is shifting from government to

[30] The doubt expressed by the multinationals over the quality of certain segments of university education in England, along with the growing sourcing of engineers on the European continent, show that the problems are qualitative rather than quantitative.

firms, within governments from central to regional and local authorities, within public research from public labs to universities, and within public research organisations from central management to labs and research teams. Now that mission-oriented public research can no longer play a pivotal role within NSIs, new market-friendly co-ordination must be implemented, with greater involvement of the financial sector, especially venture capital.

- *Foreign firms makes often more intensive use of public research than domestic ones* and the efficiency of national support measures is enhanced when recipients are parts of dynamic international networks. Government must rethink how to maximise national benefits from ISRs that involve industrial participants taking a more global perspective. Building on globalisation to increase national benefits may require easier foreign access to national programmes and the relaxation of eligibility criteria regarding the location of publicly-funded research activities, as well as greater international co-operation among governments to avoid opportunistic behaviours and distortions of competition.

Globalisation prompts public funded organisations to reconsider their role in the economy. Some now enters into broad alliances with homologue or private firms in order to create knowledge platforms, which could become key infrastructures of the "new economy".

National Systems of Innovation, Globalisation, and European Integration

In an European framework, consequently the question becomes twofold : on the one hand, it is worthwhile to analyze the evolution of the former nation-state innovation system, on the other one the possible emergence of an European innovation system. The concept of NIS has been elaborated to explain the different industrial and technological profile which are exhibited by countries and especially the persistence of areas of strength in national economies which are associated with are associated with specific institutional configurations for very long periods (Saviotti, 1997).

Among these configurations the flows circulating between the three different spheres, industrial, human capital training, R&D, which can be distinguished in the national economies are of special interest. It is very obvious that any of these spheres is closed. It has been emphasised for long that the scientific sphere has always been borderless and the increase in exchanges between domestic and global spheres dominates the usual rhetoric about globalisation.

Johnson and Gregersen (1997) have discussed the various relations between economic integration and innovation. They distinguished four main types of integration according to the nature of arrangements and process. Summing up their discussion of the influence of integration on national systems of innovation, they wrote that integration will affect innovation both because there is a tendency towards greater cross-border collaborative use of knowledge stocks and a tendency towards greater transdisciplinary complexity in technical innovation. They concluded that "the empirical evidence of what is happening to national systems of innovation as a consequence of the integration process is still rather weak. It is not yet possible to say if they are losing out to systems on the European and/or regional levels or not. Also the empirical evidence of an "autonomous" European system of innovation in a broad sense is still rudimentary". They found that "for the time being (1995-7) it is more reasonable to talk about an emerging European system of innovation in the narrow sense of the term".

But before adressing directling these questions, we have to take into account that NSI as the SSIP approach recalls are not separated of the economic production and exchanges processes therefore it is interesting to look more closely to globalisation. Recently Neil Fligstein and Frederic Merand have sustained a provocative thesis along which the evolution of the world economy since three decades is less characterized by globalisation than by "Europeanisation". "That is, a huge part of what is driving the increases in trade in the world economy is accounted for by the changes going on within Western Europe" whereas they see no evidence of a "single capitalist market". They argue that an integrated market requires a single system of rules of exchange, property rights, and rules of competition and co-operation. The EU has by and large also come to co-ordinate rules of competition and co-operation for firms involved in trade across borders and even if there has been thus far less convergence across Europe in property rights, the European Commission has recently proposed the creation of a common incorporation label, *société européenne*, that should eventually undermine the currently national systems of property rights.
They show convincingly that (1) the importance of Western Europe in the world trade has not declined during the last decades; (2) the concentration of EU trade towards Europe has substantially increased; (3) for every country in the EU the concentration of trade towards Europe has continuously grown and substantially after entry for late comers.

The European IT and telecom case

The IT and telecom sector provide us with case studies in order to analyse the dynamic of European national systems of innovation and the effectiveness of European programmes in order to build up an European innovation system. Given the overwhelming force of the American IT industry, including in terms of software packages and IT services, Europe certainly seems to suffer from structural deficiencies inherited from past "national champion" policies. Despite these weaknesses, some European countries seem to be showing their capacity to resist the American offensive, drawing on knowledge, competences or positions linked to their own institutional set-ups. In particular, the case of France, which in the past systematically developed state policies in favour of IT, shows us how actors in the innovation process rely on existing institutions to revitalise their innovation activities.
After the relative failure of national policies, the European programme seemed to be an opportunity to challenge American pre-eminence. Despite these efforts, it may be noted that the Esprit series of European programmes had no effect on existing co-operative networks and did not replace them with new arrangements. Naturally, the Esprit projects in which Bull and Thomson, as well as many software and IT service companies and research institutions such as INRIA and university teams, were active participants, allowed research networks to be extended on a European scale and brought the various players in the European IT industry closer together. From the French perspective, however, the constitution of European networks has taken place within existing local and co-operative arrangements, notably those focused around regional centres. Being established in a locality does not, therefore, seem to conflict with the extension of co-operation between the industry, universities and public research to the European scale Hiroatsu Nohara and Eric Verdier, 2001).
In 1983, the Commission of the European Communities undertook a vast programme of activities concerning telecommunications. This led to the publication of the 1987 Green Paper, followed by the liberalisation of the equipment and service markets. The principle of opening voice telephony to competition was adopted in 1993, with a calendar extending from 1998 to 2005 depending on the country.

The EEC's interest in questions related to the new information and communications technologies goes back to 1983, with the creation of a special task force on "Information and Telecommunications Technology". Three years later, this task force was merged with other departments to become the European Commission's DG XIII, responsible for telecommunications and the information industries. From 1984 to 1987, Community policy on telecommunications was organised around six kinds of actions:

1) co-ordinating the development of the supply of services;

2) developping a single market for terminals and equipment;

3) supporting the pre-competitive R&D programmes ESPRIT[31] (on information technologies) and RACE[32] (on broadband networks);

4) launching several programmes to encourage exchanges of information between European bodies and national government;

5) aiding the introduction and development of services and networks in outlying regions (STAR[33]);

6) adopting common technical specifications (GSM, MAC).

At the regulatory level, the Green Paper published by the Commission in 1987 set three objectives for 1992: total liberalisation of the terminals market, the possibility of interconnection for service providers according to "open" networks principles and the clear separation of regulatory and operation activities.

a) It is an industry that structures its environment because it provides equipment giving rise to new demands and new activities. It has gradually assumed a dominant position in the industrial fabric.

b) It is a high-tech industry that requires very costly R&D investments and a sufficient scale to cover such irreversible expenditures. It has already experienced a fundamental technological discontinuity with the shift to time switching, just as it has experienced rapid technological change with the importance of software in relation to hardware or with the role of mobility for terminals, and it might be sharply destabilised by the accelerated development of optics.

c) Technological change in this industry leads to profound transformations in knowledge, skills and know-how that are essential to manufacturers. The boundaries with other industries are shifting and porous and often lead to new strategic positions for manufacturers seeking certain access to the latest key skills.

d) The environment of this industry is subject to the effects of the deregulation of telecommunications services, videocommunication cables and television.

e) Its strong national character is outmoded. Formerly multinational, it is becoming increasingly global, with a displacement of both geographic centres of growth and high-potential activities that reflects sharp international competition.

Major industrial battles are currently underway for the conquest of markets located at the juncture of the telecommunications, computer technology and audiovisual industries. Sector-based divisions seem to be flying into pieces from the pressure of the major players in each of these sectors seeking to enter the markets of the other two. Although the current recomposition, which is far from over, can be traced back to the 1980s, it has been sharply accelerated since the beginning of the 1990s. It is manifested by a strong interpenetration of players and actors from the three sectors, but the industrial organisation (i.e., the configuration of these players and markets) that may result from the breakdown of sectoral boundaries and market transformation is still

[31] European Strategic Programme for Research in Information Technologies.
[32] Research and Development in Advanced Communications Technologies.
[33] Special Telecommunications Actions for Regional Development.

largely undetermined. Amongst the possible configurations, the most frequently suggested is that of 'convergence'. Developping similar technologies, the main players in these sectors would be called uponto integrate the activities of audiovisual technology, computer technology and telecommunications. At the end of the process, we would have a few large firms intervening on a market that would indeed be differentiated but defined by a global need--that of access to information services whose previously separate forms of processing and communication (voice, image, text, data) would be integrated in a reunified communications process.
The 'convergence' thesis is illustrated by the circulation of a few vague metaphors such as "information highways" or "multimedia", which attest nonetheless to the way the players represent their actions. Rallet (1996) nuances this thesis by showing first of all that technological convergence is a differentiated movement that does not do away with the specific features of the skills on which the division of labour between the various types of players is based. He then brings out the relative indeterminacy of the possible trajectories for the industrial organisation of the three sectors.
Generally speaking, the telecommunications sector is organised in a context of uncertainty leading to what Badillo (1996) calls "technological and regulatory slack". In such a context, the actors' strategies are preponderant and motivated by the prospects of high returns from the telecommunications market. It is doubtful that in such a framework public policies even at the European level could still play a structuring role in the future.

II) Evidence from Germany-USA comparison on Industry/University relationship: intellectual property rights (for a detailed analysis, the chapter of Christoph Buechtemann and Hans Thie in final report of July 2001)

Differences and Complementarities in Industry-Science-Relationships

Today it is widely accepted that technology transfer is not a unidirectional process and is not limited to research results that can be clearly identified and transfered. In many cases it seems to be more appropriate to talk of technology and knowledge exchange, since interaction works best when partners cooperate in close and immediate contact in order to take commercial advantage of academic capabilities. Relationships between industry and science represent an institutionalised form of learning that provides a specific contribution to the stock of economically useful knowledge. Interaction should be evaluated not only as knowledge transfer but also in other capacities (e.g. building networks of innovative agents, increasing the scope of multidisciplinary experiments).

In our interviews it has been frequently noted that academic research and industrial R&D differ in many important dimensions. Academic research is curiosity-driven. Breakthrough discoveries are its principal goal. Down the road to applied research academics usually do not go beyond solutions-in-principle: solutions that work under well-defined experimental conditions. The time horizons in academic research tend to be long with an emphasis on depth and latitude leaving open the possibility of exploring both new paths and emerging fundamental questions along the way. Often energies of academic research are dispersed in many directions. Industrial R&D, by contrast, is purpose-driven and focused. Its principal goal is product development and incremental product improvement. In most cases industry does very little research proper and tries to refine prototypes and demonstrators to marketable products that work under varying market or customer-specific real-world conditions. Time horizons are much shorter than those of academic projects and energies are focused and bundled.

Out interview partners emphasized that these differences are a potential source of synergistic complementarities. Industry research needs the idea input from academic research and can take research results further than academia could (or would) ever do. Industry can provide funding for university research in novel topic areas that would not attract public funding. Academic interviewees stressed that industry funding often has less bureaucratic strings attached compared to government research funding. Research money from industry can also compensate for declining public research support. In some cases industry gains access to the results of publicly sponsored research (e.g., NIH; DARPA in the United States; federally or EU sponsored projects in Germany) through collaboration. Access to specific technologies that individual companies would not invest in (e.g., special genomic test beds) is another reason for collaboration. Generally, collaboration lowers the cost of high-risk projects for industry.

Academics, on the other hand, often gain access to technologies, equipment or databases they could not afford themselves (e.g., genomic data bases; model organisms). Academia also obtains information about where industry's innovation activities are headed for and industry funding inflicts a sense of relevance into academic research. Collaborative research with industry can help coordinate and focus dispersed activities of university researchers (pooling of energies). Through industry collaboration academic researchers can learn to use resources more efficiently. To capitalize on these complementaries is a difficult process. Principal differences in goal orientation, mind-set, governance and incentive structures are sources of an uneasy relationship and give rise to complaints on both sides. Industry demands that universities should become more business-like, more conscious of IPR matters, more focused on "relevant" research, and more like service providers. Academia complaints about industry's short-term horizons, risk aversion, obsession with secrecy, timelines, and milestones. Coping with these mutual complaints is a delicate task.

Core Issues in Industry-Science-Relationships

For very different reasons, one of the most controversial issues and concerns emerging from our interviews in both countries is the issue of Intellectual Property Rights, alluded to from both sides as the "sore point", the "roadblock", the "most sensitive nerve" in industry-science relationships. The IPR issue has turned out to be difficult to deal with in both countries despite the fact that Germany and the United States still have very distinct regimes governing IPR.

Germany used to have a "very comfortable situation" for companies in the past. Academic partners were not IPR-oriented, had little patenting expertise and universities were even not permitted to have licensing revenue. Professors ("free inventors") were willing to give away IPR in exchange for publication rights and consulting contracts. Only companies usually had the expertise and means to file patents.

Recently, however, IPR has become an issue. Universities are given more autonomy to explore new sources of revenue, including IPR and licensing. Political moves are intended to weaken the professors' "free inventor" status in favour of universities as their employer. Because of reduced public funding there are increasing pressures on public research institutes to raise more external funding from industry contracts. Currently, universities still have a very lax attitude towards and a lack of expertise in IPR matters. But the IPR regime governing industry-university-relations is seen as moving closer towards the U.S. model.

In IPR matters German public research institutes are facing a dilemma: They need to provide more pre-development type services for industry, involving stricter IPR claims from corporate partners and they also need to retain IPR in core areas of expertise in order to prevent a "bleeding out" and remain a partner for industry in the future. Similarly, universities face the problem of becoming a low-cost R&D provider for companies compromising their primary mission, i.e. the advancement of knowledge.

In the United States universities retain full IPR in most cases. Sponsoring companies usually have the "right of first refusal" (right to negotiate non-exclusive / exclusive licenses, sometimes with the obligation to develop a product). State laws have defined rigid IPR rules for industry-science-collaborations and prohibit universities from "selling out" their IPR to industry. The "one-size-fits-all" approach of the IPR regime, however, creates problems by ignoring differing industry conditions and needs (e.g., the pharmaceutical versus the ICT industries).

University faculty criticise the IPR regime as a "roadblock" to more collaboration. They advocate de-centralization with more discretion being given to professors. The U.S. IPR regime has created a "schism" between industry, university faculty, and university administrations, with professors often viewing Tech Transfer Offices as their "foes" and industry viewing them as bureaucratic "obstructionists".

Only top universities are able to attract major industry funding. Several of the industry interviewees saw some universities increasingly taking too restrictive an approach to licensing and putting too high a value on their intellectual property contributions. Industry is increasingly seeking out second-tier U.S. universities and foreign universities for collaboration when they perceive first-tier universities to be too difficult to deal with. Some university boards of trustees may see technology transfer activities more as a revenue source than as a component of the university's public responsibility to assist in commercializing research results. This attitude can raise barriers to negotiations that actually reduce revenue over the long term.

Given that only a small percentage of university-generated inventions produce significant revenue, some participants likened the strong emphasis on protecting proprietary rights of some universities to "buying lottery tickets." Most of the discussion of this topic and suggestions from both industry and university participants focused on issues related to the university side of collaborations. There was also recognition, albeit with less detail and fewer examples, that the effectiveness of industry approaches also has a major impact.

Participants expressed a broad range of views on possible solutions to the IPR problem. It is important that faculty, as well as university and industry leaders understand that the role of intellectual property in the innovation process varies by field. Approaches that make sense in the biomedical field may not make sense in engineering and computer science.

Several participants suggested that universities consider forgoing all proprietary rights outside the biomedical area, essentially putting inventions in the public domain. Other participants responded that many universities do not seek patents on their inventions unless an industry licensee has been identified, and that this approach is more likely to facilitate commercialization than a blanket policy of not patenting inventions outside the life sciences.

To many participants, the main issue is whether universities manage their technology transfer roles to comply with the intent of the Bayh-Dole Act by enhancing the use of university- generated inventions. Several speakers believe that a well-run technology transfer operation governed by a realistic university policy can do this more effectively than a general policy of putting inventions in the public domain. In addition to university licensing policies, premature definition and valuation of intellectual property can become an obstacle at the initiation stage of a collaborative project. Granting the company the right of first refusal to negotiate an exclusive license is one commonly used practice to delay concrete negotiations until the commercial value of an invention is easier to assess.

In connection with intellectual property arrangements, many universities have created technology transfer offices to combine academic discovery with commercial promise. Patent royalties are often shared with faculty. Participating companies seek different kinds of rights: first refusal to license, non-exclusive licenses, or exclusive licenses for a certain time. With respect to publishing restrictions, universities have accepted limitations on the publication of industrially sponsored research. Industry demands vary and can comprise no limits, advance notice, review and delay of up to a year.

The proper delineation of public and private interests

Because of the tighter linkage of industry and university research that has taken hold, questions are being raised regarding the proper delineation of public and private interests. To what extent have universities abandoned their goal of fostering development of human resources? At what point does the engagement of universities in short-term gain overshadow its core mission to conduct long-term research and to educate graduates who possess the breadth and depth of knowledge needed in all sectors?

The close connectedness of academic and industrial research as exemplified in the biotech and pharmaceutical industries is not without their inherent problems. First among these problems is the tradition of publishing research results of work in public research institutions and free access to the knowledge presented in such publications. However, a survey by Blumenthal and collaborators indicates that 82 percent of companies require academic researchers to keep information confidential to allow for the filing of a patent application, which typically can take two to three months or more. Almost half (47 percent) of firms report that their agreements occasionally require universities to keep results confidential even longer. The study concludes that participation with industry in the commercialization of research is "associated with both delays in publication and refusal to share research results upon request."

The dynamics of an internetworking knowledge universe are not without its strains on the traditional role of public-sector research as envisioned in a 1945 report by the 'founder' of the post-WWII U.S. national research enterprise, Vannevar Bush, which states that public universities "are charged with the responsibility of conserving the knowledge accumulated by the past, imparting the knowledge to students, and contributing to new knowledge of all kinds" so creating an 'intellectual commons' for society at large and obliging them to 'open science' (cited after Argyres et al. 1998).
As a conclusion, Argyres et al. note that the role of basic research that is awarded to research institutions such as public universities might interfere with the 'aggressive technology transfer programs' in basic research. Such programs have been pursued in the U.S. since the enactment, in the 1980s, of legislative reforms to favor the

commercialization of basic research. This has especially benefited the emerging biotech industry. On the other hand, the authors regard this new research paradigm as a weakening of the traditional institutional mechanisms of public research.

3.3. National Coherence of Innovation System (for a detailed analysis, see the chapters of Jean-Michel Plassard and Eric Verdier in the final report of July 2001)

Introduction

Many studies have revealed "national profiles" of innovation structure that all stress the importance of the interactions between the various elements of the systems involved (public and private research bodies, higher education establishments, government policies, firms). First advanced in the mid-1980s by C. Freeman within a neo-Schumpeterian framework[34], the concept of the "national innovation system" was further developed and enriched by many authors, namely Lundvall, Nelson and Edquist[35]. Although the various schools approach the notion differently, national innovation systems can be defined as networks of institutions operating in the public and private sectors whose activities and interactions generate, modify and diffuse new technological innovations. This approach stresses the specificity of the choices that shape the various national systems, in particular through public policies on education, academic research, legislation on intellectual property, the banking system and access to finance for emerging technologies. The resultant coherence between various institutional arrangements – or strategic institutional complementarities (Aoki[36]) – tends to create a sort of irreversibility contained within "particular institutional infrastructures". Such institutional infrastructures correspond, therefore, to the incentive mechanisms through which the strategic behaviour of the various actors (firms, institutions and individuals etc.) is mediated. Thus firms are able to "exploit" the cognitive and institutional resources of their countries of origin in order to construct their competitiveness. In effect, once created, this coherence within a national system of innovation represents both a resource and a constraint for firms, since it tends to favour a certain way of innovation while at the same time precluding any deviation from a dominant pattern. This creates institutional inertia, a phenomenon known as "path dependency", which effectively defines national innovative trajectories over time.

However, the relevance of the notion of the "national" innovation system is now being seriously challenged both by recent developments and by new theoretical stances. It goes without saying that "globalisation" represents a radical change in the world economy, bringing with it increasing cross-border transfers of information and knowledge, the importance of research-related foreign direct investment, the explosion of international strategic alliances in science and technology and the

34 See namely Freeman Ch., 1987, "*Technology and Economic Performance, lessons from Japan*", Pinter Publishers, London.

35 Lundvall B-A., 1992, "*National Systems of Innovation, toward a theory of innovation and interactive learning*", Pinter Publishers, London.
Nelson R., 1993, "*National Systems of Innovation : a comparative study*", Oxford University Press.
Edquist Ch. (ed.), 1997, "*Systems of Innovation, Technologies, Institutions, and Organizations*", Pinter Publishers, London and Washington.

36 Aoki M.(1988), Information, incentives and bargaining in the Japanese economy. Cambridge, Cambridge University Press.

"multinationalisation" of large firms. Such developments pose a serious threat to the importance of national R&D programmes, to the ability of nation states to protect their domestic markets and to the role of state in the management of scientific/technological policy; in short, they threaten to weaken "national" borders, which to date have been considered as the natural framework for innovation systems.

This previous part seeks to address some of the key issues arising out the vigorous debate on national diversity in innovation systems in the context of "globalisation" of innovation systems. It seeks to combine micro-level findings drawn from our empirical studies with institutional knowledge drawn from macro-level or statistical studies.

3.3.1. The UK: maintaining specialisation in a context of academic excellence

The United Kingdom is incontestably the European country, at least among all those studied in the present project, which has been strongly science-oriented. However, industry's ability to take advantage of the research being carried out in the UK is on the decrease. it should be pointed out, also, in this connection that any excessively heavy orientation on these matters might detract from the strong point on which Britain has relied for its success, the level of scientific excellence in many fields, from which the emergent bio-technology sector[37] is now benefiting, as the pharmaceutical industry did in the past. The risk arising here are all the greater as the previous Conservative governments did very little to reinforce the basic infrastructures of fundamental research.

The risk of under-investment in R&D for both public and private sectors

At higher education institutions, the increasing "professionalisation" of technology transfer carries the risk of academic research becoming over-commercialised. This might have the undesirable effect of changing the "blue sky" basis of academic research. This shift of agenda might mean that focusing on readily exploitable research might erode the traditional basis, along with the advantages previously inherent to academia. In addition, enhancing of the spin-off process might promote the creation of companies with no sound technological basis, and might stimulate synergies within the walls of academic research spheres.

Although the UK is noted for its high intellectual standards of biomedical research, the scale of investment in science might not be large enough to create an adequate supply of highly trained scientists and entrepreneurial managers for the pharmaceutical sector and specialised biotechnology firms. Moreover, in recent years, the focus of government policy has been aimed towards commercialising science and integrating fundamental and applied research. One potential risk inherent this approach is that the basis of science itself may be weakened. Casper and Kettler have argued that the main long-term problem facing the UK biotechnology sector might be a problem of scale: that of producing a sufficiently large, high quality science base to generate the scientific and managerial expertise required.

This does not mean that the private sector is devoid of the risks surrounding output-oriented, short term strategies. Also, as the SESI case studies have shown, the

[37] Cf. WP6 Alice Lam op.cit. and Appendix 4 to the present report for information about the main indicators.

amount of R&D conducted by the commercial sector in the UK has significantly decreased during recent years, which has weakened the industry's ability to make good use of scientific research. This under-investment in R&D by UK industry has strongly affected the absorption capacity of firms, and thus reduces the effectiveness of government policies designed to promote links between academia and industry. The 'disconnection problems' in knowledge transfer experienced by many of the ICT firms included our study clearly illustrate this point. Public investment in research can possibly serve as a complement to private investment, but it certainly cannot be a substitute.

Excessive financial advantages for the "top universities"?

The standard of fundamental research in Britain is largely due to the excellence of the leading universities, such as Oxford, Cambridge and Imperial College. Scientific policy in Britain involves extremely selective patterns of funding which favour the top universities (Evidence of this is provided by the fact that in the UK, 33 per cent of all the university research funds originating from industry went to only 6 per cent of all the existing institutions (seven institutions) in 1996-97; in line with the current assessment procedures, this public policy trend is liable to lead to the distribution of both public and private funds being far too strongly concentrated on the top universities. Firms do in fact tend to follow the signals emitted by public policy and focus their co-operative arrangements with the higher educational system on these universities, which is liable to have non negligible undesirable effects.

First, “this tendency can result in new scientists working at low graded institutions being prevented from developing their potential. Secondly, researcher workers at institutions with low resources will not be given much incentive to carry out fundamental research and may become stale or obsolete. Thirdly, universities may not be prepared to meet the real opportunity costs which might arise if they invest their low resources in contract research for industry. This could result in contract research for industry becoming a form of public subsidy to particular industries for the type of research that firms would otherwise have had to finance themselves on a full-cost basis. Considering the under-investment of UK firms in R&D, and the previous lack of application of the UK science base, this would seem to be another strong indictment of the current government research funding policies.

The increase in competitive university research funding may further exacerbate the cumulative self-reinforcing effects undermining the process of scientific production. This might result in the so-called "Matthew effect" (Merton, 1968)" (Lam, National report, WP6).

Now developing a "science based economy" requires a higher educational system with a much wider knowledge production base than that which can be obtained by concentrating the means available on a few universities, however efficient these may be, especially if the chosen few are accustomed to working with large companies with substantial R&D funds at their disposal. SMEs might have no access to these resources, which is contrary to the aims pursued by the authorities in promoting technology transfers towards smaller companies. If nothing is done to stop this two-fold selective process, public programmes such as The University Challenge Competition and the Science Enterprise Challenge, that can be said to be incentives promoting long-term research projects, might strengthen the "Mathieu effect" even further. Means of counteracting these tendencies need to be found.. *Ex-post* assessments of university research performances (via the RAE, for example) can lead, for example, to focusing on an institution's recent quantifiable outputs without taking into account the work in progress at less prestigious younger universities or their plans for long-term projects.

All in all, there are two aspects to the challenge with which public policy in Britain is now faced: finding ways of preventing the undesirable effects of the tendency for public research to become more market-based at the expense of its long-term investments; and ensuring that the funding of public research does not result in the pattern described as "the Mathieu effect". This leaves very little scope for what is known in the United Kingdom, when talking about STI policies, as "the third stream of funding" to foster knowledge transfer. This stream has provided financial support for increasing the links between research institutes "and companies and has taken the form of competitive funding under the University Challenge (UC), Science Enterprise Challenge (SEC) and Higher Education Innovation Fund (HEIF)[38] schemes" (ibid.).

Technology transfer and networking policies

The promotion of innovation networks is one of the possible means available for efficiently bridging the gap between universities and industry and encouraging the industrial use of research. Although this programme may be destined to become the normal way of conducting research, it raises problems as to how the future collaborative research projects should be co-ordinated.

Networks of two kinds supported by public programmes were investigated in the framework of the SESI project:

- *Informal and social networks.* These make an important contribution to the innovation process, because much of the knowledge transferred via personal networks is tacit and personal interaction is needed for tacit knowledge to be transferred. These are deliberately designed virtual research networks with public and industrial funding, in which consortia of universities and companies work together on areas of technology identified as priorities by the Foresight Communications Panel. What are the main challenges for these networks and the relevant public policies? One of the main problems appears to be intellectual property rights arrangements. The range of agendas covered by the innovation networks plays also helps to determine programmes of common interest. There is a risk that larger companies may have a greater say than smaller ones in choosing areas of research and controlling intellectual property ownership rights. Another more fundamental problem is the failure of these innovation networks to attract SMEs and sustain their participation.
- Another form of innovation network supported by government policy is that called *Clusters* (Porter, 1990). It is not thought to be part of the Government's role to create clusters. The Government seeks, however, to create conditions which are favourable to the formation and growth of clusters. This can mean, for example, ensuring that neither national nor regional policies inadvertently impede the development of clusters,

[38] The objectives of these funding schemes are to encourage: systematic and sustainable changes within institutions in their relations with businesses, and especially changes in the institutional and academic approaches; more widespread and rapid transfer of new ideas, products and processes generated within the research base to businesses; entrepreneurial activities; the incorporation of business courses into science and engineering curricula; contributing to the economic development of the nation.

catalysing the formation of social interactions and collaborative projects within a cluster, and providing research and innovation with support programmes based on existing strengths so as to work in line with the grain of cluster development.

The main challenge in the future will be to strengthen the participation of the universities in local initiatives of this kind, on the lines adopted in science parks, for example, to ensure that SMEs participate more fully and satisfactorily than they have been doing so far. Here the relationships must not depend entirely on formal arrangements, which are often not very appropriate for purposes of this kind, but rather on personal and social links. Links of this kind are necessary, in fact, for the absorption capacity of small firms to be enlarged and improved.

Generally speaking, most of the policies designed to promote these networks so far have come up against one of the potential pitfalls surrounding attempts to make universities more entrepreneurial. The problem here centres on the management of intellectual property rights (IPR), which has to be given a more formal structure in this context. Policies adopted at British universities can inhibit the transmission of the knowledge necessary for innovation to occur. Although the devolution of IPR to universities is a potentially positive step, it has caused many universities to concentrate on drawing up formal rights, and this has set obstacles to the innovative flexibility of new technology-based firms. In addition, as many of our case studies have shown, IPR negotiations have become laborious as the result of the universities' increased awareness of the IP ownership issues.

Reforms designed to fill the "skills gap"

The “skills gap” problem is strongly linked to the limitations of conventional academic specialisation as a means of preparing the next generation of scientists and engineers to participate efficiently in the new mode of R&D and innovation (see Alice Lam) : "The type of skills and competence profiles required of R&D workers are now more demanding in multiple dimensions, particularly in the combination of technical disciplinary expertise with a broad range of business, management and social skills. The effectiveness of R&D workers depends on their ability to apply scientific and technological expertise in shifting problem contexts, to operate in inter-disciplinary[39] and trans-disciplinary environments and to sharpen their project management skills".

The gap was particularly wide in the United Kingdom because of the predominant status of academic learning in this country. This explains why another major thrust of government policies is towards the education and training of science and technology students in business management and entrepreneurship. This innovation was instigated via the Science Enterprise Centres and the Teaching Company Scheme, CASE studentships and Postgraduate Training Partnerships.[40] The

[39] From this point of view, public policy-makers should take care to ensure that the *system of assessment* should not be particularly unfavourable to interdisciplinary research. It might be argued that interdisciplinary research has become crucial because the traditional academic disciplinary divides have become too rigid. As shown by our case studies, the potential to generate "disruptive" technologies which go beyond traditional disciplines is vital to find the radically new ideas on which industrial activities thrive.

[40] The **Science Enterprise Centres** were established in 2000 to increase the awareness of the importance of business enterprises at all levels at universities, and to justify commercial activities as a valid aspect of academic life. Each centre has a business plan to ensure these activities will become self sustaining within

purpose of these initiatives is to adapt teaching curricula to meet industry's needs for skilled graduates in new technologies and fill the "skills gaps" which have obviously occurred.

These programmes have made it possible to carry out some particularly promising experiments which it is intended to apply systematically in forms which have been specially adapted to the various sectors.

The stakes are particularly high in the ICT Industry :

- The first point at stake is the types of skills and competence profiles required of the R&D workers in response to the shift in R&D organisation and the changing nature of innovation activities. The requirements are now more demanding in many respects, particularly as regards the need "to combine technical disciplinary expertise with a broad range of business, management and social skills. R&D and innovation activities are no longer confined to the R&D labs but are widely distributed and dispersed throughout the entire business firm" (Alice Lam, National Report op.cit.).
- The second point is the mismatch between the expectations and of graduate engineers and the realities of the work roles they are expected to play. Engineers from universities have the impression that that they have been trained to "make things", whereas the reality is that a large proportion of them will not be "making things" but will end up in a "service" environment dealing very closely with the customers and markets. This reflects a general shift of the IT industry towards the service sector
- The third point is the increasingly distributed and network-oriented form of R&D activities. Along with the fast increase in technological progress, this development means that the careers and work roles of R&D staff will be increasingly characterised by volatility and diversity. "Their knowledge and skills are being deployed and continuously reconfigured in flexible and transient forms of organisation" (Lam, ibid.). An increasing number of these employees will be deployed outside the traditional R&D framework. One of the main challenges to be met by educational institutions is to parallel the diversity of the career paths in their curriculum design.

This also requires firms to be much more committed to training future R&D workers than they are today, especially in the form of joint vocational training courses: according to Mason (1999), only 38 % of the firms consulted had provided training courses. A much greater level of involvement of industry in the education and training of the next generation of scientists and engineers must therefore become an increasing feature of the collaborative landscape between universities and industry.

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five years. The **Teaching Company Scheme** was launched in 1975 to improve economic performances via links between university and industry. Academics have been working with companies on various technical and managerial projects and the work of groups of young undergraduates has been jointly supervised, and university syllabuses have thus been made more relevant to industry. The **CASE scholarships** (Co-operative Awards in Science and Engineering) are intended to support research students on projects which are jointly devised and supervised by academic departments in co-operation with representatives of industrial and commercial organisations. **Postgraduate Training Partnerships** involve collaborative research between selected universities and Research and Technology Organisations (RTOs), where students carry out research at the RTOs while still under the supervision of the university.

In the pharmaceutical industry, what is at stake is for Britain to keep its leading position in the field of biotechnology in Europe. With this aim in mind, filling the skills gap will involve meeting the following three challenges:

- providing relevant competences and qualifications in new disciplines such as genomics;
- improving the standard of UK graduates in Chemistry. One of industry's serious concerns is the general lack of practical laboratory experience and problem-solving skills among the graduates. Companies have responded by recruiting Chemistry graduates from the wider European market (which shows that the British system of innovation at least has the structural ability to widen its horizons beyond the strictly national scene, although this quality can be counter-productive[41] if it is too pronounced);
- promoting the recruitment of PhD graduates: this is a vital mechanism for maintaining firms' absorption capacities and for mediating the transfer of knowledge from academia to industry.

In addition, the British pharmaceutical industry is facing a "brain drain threat". The risk of losing its resources must be turned to advantage by taking innovating measures in this sector, especially in the bio-technological field: the flow of scientists to the United States, which has reached quite large proportions, can have positive effects if the international experience and expertise gained by researchers enriches the scientific community in Europe on their return. These advantages suggest that international mobility among research workers should be promoted if they can also be encouraged to return.

The entrepreneurial university in gestation

All the national policies on RDT matters have tended to encourage university graduates and research workers to show greater mobility towards industry. It turns out that despite the financial incitements proposed for this purpose, the employment contracts signed by UK academics are not actually flexible enough for them to be able to take temporary leave or accept part-time positions in industry while still keeping their university appointments and advantages. As noted in a Pharmaceutical case-study, it is still very much the case that a scientist is engaged in either academic research *or* an industrial firm, but not both together. Acknowledging the possibility of combinations and encouraging academics to create links with business firms and engage in entrepreneurial activities while still depending on their universities would seem to be a more reasonable attitude and one which would probably more effectively induce greater mobility between academia and industry. The current move to give scientists and technologists more education and training in management and business related skills would seem to be an attempt to rectify this situation, but it is not easy to make

[41] We have been warned that this increase in the supply of overseas scientists might make it less lucrative for local graduates to pursue an academic career in the UK, since the benefits resulting from importing scientists from abroad are widely distributed among society, whereas the costs are borne by the native scientists. It was therefore suggested that the availability of international pools of highly skilled graduates should not be allowed serve as a substitute for training and investment in the local labour force and improving the conditions of employment (Mahroum, 1999).

academic careers more flexible, and a change in the whole spirit of academic research may also be required.

In the long run, public policy-makers are having to make a rather delicate compromise between promoting the marketing of scientific results and continuing to excel in the production of generic knowledge by maintaining the centres which excel at fundamental research by allocating most of the research funds to just a few universities. What is more, the higher educational system has started to reform the basic training curricula in order to close up the "skills gap" resulting from having adopted a too narrowly academic vocational training model. The process of compromise and reform which has been initiated and now requires to be extended means that the British system of innovation will have to make adjustments which run counter to the traditional logic of specialisation in some of the sectors and disciplines renowned for their academic excellence.

3.3.2. The French higher education and research system in the perspective of innovation: a political turning point

Contrary to what has happened in Britain, the French system is now facing to the need to make some complete institutional and organizational changes. The first step in this direction was the law of 12 July 1999 on innovation[42]. However, it is still too early to be able to judge whether the results obtained will be satisfactory in the long term.

At the official level, ministerial statements and parliamentary reports introducing the legislative debates have taken care to set the new measures in the context of the 1982 law on research and that of 1984 on higher education. This rhetoric of continuity has been part of the civic justification of reforms which constitutes a kind of "societal benchmarking": this procedure, was very directly inspired by the American example of start-ups and spin-offs referred to by the OECD. In other words, this was a kind of "translation", into the French context, of procedures making the borders between market and non-market spheres more permeable. The intention was to create a legitimate compromise between a "mutation" (to borrow the term used by the OECD in 1999 to qualify the French reforms and schemes) and the official French policy-makers' ideas about the independence of science in relation to the world of business. This is why the term "turning point" seems to be a fairly appropriate way of describing the "gentle and gradual break" which has been made with the previous course of events, a kind of bifurcation in the evolutionary sense of the term. The implementation of the spirit of the law is based here on a series of directives adopted by a meeting of the French interministerial board on scientific and technical research in June 1999.

The shift from a mission oriented policy to a diffusion oriented policy

[42] The parliamentary report, meanwhile, which is devoted more specifically to the organisation of public research (Cohen and Le Déaut 1999), takes up the OECD's recommendations in order to emphasize the fact that the quality of a system of innovation depends on the intensity and fruitfulness of relations between its various constituents—companies, universities and research institutes. As a result, the public authorities should adopt a regulatory role, and even more so, one of co-ordination "to reduce the obstacles which prevent the formation of networks and see to it that the public research infrastructure functions in close collaboration with the business sector" (Cohen and Le Déaut, 39, citing the article in the OECD journal entitled "Promoting scientific and technological progress".

All the official reports (such as that by Guillaume, 1998, which has been given the most publicity) argue for a shift from the model based on the "major technological programme" involving a public agency, a research institution and a large industrial group, to that based on an interactive network where the players gain organisational experience via a process of co-operation the change was therefore from a top-down policy to a bottom-up policy. when confronted with the need to accelerate modernisation in order to catch up with rival countries, the French State privileged public co-ordination via the intermediary of "major programmes" up to the nineties. This is a top-down form of innovation "adapted to the complex technology used for major public infrastructures, as opposed to the bottom-up model for innovation via market selection, which is suitable for mass markets and, it must be said, for producing endless hybrid versions of today's technologies, as well as for the general trend towards market deregulation on the international scale and the process of globalisation in general" (Barré and Papon 2000). As this quotation suggests, these "major programmes" have led to outstanding achievements in the fields of rail transport, telephone communications and the nuclear and aerospace industries.

There has been a significant shift towards public interventions designed to further the spread of technologies; these interventions have included new incentives for research workers to develop their work at both the technological and industrial levels. They have also involved schemes encouraging companies and public research groups to set up networks for the production of knowledge and the creation of start-ups.

To shift in this way from a policy of one kind to another, several prerequisites are necessary.

Public interventions orientated to SMEs

The multiple forms of public action which occur in response to the complex regulations and schemes devised are often reduced to perpetuating forms of management which follow the current, without any capacity for analysing, much less assessing, the overall coherence. As a result, every new problem or objective leads to the creation of an additional organisation or aid scheme. We thus end up with the well-known French paradox, which can be summarised as follows: the predominance of "public matters" (*res publica*) over "private matters" has led to the proliferation of public and para-public bodies. Their missions intersect, if not overlap, to the point of creating sharp inter-institutional competition instead of the co-operation and complementarity which should prevail if the final recipients of public aid schemes (i.e., the companies, especially the SMEs, and research scientists) are to benefit from a coherent group of services and incentives which are complementary rather than redundant. Ultimately, the State and the public authorities in general are at once omnipresent and rather powerless, or in any case handicapped.

In this institutional context, the mechanisms promoting the transfer and spread of knowledge (as distinct from the production of applied research) are overly complex due to the multiplicity of the players, including certification structures at the main institutions and universities, CRITT, SRC, industrial parks, industrial technical centres (CTI), technology distribution networks and so on.[43] These mechanisms have a very

[43] CRITT: regional centres for innovation and technology transfer, "created in response to the Regions' desire to take charge of the management and structure their own research potential, in parallel with their concern for making the more traditional SMEs aware of technology and R&D".

low level of legibility for the SMEs, especially at the regional level, where "the multiplicity of players is experienced . . . as the consequence of a stratification over time of measures and schemes which survive independently of any evaluation" (Guillaume 1998, 22). Contractual agreements (between the State and the regions, the main organisations, the universities, etc.) defining common objectives and drawing on common resources are a very poor substitute for the lack of co-ordination and in any case, contribute to preserving the former forms of intervention.

It is therefore not hard to imagine what far-reaching reforms will be required before a "bottom up" policy structure is installed. This will involve revising not only the legal texts and incitement schemes, but also the everyday working habits of the French administrative departments, at both national and regional levels.

A temporary compromise between mission and diffusion oriented policies

What has occurred in the case of bio-technology and especially that of genomics exemplify this particularly delicate transformation which the public authorities are having to undergo. In this respect, the national and local public partners, private firms and non profit-making organizations have the same system of reference , which can be summarised as follows: the aim of the links created between the public and private sectors is "to create an innovative environment including firms which have sprung from universities of research laboratories (spin-offs), tripartite initiatives (cf. the triple helix model) for economic development based on knowledge, strategic alliances between firms of various sizes, using variably advanced technologies, public laboratories and university research groups. These institutional arrangements are often encouraged by incitement schemes without being government-controlled, or only indirectly via the new "rules of the game", as well as benefiting from direct and indirect forms of aid and the support of institutions create to promote innovation". However, at the same time, the real-life experiment which the launching of the Evry genopole can be said to constitute shows that complete departures form "mission oriented " forms of public action can be extremely dangerous, since it is necessary to catch up with the outside competitors in Britain and the USA, as well as those in Germany. Having to make up for lost time tends to incite the players to hand onto the advantages associated with mobilising sufficiently large resources under the auspices of the State to be able to reach an irreversible situation which is also positive. Studies on this local processes have shown that they are in fact at the crossroads between two strategies, one of which is mission-oriented (a national tradition which helps to catch up at the international level) and the other, diffusion-oriented (based on local co-operative

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These centres have suffered, however, from the multiplicity of the statuses and missions, which are overly diversified and constitute "an extremely confused panorama" (Guillaume 1998, 97).

SRC: contractual research companies having industrial R&D as their main activity. These companies facilitate intersectoral transfer and the access of industry to top-rate technologies by providing firms with scientific and technical knowledge integrated into operational solutions. They have been certified by the ANVAR, and fall into three legal categories.

CTI: 18 centres involving 115,000 industrial concerns and 1,700,000 employees. These centres include some 4,000 staff members (1,800 of whom work for the Institut français du pétrole) and 36 plants and laboratories. Their missions include "marketing analyses of industry's needs", largely through technological intelligence, and "setting up collective activities (standardisation, quality assurance, etc.)".

RDT: the technology distribution network is designed to co-ordinate the technology transfet among the main public players working in the field. It was created in response to the excessively complex interface mechanisms and the resulting need for co-ordination.

arrangements within a network) (Branciard 2001). The problems associated with "making up for lost time" are leading to the development of a volontarist type of activity, where efforts on hierarchical co-ordination lines prevail over co-operative attempts to carry out collective learning experiments at a pace which is not necessarily dictated by the need to overtake competitors.

The above example suggest that it might in fact be dangerous to completely relinquish the advantages of mission oriented policy. As Amable, Barré et Boyer (1997) have pointed out, the French system based on a set of major programmes - which these authors describe as a component of a model for European integration based on public interventions - "finds complete logical at those times when a backward country is trying to set up the institutions it needs to make up for its technological handicap".

French-style public intervention does not have much scope for action here, as we have already been taught by the difficulties encountered when attempting to reconvert the "military-cum-industrial complex, as it has been called. For the moment, France is indeed way behind Britain and the United States, as far as setting up dual research structures is concerned (it was Clinton who launched the idea of combining civil and military structures, which resulted in "financial incitement programmes designed to promote the development of technologies which meet both national defense requirements and market demands" OCDE, 1999)

Reforms in the higher education and the production of skills

The key themes here are the mechanisms for guiding the decisions of secondary school-leavers, the content of doctoral training curricula, and the ability to produce the skills required in generic disciplines and technological fields (ICT, biotechnology).

The number of science graduates continue to increase

During the most favourable period for the development of higher education (1984-1995), the numbers enrolled in the second and third study cycles in science increased much more rapidly than that in the arts, social sciences and economics on the whole, although the latter courses were considerably less expensive and their entrance policies were less selective. The same is true, moreover, of the most selective colleges of all in France, namely the "Grandes Ecoles", while the number of engineering school graduates increased more than two-fold (+150 % from 1984 to 1996) at a rate which was slightly greater, and above all more regular, than at the business schools. The increase in the number of industrial vocational diplomas (BTS-DUT, two-year post-*baccalauréat* higher technician training programmes for industry) was less conspicuous, but it should be mentioned that the expansion of this programme occurred earlier than in the case of full-time higher education. A real tendency therefore occurred at that time for the various higher education systems to be fairly science- and technology-oriented.

The ability of the French system to produce graduates equipped with the basic knowledge required has not yet been put to the test. New reasons for future concern have arisen, however, due to the apparent loss of interest in university science programmes shown by science *baccalauréat*-holders since 1995. This trend is becoming so pronounced that some universities are now trying to reform these studies in order to stem the decrease in the numbers of students enrolled.

The private sector recognize the value of doctoral training (the PhD)

Apart from Pharmacy and Chemistry, the doctoral training undergone by PhD graduates is not properly recognized at firms.

In the business world, the societal image of the engineer trained at a specialised college still prevails and constitutes the main mode of access to R&D positions. In the large companies, the engineering diplomas give access to a space of internal mobility which leads to other functions. This space is less easily accessible to those with purely academic PhDs; and this is one reason for developing a model for innovation based on a high degree of human circulation and the production of hybrid knowledge acquired by combining research activities and other more practical functions[44].

It is partly thanks to engineering diplomas, moreover, that the doctoral thesis has obtained some recognition on the labour market. Graduates with PhDs in engineerig benefit from noticeably more favourable conditions of labour-market entry than other doctoral graduates, and those with CIFRE engineering PhDs enjoy outstanding conditions of entry into working life.

That much said, the increase in the number of CIFRE fellowships, nearly 80 percent of whose holders then go into the private sector, shows that a joint company/higher education space is probably emerging around the thesis. The process is tricky to handle, however, because the quality of the relations between laboratories and companies, the PhD’s determination to acquire professional experience and the company’s long-term investment in the field of knowledge covered by the doctoral research seem to be decisive (Perret and Paul 1999).

Along with the ever-present competition between engineering colleges and university, these features show the limits of political voluntarism in these matters, as the authors of the report on the parliamentary mission on research priorities implicitly recognise: "The research sector, for reasons of French company culture, recruits less than 20 percent of the PhDs trained in our universities. . .. It is clear that concrete proposals for increasing the recruitment of PhDs in the private sector are indispensable (Cohen and Le Déaut 1999, 24). Indeed, according to the same source, although a large majority of these graduates want an academic career, "out of 11,000 PhDs, fewer than 4,000 will become research scientists or senior lecturers".

It is farther upstream, a the new doctoral colleges, that vocational training modules could be introduced which include periods of placement with firms, during which doctoral students could be trained to carry out managerial tasks or to take business decisions, which would constitute an extension of what is learned in the framework of the CIFRE fellowships.

Here again, there is a long road to be covered before the SME begin to take a sufficient amount of interest in the doctoral pool of resources. It is nevertheless essential that they should do so in order to significantly increase their knowledge absorption capacities.

[44] The reason why the computer engineering services sector is flourishing in France is mainly societal. French computer engineering services firms are creaming off a significant proportion of the newly qualified engineers from the "Grandes Ecoles", which the supply of human resources with the highest social status. The mutual attraction exerted between these firms and the "best engineers" is certainly one of the strengths of the French IT services sector.

Problems involved in producing skills in some key sectors

The skills needed in the emerging field of genomics, such as bio-computing skills, have given rise to some controversy between biologists and computer specialists. While this type of conflict may be productive for research, it delays the creation of new academic disciplines at the universities, and the creating of a new system of teaching in general which is conducive to the production of highly sought after new types of university graduates.

In the pharmaceutical sector, one of the problems encountered by firms in the management of their human R&D resources is due to the heavy segmentation occurring between the academic and professional specialities of pharmacologists, biologists, veterinary surgeons, physicians, physicists, chemists, etc. Each of these specialised departments has its own internal regulations, its own knowledge base and applied competences, and its own institutions. Although each of these professional training paths compares very favourably with other training programmes available at the European level, the isolation of these professions is one of the reasons why relatively few changes have occurred at human resources departments in the French pharmaceutical industry. Although industry needs co-ordinated competences and compatibilities between various different highly specialised spheres of knowledge, the system of higher education is continuing to produce qualifications which show relatively little awareness of either the intellectual environment or matters relating to industry.

In the telecommunications sector, the combined effects of deregulation and the withdrawal of the major French programmes might disrupt the historic "telecommunications circle" which has created strong ties between science and industry by forging links between various players, including the Ministry of Telecommunications, France Telecom (the French telephone company, which was recently privatised), the Centre national des études en télécommunications (National Centre for Telecommunications Research, CNET) and the three national telecommunications engineering colleges. These colleges are attended by some two thousand engineering students as well as four hundred doctoral candidates and four hundred research professors working at approximately a hundred laboratories.

The public higher education and research system in question

In the Attali Report (1998), the higher education system was referred to as "Gulliver tied up in knots": an often inefficient "university government" caught between ministerial supervision which is much more extensive than the autonomy theoretically accorded to the university presidents and the feudalism of the long-standing but old-fashioned training and research units, which resist the idea of participating in co-operative projects of any kind. This is especially true because, behind the national standardisation of university rules and diplomas, "an implicit hierarchy of universities has emerged. Their size and their means vary considerably from one university to another" (Cohen and Le Déhaut, 12). In addition, some of them are multidisciplinary, while others are divided into groups of disciplines. And because of the excellence of their curricula, a number of "Grandes Ecoles" jealously cling to their individual prerogatives, which only accentuates the Balkanisation of the system, while it is far from certain that in the future these schools will have the necessary critical mass, notably in the area of research. The system as a whole is therefore difficult to comprehend, for foreign and private partners in particular, and it is highly resistant to reform.

Developing a system of assessment based on the results achieved in the field of teaching, fundamental research and the ability to communicate and co-operate with firms.

Considerable progress still needs to be made so that the various disciplines are organised and run more flexibly with a view to improving the relations between academia and firms. In the case of the life sciences, for instance, the lag in the development of links between the public and private sectors has been aggravated by the fact that the institutional landscape is even more complex than in the case of chemistry. Publicly-funded chemical research in France is co-ordinated by a single institution (the CNRS), whereas research in biology and medicine is funded by various bodies (the CNRS and the universities are responsible for fundamental research, the French national health and medical research institute, for research in the framework of the university/hospital system, and the National applied research institute, for other types of applied research). All the funding organizations have different missions, and there is relatively little co-ordination between them. This does not facilitate co-operating with industry. Nor do these institutions do not have any common policies as to how to protect their intellectual property rights when dealing with business enterprises.

Lastly, it is difficult for new disciplines to emerge and achieve recognition in a system which is both atomised and lacks flexibility because of the national legislation, which leaves the universities little scope to handle their own affairs, if only by creating new positions corresponding to the requirements of the latest disciplines.

3.3.3. Main stakes in the German ICT and Bio-technology industries

As suggested by Casper (1999, op.cit.), in Germany it is a question of continuing on the lines whereby the already more entrepreneurial regulations and incitements are adjusted to fit the existing institutional framework. This process has contributed to the outstanding technological and commercial success achieved by several industries producing consumer goods for households and firms.

i) ICT: higher educational reforms to remove the barriers to innovation

Making university training and organisations less strictly academic is incontestably one of the main challenges to be met in the key sector of ICT.

A shortage of qualifications

One of the main problems encountered by German firms in this sector is due to the lack of trained computer engineers and information technology specialists in general. During the latter half of the 1990s, the German ICT sector, especially the software sector, which has won several important industrial battles, has increased its demand for higher education graduates. The shortage of qualified IT and engineering specialists has become a severely limiting factor preventing the full deployment of Germany's capacity for innovation. Since this shortage reflects some of the main features of the German system of higher education (a strong tendency towards specialization, and career paths which depend on the cyclical hiring patterns of firms), it should provide the movement of reform with considerable momentum: towards broad, non-specific skills and towards long-run educational goals. Human capital investment in

Germany has been largely firm- and industry-specific so far, and employees have had little opportunity for mobility between firms, professions and industries. In order to respond *quickly to* industry's demands for more qualified personnel, the Federal Government launched its much debated 'Green-Card-Initiative' early in 2000.

The academism of university training courses

Commercial and economic issues feature very little in university curricula. Especially at universities (as opposed to the 'Fachhochschulen'), technical programmes appear to be strongly geared towards theoretical competences and reasoning rather than to applications, and this has been cited as one of the reasons for German engineers' highly deductive brain-set and their specification-driven approach to real-life problems . Graduates complain that they lack interdisciplinary knowledge as well as communication and business administration skills. The failure to integrate practical experience into the education process seems to be one of its main weaknesses. Against this background, it is not surprising that only a small fraction of engineers take the risk of becoming self-employed after they have graduated.

In his account of the discipline’s history in Germany, Eulenhöfer states that the founders of computer science as an academic field did not include applied problems in their teaching of the principles of "Informatik" (Eulenhöfer 1998: 265). From the early beginnings in the late 1960s, real-world, applied data processing was thought to be non-scientific and was practically excluded from teaching. This tradition picture of computer science as a theoretical, mainly mathematical discipline has apparently prevailed for the past 30 years. Wherever computer science has been more application-oriented, however, it has focused on the large-firm sector. The latter sector has been reinforced by the leading information technology research and transfer institutions (Gesellschaft für Mathematik und Datenverarbeitung - GMD - and the IT institutes of the Fraunhofer-Gesellschaft -FhG), which are large-scale research institutions largely geared towards heavy industry and in addition, have diverted many resources (financial means and human capital) away from more entrepreneurial activities and fields.

The German Computer Science Society recommends reforming computer science education on the following lines: more applied knowledge and more integration of practical tasks, participation of the students in two long study projects each lasting about twelve months, teaching social and business skills. Numerous efforts have been mad recently to change existing curricula on these lines and to create entirely new degrees, including computer science master courses run in English and other new courses providing growing markets, such as the multimedia and telecommunications markets, with qualified personnel.

Lack of the entrepreneurial spirit at university

As in France, the performances of the universities were found to be satisfactory as far as strictly scientific matters were concerned, but little was being done to make industrial use of scientific findings. For instance, Germany’s weak competitive position in data processing cannot apparently be accounted for by the country's level of scientific expertise. An official report has concluded that there is a high potential for interactions between industry and science in the field of data processing and likewise, in the field of optics (ISI, Ifo, ZEW 2000: 23).

However, contrary to what is happening on the opposite side of the Rhine the question which arises is not so much how to improve technology transfers towards the SMEs, thanks to the excellent work carried out by the Fraunhofer Gesellschaft, but how the research scientists themselves might apply their results.

The recent upheavals on the capital markets are certainly one of the main reasons why there is such a small number of New Technology Firms in Germany. In addition, the organizational patterns and the non-competitive funding of many academic and other public research institutions seem to prevent the spirit of innovation from developing. In comparison with the USA, German public research institutions are less numerous, larger and tend to be more homogeneous in their size, the administration on which they depend, and their methods of management as well as in the overall scope of their research projects.

The development of clusters in the field of ICT

Although German firms have had a resounding success with their software programs, the results obtained on the hardware side have been much more disappointing. One of the reasons for this weakness seems to have been the lack of strong regional clusters of IT expertise. This has made it difficult for the German hardware industry to take advantage of the economies which can be achieved by agglomerating. This may be a crucial factor, because it remains to be seen whether the transition towards a knowledge-based economy can be successful without having significant indigenous IT hardware strengths.

ii) Biotechnology: marching on from strength to strength

The number of small research-oriented biotech firms increased from 75 in 1995 to 279 at the end of 1999 (Schitag Ernst & Young 1998, Ernst & Young 2000). As several observers and many politicians have proclaimed, Germany has surpassed the United Kingdom as Europe’s leading biotech country in terms of the number of core biotech companies.

The sustainability of this take-off, still remains to be proved, however, during the years to come. New companies have not yet passed the real test of the market, which will require sustained growth, high-level research alliances, developing their own technologies and products and floating the company successfully on the stock market. The main question which arises is whether German biotech companies will be able to generate novel proprietary technologies and patented products, and in particular, to find some promising new candidate drugs.

An appropriate supply of skills

In quantitative terms, providing a sufficiently large supply of qualified specialists has not been a major problem, but this may prove to be a limiting factor in the near future, especially if Germany’s biotechnology industry continues to grow as fast as it did during the past five years.

A much more critical issue, however, is the biotech sector’s ability to attract graduates and experienced researchers who excel in their field of research as well as being commercially oriented. During the 1980s and on an even larger scale in the 1990s, many of the most talented German life-science researcher workers went to the

United States for post-doc training and stayed on there, working either in public research or in private companies. If more of the German scientists who have accumulated scientific as well as management know-how in the United States returned, Germany's young biotech sector would be greatly boosted.

German biotech companies suffer from the "technophile" attitude of German university graduates. They tend to be highly qualified in their respective specialized fields, but business-like thinking and management skills are still quite rare phenomena among natural scientists.

Nor does Germany's public research sector, which consists of university centres and large public laboratories, have a particularly strong marketing record. There do exist institutional and in many cases, personal ties between those working for established companies and the generously funded public research institutes. Yet before it can establish anything at all comparable to the US industrial and scientific community, Germany still has a long way to go.

The emergence of new disciplines

In the long run, the German system of higher education itself has to prove its ability to adapt to the demands of the modern biotechnology business. As acknowledged by many observers and recently confirmed by a survey of German post-doc graduates working in the USA, the quality of life-science education at German universities is still excellent as far as the basics and the principles of the disciplines are concerned. What is lacking on all sides, however, is the ability to quickly integrate new fields of research into university curricula and the willingness to cut across conventional discipline demarcations[45].

The dynamism of local innovation networks

In addition to the co-ordinating centers in the BioRegions, science and technology parks and technology transfer organizations form a large part of the upcoming industrial and scientific network which is developing in Germany, but in comparison with the USA, this country still has a long way to go.

What Germany has achieved in the field of Biotechnology might serve as an example to countries such as France: this shows how a country with a 'top-down' type of public structure, by consistently persevering with a series of relevant interventions, can generate a 'bottom-up" process of technological and industrial creation which fits inn with the previously existing structures.

3.3.4. Austria and Portugal: the lessons taught by smaller members the European Union

Although Austria and Portugal have completely different, not to say opposite political, economic and scientific histories, it can be highly instructive to examine the experience acquired by countries where the national systems of innovation are bound

[45]One exception is the University of Heidelberg's new "Biobusiness" curriculum developed in co-operation with the University of Mannheim and industrial partners: this course was designed to provide life scientists with business skills.

to be extremely incomplete, open to the outside world, and subjet to the influence of large multinational firms originating from elsewhere.

i)Austria: from industrial dynamics based on incremental innovation towards a knowledge based society

As far as knowledge sourcing is concerned in Austrian business companies, the HERS plays a fairly subordinate role in this country. Consequently, the linkages and interactions between the higher education sector and the business sector are weak in terms of flows and funds. The typical innovation model adopted in Austrian companies is based on the continuing improvement of their products and processes and therefore on a process of very gradual innovation. This strategy is rather a ginger one, but it promises to pay off in the end. Austria´s business firms have therefore launched many small-scale; low-cost innovation projects. This further shows how cautiously they proceed whenever it comes to introducing technology which is new to a market." (based on ART 1999, p.21). The outcome has in fact been a successful process of gradual innovation with rather low R&D quotas, although the system has recently had some difficulty in finding its feet in the "New Economy" business world.

Most entrepreneurs have been pursuing a recruitment strategy whereby preference is given to graduates from vocational/ technical secondary schools and post-secondary vocational courses over university graduates. Engineers with this educational background are cheaper to hire on the one hand, and less ambitious to take over the leading managerial role of the entrepreneur on the other hand (who typically has no academic degree either). Nevertheless, these recruitment strategies are thought to have been interacting with innovation trajectories: technological process innovation and gradual network innovation were shaping the innovation process at the expense of product innovation and "radical" innovation.

Dissatisfaction with this situation – producing theorists and generalists at the universities on the one hand and vocational engineers at technical and vocational secondary schools on the other hand – and the conviction that many undergraduates at universities would be better off attending a more vocational course, has led the Austrian Government to enrich the HERS with ten experimental *´Fachhochschulen´* (FHS) in 1994. The FHS were intended to provide a more flexible and practical alternative to academic university studies. Eight of them specialise in fields relating directly to the ICT sector, and most of them have one or more curricular modules devoted to information technology.

The relevance of network and consortia policies to stimulate innovative SMEs

Several measurements have been implemented in Austria to strengthen the relationships between research institutions (mainly universities) and enterprises. The most important programme is the K-plus programme. The K-plus Competence Centre Program was launched in 1998 to promote long-term co-operation between innovative enterprises and top-level research groups in order to contribute to a lasting improvement in the co-operation between science and industry. One of the key prerequisites for a Competence Centre to be established and able to function is that it must be able to enlist the long-term participation of research institutions and at least five enterprises. At the moment, 12 K-Plus Centres have been established and 9 further applications are currently being assessed.

The K+ initiative might certainly be the best possible practice in terms of the goals of the SESI project because it has generated ***two ideal models*** for the knowledge based economy, the success of which was based on developing work process knowledge and sound technological knowledge.

These two models (both of which are set in the ICT context) again illustrate the two-fold process of adjustment and bifurcation which seems to underly the transformations undergone (with success) by most of the European systems of innovation involving a renovation of the relations between Science and Industry:

The *Kapsch "risk avoiding close to market model of knowledge sourcing"* can be viewed as an upgraded extension of the traditional Austrian trajectory mainly continuing on similar lines to the Austrian model.

-The *AT&S "network-based just in time model of knowledge sourcing"* can be seen as a major departure from the traditional Austrian model. First, due to the firm and ambitious decision to move towards a technological leader and secondly, due the new strategies dedicated to building links between the various actors in the economic process (firm departments, suppliers, customer, universities, etc.) with a view to establishing a ***tacit knowledge base in the area of scientific and*** theoretical knowledge. The tacit knowledge base relating to the work process and other fairly practical considerations has therefore now been combined with a new tacit knowledge base at the more theoretical scientific level. The problem of the firms' absorption capacity has been solved by setting up of small – but top-flight – R&D departments initiating, steering and managing the ISR and as well the other knowledge intensive network and relationships.

In terms of lessons for policy, the AT&S case is clearly the most interesting because sophisticated work process knowledge seems to be an asset which many Austrian companies have. But the second step, that of combining process knowledge with academic knowledge, is one which only a few companies are able to take. Consequently, the question has to be raised as to how can those companies might be assisted with taking the second step?

The formation of the appropriate skills for a knowledge based economy

The implementation of the "Fachhochschulen" in 1993 could be see as an appropriate answer of the Austrian system of skills supply to assist the *Kapsch "risk avoiding close to market model of knowledge sourcing"* in the road towards the knowledge based economy. Since the "Fachhochschule" courses provide students with a vocationally and technically oriented educational programme at higher educational level, they perfectly fit a model where the aim is to continually upgrade a sound technological knowledge base mainly including upper secondary technical school skills so as to be able to face new competitive and innovative forces developing outside. And indeed the Austrian technologically oriented businesses are scrambling for "Fachhochschule" graduates[46].

[46] The following quote by Dr. Kapsch (the CEO of Kapsch), who really welcomes the "Fachhochschulen" but is sceptical about the universities, is an illuminating illustration. "I feel the *upper secondary technical schools* we have constitute a very good system. However, the problem is that in these schools, not much store is set on general education issues, and hence the new *"Fachhochschulen"* are idea. they are very valuable. we strongly support the "Fachhochschule" system…in my opinion, our *universities* have some serious shortcomings".

Doctoral training could be adapted in the case of some PhD courses to the Occupational Labour Market. To become a research scientist at a pharmaceutical company, a PhD is useful if not a pre-requisite, but young PhD graduates are not regarded as having finished their education. Only Post-doc graduates with several years of practical experience (preferably in a foreign country) are regarded as "trained" (although the position of a PhD graduate in a pharmaceutical research group is somehow different from an internship.).

An occupational labour market for PhDs may emerge in the fields of Science that are relevant to pharmaceutical research as well as other fields such as physics (e.g. chip-design) or even mathematics. In the ICT sector (with the exception of the above-mentioned hardware areas), however, PhD diplomas are thought of as being too scientific and too theoretical..

Science base: how compatible would this be with the roots of the Austrian system of innovation ?

There have been several trends which show that attempts have been made in Austria to make greater commercial and industrial use of the country's scientific potential by taking more market-oriented options. The question now arises as to whether this orientation is compatible with the traditional basis of the Austrian system of innovation, which has achieved considerable industrial success, mainly thanks to the gradual pace at which innovation was introduced.

Measures of two kinds have been adopted to make the system more flexible: the first focus on the way in which university workers' status and careers are managed; and the second, on the development of venture capital:

In May 2001, the government and union representatives signed an agreement on the legal reform of the status of civil service university employees. This reform means that people working at Austrian universities will no longer have civil servant status. The other aims of the reform include increasing the permeability of academic positions, opening the universities to larger numbers of young research scientists and the abolishing the research supervision diploma as a pre-requisite for a professorship. This reform was hotly debated, and the university staff threatened to go on strike at the end of May. Several of the issues that the new government is currently discussing in the education and higher education sectors are viewed by many critics within the institutions in question as liable to weaken rather than strengthen the long term research basis. The main points at issue are the financial problems associated with the new government's promise to wipe out the deficit in the national budget from 2002 onwards.

Many measures have been taken to increase the amount of venture capital made available by public and private sources in Austria. The lack of capital was one of the main criticisms put forward in the discussion about new firms, spill-overs and the fear of a technological relapse in Austria. Now several observers have stated that sufficiently large funds are available, although firms, founders and research workers are still claiming that there is a lack of venture capital. Several initiatives and consulting institutions and associations have also been established to facilitate the establishment of companies. All the necessary information is now easily accessible.

ii)Portuguese paradoxes

There exist some strong Portuguese specificities which explain why the path taken here has differed considerably from those described in the case of Austria, Britain, France and Germany.

The competitive Portuguese model has been called the **"Portuguese paradox"** in the sense that "..in macroeconomic terms, the country has had a remarkable performance, namely after the adherence to E.U., in 1986, but has been unable to change the competitive pattern, which is almost the same since the 70s…." (Lança, 1999:317). This satisfactory performance can be judged, for instance, by the way the *per capita* income has caught up with the average European figures, which increased from 55.1% in 1983 to 68.4% in 1995. Since the beginning of the seventies, the OECD member countries have reinforced their investment in science-based industries, which increased the contribution of the corresponding products to the export rates from 9% to 13% between 1970 and 1993. Portugal not only has a different pattern of specialization, but it has developed quite differently during the same period by reinforcing the labour-intensive industries and decreasing the science-based industries. One might add that a relatively low proportion of the total DTID expenditure in Portugal goes to industrial R&D, which accounts for only about one third of the European average.

Limited scope for the high tech industries

By studying the history of firms and sectors, it is possible to determine whether they are on an upward or downward competitive and innovation trajectory. As far as Portugal is concerned, we can conclude that:

- The pharmaceutical sector is obviously undergoing a downward phase as far as competition and innovation and the process of de-industrialisation are concerned. These firms do not need academic knowledge, and the recruitment rates of graduates are very low. These graduates are recruited mainly by the traditional chemical sectors.
- The telecommunications sector – i.e., software design for telecommunications – has been in an upward phase, but is highly dependent on the strategies adopted by multinational firms established in the country. In these cases, flows of knowledge occur in a closed circuit inside the industrial group, and this explains the weakness of relationships with the national HERS.
- The software industry is on the rise, especially the "Basic software industry". The weak point is that this segment consists almost entirely of start-ups. Academic knowledge is needed and if engineers and PhDs trained abroad could be recruited, it would certainly help this segment to expand.

The weakness of the intermediate institutions

Some of the interfacing organizations are in a very unfavourable financial situation not far from bankruptcy, because after receiving public funds to implement and develop their infrastructures, they were supposed to work for industry in a market oriented spirit. However the demands of industry have been very low. This seems to be a case where the distance between the two spheres is too great.

In this case, rather than looking to HERS for a solution, the recommendation was to look to industry for a solution. This is the main specificity of the Portuguese situation, as far as the topic of the present SESI project is concerned. The need for institutions and organisations to solve the problems of intermediate institutions are an unexpected form of failure. Important lessons could be learned from these cases if we could identify the reasons for failures, implement solutions and prevent similar experiences from occurring in other countries, namely the East European countries which in some cases, such as Slovenia, have similar industrial structures.

Entrepreunarial universities: the main challenges

In Portugal, PhD graduates working at universities or other laboratories need to be encouraged to identify business opportunities for applying their knowledge, and the number of high tech firms needs to be increase, as mentioned in the OECD report. Venture capital and regulation barriers are important, but these are not the only problem. And we cannot expect the same person to be highly specialized in a specific scientific area and at the same time to be a competent marketing specialist and a manager, etc. These new professions are the keys to promoting high tech business, however.

Since the Portuguese industrial firms are not dealing much with science based products, their absorption capacities for generic knowledge are low. Given these structural conditions, one of the possible ways of setting up a knowledge based economy in Portugal might consist of developing a strong spirit of business enterprise at the universities. The upstream condition which needs to be met for this project to be possible is that the research groups must be producing work of a sufficiently high standard to constitute potentially marketable material.

4.Conclusions and policy implications

In this report, it was attempted to describe the characteristics of a general model for the relations between firms and academia which might serve to improve the efficiency of the exchanges between these institutions. The aim of this model, which was mainly based on the results of the monographs drawn up on individual firms in the framework of the present project, was to identify goals and modes of action. What should the priorities be for the public policy-makers responsible for building and circulating knowledge (tacit and codified, as well as generic and applied knowledge) and the competences and skills embodied in persons.

On the whole, this approach is in line with the triple helix model (Etzkowitz 2000) for the interactions between science/industry/public authorities. In addition to being extremely general, one of the great advantages the latter approach is that it gives the public authorities a leading role in the relations between Science and Industry in terms of both the analyses and the standards they are required to produce. Public incitements are bound to influence the decisions and attitudes of individual actors in one way or another, and can have either positive or negative effects from the point of view of economic and social welfare.

Looking at the problem in question in terms of the production of standards and analyses seems to be a promising approach, all the more so as the Triple Helix model was not designed just to analyse the interactions between the three categories of protagonists. It also takes into consideration the internal transformations which each of the protagonists undergoes as the result of their relations being redefined. Here there is a shift of emphasis towards the increasing tendency for overlaps to occur between the three types of partner, and more importantly, for hybrid structures to emerge, as exemplified by the "entrepreneurial universities" , which are having direct effects at the regional and local levels. Three-part initiatives classically involve agreements which can take various institutional forms, but which in addition, tend to generate common structures, such as the spin-offs which are frequently being given as an example these days.

Apart from these general considerations , it is proposed to deal in the present chapter with the institutional specificities of the countries studied, with a view to drawing up some recommendations without losing sight of the specific national contexts. These recommendations are mainly based on the monographs in which firms were re-analysed with a view to drawing some initial conclusions which might be of use to public authorities. Taking as a starting-point the idea that relations between firms and universities are rooted in configurations of actors and the rules of the game, many of which are dictated by the given national context, it is proposed to deal with each country separately in turn. This does not mean that the effects of globalisation and/or Europeanisation are held to be negligible or secondary. The contrary is the case, since our country-by-country approach also makes it necessary to look at the overall tendencies from two different angles.

- How do public and private actors adapt their national systems of innovation to converge with other countries, or on the contrary, to accentuate the differences?
- Is the national level still that to which the coherence of the systems of innovation is built first and foremost?

It is not within the scope of this chapter on recommendations to public actors to attempt to answer these three questions in detail. For a closer analysis, readers are referred to the reports, especially the national ones, in which all these aspects have been covered[47]. Here the same national reports will be used as a basis to define possible orientations and suggestions for public policy-makers, focusing in particular on the high tech, ICT and pharmaceutical sectors (in the latter case, especially as far as biotechnology issues are concerned).

4.1. Co-ordination of actors and incentives at the micro-level

4.1.1. Introduction : the scale and diversity of relations

The scale of the relations between scientific research and industry, and the vigour with which they have been pursued in recent years, are phenomena too significant to be regarded as merely contingent or accidental. On the contrary, they have to be viewed against the background of certain pronounced trends and developments in both the general economic and technological environment and in the processes of innovation themselves.

The structural changes that have taken place in the developed countries reflect the growing importance of the production, diffusion and application of knowledge. Science and technology are progressing ever more rapidly and the advances being made are permeating all areas of economic activity. The available statistics indicate that the structural bases of the knowledge economy are becoming increasingly significant and evident. The increasing level of investment in information and communications technologies (ICTs) as well as in intangible assets such as education, R&D and software, together with the expansion of knowledge-based industries, are important and widely acknowledged indicators of these developments.

However, these phenomena have not always evolved linearly, particularly when it comes to the overall volume of expenditure on R&D and the distribution of that expenditure between the private and public sectors. This type of variable has proved to be very sensitive to the influence of military expenditure, to attempts to stabilise budget deficits and to the general economic situation. Modes of funding are not neutral in their impact either, and they also tend to influence the direction of R&D in terms both of applied and basic research.

There are still very considerable differences between countries in respect of innovation, even though R&D and scientific research have become globalised. The findings of the SESI project, whose sphere of investigation encompasses the computer industry, telecommunications and pharmaceuticals, all of which are high-technology industries, confirm the existence of these differences in the sample of countries studied

[47] CRIS International, 2001, Biotechnology : Industry-Science Relationships in Germany, WP 2.2., SESI PROJECT CONTRACT N° SOE1 - CT97-1054 Project n° 1297.
CRIS International, 2001, Information and Communication Technology: Industry-Science Relationships in Germany, WP 2.2., SESI PROJECT CONTRACT N° SOE1 - CT97-1054 Project n° 1297.
Lam Alice and Nicolaides Andy, 2001, UK Policy Reforms on Academic-Industry Relationships: Challenges for Knowledge Transfer and Competencies Building, WP 6, SESI PROJECT CONTRACT N° SOE1 - CT97-1054 Project n° 1297.
Mayer Kurt, 2001, Sector report: Industry-Science relationships in the Austrian ICT Industry, WP 6, SESI PROJECT CONTRACT N° SOE1 - CT97-1054, Project n° 1297.
Unger Martin, The Pharmaceutical Industry, Sectoral Monograph, WP6, SESI PROJECT CONTRACT N° SOE1 - CT97-1054 Project n° 1297
Verdier Eric, 2001, The French higher education and research system in the perspective of innovation: a political turning point ?, WP6, SESI PROJECT CONTRACT N° SOE1 - CT97-1054 Project n° 1297
We used here many sentences and analysis of these different national reports. But The author of this chapter is responsible for the proposals and recommendations and of course for any misunderstanding.

in the course of the project. The differences observed between Portugal, Austria, Germany, United Kingdom, France and the USA reveal in particular the role of national fields of specialisation, of a competitive base of national firms and of size of country .

It is nevertheless the case that innovation is now globalised to a much greater extent than in the past. This trend has to be viewed in the context of another recent development, namely the increasing amount of interaction between companies and the growth of network organisations, as evidenced by the expansion of foreign direct investment and the rapid proliferation of international alliances between firms (OECD 2000).

The changes are no less significant at the level of human resources, both in quantitative and qualitative terms. As measured by the flows of graduates leaving higher education systems, there has been a considerable expansion of education provision. Moreover, higher education has not developed solely by matching provision to the supply of public-sector and teaching jobs; it has also expanded in order to meet industry's demand for graduate engineers and researchers, which suggests that the various systems have in general been able to engage in a process of socialisation more in line with firms' expectations. The national reports compiled in the course of the SESI project may serve to put this statement into context in various respects by drawing attention to the possible existence of relative shortages, which are, incidentally, neither necessarily nor wholly attributable to the various national education systems. It retains its validity, nevertheless, and even though there has been a certain decline in the popularity of science courses among high-school graduates, the example of France is fairly typical of the developments that have taken place over the past 15 years. In a country in which the humanities and social sciences have traditionally been very important, there has been a very real shift within the education system over that period towards science and technology (see Verdier 2001). Far upstream of the innovation process itself, this is one of the basic preconditions for a dynamic innovation system.

Moreover, it is now generally agreed that the performance of innovation systems depends more than in the past on the intensity and effectiveness of the interactions between scientific research and industry. Connections are made between this basic position and some of the key phenomena observed in innovation processes and their principal determinants.

The first of these phenomena relates to the research cycle rhythms that result from the various competitive regimes. Firms are increasingly using innovation as an instrument of competitiveness. Ever harsher competition is leading them to seek short-term competitiveness by accelerating the product development process. The shortening of technological cycles reflects a shift of emphasis in research towards a more applied approach more closely linked to corporate strategies, which brings with it a certain risk of "short-termism".

At the same time, many of the technologies that are transforming society are the result of basic scientific research. The links between innovation and the science base are closer than in the past. Particularly in key sectors such as information technologies and biotechnologies, innovation seems to be closely linked to advances in the basic sciences. These are sectors in which close links have developed between technologies, scientific publications and commercial successes.

Moreover, large-scale, complex developments linked to the expansion and application of knowledge are restructuring the space and architecture of knowledge itself. Knowledge is diversifying as a result of technological convergence at the same time as new disciplines are emerging. However, knowledge is also diversifying because the sources of knowledge are themselves becoming more diverse. Knowledge is generated by scientific research but also by clients. Thus the development of industry-science relations may be an instrument for reconciling requirements that seem, on the face of it, to be contradictory.

The scale of the links between industry and science goes hand in hand with a very considerable diversity of institutional forms and modes of coordination.

As far as the production of knowledge is concerned, the SESI research has uncovered a wide variety of mechanisms intended to establish cooperation.These mechanisms may be more or less formalised and range from joint laboratories to informal contacts within professional networks via spin-offs, the granting of licences, research contracts, researcher mobility, joint publications and specialist conferences, exhibitions, media etc.

It should be stressed that the formal mechanisms through which industry-science links are mediated constitute only the most visible and not necessarily always the most important part of these links. Many such links are mediated through informal, indirect channels.

Over and above their specific characteristics related to sector, size and national origin, virtually all the firms in the SESI sample take the view that the production of a flow of graduates channelled towards industry constitutes a particularly important, if not decisive, medium for science-industry links. The reasons generally adduced are already familiar. For firms, the principal objective is to have better access to better educated human resources. They also expect to gain access to new scientific knowledge, to established networks and to problem-solving capabilities. Thus the production of a flow of graduates must be understood in both quantitative and qualitative terms. In the latter respect, firms are seeking in particular to influence the contents of courses and training programmes, thereby giving themselves an opportunity to make their views heard in the debates that shape the construction of competences and knowledge.

Conversely, these collaborations can give higher education establishments an opportunity to facilitate their students' entry into the world of work and improve their job opportunities, to update their training programmes and to obtain financial support with a view to producing innovations. These links also raise their profile in the continuing education/training market, both for specific, short-term programmes aimed at company employees but also for longer-term arrangements in a context in which education and training over the life cycle is becoming a strategic issue.

The diversity of institutional and organisational arrangements makes it necessary to adopt a twofold approach, one that is both analytical and normative.

On the one hand, we need to investigate, from a positive perspective, the reasons that have prompted the actors to choose certain types of arrangements rather than others. The aim here will be to re-examine the actors' plans and objectives as responses to the challenges posed by the current environment or the changes that have taken place. On the other hand, this diversity can be given a more normative interpretation, in which the central issue at stake is the problem of efficient relations. These two perspectives come together fairly rapidly once the approach is located within the framework of a broadly based rationality and a concept of efficiency that revolves principally around the notion of congruity with the firm's environment.

However, the approach does not in any sense subscribe to the notion of "one first best way". The aim rather is to discuss and reveal the various possibilities for conflict resolution in terms of their advantages and disadvantages. In a context characterised by pronounced heterogeneities, joint actions must take account of diversity in order to determine what constitutes "good practice" and the measures best suited to the various institutional and organisational frameworks.

On the micro-economic or micro-social level, any analysis of cooperation between actors now begins with an investigation of the organisational principles at work. From this perspective, it is well known that problems of coordination and incentive occupy a central position.

The particular nature of the two actors involved in the relationship, who have their origins in two different worlds, naturally leads us to enquire into the organisational and institutional modalities through which effective collaborations can be mediated (1).

It also encourages us to investigate each partner's internal organisation and the possible reorganisations or restructurings that might facilitate appropriation of the results of the collaboration (2).

Finally, given that the key issue at stake in the relationship is the production of knowledge, it is advisable to tackle the question of whether the two actors succeed, through a process involving the co-production of competences and knowledge, in developing a joint response, which may involve the establishment of a high-level occupational market (3).

4.1.2. The organisational and institutional factors encouraging efficient collaboration

The multiplicity of apparently pertinent situations observed makes it virtually impossible to identify one single, simple form of efficient collaboration between partners. In fact, the determinants of a good relationship between industry and scientific research are to be found in various spheres and tend to take a variety of different forms. They include rules, incentives and the definition of property rights, as well as the hybrid or interface organisations.

A number of lessons can be learnt from the examples of successes and failures recorded in the case studies produced during the various phases of the SESI project. These lessons are located at the following three strategic levels:

. that of the factors of risk and uncertainty,
. that of the processes whereby interests converge and, finally,
. that of the interfacing institutions, agencies and "bodies".

a) The hazards of innovation and of science-industry relations

Risk, uncertainty and the behaviour of the actors involved in innovation

It will come as no surprise to learn that risk or uncertainty is one of the elements shaping the actors' behaviour and decision-making.

By its very nature, innovation is a particularly risky investment activity. The time taken to produce a result, and hence the cost of obtaining that result, is uncertain. In addition to the technical uncertainty, the outcomes are also subject to the vagaries of the market, because of the behaviour of both consumers and competitors (Guellec and Van Pottelsberghe 2000).

In addition to the factors linked to demand and to the technology, two further factors make research a riskier activity than many others. The profits structure in innovative markets is asymmetrical, with high profits for the winners and considerable losses for the others. The literature on the rush to patent is based largely on the notion of a treasure hunt in which the winner takes all. Investment in research is largely irreversible. The specific nature of a research project's interim findings is linked to the fact that a large part of the knowledge accumulated by that stage is tacit and therefore non-transferable in the short term, which deprives it of any market value.

Thus cooperation between firms and higher education takes place in a context in which firms are seeking to minimise costs and diversify risks. At the same time, the specific forms of cooperation reflect judgments based on an assessment of the nature of the risks and uncertainty inherent in the relationship between partners from two different worlds.

The dominant approach to risk in the literature takes the firm as its initial reference point. The approach adopted in the SESI project, which puts the production of knowledge firmly in the spotlight, has proved to be more balanced. The firm is still a key actor, but account is also taken of the other partner and, in particular, of the risk that universities run in tailoring their research agenda to the specific needs of companies, thereby reducing the 'public good' element of their output, particularly if firms' needs are driven by short-term considerations.

Thus it seems particularly important to give equal weight to the two protagonists, their objectives and their behaviour in formulating policies and recommendations. This is the price that has to be paid in order to avoid the use of tools that cannot realistically contribute to a process of social optimisation.

Given these differences in objectives and behaviour, it is readily understandable that any collaborative venture between industry and higher education will pose particularly difficult challenges.

Greater involvement by firms in public research gives rise to costs and the possible loss of positive externalities for society as a whole. For example, if the norms of private appropriation replace the norm of total disclosure currently in force in open science, then the diffusion of knowledge may be slowed down as a result. Similarly, applied research may be privileged to the detriment of basic science, which may in the long term lead to a decline in social well-being.

This has implications for the criteria used to draw up regulations. The general regulations must take account of the interests of all the actors in the cooperative process. Policies must be targeted principally at supporting or achieving compromises.

Just like firms, universities are confronted with contradictory constraints to which they have to respond by reaching the most satisfactory compromise possible in the light of the human and financial resources at their disposal and the legal and regulatory frameworks within which they operate. Their principal concern here is to develop policies and procedures that allow them to avoid both the risk of subjugation to the needs of firms and that of becoming completely disconnected from social demand and the productive system.

Economic challenges, externalisation and the search for partnerships

From the point of view of firms and their expectations of what can be realistically achieved in the area of knowledge production, the importance and growth of science-industry links can be measured by the yardstick of the technical and organisational changes that have affected the manufacturing sector in particular. The rapidity of technical change, combined with the dismantling of the barriers to international trade, has helped to create new organisational and strategic opportunities.

The development of links with higher education is one consequence of the new strategic choices firms are making.

The economic environment tends to exacerbate the tensions between objectives attuned to different time horizons. Firms are constantly faced with the task of reconciling the need to balance income and expenditure over the short term with the long-term demands of forging their core competence on the basis of sustained competitiveness. Walking this tightrope is becoming increasingly difficult because of the importance of R&D work in the new technologies, which requires the investment of increasingly large sums of money.

Faced with rising costs and ever greater uncertainty as to the results of research, firms are seeking to share these risks and costs by forging alliances and networks or through externalisation. At global level in particular, strategic alliances of various types, particularly those intended to share the costs and risks of R&D in the field of electronics, have become more crucial. The rise to prominence of such alliances has blurred firms' organisational boundaries and increased the need for coordination between market and non-market organisations. Cooperation between firms and higher education is part of this trend. However, the dynamic of cooperation also has to be viewed against the background of the budgetary restrictions that public research establishments and universities are increasingly facing; as a result of these constraints, they are being forced to seek other partners in order to diversify their portfolio of funding sources.

The shortening of technological cycles and new strategies in respect of knowledge

Recent years have seen a heightening of the challenges and points of tension as well as an increase in the opportunities for cooperation.

Thus technological cycles in leading-edge sectors have tended to become shorter because of the pressure of competition. As a result of this shift, which tends to favour short-term activities and which is further exacerbated by the application of more rigorous standards of corporate governance, firms have been forced to cut R&D costs while at the same time seeking rapid access to new knowledge. Higher education may well be the new source of knowledge firms require for their innovation activities.

This shortening of research cycles reflects an approach to research that is more directly linked to corporate strategies. The risk inherent in this approach is that too much emphasis will be placed on shortening R&D and product cycles, which might in turn lead to underinvestment in generic technologies and undermine the future prospects for technological progress and innovation.

However, the pace of technological progress has quickened and the market has developed in areas in which innovation is based directly on scientific activity, which increases the demand for links with the science base. Because of the long gestation periods, the high costs and the technical and financial uncertainty that go hand in hand with radical innovations, firms have entered into cooperation with each other and into partnerships with scientific institutions in a bid to reduce the costs and risks of innovation.

Similarly, the increasing diversity of the knowledge that has to be acquired is forcing firms into operating within networks and externalising certain functions in order to mitigate the technical and commercial risks. As competition and globalisation have intensified, the range of sources of new technologies and of innovative concepts has widened considerably, to the point where most firms are no longer able directly to control this diversity of knowledge.

The ranges of technologies required for innovation have also expanded as technological advances have pushed ever closer to the limits of scientific knowledge; moreover, each individual technology has become more complex because of the increasingly diverse knowledge on which it is based. Thus firms are no longer in a position to cover the whole range of useful scientific disciplines as some were able to do in the past. Furthermore, monitoring other firms across the entire globe and in different markets seems to be a crucial factor in identifying sources of knowledge of relevance to firms' innovation drives.

b) Ensuring the convergence of interests

All cooperation presupposes the existence of institutional structures that favour the convergence of objectives or requires the creation of ad hoc institutions, both for organisational purposes and in order to provide common points of reference for the actions of the various protagonists. From this point of view, the studies of national innovation systems generally indicate the existence at regional or national level of jointly agreed arrangements specific to the organisations in question that aim to reduce cognitive gaps or adjustment costs in order to facilitate closer links between HERS and firms. The system of intellectual property rights, in all its various forms (duration, scope, conditions for the granting of rights, etc.), is not a neutral factor in this process of convergence.

The initial challenge : the cognitive and cultural "gaps" between "science" and "industry"

The literature provides many opportunities to identify the disparities between the two worlds of scientific research and industry, whose members pursue very different objectives, are motivated by very different forms of incentive and are subject to very different evaluation procedures.

In some cases, these two worlds that produce and utilise knowledge are even depicted as being governed by antinomic sets of rules (the "republic of sciences" and "the kingdom of technology"). The objective then becomes one of reducing or managing these differences by establishing rules intended to close the gap between the two worlds while at the same ensuring that this reduction of disparities does not diminish the mutual gains derived from collaboration, thereby seriously undermining the aims of the exercise.

However, differences in the actors' initial endowments in terms of knowledge levels can play a not insignificant role. Introducing the notion of the relationship between or the proximity of the actors' various spheres of research competences makes it possible to identify any horizontal cognitive gaps that might exist between the partners[48]. Too great a horizontal gap undoubtedly increases transaction and coordination costs and thereby reduces the incentive to cooperate.

The simple notion of complementarity suggests that the vertical cognitive gaps[49] between the two partners should not be so great as to inhibit the development of the kind of synergies and problems likely to play a part in making significant advances. The notion of "gap" can be extended beyond the cognitive dimension to encompass more cultural aspects as well. The cognitive and cultural gaps between the two systems may be traceable back upstream to the output of the training and education system. The gaps may depend on the technological regimes and the various models of science-industry relations. Although a quantitatively and qualitatively adequate output from the higher education system is required in all cases, such an output is not a wholly sufficient condition, particularly in a system in which economic and technological competition is truly global. In this regard, the national systems still seem to be very different : the various national reports compiled in the course of the SESI project revealed the extent of the cognitive technical gap (with Portugal being the emblematic case) and certain heterogeneities with regard to social gaps, which are closely linked to the specificities of the various "national models", and in particular to the configuration of the engineering and research professions in each country. It is very difficult, therefore, to draw any systematic lessons for firms, apart from the need to incorporate these particularities into their management processes.

It should be noted in this connection that the duality of the French higher education system is not without its consequences either. Thus the engineering school system provides a generic resource capable, by virtue of their dual training (and this applies particularly to engineers with PhDs), of positioning itself in both the academic world and in industry. On the other hand, there may be a cultural and cognitive gap between the teams working for the industrial partner, which are made up of graduates

[48] The horizontal gap denotes the specialisation of the agents in particular fields.
[49] The vertical gap denotes the agents' levels of advancement within a single field.

from the *Grandes écoles*, and the academic researchers, who tend to be graduates of the university system and have very academic CVs.

Two models of industry-science linkages

On the basis of the data gathered by the SESI teams, various "topological" divides were formed and used as a basis for putting together significant groupings. Several models of matches between the interests of the different actors coexist, each type having its advantages and disadvantages.

The complementarity of the actors' activities, both of whom are rooted in the production of knowledge, emerges as an important factor in securing relations between firms and universities. Nevertheless, it is still necessary to go beyond the tensions and to manage the risks, both of which arise out of the differences in the actors' agendas.

Nothing is being said at this stage about the mobilisation of human resources and the transfers of competences and knowledge through the flow of graduates from the university system to industry. They are the object of a separate study (see point 3.2. in this report).

The diversity of industry-science relations suggests typologies reflecting the actors' various strategic choices in respect of risk management. From a dynamic perspective, two polar models (see point 3.2. in this report) seem to emerge, in which the overall strategies of the academic and industrial actors tend to come together to produce a response to technological risk that is underpinned by a coherent set of functional and specialised principles.

In the first model, firms benefit from research at a relatively low cost and in an integrated and systematic way, while the academic partner's main concern is to maximise the volume of research. The latter pools information on firms' needs and codifies their technical problems in order to provide standard scientific responses. There is a relatively low level of technical risk here, and the commercial risk is mitigated by a close-knit collaborative network. This is a generalised version of Kline and Rosenberg's chain-link model or interactive chain-link model (Kline and Rosenberg 1986), in which the technology is no longer appropriated autonomously by the firm's research laboratory.

In terms of the practicalities of cooperation, the rules whereby cooperation is managed must enable the partners to face and respond effectively to the classic problems of balancing risks and incentives. To this end, the research establishment or university involved can help to spread the risk by adopting a form of contract that combines fixed payments with deferred payments that are dependent on the returns to the knowledge produced in the course of the collaboration.

In the second model, the academic partner's research agenda remains in place, the aim here being to advance knowledge in a clearly defined field of scientific excellence. As far as the industrial partner is concerned, the objective is to tackle a promising area of research in order to open up a significant lead over rivals. The much greater level of technical risk is mitigated by a "self-protective" approach, which reduces the probability of failure by making academic excellence the principal criterion for choosing academic partners.

This tendency towards bipolarisation among higher education establishments on the basis of their functional specialisation - with the leading establishments seeking to become major players in the "knowledge market" and the less prestigious ones providing support for firms and undertaking contract research, is not, however, inevitable or necessarily desirable.

It is encouraged by a system of financing that gives rise to intense competition for core funding, as the British case demonstrates (see Lam and Nicolaides, 2001).

However, the principle of risk diversification would suggest that several types of cooperation are possible, or even desirable. In order to diversify their portfolios of risk activities, companies' departmental managers can make use of the two polar forms of cooperation, since each model of industry-science relations has different advantages for firms. Public research institutions can also seek to diversify their activities by allocating their human resources to the various parts of their research programme. An excessively short-term approach can turn out to be disadvantageous in the longer term, since a research institute's applied research has to draw on a stock of more basic knowledge. Hybrid needs must be supported by hybrid solutions and pose the problem of the joint construction of occupational identities capable of sustaining these processes of cooperation.

A similar kind of problem, but related this time to firms' decisions as to whether or not to enter into collaboration with local university research institutes, also tends to make itself felt particularly acutely. Increased globalisation brings with it greater opportunities for choice; nevertheless, changes in firms' strategies and choices that make academic excellence the sole criterion at the expense of the local dimension can give rise to unrecoverable costs, since past investments might well have served not only to establish lasting and productive relations but also to reduce the cognitive gaps between the partners.

However, it should be added that local centres of industry-science collaboration are all the more likely to develop or survive in the new global context if they have a significant competence base (that is an adequate range of disciplines and education and training provision and an innovative base alert to firms' needs and capable of reacting to them) and an adequate knowledge base (that is a potential panel of service providers open to both basic and applied research). The examples drawn from the case studies of multinational companies operating in France clearly reveal the importance of the transparency and complementarity of the diversified supplies of competences and knowledge that have been constructed in the various technological districts, such as Grenoble and Toulouse (Nohara and Verdier 2001). It is the role of the public authorities to put in place programmes that encourage the development of long-term synergies, thereby ensuring that these various types of knowledge and expertise are combined. Such programmes should both foster the formation of endogenous technological development capabilities and make the local area attractive to R&D investment by outside firms.

The issue of intellectual property rights

Intellectual property rights (IPR) are another important issue. The problem is made particularly complex by the instability of regimes over time and from one institution to another, even within the same national system. IPRs have led to significant changes and disruptions in the choices made by the various actors, particularly those between short and long-term considerations. On this latter point, it is clear from the surveys conducted in the course of the SESI project that this question of IPRs is one of the most contentious issues - given the extreme diversity of national rules in this area, this is a somewhat paradoxical finding.

The bipolar schema outlined above may shed some light on the choice of IPR regime. In the first model, the academic partner, whose primary concern is to increase the volume of research, is less preoccupied by the intellectual property rights relating to collaborative research, whereas the industrial partner is more concerned to retain ownership of knowledge that is fairly close to being developed. The lower level of technical risk makes it easier to enshrine in specified contracts commitments by means of which the problems of risk and incentive can be settled relatively effectively. On the other hand, too high a level of uncertainty - particularly one that is difficult to measure - may make it more difficult to draw up and specify contracts and brings the question of property rights into the spotlight.

However, there are other considerations to be taken into account as well, since giving priority to the academic partner is likely to give rise to patterns of management behaviour similar to those adopted by the private investor, i.e. ones that go beyond the mere use of royalties. This brings us to the question of academic entrepreneurship.

As far as this form of entrepreneurship is concerned, it might legitimately be asked whether certain incentive structures have not gone too far and threaten to undermine the production of generic competences and knowledge. From this point of view, the positive effects achieved in the short term may be merely illusory and the system would not be protected from a reversal of the trend in the longer term.

While most of the intellectual property rights regimes in force have their own particular advantages and disadvantages, the existence of a diversified assignment system within a single country depending on the nature of the research establishments involved is more puzzling. This merely increases complexity in an area that is already quite complex enough and may well damage both industry-science relations and cooperation among public research institutes. The lack of clarity and the transaction costs incurred by firms, particularly SMEs, engaged in cooperative ventures may well lead to a reduction in the commercialisation of research. More generally, it is likely that harmonisation at the European level would be an effective way of limiting opportunistic behaviour (on these issues, see 3.2. in this report).

c) Institutions, agencies and interface bodies

A distinction needs to be made between the actors involved in collaborations and the underlying institutional principles. Moreover, both have to be apprehended from a dynamic perspective : an interface actor’s position can change considerably in a short space of time.

Taking account of the institutional diversity of industry-science relations

Examination of the relations between higher education and industry reveals that the types of relations are very diverse and that a large number of actors is involved. In this intense relational "magma", the informal aspects and individual relations prove to be of considerable significance. From the point of view of the actual actors involved, however, relations between the two worlds - in terms of the production of both knowledge and competences - are mediated through two main channels.

Individuals and social networks constitute the first vector, now well established, for industry-science relations. The doctoral student whose thesis is being jointly supervised or the post-doc researching a topic of mutual interest are the bridges and gateways through which knowledge flows between the two worlds. The informal networks that develop around lecturers and former students, those that develop around former researchers and their old research institute and the members of the business associations represented on department or university boards are some of the channels for the exchange of knowledge between industry and public research. The new information and communications technologies cannot but strengthen the role of these social networks in industry-science relations.

The explicit organisational structures that constitute the second vector for industry-science relations also take a great variety of forms. They may be consortia of private and public partners, joint research units set up for a period of several years, joint laboratories "without walls" in which the links between public and private researchers are institutionalised, a joint technological "platform" supported by several university laboratories, etc. Spin-offs take several forms : i) firms founded by public-sector researchers, ii) start-ups that have licensed public-sector technologies and iii) firms in which a public institution has taken an equity stake or which have been set up by a public research institution. Spin-offs are the channel through which knowledge produced by public research is commercialised. Although the system is developing, it nevertheless remains small in quantitative terms.

The principles underlying industry-science linkages : the relative value of intermediate actors

The animating principles underlying industry-science links are diverse and increasingly targeted at specific objectives.

Usually, and particularly when they are perceived as strategic, the relations tend to be institutionalised in forms that reflect the underlying functional principles.

The "portfolio management" principle leads the partners to look for a relatively simple organisational design in order to coordinate essentially bilateral relations between independent organisations. A high level of flexibility produces considerable capacities for adaptation, the task of coordination being entrusted to "gatekeepers", which makes it possible to absorb risk by confining it to the boundaries of each organisation.

The principle of "embedding" industry-science relations in the two partners' organisational and management structures has the effect of fostering the establishment of various hybrid entities, such as mixed research units, outline agreements, independent entities, joint platforms, consortia involving firms and higher education systems and conglomerates. This type of relation tends to minimise the tensions between the two worlds and gives rise to irreversibilities that impair each partner's ability to cause or initiate movement.

A third animating principle involves the use of an already constituted intermediate actor to fill the gap in knowledge levels and fields of specialisation that may separate the partners. It may lead ultimately to the creation of a hybrid collective actor or of an institutionalised collective actor independent of the partners. The fact of having an intermediate organisation subject to its own rule and value system leads to the externalisation of the risk inherent in the science-industry link. It is far from immune from the possibility of failure, particularly because of excessively wide cognitive gaps and/or disparate animating principles.

These gaps, and the ensuing adjustment costs, can be reduced by exploiting the opportunities that exist for establishing "bridges" between the two worlds and by mobility of personnel. Such mobility helps to activate and strengthen complementarities between the actors and to diffuse knowledge and is an important channel for technology transfers. Thus the hybrid actors, the so-called "gatekeepers", facilitate the coordination of relations and the management of possible horizontal cognitive gaps by establishing continuity between the various forms of knowledge produced by the partners.

4.1.3. Challenges for the partners' internal organisational structures

Cooperation cannot in itself provide solutions to the various challenges faced by each of the categories of partners (firms and higher education institutions) unless the form it takes coheres with the partners' internal organisational choices. If there is a number of challenges specific to the different actors, effective joint responses are possible.

For firms, the main objective is to resolve the problems posed by the transition from knowledge to competences, whereas for the university involved, the major challenge revolves around the emergence of new disciplines and academic entrepreneurship.

a) The internal challenge for firms

From knowledge to competences

The conceptualisation of innovation processes in conjunction with the specific characteristics of the firms that implement them has evolved considerably over the last 30 years. The linear model led naturally to a concern with the factors determining firms' investment in R&D but did not reveal all the specificities. After all, investment in R&D produces learning in support of innovation (Cohen, Levinthal, 1989). This is a highly specific form of investment in the knowledge that firms can possess, acquire and produce, and it is one of the factors that serves to differentiate firms on the basis of their capacities for learning.

Account also has to be taken of the technological knowledge that firms derive from their environment . The notion of absorption capacity (Cohen, Levinthal 1990) can usefully be applied to the innovation process, since it suggests, on the one hand, that firms combine the knowledge they derive from their external environment with their own internal stock of knowledge and, on the other, that the knowledge that firms are able to assimilate from the external environment turns out in fact to be heavily constrained by their previously accumulated stock of knowledge.

Similarly, the complexity of the process frequently turns out to be better captured by explicit models with more than one principal line of action leading from invention to market. In this respect, Kline and Rosenberg's chain-link model (Kline and Rosenberg 1986) may prove to be more realistic and relevant, in the sense that it acknowledges the multi-dimensional nature of the innovation process and of the numerous links and feedback processes between the various phases of product development and the sources of knowledge outside the firm. It also has the merit of drawing attention to a strengthening of the links with commercial activities. The twofold approach to analysis of the innovation process that focuses on both technical and commercial success is reinforced by the development of networking, cooperative ventures and alliances.

Innovation comprises, on the one hand, a process whereby externally derived generic knowledge is transformed into specific knowledge through the development cycles initiated by firms and, on the other, a process in which various resources are deployed in order to coordinate this locally produced knowledge. Certain modes of internal organisation tend to foster the development of absorption capacities as well as the ability profitably to manage knowledge derived from an increasingly diverse range of sources, including spin-offs, public research teams and firms' technological partners. At this stage, our analysis will focus solely on large multinational companies and will exclude small firms.

Internal organisation and project-based management

Project-based management is a form of organisation used by many of the large companies in the SESI sample and is intended to stimulate cooperation between the various occupational groups. This form of management leads firms to take on board the views of outside agents - those of industrial and academic partners and of management supervisors. Thus project-based management is a means of drawing together resources produced by scientific and technical partners, both inside and outside the firm; in this sense, it is a mode of organisation that goes beyond the boundaries of the individual firm.

In the case of Pharma 1, each project has a *project leader* responsible for the scientific aspects and a *project manager* in charge of the operational aspects. In this way, the configuration of the two worlds is reproduced but within a unified whole.

Project-based management emerges, de facto, as an instrument for mastering diversity, since it fosters convergence. Thus a tool originally designed as an internal management instrument can become an effective form of interface organisation.

From the organisational point of view, network-type structures can be used to eliminate the divide between central laboratories and business units.

In recent years, there has been a general trend within large companies towards the transfer of corporate labs to the various business units. This is one important indicator of the emergence of a market-driven approach, with firms seeking to convert the fruits of research as effectively and efficiently as possible into successful products. At the same time, this trend towards decentralised development has come up against problems of size, such as difficulties in coordination and inadequacies in the accumulation of knowledge that have weakened the knowledge dynamic.

The establishment of network-type organisational structures seems to be an effective compromise between the decentralisation and centralisation of research. This new way of operating makes it possible to decouple short and medium-term activities from long-term activities and falls within the scope of the third generation model of R&D

(Reger and von Wickert 2000). Networks represent a viable compromise between centralisation and decentralisation, which itself encourages the development of local initiatives in respect of industry-science links.

The configuration, implementation and management of R&D activities: the need for specific competences

Individual competences are required to manage networks and the diversity of knowledge and sources of knowledge. Acquiring and maintaining these competences poses the problem of how they should be managed.

a) A firm must have in its workforce individuals with the 'absorptive' capacities and architectural competences required to act as 'gatekeepers'.

With regard to the changes taking place in R&D systems, there is a growing need for people with specialist skills in internal and external coordination and the transfer of knowledge across functional and organisational boundaries. An aptitude for collaboration and negotiation with external agents and for exploiting externally derived knowledge must be part of R&D workers' competence profiles. From this point of view, technical competences are of course required, but the full range of skills needed extends beyond them to encompass managerial and social competences.

In general terms, the competences required of R&D workers in leading-edge industries can be said to fall within the scope of the categories of competences identified by Lundvall and Johnson (1994):

- know what (substantive knowledge)
- know why (understanding of basic principles)
- know how (skills and competences necessary to act intelligently
- know who (social capability to cooperate, to communicate and establish trust relationships).

In the new context that is emerging, the *know why* dimension may take precedence over the *know what* dimension because of the rapid obsolescence caused by technological change, with the last two dimensions playing an increasingly strategic role as "mode 2 knowledge" in Gibbons' sense of the term establishes itself.

b) The extension and modification of the range of individual competences cannot but have an effect on the various modes of human resource management. The very notion of "management mode" suggests a cohesive system of more or less formalised practices in matters of pay, training and mobility, the effectiveness of which lies in their being used in conjunction with each other rather than in isolation (Holmstrom, Milgrom, 1994).

The management of research staff poses specific problems which are far from being always satisfactorily resolved. From the positive point view, this difficulty exists because approaches to the management of R&D personnel seem little different in practice from the general models of personnel management adopted by firms. Nevertheless, recent years have seen the emergence of a trend, driven by the globalisation of R&D, towards the development of dedicated human resource departments for R&D personnel. Particularly within the corporate labs, a process of homogenisation is under way with the aim of eliminating the pay gaps between subsidiaries in order to establish pay equity within companies and to make available tools for evaluating individual competences. In this respect, the management of competences becomes a crucial aspect of HRM, particularly through the generalised use of competence management tools (regularly updated charts of the competences of R&D personnel, periodic assessments of individual competences by means of formalised evaluation procedures).

These management tools constitute instruments that can be used to promote internal flexibility, with the evolution of job contents being regarded as a substitute for the generally very low levels of mobility among engineers, who find it easier than other scientific personnel to transfer to other functions within the firm. The use by ICT3's human resources department (see Paraponaris, chapter 2 in this report) of an expert system based on competence mapping for the management of competences and careers is a tool used for the dual purpose of managing the internal market and managing knowledge.

It should also be noted that research personnel are beginning to be distinguished from employees in other functions in terms not only of pay but also of career development (innovation bonuses, dual career ladder) (Lanciano and Nohara, 2001).

c) As a general rule, recent developments tend to foreground the central issue of adapting a mode of management to its new context. It is known, for example (Caroli, 2000), that the construction of a firm's competence base can take place at two very different levels. It may be left to individuals or it may be the responsibility of the group, that is of the organisation as a whole. A firm's choices when it comes to internal or external flexibility are dependent on this knowledge base.

The highly tacit nature of the knowledge base (Lam, 2000) encourages internal flexibility, while external flexibility seems to be linked to the diffusion of new information and communication technologies. Whether innovations are incremental or radical also affects the choice of model, and judgements have to be made. In some cases, the existing stock of competences many not be suited to the adoption of far-reaching innovations, because of the risk of devaluing the firm's knowledge base and because of the existence of rigidities caused by lengthy careers. A similar phenomenon became apparent as hardware companies were transforming themselves into IT service providers. Thus one of the telecommunications companies studied has been unable rapidly, in a context of very rapid internal change, to construct a base of operational competences .

Radical new technologies are not usually introduced by firms already operating in the industry in question, while most incremental innovations are introduced by already established firms (Henderson, 1993). Internal flexibility and incremental innovation are not necessarily contradictory. However, the management of long-term careers should not be regarded as a matter of concern for the R&D department alone.

Internal mobility flows between R&D departments and business units, and vice versa, and external mobility involving other constituent parts of the networks can make a useful contribution to the development of innovation processes, in that they can be a means of testing all the links and loops of the process.

All firms are experiencing difficulties in recruiting sufficient numbers of adequately skilled workers. The quantity problem may well be exacerbated in future by demographic developments, by the age pyramid in private and public-sector companies and by global scientific competition. It is further aggravated by the relatively low elasticity of the supply of scientific personnel.

The quality problem, and that of the extension of the range of competences required, will undoubtedly be resolved in part by a strengthening of the links with higher education. As the previous part suggests, firms collaborate with higher education in the first instance in order to recruit. In this respect, a client market is undoubtedly a more effective means of controlling quality than an anonymous market, even one controlled by signals, since it offers opportunities for testing candidates (through work placements, for example) and intervening upstream of the recruitment process itself in the production of education and training.

Taken as a whole, however, the complex judgements that have to be made require more general arrangements, such as the construction of a high-level occupational market.

b) The internal challenge for academic organisations : new disciplines and the entrepreneurial university

Encouraging the emergence of new disciplines

The challenges posed by interdisciplinary education and research have undoubtedly become greater, for both the public and private sectors, even though curricula and education/training systems can be slow to adjust, particularly at PhD level, where programmes are still very specialised.

Nevertheless, this is a phenomenon that varies from country to country and from institution to institution, and in general education systems are proving to be considerably more sensitive than in the past to changes in economic demand. Nevertheless, it still has to find a guarantor within a sufficiently flexible university system.

Moreover, scientific progress has made knowledge in any given field more specialised and increased the need constantly to recombine these highly specialised areas of knowledge (see the examples of molecular chemistry and biochemistry). Indeed, new fields of knowledge are emerging at the point of overlap between different disciplines. Thus policies on education and the organisation of higher education have constantly to strike a balance between specialisation and the promotion of interdisciplinarity.

The ways in which ICTs have been diffused and applied in new fields of research illustrate these processes, which may be crucial to the production of new knowledge and its subsequent commercialisation. Bio-informatics is a good example in this regard : the increase in computers' processing power has made it possible to substitute digital modelling for instrumental analysis ; it suggests that researchers specialising in the biotechnologies will have to demonstrate increasing levels of competence in IT and expertise in the use of the corresponding computer tools in order to be able fully to exploit the available resources within their original area of specialisation.

If it is further assumed that non-technical competences are playing an increasingly significant role, PhD programmes, or at least an increasing proportion of them, will have to be expanded in order to facilitate the construction of the social and managerial competences required for integration into complex multi-disciplinary and multi-functional networks.

In general terms, it would certainly seem the right time to try to increase the reactiveness of higher education institutions with regard to the development of new disciplines. Moreover, the various kinds of university and research establishments are not necessarily starting from the same point in this respect. Comparison of the *Fachhochschulen* in Germany (and now in Austria) and of the engineering schools in France, on the one hand, with conventional universities, on the other, would suggest that the former are much more likely than the latter to engage in this recombination of knowledge, which may eventually lead to the emergence of new disciplines. More generally, given their more flexible modes of governance and organisational structures more attuned to the demands of business and industry than the regular universities, these more specialist institutions seem to be able to react more quickly to these challenges than conventional, generalist universities.

Nevertheless, safeguards are necessary, even though they will necessarily have some rough edges because of the multitude of contradictory issues at stake. A system that tends to emphasise cost control logically restricts the preposterous demands that can be made but may unduly delay the emergence of new courses because of the corporatism of the established disciplines. This situation can prove to be particularly detrimental when the phenomenon itself emerges in a context in which the traditional discipline is being eroded. This creates problems downstream for both basic research and firms when it comes to the selection of students, since formal qualifications no longer provide adequate signals as to the quality of candidates.

A regular audit of the relevance of university organisation might provide a minimum level of assurance in order to avert difficulties of this type, provided it is based on an accurate forecast of likely labour market opportunities and is carried out by an outside expert. Such an audit in no way reduced the need for an *ex post* evaluation of university systems.

Academic entrepreneurship - scope and limits

Teaching and research no longer adequately summarise the totality of a university's basic functions. The debates around the notion of the "service university" emphasises the diversity of functions undertaken by universities as a result of new circumstances and the internal and external consequences of these changes for institutions of higher education.

The notion of the entrepreneurial university has the merit of encompassing additional functions related to economic and social development and of being more explicitly aligned with the SESI project's sphere of investigation (Etzkowitz, 1998). However, there is no need to go as far as advocating changes to the current norms (as triple helix theorists do) to recognise that the changes in industry-science relations have given rise to a need for organisational change and for the introduction of incentive structures in order to take account of the new conditions under which knowledge is produced and to manage the transformation of that knowledge into effective economic activities (patents and spin-offs).

How can these activities be organised in order to reduce the conflicts of interest surrounding the income from IPRs? It is obvious that technology transfer and collaboration in research are heavily dependent on the regulations governing intellectual property rights. For universities and public research institutions, these rights are the main incentive they have to exploit research and knowledge with a view to producing innovation. National legislation differs considerably in this respect. It is undoubtedly the United States which, in passing the Bayh-Dole Act, has adopted the regime best suited to the changing requirements of public-private cooperation.

Intellectual property rights regimes are not neutral. The granting of property rights to establishments rather than to individual researchers tends to encourage non-exclusive licences. Public research institutions are inclined to favour non-exclusive licences since they ensure a wider diffusion of knowledge and broaden the sources of royalty revenues. Moreover, they do not entail any restrictions on the freedom to publish. On the other hand, problems of "exclusivity" arise in sectors where product development is very capital-intensive and lengthy. As a result, a balance has to be struck between the "open science" model and commercial risk. The granting of an exclusive licence for a clearly defined period may in this case be an honourable compromise; the example of biotechnologies and the therapies derived from them is revealing in this respect. For all that, rigid rules governing the granting of licences might well produce perverse effects. They do not obviate the need to examine situations on a case-by-case basis. This "customised" mode of management means it is all the more important to make the appropriate choices when it comes to organising the commercialisation of research.

Indeed, it is important for research organisations to develop a policy on the commercialisation of their patents. They have two options. A company can be founded specifically for the purpose of commercialising research or a specialist department can be set up within the university. In the first case, the company set up to approach entrepreneurs may help universities, including the less well-known ones, systematically to develop their portfolios of "available" inventions. Nevertheless, a critical mass of patents is necessary for such a company to be viable. In the second case, a specialist technology transfer department located in publicly funded research organisations and universities may well help to reduce overheads and to ensure close links between commercialisation and basic research, with the latter having everything to gain by getting to grips with the problems identified by "users" of its results. However, there is a risk that on-site agencies may focus on existing relations with private partners rather than encouraging the establishment of new industry-science links and thereby encouraging more "radical" and profitable innovations, even though the risks incurred may be greater.

Another solution is to encourage the emergence of start-ups. Various forms of equity investments by universities in these start-ups are currently being discussed. Thus some universities are choosing to acquire holdings in the newly set-up companies in exchange for granting patent rights. In this way, universities can encourage commercial start-ups without incurring any additional costs in commercialising its research while at the same time having a stake in the results. Such arrangements can help to avoid any possible conflict between commercialisation and research. That said, however, setting up a number of companies can tie up funds that could otherwise be devoted to basic research and force the university to act as a shareholder, which is not necessarily within its province.

Responsibility for technology transfer and licensing could also be assigned to a public or private intermediary acting on behalf of those universities that do not have the critical mass (inadequate competence and customer base). This will often require pubic support. Another issue is the distance of such intermediaries from research institutions, which may limit their role in making researchers aware of the potential for commercialisation. To this end, specialist agencies can be set up to provide assistance, albeit at the risk of making the organisation of the commercialisation process excessively complicated. In any event, it is important to raise awareness among the various protagonists in industry-science relations of the competences of the various organisations involved in technology transfer, whatever their institutional positioning, and to evaluate their effectiveness on a very regular basis. It is important to prevent the imperatives of internal management taking precedence over the need for appropriate science-industry interactions around the commercialisation of basic research. One of the main criteria in this evaluation must relate to the extent to which SMEs have access to the industry-science links engendered by these commercialisation processes.

In terms of governance, the establishment of entrepreneurial activities requires both the ability to devise a strategy for clearly identifying the principal functions and objectives of commercialisation and considerable development of the procedures for evaluating the organisations engaged in basic research. Greater autonomy for universities, a more competitive, performance-related system of funding and an increased role for universities in the commercialisation of publicly funded research are generally positive factors in industry-science cooperation, but on condition that these changes are accompanied by a strengthening of the mechanisms for evaluating publicly funded research.

Evaluation mechanisms must change for two reasons (OECD 2000, p. 205-205). Firstly, evaluation must be based on a sufficiently open concept of a researcher's activities that takes account not only of excellence in research but also of the quality of his or her activities in the training of graduates that help to encourage the application in industry of the results of academic research. Secondly, in the case of "applied research", it is necessary, when evaluating research for the purpose of obtaining core funding, to combine the traditional criteria with the ability to obtain funding from industry. Finally, the organisation of basic research must balance incentives for commercialisation and support for longer-term research in order to avoid an excessively entrepreneurial bias in basic research.

4.2. National public policies : challenges for effective transfers in the high tech industries

Apart from the previousl considerations, it is proposed to deal in the present chapter with the institutional specificities of the countries studied, with a view to drawing up some recommendations without losing sight of the specific national contexts. These recommendations are mainly based on the monographs in which firms were re-analysed with a view to drawing some initial conclusions which might be of use to public authorities. Taking as a starting-point the idea that relations between firms and universities are rooted in configurations of actors and the rules of the game, many of which are dictated by the given national context, it is proposed to deal with each country separately in turn. This does not mean that the effects of globalisation and/or Europeanisation are held to be negligible or secondary. The contrary is the case, since our country-by-country approach also makes it necessary to look at the overall tendencies from three different angles.

- To what extent are the overall policy statements, such as those produced by the OECD (OECD 2000)[50] in the form of regular recommendations strongly inspired by the American model, adopted and implemented in the various countries?
- How do public and private actors adapt their national systems of innovation to converge with other countries, or on the contrary, to accentuate the differences?
- Is the national level still that to which the coherence of the systems of innovation is built first and foremost?

It is not within the scope of this chapter on recommendations to public actors to attempt to answer these three questions in detail. For a closer analysis, readers are referred to the reports, especialoly the nationl ones, in which all these aspects have been covered[51]. Here the same national reports will be used as a basis to define possible orientations and suggestions for public policy-makers, focusing in particular on the high tech, ICT and pharmaceutical sectors (in the latter case, especially as far as biotechnology issues are concerned).

In the case of each country, our analysis will therefore focus on the combined effects of the three-fold instances mentioned above :

- What lessons can be learned from the reforms introduced during the last few years with a view to making the relations between Science and Industry and R&D policies in general more efficient? To determine what the general sources of inspiration have been, it is worth consulting the recommendations on research, development and technology (RDT) policies made by the OECD. These recommendations recently served as a reference frame for adopting the reforms recommended by the OECD experts (OECD 2000) in the various countries. They can be summarized as follows:

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[50] OECD (2000) *OECD Science, Technology and Industry Outlook 2000*. Paris: Organisation for Economic Co-operation and Development.

[51]CRIS International, 2001, Biotechnology : Industry-Science Relationships in Germany, WP 2.2., SESI PROJECT CONTRACT N° SOE1 - CT97-1054 Project n° 1297.

CRIS International, 2001, Information and Communication Technology: Industry-Science Relationships in Germany, WP 2.2., SESI PROJECT CONTRACT N° SOE1 - CT97-1054 Project n° 1297.

Lam Alice and Nicolaides Andy, 2001, UK Policy Reforms on Academic-Industry Relationships: Challenges for Knowledge Transfer and Competencies Building, WP 6, SESI PROJECT CONTRACT N° SOE1 - CT97-1054 Project n° 1297.

Mayer Kurt, 2001, Sector report: Industry-Science relationships in the Austrian ICT Industry, WP 6, SESI PROJECT CONTRACT N° SOE1 - CT97-1054, Project n° 1297.

Unger Martin, The Pharmaceutical Industry, Sectoral Monograph, WP6, SESI PROJECT CONTRACT N° SOE1 - CT97-1054 Project n° 1297

Verdier Eric, 2001, The French higher education and research system in the perspective of innovation: a political turning point ?, WP6, SESI PROJECT CONTRACT N° SOE1 - CT97-1054 Project n° 1297

We used here many sentences and analysis of these different national reports. But The author of this chapter is responsible for the proposals and recommendations and of course for any misunderstanding.

- The modes and possibilities for developing the national institutional framework . These are "path dependent ". Casper (1999)[52] has suggested that there exist three basic scenarios which can be used to interpret patterns of institutional reform:

. a process of *convergence* towards an American oriented Framework, which means making radical structural transformations in R&D policies of the European mainland countries such as Germany and France;

. a process of *specialisation,* which means reinforcing the specific national frameworks and approaches to the globalisation of Research, Development and Technology;

. a process of *adjustment* of the present institutional frameworks in France and Germany, for example, to make room for at least minimal forms of entrepreneurial science-based innovation without undermining the country's particular achievements in the field of Innovation.

- the development of infra-national initiatives liable to yield increasingly diverse sets of local innovations and relationships between Science and Industry in particular. The national institutional frameworks should not indeed be viewed simply as constraints weighing on the decisions of the micro-economic actors, but rather as examples of decisions in which such and such an economic or technological factor was given priority. The National Institutional Framework can influence these strategies by determining the relative cost of building the organisational competences they require; for example "a company management faced with international competition can survey the spectrum of possible organisational arrangements prevalent within their [national] industry, and attempt to shape a coherent strategy" (Casper, ibid, 6). Public policies may influence the conclusions of this "survey", and hence the choice of strategy made by the firms and individuals, but only within certain limits.

This non-deterministic approach, which nevertheless takes the path determinants (dependency) into account, is all the more useful as the dynamism of innovation systems is resulting increasingly from the emergence of innovation networks within which tacit forms of knowledge are circulating, and which involve various institutional arrangements, from clusters of technological districts to more widespread innovative milieus (cf. the previous chapter). This is in fact what public policy-makers have been striving to achieve by encouraging local initiatives on these lines (Lundvall and Borras, 1997)[53].

[52] Casper, Steven (1999). National Institutional Frameworks and High-Technology Innovation in Germany. The Case of Biotechnology. Berlin: Wissenschaftszentrum Berlin für Sozialforschung

[53] Lundvall, B-A., Borras, S., 1997, "The globalising learning economy: Implications for innovation policy, Report based on the preliminary conclusions from several projects under the TSER Programme, DG XII, Commission of the European Union, Draft Paper.

Based on the systems of classification proposed Amable, Barré and Boyer (1997)[54] and by Casper (ibid.), the lessons learned by public policy makers will be dealt with her in the following order:

- The United Kingdom, where the policies and regulations are typically market oriented and the orientation adopted as far as science, technology and innovation are concerned is undergoing a process of specialisation.
- France and Germany, where the relations between Science and Industry are facing fairly similar challenges, especially in comparison with those being met on the other side of the Channel, and where the scenario tends to alternated between radical change and a process of accommodation.
- Austria and Portugal, which have rather different technological and industrial structures, but are both facing the special challenge of adapting the small-scale national systems of innovation to the European Union and world-wide competition in general.

The main recommendations at the national level (see the complete final report for a detailed presentation)

The UK: maintaining specialisation in a context of academic excellence

Preventing both public and private sectors from under-investing in R&D
Avoiding too much focusing of financings in the "top universities"
Optimising technology transfer and networking policies
Pursuing promising reforms designed to fill the "skills gap"
Encouraging the entrepreneurial university

The French and German cases: between accommodation and bifurcation

The French higher education and research system in the perspective of innovation: a political turning point ?

. Handling the shift from a mission oriented policy to a diffusion oriented policy
. Simplifying public interventions designed for SMEs to make them more efficient
. Reaching a temporary compromise between mission and diffusion oriented policies
. Higher education and the production of skills : consolidating what has been achieved by the reforms
- <u>Ensuring that the numbers of science graduates continue to increase</u>
- <u>How to make the private sector recognize the value of doctoral training (the PhD)</u>
. Overcoming the problems involved in producing skills in some key sectors
. Improving the running of the public higher education and research system

Main stakes in the German ICT and Bio-technology industries

. ICT: higher educational reforms to remove the barriers to innovation
- <u>Coping with a shortage of qualifications</u>
- <u>Reducing the academism of university training courses</u>
<u>- Developing the spirit of enterprise at university in order to make better use of the scientific potential</u>
- <u>Favouring the development of clusters in the field of ICT</u>
. Biotechnology: marching on from strength to strength
- <u>Ensuring that an appropriate supply of skills is available</u>
- <u>Promoting the emergence of new disciplines</u>
- <u>Sustaining the dynamism of local innovation networks</u>

Austria and Portugal: the lessons taught by smaller members the European Union

[54] Amable, B., Barré, R. & Boyer, R. *Les systèmes d'innovation à l'ère de la globalisation*, Economica Paris, 1997..

Austria: from industrial dynamics based on incremental innovation towards a knowledge based society

. Confirming the relevance of network and consortia policies to stimulate innovative SMEs
. Stimulating the formation of the appropriate skills for a knowledge based economy
. Reforming the science base: how compatible would this be with the roots of the Austrian system of innovation ?

Portuguese paradoxes

. Limited scope for the high tech industries.
. The weakness of the intermediate institutions: can they be relied on ?
. Entrepreunarial universities: the main challenges

5. Dissemination and/or Exploitation of Results

Section 7 shows that numerous dissemination activities occurred during the course of the project, including publications and conference presentations.
A specific seminar was organized in the EC with external experts (Rémi Barré, OST Paris, Geoff Mason, NIESR, London, Edward Lorenz, CEE and University of Compiègne) in order to discuss the main results of the Sesi project. A conference shall be held in April 2003 in Aix en Provence for discussing a set of papers stemmed of this project in the perspective of a future book. The main topics could be summarized as follows :
The new public devices for organizing and institutionalizing the Science-Industry Relationships
The School to Work Transition of the PhD and the Labour Market of Scientists and Engineers
Innovation in the Firms, Networks (European, national and local levels) and the Management of Knowledge.

Different researchs in progress are stemming of this project.

a) Economic competences of scientific actors and public policies: the development of spin-offs from public research (C. Lanciano-Morandat, H. Nohara)

The objective of the French Innovation Act of July 1999 is to make better use of the knowledge produced by publicly funded research. A study of the social conditions under which high-tech companies develop was begun as part of the SESI project; this study is due to be extended in future. More specifically, the aim is to identify what it is that influences the establishment of these companies, whether it is public policies at national level, territorial dynamics or knowledge and know-how produced in local entities. This research is being carried out at the moment by comparing spin-offs from the same research institution – the Institut de Recherche en Informatique et en Automatique, (INRIA) – on three different sites or 'territories' (Grenoble, Rennes and Sophia Antipolis). These high-tech companies established on the basis of publicly funded research are analysed as actors mediating between three spaces, the higher education and research, industrial and public spaces, which together are likely to generate the innovation dynamic. This research is also very closely linked to a number of studies dealing with the territorial aspects of innovation. Comparisons with Japan are currently being constructed and should become a well-established routine in the years to come.

b) The construction and development of the competences of scientific personnel (PhDs and engineers) (P. Béret, C. Lanciano-Morandat, H. Nohara, I. Recotillet, E. Verdier)

This approach will be applied more particularly to the training of PhDs and engineers, whose quality is one of the essential factors in innovation. A dual perspective is adopted. As far as the problematic is concerned, international and inter-site comparisons of the institutional and societal bases of the construction of competences will be conducted. As far as methodology is concerned, use will be made of longitudinal sources and econometric methods suited to assessing the conditions under which these courses and competences are built up and utilised (see, for example, the contribution of post-doctoral contracts, which are symptomatic of the new links mentioned above). LEST enjoys privileged access to the French sources (CEREQ data on the labour market entry of PhDs, data on the CIFRE grant programme) and is involved in a European project and an OECD group investigating these issues.

This programme will develop in several different directions; one particular starting point will be the survey carried out in 2001 among 60,000 young people who left the education system in 1998. On the one hand, the aim will be to analyse the development over time of the process whereby PhDs enter the labour market by comparing the CEREQ surveys carried out in 1997, 1999 and 2001. Indeed, comparison of the first two surveys shows that economic circumstances play a major role in the process of labour market integration.

c) *A PhD « Organisation of R&D, Knowledge management and learning process"* (Director :Claude Paraponaris) is concerning an important FMN of the Sesi sample.

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7. Annexes

7.1.. List of project Outputs

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7.2. Deliverables

Work Package 1 Literature Survey

LEST (M. Gadille, C. Lanciano-Morandat, H. Nohara, E. Verdier) and LIRHE (N. Carayol, J-M. Plassard), 1998, *Systèmes nationaux d'enseignement supérieur et innovation*, Survey, Projet SESI, CNRS and Université des Sciences Sociales de Toulouse, June, 166p.

Work Package 2 State of the art concerning the three selected Industries and the National Higher Education and Research Systems

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Work Package 3 Comparative Analysis (Summary)
C. Lanciano-Morandat, 1999, *Transversal Synthesis*, Lest, Cnrs, Aix en Provence, 68 p.

Work Packages 4 and 5 : Firm Monographs (for detailed informations, please, contact the teams of the Sesi project) in Information, Telecommunications and Pharmaceuticals Industries (9 for Germany, France, UK and US, 6 for Austria and Portugal)

Work Package 6 National reports including the results of Firm Monographs

K. Mayer, 2001, *Industry – Science Relationships in the Austrian ICT Industry*, Department of Sociology, Institut für Höhere Studien, Wien, 74p.
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