Innovation Systems and European Integration (ISE)

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The ISE Final Report:
Scientific Findings and Policy Implications of the 'Innovation Systems and European Integration' (ISE) Research Project

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Abstract: The report describes and summarises the results from the Innovation Systems and European Integration (ISE) Research Project. The main emphasis has been placed on scientific findings and policy implications.

Keywords: Systems of Innovation, Innovation, Innovation Policy, Technology Policy.

Contents

Preface

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The Innovation Systems and European Integration (ISE) Research Project as a whole is described in section 1 below. There, the nine participating research groups, the nine sub-projects, and the resulting research reports are listed. More detailed descriptions of the findings of each of the nine ISE sub-projects follow in sections 2–4. The various sub-projects are reported there in a similar manner and each sub-project report—except the final one—includes the following sub-headings:

- Objectives
- Progress
- Methodology
- Scientific Findings
- Interdependencies Between Elements in Systems of Innovation
- ISE Coherence: Relations to Other Sub-Projects
- Policy Implications

The scientists in charge of the various sub-projects have had the main responsibility for writing the sub-project reports. The main emphasis in the sub-project reports was placed on 'Scientific Findings' and 'Policy Implications'. Only very brief summaries of the 31 scientific reports, however, can be made here. I therefore strongly recommend reading these reports—listed in section 1.2—as a supplement to the summaries presented here.

There is also another, final ISE report entitled "The ISE Policy Statement—The Innovation Policy Implications of the 'Innovation Systems and European Integration (ISE)' Research Project". That report, written for politicians and policy-makers, deals only with policy implications and treats them in a more integrated manner. It can be ordered from the ISE Co-ordinator (for addresses, please see Section 1.1) and is also available for down-loading from the ISE home page at the following address:

<HTTP://WWW.TEMA.LIU.SE/SIRP/ISE/>

At the ISE home page, all the ISE scientific reports—listed in section 1.2 below—are also available. The 33 ISE reports are also available on a CD-ROM, which can be ordered from Francois Texier at SIRP. As mentioned at relevant

places in this report, many ISE research reports will be published as books and articles in the near future.

The following ISE Workshops were held:

- 29–30 January 1996: First ISE Workshop in Linköping
- 18–20 September 1996: The Second ISE Workshop in Milan
- 12–15 March 1997: The Third ISE Workshop in Athens
- 17–21 September 1997: The Fourth ISE Workshop in Vienna
- 6–7 March 1998: the Fifth ISE Workshop in Helsinki

At these workshops all reports produced within ISE were discussed. The most important work within ISE was, however, performed by the participants in the interims between these workshops. All the sub-projects were carried out according to the original plans, except for a few minor changes and delays—which were discussed and agreed upon with the TSER Research Officer for this project (Ronan O'Brien). I sincerely want to thank all the participating researchers for contributing to the extremely successful completion of ISE and for making the task as co-ordinator a very easy one! It has been very interesting and a great pleasure to work with you all!

Charles Edquist
Co-ordinator

1 A Description and Summary of the ISE Project

The 'Innovation Systems and European Integration (ISE)' Project was carried out between April 1996 and March 1998. It had a budget of 926 000 ECU and was funded by the Targeted Socio-Economic Research (TSER) Programme of DG XII, The European Commission [Contract no: SOE1-CT95-1004 (DG12-SOLS)].

The overall purpose of the ISE project was to elaborate a Systems of Innovation approach to:

- ◊ Evaluate this new understanding of the development of science, technology and innovation.
- ◊ Develop new policy options and implications.

1.1 The Research Groups

ISE included nine research groups in nine European countries. They were:

Co-ordinator:

The Systems of Innovation Research Programme (SIRP) at the Department of Technology and Social Change (Tema T), Linköping University, S-581 83 Linköping, Sweden. (Charles Edquist; e-mail: Charles.Edquist@Tema.Liu.se).

Contractors:

1. CESPRI, Universita' Commerciale 'Luigi Bocconi', Via U. Gobbi 5, 201 36 Milano, Italy. (Franco Malerba; e-mail: Franco.Malerba@uni-bocconi.it).

2. IKE-Group, Department of Business Studies, Aalborg University, DK-9220 Aalborg Öst, Denmark. (Björn Johnson; e-mail: bj@business.auc.dk).

3. Fraunhofer Institute for Systems and Innovation Research, Breslauer Strasse 48, D-76139 Karlsruhe, Germany. (Thomas Reiss; e-mail: rt@isi.fhg.de).

4. Studies in Technology, Innovation and Economic Policy (STEP Group), Storgaten 1, N-0155 Oslo, Norway. (Keith Smith; e-mail: Keith.Smith@step.no).

5. Group for Technology Studies, VTT, Tekniikantie 12, 02150 Espoo, Finland. (Tarmo Lemola; e-mail: Tarmo.Lemola@vtt.fi).

Associated Contractors:

1. Bureau d'Economie Théorique et Appliquée (BETA), Louis Pasteur University, 38 Boulevard d'Anvers, F-67070 Strasbourg, France. (Patrick Llerena; e-mail: pllerena@cournot.u-strasbg.fr).

2. Department of Technology Studies, Austrian Research Centre Seibersdorf, A-2444 Seibersdorf, Austria. (Fritz Ohler; e-mail: ohler@zdfzs.arcs.ac.at).

3. Center of Financial Studies, University of Athens, 5 Stadioy Street, Athens 105 62, Greece. (Lena Tsipouri; e-mail: lena@tsipouri.ath.forthnet.gr).

1.2 The Sub-Projects and the Research Reports Produced in Each

To develop coherence and integration among the participating groups, the ISE Research Project was divided into nine sub-projects. They are listed in the following sub-sections and were described in detail in the original project description. The sub-projects were clustered in three phases:

- 1. Policy Implications of the State of the Art
- 2. Issue-Oriented Empirical Sub-Projects
- 3. Synthesis and Policy Implications

1.2.1 Policy Implications of the State of the Art

1.1. Systems Theories of Innovation: General Policy Implications

The objective of this ISE sub-project was to explore the policy implications and conclusions which can be drawn from the existing system approaches to innovation and technological change. The aim was both to draw together the policy lessons from systems of innovation research of the past ten years and to establish a framework within which the overall ISE project can contribute to developing new policy options.

Reports produced:

- Malerba, Franco: ”Public Policy and Industrial Dynamics: An Evolutionary Perspective”.
- Smith, Keith: ”Systems Approaches to Innovation: Overview and Policy Issues”.

1.2. Innovations, Employment, and Growth

Increased employment and more rapid economic growth are important objectives for Europe—in which innovations and innovation policy may be instrumental. The purpose of this sub-project was to increase our understanding of the sources of growth and employment as perceived by the systems of innovation approach in contrast to traditional approaches. In addition, the relationships between short-term macro-economic policies and long-term innovation policies were investigated.

Reports produced:

- Edquist, Charles; Hommen, Leif; and McKelvey, Maureen: ”Innovations and Employment in a Systems of Innovation Perspective”.
- Gregersen, Birgitte and Johnson, Björn: ”How do Innovations Affect Economic Growth? – Some Different Approaches in Economics”.

1.3. European Integration and National Systems

This project focused upon issues of co-ordination between the European Union and the member states. The objectives of the project were to:

- a) Clarify in which areas and in which ways the national systems of innovation in Europe are affected by the on-going process of European integration.
- b) Explore the possible emergence of a European System of Innovation, partly as a consequence of the process of integration. This sub-project enabled the ISE Research Project to explore the resulting policy consequences in terms of new roles for, and new balances between, national and European innovation policies.

Reports produced:

- Gregersen, Birgitte and Johnson, Björn: ”European Integration and National Systems of Innovation”.
- Smith, Keith: ”Public R&D Policy, European Integration and European Innovation System”.

1.2.2 Issue-Oriented Empirical Sub-Projects

2.1. Science-Based Technologies and Interdisciplinarity

The characteristics of technological innovation are currently undergoing a series of changes. There is a long-term process of structural change in knowledge production and diffusion. This project emphasised two of these changes:

- The increasing importance of science (and therefore of basic research) for technology and innovation.
- The growing importance of multi- and interdisciplinarity, which is a reflection of the fact that technologies are increasingly overlapping and highly dynamic.

Reports produced:

Hinze, Sybille; Reiss, Thomas; Schmoch, Ulrich; and Strauss, Elke: ”Statistical Analyses of Patents, Publications and External Trade in Sub-fields of Pharmaceuticals and New Materials”.

Reiss, Thomas; Sandström, Ulf; Tisell, Agneta; Llerena, Patrick; Matt, Mireille; Trenti, Stefania; Lemola, Tarmo; and Palmberg, Christopher: ”Case Studies on Autoimmune Diseases and Electrically Conducting Polymers”.

2.2. Public Technology Procurement as a Policy Instrument

Public technology procurement means that a government authority places an order for a product or system which does not currently exist on the market, but which could (probably) be developed within a reasonable period. It is an innovation policy instrument working from the demand side. It might be helpful in demand articulation and can influence R&D from this end. This project dealt

with public technology procurement as an instrument of innovation policy and industrial policy.

It appears that most national systems of innovation in Europe are currently too small for handling technology procurement in many areas of technology. There are therefore strong arguments for using technology procurement at the EU level; it may be a new policy option for the EU. The experiences at the national level in Europe were analysed, both conceptually and with new case studies, in this sub-project. The reasons for doing so were:

- ◊ to examine whether the national level really is no longer relevant for procurement
- ◊ the positive and negative lessons which can be learned
- ◊ to identify the implications for a future European level of technology procurement.

Reports produced:

- ◊ Edquist, Charles; and Hommen, Leif: ”Government Technology Procurement and Innovation Theory”.
- ◊ Edquist, Charles; Hammarqvist, Per; and Hommen, Leif: ”Public Technology Procurement in Sweden. The Case of High Speed Trains”.
- ◊ Edquist, Charles; Hommen, Leif; and Tsipouri Lena: ”Scientific Findings and Conclusions of the Procurement Case Studies”.
- ◊ Fridlund, Mats: ”Shaping the Tools of Competitive Power: Government Technology Procurement in the Making of the HVDC Technology”.
- ◊ Fridlund, Mats: ”Switching Relations: The Government Development Procurement of a Swedish Computerized Electronic Telephone Switching Technology”.
- ◊ Husz, Martin: ”Implementation of the Austrian Computerized Digital Switching System (OES)”.
- ◊ Kaiserfeld, Thomas: ”A Case Study of the Swedish Government Technology Procurement Project: ‘The Computer in the School’ (COMPIS), 1981-1988”.
- ◊ Llerena, Patrick; Matt, Mireille; and Trenti, Stefania: ”Government Technological Procurement: The Case of Digital Switching Systems in Italy”.

- Llerena, Patrick; Matt, Mireille; and Trenti, Stefania: ”Government Technology Procurement: The Case of Digital Switching Systems in France”.
- Ohler, Fritz; and Jörg Leonhard: ”Public Procurement as Collective Action: the Case of the Austrian Low-Noise Rail Programme”.
- Palmberg, Christopher: ”Public Technology Procurement in the Finnish Telecommunications Industry”.
- Tsipouri, Lena: ”Procurement of Public Switching Centres by OTE, the Greek Telecommunications Operator”.

2.3. Financing of Innovations

The purpose of this project was to analyse how financing affects innovations. Theoretical and empirical research on financial determinants of innovation is sparse compared to its undisputed importance. This project therefore aimed to advance the present state of the art through empirical research, although the conceptual and theoretical foundations of this empirical research needed to be strengthened at the same time.

Report produced:

- Christensen, Jesper: ”Financing Innovation”.

2.4. Corporate Governance and Innovation Performance

Despite the completion of the internal market and increasing European integration, there remain a number of key institutional differences in Europe that play a central role in structuring system differences. The objective of this project was to develop some conceptual and empirical analyses of the ways in which differences in the innovative performance of European firms are shaped by differences in national methods of corporate governance (i.e. the general system of policies and regulations by which companies are owned, directed and controlled). This issue was studied in a dynamic perspective in relation to changes in governance, including the fact that a number of countries in Europe are pushing for a more UK/US-styled system without fully considering the implications.

Reports produced:

- Brusoni, Stefano and Orsenigo, Luigi: ”State-Owned Enterprises and Managerial Structure: The Italian Experience in Steel and Oil”.
- Lazonick, William and O’Sullivan, Mary: ”Governance of Innovation for Economics”.
- Lazonick, William and O’Sullivan, Mary: ”Corporate Governance and the Innovative Economy: Policy Implications”.
- O’Sullivan, Mary: ”Corporate Governance and Innovation in Europe: a Review of the Issues”.

2.5. Technological Entry: Diversification vs. New Innovators

The purpose of this sub-project was to analyse entry into new technologies during the 1990s as a part of the process of structural change taking place in the various European innovation systems. In particular, the analysis assessed differences across technologies in the entry of new firms and in the role of new innovators. In addition, it examined the balance between entry by totally new innovators (i.e. firms which never introduced any innovation before) and entry through diversification by established firms (i.e. firms that have previously innovated).

The analysis covered sectoral entry by new firms in Europe and technological entry by new innovators and by diversification in all the EU countries, the United States and Japan, from 1978 to 1994. Understanding the specific relevance of sectoral and technological entry is important so that EU policy will support innovation and R&D.

Reports produced:

- Hinze, Sybille; Reiss ,Thomas; and Schmoch, Ulrich: ”Statistical Analysis on the Distance Between Fields of Technology”.
- Malerba, Franco; Breschi, Stefano; and Lissoni, Francesco: ”Patterns of Technological Entry and Exit: Evidence from France, Germany, Italy and the UK”.
- Malerba, Franco; Breschi, Stefano; and Lissoni, Francesco: ”Technological Vs. Industrial Dynamics: Evidence from Telecommunication, Audio-Visual, and Information Technology”.

- Malerba, Franco; Breschi, Stefano; and Lissoni, Francesco: ”Knowledge Proximity and Technological Diversification: an Analysis of the Determinants of Technological Diversification in Europe, United States and Japan”.
- McKelvey, Maureen; Texier, François; and Alm, Håkan: ”The Dynamics of High Technology Industry: Swedish firms Developing Mobile Telecommunication Systems”.
- Palmberg, Christopher and Lemola, Tarmo: ”Nokia as a related Diversifier – Nokia’s Entry into Mobile Phone Technologies and Markets”.

1.2.3 Synthesis and Policy Implications of ISE

The objective of this sub-project was to synthesise the results reached in ISE. The scientific findings and the policy implications of the various sub-projects are presented in detail in this report. In another report entitled ”The ISE Policy Statement – The Innovation Policy Implications of the ‘Innovation Systems and European Integration’ (ISE) Research Project”, we present a more integrated synthesis of the policy implications of ISE.

Reports produced:

- Edquist, Charles: ”The ISE Final Report: Scientific Findings and Policy Implications of the ‘Innovation Systems and European Integration (ISE)’ Research Project” (this document).
- Edquist, Charles; Hommen, Leif; Johnson, Björn; Lemola, Tarmo; Malerba, Franco; Reiss, Thomas; and Smith, Keith: ”The ISE Policy Statement – The Innovation Policy Implications of the ‘Innovation Systems and European Integration (ISE)’ Research Project”. (Available also in French.)

2 PHASE 1: POLICY IMPLICATIONS OF THE STATE OF THE ART

This first phase of ISE comprised three sub-projects (3.1.1 - 3.1.3). The first phase consolidated state-of-the-art knowledge regarding Systems of Innovation (SIs) in general; SIs in relation to growth and employment; and SIs in relation to European integration. The purpose of the three sub-projects was to propose quidelines for government policy at different levels, both European and national.

These three sub-projects were completed according to the original work programme and the results presented to the Commission. Following are our reports on the three sub-projects.

2.1 Sub-Project 3.1.1: Systems Theories of Innovation: Policy Implications

Group in charge of sub-project: STEP. **Scientist in charge of sub-project:** Keith Smith. **Staff:** Keith Smith. **Collaborator 1:** CESPRI. **Tasks of collaborator 1:** To carry out a literature survey on public policy in the evolution of industrial sectors from a systems of innovation perspective. **Scientist in charge:** Franco Malerba. **Staff:** Franco Malerba.

2.1.1 Objectives

The objective of this ISE sub-project was to explore the policy implications and conclusions which can be drawn from the existing systems approaches to innovation and technological change. The aim was both to draw together the policy lessons from systems research of the past ten years and to establish a framework within which this overall project can contribute to new policy directions.

The reason for focusing on this issue at the outset of the ISE Research Project was that the policy implications of systems theories of innovation appear to be very different from those of the conventional approaches. Systems approaches offer the possibility of new insights into the fundamental rationale of policy, into its key tasks and objectives, and into its instruments.

The standard ”market failure” approach to knowledge production leads to a relatively simple set of proposals for government policy. The basic policy task

is to encourage discovery-oriented activities such as science, and then to protect the use of results (through patents, etc.). It suggests that the public sector should either produce knowledge directly, or provide subsidies to knowledge-producing organisations like firms. The appropriability problem implies the existence of a major positive externality to society beyond that captured by the individual. This suggests policies of either subsidy or the creation of property rights (via patents or other intellectual property protection).

In a systems approach, technological knowledge has complex characteristics. First, it is differentiated and multi-layered, consisting of articulated forms of quite different knowledge. Second, it can be firm-specific. Third, knowledge is developed through costly processes of search—through processes of learning and adaptation. It is cumulative over time. In short, knowledge is internally systemic in the sense of being part of an overall production and marketing system that has many components. Innovation therefore usually involves, either explicitly or implicitly, structured interactions between organisations, involving processes of mutual learning and knowledge exchange.

The aim of the project was to explore the broad policy implications of these ideas from existing systems theory. Two papers explored the following issues:

- Implications of systems theories of innovation for the scope, foundations and objectives of innovation policy
- The evolutionary foundations of industrial dynamics and their implications for public policy

The two central papers for this sub-project were:

- Keith Smith: ”Systems Approaches to Innovation: Overview and Policy Issues”.
- Franco Malerba: ”Public Policy and Industrial Dynamics: An Evolutionary Perspective”.

Although these papers took different approaches to the question of policy issues in a systems context, they came to broadly similar conclusions concerning the relevant focus for innovation policy in a non-neoclassical framework. Both placed considerable emphasis on three issues:

- The problem of learning, which is inadequately integrated into current rationales for policy

- The problems of transition between technological paradigms, and specifically the problem of overcoming ‘lock-in’ to dominant but inferior technologies
- Problems of provision and use of technological infrastructures

2.1.2 Progress

This sub-project encountered no significant difficulties in its progress. It also produced one related report, namely a paper that discussed the European Commission’s working paper for the Fifth Framework Programme from a broadly systems’ perspective on policy.

2.1.3 Methodology

These projects were essentially aimed at exploring policy implications of existing theory and applied analysis. The basic methodology was therefore that of a literature review.

2.1.4 Scientific findings

The first of these papers had the objectives of identifying conceptual and empirical foundations of systems theories of innovation and of exploring implications for the rationales for and conduct of public policy. It is based on a discussion of recent theories of technological knowledge; it stresses the sharp differences between approaches found in the neo-classical mainstream of economics and what we have learned from theoretical and especially empirical studies of innovation in recent years. The paper discusses the following topics:

- current types of system theory
- neo-classical conceptions of technology and the implicit views about the nature of the knowledge that underpins these conceptions.
- conceptions of knowledge springing from modern innovation research, stressing the interactive character of the learning processes through which they are developed and the ways in which they give rise to systems.
- general implications for policy, focusing not on specific recommendations but on ‘policy capabilities’ and on general arenas and objectives of policy action in a systems context. The argument of the report is that systems

approaches imply a new conceptualisation and foundation for policies in this area.

Current policies for research and technological development (RTD) are based on notions of market failure associated with the production of knowledge. The basic argument of 'mainstream' theory is that technological or productive knowledge is broadly applicable across firms, easily transferable, and hence difficult to appropriate. The inability of firms to appropriate the benefits of new knowledge means that firms do not have incentives to create it: there is therefore a market failure which leads to sub-optimal creation of knowledge. This leads to an argument for public policies based on creation of property rights in knowledge, or public subsidies. It is important, however, to note that these recommendations follow from an underlying conception of technological knowledge which sees it essentially as codified and easy to transfer.

By contrast, systems theories of knowledge rest on the following ideas: that knowledge is differentiated and structured in different ways, that it takes different forms across sectors, that it is frequently tacit, that it rests on historically cumulated experience and practice, and above all, that it is developed interactively.

Against this background, the policy capabilities that are discussed focus on the need to identify system specificities in terms of technological specialisations and the need to map and understand the nature of the technological knowledge bases that underpin them. Arenas of action include the provision of infrastructures which support creation and distribution of knowledge, actions related to discontinuous shifts in knowledge bases (that is, in qualitative transitions), the management of 'lock-in' problems, the management of externalities and inter-sectoral flows, and the division between national and transnational policy actions. Some of these policy issues are discussed more fully below.

The paper by Collaborator I, (CESPRI, Milan), focuses on the evolutionary dynamics of knowledge growth at the level of sectors. This paper reviews the evolutionary foundations of public policy in industrial dynamics. It aimed to assess the basic theoretical evolutionary reasons behind public intervention during the evolution of industrial sectors. That is, this paper did not discuss technology policy in a system perspective as a whole but focused specifically on theoretical foundations and issues from the perspective of evolutionary economics.

Contrary to neoclassical literature, evolutionary literature has not identified optimal policies, nor has it developed welfare theorems or general welfare analyses through which the welfare implications of public policies may be assessed. Rather, evolutionary theory has identified major issues, traps, and trade-offs in which public policy may intervene in the course of the evolution of an industry, and provided examples at various levels of analyses. More fundamentally, evolutionary theory proposes some ubiquitous trade-offs, such as between exploration and exploitation, between static and dynamic efficiency, and so on by boundedly rational agents in a changing, uncertain and complex world.

The basic argument is that the key dynamic process within industries is the process of learning, which underpins innovation and growth. Through learning, firms accumulate capabilities which not only exhibit inertia and path dependence but also generate variety within the economic system. The key elements of dynamic change within the system are, on the one hand, variety creation via learning, and on the other hand, selection mechanisms (both market and non-market processes) which reduce the amount of variety and which tend to encourage more standardised products and techniques. Within this framework there is no 'optimal' amount of knowledge creation, but there are things which can go wrong. That is, there are what the report refers to as 'evolutionary failures', that is, processes which prevent or hinder either the creation or diffusion of knowledge or which hinder flexibility in changing circumstances.

These 'failures' form a starting point for thinking about policy issues; they are outlined in more detail below. Here, the term "failure" is not used with respect to any optimality situation, as compared with the term market failure used in the neoclassical literature. "Market failures" refer mostly to a static framework and call for public policy intervention due to missing markets, the lack of appropriability and the public good aspects of scientific research, and the indivisibility and uncertainty related to R&D projects. In this paper, on the contrary, the term "failure" refers to the absence or ineffective working of the key evolutionary mechanisms that are at the base of industrial development. The specific failures which might influence policy thinking are outlined in the section on policy conclusions below.

2.1.5 Interdependencies Between Elements in Systems of Innovation

In the previous section it was stressed that knowledge is developed interactively. Interactive knowledge creation implies the operation and activity of different organisations that create, share, and apply knowledge. Therefore the interactivity between various organisations is absolutely crucial in the systems of innovation approach.

2.1.6 ISE Coherence: Relations to Other Sub-Projects

The two reports produced in this sub-project relate most closely to those other parts of the ISE project that seek to explore or sum up implications of systems theories as they have been developed in recent years. The most relevant connections are therefore with projects:

- 3.1.2 Employment and Growth
- 3.1.3 European Integration and National Systems

2.1.7 Policy Implications

The two reports in this sub-project have closely related approaches to exploring the scope, foundations, and objectives of public policy. Within 'orthodox' theory, policy is based on problems in achieving an optimal (static) allocation of resources. These papers adopt a more dynamic approach based on the problems involved in a more detailed and realistic approach to learning in firms and industries; they therefore seek to identify problems or failures which might arise in the dynamics of learning, especially where such learning is interactive in character and where path dependence produces problems in adaptation and flexibility. Here, we outline the basic approaches of the two reports in turn.

"Systems Approaches to Innovation: Overview and Policy Issues"

This paper addresses two broad policy questions, namely:

- *The rationale for policy action.* What is the underlying justification for policy intervention, and do these justifications throw any light on the general scope, objectives, and methods of policy?
- *Policy capabilities.* In a systems context, what competences, skills, and resources do policy-makers need, and to what extent do these differ from current views?

Rationales for policy action

The report argues that four types of failure can emerge in systems contexts. These are:

◊ failures in infrastructural provision and investment

Two types of interaction between firms and infrastructures are important within innovation systems: first, with physical infrastructures usually related to energy and communications; second, with science-technology infrastructures such as universities and publicly-supported technical institutes. The paper argues that infrastructural support is an important but neglected issue at the present time.

◊ 'transition failures' and 'lock-in' failures

Dynamic learning processes imply that from time to time there are more or less major discontinuous changes in relevant scientific and technical knowledge bases. The phenomenon of 'lock-in' implies major adaptational problems for firms, industries or even whole economies. The paper argues that an important role for policy lies in identifying such shifts and facilitating adaptation by firms and industries when they occur; this is particularly important at the present time when major shifts in 'generic' knowledge bases are occurring.

◊ institutional failures

System approaches place considerable emphasis on institutional and regulatory frameworks as promoters or obstacles to innovation. For example, the operation of the market for corporate control changes the time horizons of firms, with important implications for their abilities to invest in the intangible assets which are central to innovation capabilities. The report argues that such frameworks ought to play a more central role in general innovation policy.

Policy capabilities

The report argues that adopting an approach to policy based on systems concepts and more nuanced understanding of the diversity of learning places considerable new demands on the knowledge that is required for policy itself, both in terms of policy formation and policy implementation. The relevant knowledge affects at least the following areas:

- the assessment of system specificities, where policy-makers require a more detailed grasp of scientific, technological, and organisational specialisations.
- the understanding of relevant knowledge bases, where policy-makers need a closer understanding of the direct and indirect knowledge inputs to industries.
- the assessment of system dynamics, particularly those related to discontinuous changes or shifts in technological paradigms.
- system co-ordination within the policy field itself, particularly between policy arenas that are at present rather uncoordinated (such as links between macro-economic or financial policy, and the dynamics of the innovation system).

”Public Policy and Industrial Dynamics: an Evolutionary Perspective”

The report focuses on the main ”evolutionary traps”, ”trade-offs”, and ”failures”. From the evolutionary literature, the following principal problems are identified:

- *Learning failures.* Firms may not be able to learn rapidly and effectively.
- *Lock-in traps*. Industries may be locked into existing technologies and may be unable to jump to the new technologies.
- *Exploration-exploitation trade-offs*. Some industries may be characterised by much exploration and experimentation and too little exploitation of what has been discovered. Others may be characterised by much exploitation, modifications, and incremental innovations and too little exploration and experimentation.
- *Variety-selection trade-offs*. Industries may be characterised by much variety generation with weak selection processes or by tough selection with little variety generation. Tough selection may rapidly kill off variety, experimentation, and competition and lead the system into a ”one-view” situation. Weak selection processes, on the other hand, may allow the persistency of too much experimentation and too many inefficient firms, thus blocking the exploitation of technologies.
- *Appropriability traps*. Too stringent appropriability may greatly limit the diffusion of advanced technological knowledge and eventually block the development of differentiated technological capabilities within an industry.

- *Complementarities failures*. The appropriate dynamic complementarities required for successful and sustained innovative activities may not be present within an industry or an innovation system. If they are present, they may not be connected, so that the positive effects from complementarities may not take place.

In addition, the report emphasises that public intervention also may face problems. The government may not have the capability to carry on its tasks; it may misrepresent the specificity of the environment; and it may not have the long-term vision needed in the development of technologies or industries: it may lack the co-ordination abilities needed to organise and connect complementarities within a system of innovation.

2.2 Sub-Project 3.1.2.: Innovations, Growth, and Employment

Group in charge of sub-project: Tema. **Scientist in charge of sub-project:** Charles Edquist. **Staff:** Charles Edquist, Leif Hommen, and Maureen McKelvey. **Collaborator 1:** IKE. **Task of Collaborator 1:** A study of approaches in economics dealing with the relations between innovations and growth. **Scientist in charge:** Björn Johnson. **Staff:** Björn Johnson and Birgitte Gregersen.

2.2.1 Objectives

The objective of this sub-project was to increase our understanding of the sources of growth and employment as perceived by the Systems of Innovation Approach in contrast to traditional approaches. The following questions were among those addressed:

- How does the SI approach identify and evaluate the sources of growth and employment as compared to other approaches?
- How can innovation policy mitigate problems of low growth and high unemployment?
- How can research within the SI approach contribute to the development of long-term innovation policy instruments? What are the prospects of the ”new growth theory” in this respect?

- What are the relationships between short-term macro-economic policies and long-term innovation policies?
- How can the consciousness of politicians and policy-makers about the role of innovation policy for macro-economic variables (like growth and employment) be increased?

2.2.2 Progress

According to the contract with the Commission one report of 40 pages was planned. The project was successful in achieving the objectives listed above through the writing of two papers:

- Birgitte Gregersen and Björn Johnson: ”How do Innovations Affect Economic Growth? - Some different approaches in Economics” (IKE, Aalborg, 25 pages). (A slightly revised version of this paper will be published in 1998 in Herlitz, L. (ed.), Mellem Økonomi og Historie, Aalborg Universitetsforlag.)
- Charles Edquist, Leif Hommen and Maureen McKelvey: ”Innovations and Employment in a Systems of Innovation Perspective” (TEMA Discussion Paper, Linköping, 137 pages). (A shorter version of this paper was presented at the European Association of Evolutionary Political Economics [EAEPE] Conference in Antwerp in November 1996. It was published in the proceedings from that conference in a book edited by J. Mitchie and A. Reati and published by Edward Elgar Publishers, 1998. The report as a whole is in the process of being revised for publication as a book in 1998 entitled *Innovations and Employment in a Systems of Innovation Perspective* by Charles Edquist, Leif Hommen, and Maureen McKelvey.)

2.2.3 Methodology

The main methodology has been to analyse existing literature, including the theoretical literature, the literature on empirical research results of relevance for the consequences of innovation on growth and employment as well as literature directly dealing with policy issues and relations between different policy areas. The emphasis has been on manufacturing because of the main focus of existing literature. Innovation in services, however, has also been covered to the extent possible.

2.2.4 Scientific Findings

2.2.4.1 Growth

The paper on growth discusses various approaches to how innovations affect economic growth:

- standard macro-economic equilibrium theory
- neo-classical growth theories
- growth accounting
- new growth theories
- catching-up theories and late development theories
- evolutionary theories
- theories of techno-economic paradigms
- theories of co-evolution
- the systems of innovation approach

The purpose of the paper was to illustrate a development towards an approach that sees growth as emanating from processes of interactive learning and focuses on the relations between institutional and technological change. The paper raises the question of which role the innovation systems approach might have in economic theorising about growth and in relation to policies for growth. Throughout the text distinctions between product and process innovations are made. Organisational and institutional innovations are also considered.

The paper first discusses theories that operate on a very simple innovation concept: standard macro-economic equilibrium theory (in which technical change is exogenous and all markets clear) and neo-classical growth theories (including new growth theories and growth accounting). Theories which emphasise non-price factors and international relations and which have more refined concepts of technology and innovation are then discussed: catching-up growth theories.

After this some approaches which use the concept of institutions and institutional change and where the characteristics of technology and the process of innovation are a central theme are covered: Evolutionary theories in which evolution is fuelled by technical change, theories based on the concept of

techno-economic paradigms, and theories on co-evolution between different subsystems in society.

Finally, some possible future contributions to the understanding of growth which come from the 'National Systems of Innovation' and the 'Learning Economy' approaches are discussed.

One main scientific finding is that relations between innovation and growth must be analysed in an open economy framework. The international diffusion of technologies, organisational forms, and institutions are fundamental factors in the economic growth of any national economy. The processes of catching up, falling behind, and forging ahead are crucially important for an understanding of economic growth.

Another finding is that technology, organisations, and institutions co-evolve and that the interaction between them must be considered in growth theory and should be included in attempts to endogenise technical change. The matching and mis-matching between technology, organisations, and institutions provides important insights into the growth processes.

A third finding is that the innovation systems approach has the potential to contribute to growth theory by identifying the sources of growth and focusing on how they feed upon each other. The main contribution of the systems of innovation approach to growth theory lies in its emphasis on the importance of institutions and institutional change and especially in the focus on interactions between institutional, organisational, and technical change as the basic source of growth. Institutions and institutional change are at the very heart of the economic process; they define the character of the economic problem for the actors and shape the whole process of growth. Without a thorough treatment of the institutional foundations of growth, any growth theory is flawed.

2.2.4.2 Employment

The second paper deals with the complex relations between innovations and employment. These relations are seldom direct and usually mediated by a number of offsetting factors. In the paper, the point of departure is that the Systems of Innovation approach has a rather differentiated innovation concept and that it can encompass product innovations (material goods and intangible services) as well as process innovations. With respect to the latter category, it can also distinguish between technological and organisational innovations.

Politicians and mainstream economists often argue that ‘more rapid growth’ would solve or mitigate the unemployment problem. The relation between ‘growth’ and ‘employment’, however, is by no means simple and mechanical. Some kinds of growth create jobs, other kinds destroy jobs, and there is the phenomenon of ‘jobless growth’. Economic growth (GDP growth) and productivity growth do not automatically lead to employment growth—and the employment consequences differ substantially between these two kinds of ‘growth’. Therefore, a general policy of ‘growth’ will not necessarily create more jobs. Moreover, specialisation at the firm, industry, and national levels will influence future ability either to continue along or to shift between labour-saving and employment-generating trajectories. Below we outline a more detailed and differentiated understanding of the relations between ‘growth’ and ‘employment’ with reference to innovations.

There are many problems associated with measuring productivity growth. Analytically it is important to distinguish between quality changes in products on one side and increased output—which is associated with demand growth—on the other. The importance of these differences has led us to try to further clarify and distinguish productivity and economic growth and their relationships to employment, as summarised in the following points.

1) Productivity growth that is associated with more of the *same* kind of output and produced by the same amount of input leads to a reduction in the number of jobs (per unit of output). Labour productivity is the ratio between production value (value added) and amount of employment. Thus, if output (production value) is constant, this kind of productivity growth means that the *denominator* (amount of employment) in this ratio decreases. The most important source of this kind of productivity growth are technological or organisational *process innovations*. While compensation mechanisms can mitigate job losses, they promote net employment gains only when growth in production (i.e. demand) outstrips productivity growth.

If the general level of demand is kept constant and if the price elasticity of demand for the product is below 1, jobs (in the world economy as a whole, i.e. in a closed economy) will be lost in the sector of production where the process innovation occurred. If the elasticity is above 1, the number of jobs will increase in that sector (in the world economy as a whole) in spite of the process innovation. The price elasticity is, however, normally below 1. Thus, on the whole, labour productivity growth associated with process innovations is labour saving. If there is an increase in the exogenous demand for the product, jobs will, of course, be created.This is not, however, the result of productivity

growth but of economic growth, i.e. increased output. Output and the number of jobs increase, but the number of jobs *per unit of output* does not increase.

The case of increases in exogenous demand underlines the crucial importance of co-ordination between innovation policies and macro-economic policies, including fiscal, monetary, and exchange rate policies. A reasonable degree of macro-economic stability is important for innovation processes and for investment in general—and therefore for economic growth and employment creation. However, it seems extremely difficult to solve the problems of low growth and high unemployment in Western Europe through innovation policy if macro-economic policies remain excessively strict. Fiscal and monetary policies in Europe might become less restrictive once the European Monetary Union has been established—and national governments may thereby avoid the contractionist grip of the Maastricht convergence criteria (of low public debt, low government deficit, low inflation, low interest rates, and a stable exchange rate).

2) Productivity growth (as it is normally measured) which is associated with *new* kinds of output leads to job creation. This is the case of *product innovation*. Productivity growth of this kind reflects the quality improvements of output as well as the monopolism often associated with new products. It influences the *nominator* in the ratio between production value (value added) and amount of employment (i.e. labour productivity), resulting in a higher price paid for the new products. (This kind of productivity growth [measured in price terms] is not 'real' [in physical terms], but it still matters to the welfare of the members of the unit producing the innovation.) The denominator (employment), however, is not directly influenced by productivity growth associated with product innovations. In other words, the amount of labour needed per unit of output does not decrease; labour is not saved through product innovation.

Instead, the production of new products influences production value (value added). Product innovations often lead to the establishment of new units of production, which means new investments and structural change, and possibly more jobs *as well as* higher productivity. A new product which satisfies a completely new kind of demand or serves a new function contributes most to increased employment. This statement holds whether the product is new to the world, or new to a country, region, or company, that is, if the production of a product diffuses. Thus the 'immediate' effect of a product innovation is to increase employment.

However, employment generation caused by product innovation can be counteracted through a) substitution between old and new products and b) new

products becoming process innovations in a later incarnation. If the new product functionally replaces an old one, either increased or decreased employment may result. The net employment effect depends on whether demand for satisfying the function changes when the new product replaces the old one and whether there are changes in the labour intensity of the process used for producing the new product.

Some new products are transformed into process innovations in a second incarnation. (In other words, the same artefact can be a product innovation as well as a process innovation.) These products generally lead to a net reduction in the number of jobs in the economy as a whole. However, only investment products can play this double role over time. Therefore, the net employment-generating effect of consumer products and intermediate products is larger than that of investment products. Because the proportion of investment products is smaller in services than in goods, the production of services destroys jobs to a lesser extent than does goods production. Product innovation in services is, in this respect, more employment generating than product innovation in goods production.

Thus, productivity growth associated with product innovations is not, on the whole, labour saving. On the contrary, new jobs are created, mostly through the development, production, and use of new products that satisfy new needs and wants. Moreover, the demand for new products often grows more rapidly than does that for old products. This implies an increase in (production and) employment in some industrial sectors as well as in (some) service sectors.

On average, technological process innovations seem to increase labour productivity faster in goods production than in service production. Therefore process-related job destruction seems to be larger in manufacturing than in services. In both cases, however, the variation between sub-sectors is large. A net increase in employment can be expected in some industrial sectors and in some service sectors (due to product innovation).

The implications of these arguments are that the firms, regions, and countries producing new products do so for markets that are often growing rapidly. Growing markets mean an increase in output (demand), which reinforces the intrinsic employment creation effect of product innovations. Again, this effect is not associated with productivity growth but with economic growth.

The distinction made between product and process innovations is necessary to understand the relations between innovations and employment. To make such

an analytical distinctions is not to deny that the two categories are closely interrelated in the real world and go hand in hand.

In summary, firms, industries, and national economies that specialise in product innovations generally create more employment than those that specialise in process innovations. The overall extent of employment creation or destruction depends on factors such as changes in market growth and in demand (price elasticity) as well as dynamic effects within the economic system. Product innovations which neither substitute for an existing product nor are later used as process innovations have the greatest positive effect on employment creation. Both manufacturing and service sectors can be roughly divided into those that are more R&D (knowledge) intensive and product innovation oriented and those that concentrate less on R&D and are more process innovation oriented. The links between dynamic manufacturing and service sectors seem to offer the greatest potentials for employment growth.

2.2.5 Interdependencies Between Elements in Systems of Innovation

Interaction and interdependence are one of the most important characteristics of the SI approach. These interactions are mainly between organisations that constitute elements of the innovation systems: firms interact with other firms as well as with non-firm organisations like universities, research institutes, financing organisations, government agencies. In the present sub-project, we have seen that product innovations are of particular importance for employment creation. In such innovation processes, the kinds of interaction that are most crucial are those between various kinds of firms (users, suppliers, competitors) as well as between firms on the one hand and research organisations and financing organisations on the other. Also, institutional rules which influence these kinds of interactions are of crucial importance for employment generating product innovation.

We referred above to the importance for employment generation of dynamic links between ‘growth’ sectors in manufacturing and services. A relevant finding of the sub-project has been that in Europe, compared to the United States and Japan, employment growth has been slower partly because these linkages have been less well developed. This problem, in turn, has been attributed to excessive regulation of product markets (particularly for services) in Europe.

2.2.6 ISE Coherence: Relations to Other Sub-Projects

The growth and employment sub-project has important relations to several other ISE sub-projects; we will briefly mention the most important ones here. The most obvious link is with the entry and diversification sub-project, which focusses on transition processes to new technologies and new markets. The entry of new firms or the diversification of existing firms is a necessary mechanism if resources are to be transferred from process innovation to product innovation as well as from old products to new ones. Diversification and 'new entry' are engines for the creation of growth and employment; they do this by opening up new trajectories through innovation. Also specific governance rules might influence the propensity of existing firms to diversify or the possibilities for new firms to emerge.

To the extent that these new trajectories are initiated in the realm of research there are also strong links to the sub-project on science-based technologies. The work within the sub-project on financing of innovations might also be of great importance for growth and employment generation since shortage of funds might be a major obstacle for product innovation. Similarly, public technology procurement may be a demand-side-oriented policy instrument which can enhance the opening up of new product areas and thereby trigger growth and employment creation.

2.2.7 Policy Implications

2.2.7.1 Growth

On the basis of the analysis presented in the paper on growth, only fairly general policy implications can be drawn since the paper is primarily theoretical. Cautious interpretation is called for.

The Systems of Innovations approach seeks to identify the sources and determinants of innovation. So far this approach has not had much to say about how innovations translate into economic growth; it is more a theory of innovation than a theory of growth. The so-called 'new growth theory', on the other hand, has only a primitive and biased way of treating technical and organisational innovation. A 'complete' growth theory should include a sub-theory of the sources and processes of innovation as well as one of how innovation induces growth. This is simply because innovation is the most important source of productivity growth. Therefore, the systems of innovation

approach may be seen as a complement rather than a substitute vis-à-vis new growth theory.

Formal growth models have always been built without giving much thought to the institutional framework of the economy. Endogenous institutional change is much more difficult to model than endogenous technical change and this has induced a bias and flaw into production function centred formal growth theory. The main contribution from the systems of innovation approach to growth theory lies in its emphasis on the importance of institutions and institutional change and especially in the focus on interactions between institutional, organisational, and technical change as the basic source of growth.

Therefore, the main policy implications are that the most important thing is to get the institutions right in a policy of stimulating growth. Designing and implementing changes which continuously support technical and organisational learning and innovation is the same thing as a more or less permanent process of institutional learning. With this as a guide-post, it is crucial to study in detail the role of various specific institutions - like laws, norms, rules and routines - for innovation, and thereby for growth. Institutional 'framework conditions' are crucial.

For policy-makers, who try to stimulate growth by supporting innovations, the focus should be on designing and implementing institutional changes that continuously support technical and organisational learning and innovation, i.e. they should try to implement a more or less permanent process of institutional learning.

2.2.7.2 Employment

The implications of the scientific findings for government policy with regard to innovations and employment can be summarised in the following points.

- 1) Employment policies need to reflect the differences between those sectors highly concentrated on process innovations and those highly concentrated on product innovations. If a country (time period, firm, or region) is characterised mainly by process innovations (technological or organisational), the tendency is for employment to decrease. If pr2oduct innovations dominate, there is an opposite tendency of increasing employment.
- 2) A reallocation of resources from process to product innovation will generally have positive employment effects. An example is policy that identifies and strengthens those manufacturing and service sectors where product innovation dominates over process innovation, namely those with

a high R&D (knowledge) intensity. Such a policy would support structural change in the economy in the direction of new sectors. (On the whole, these sectors are characterised by higher productivity and higher productivity growth, and therefore can carry higher wages and profits. They are also characterised by more rapid market growth than are other products.) Such a policy of structural change would increase employment in the long run.

- 3) However, technological and organisational process innovations should not be stopped or hindered in any firm, region, or country. While employment problems can be solved by decreasing productivity in the short term, in the longer run such a policy would have devastating consequences. Productivity growth is the main source of increased material welfare, and competitiveness (of the firm, region or country) depends on productivity growth. Those that attempt to avoid process innovations will end up lagging behind, with deteriorated prospects for gaining material welfare.
- 4) Any policy that gives priority to employment generation over productivity growth by preventing process innovation will fail, partly because competition normally requires that potential increases in labour productivity be exploited in the long run.
- 5) Policies for increased employment should—*ceteris paribus*—support more capital-saving types of organisational process innovations rather than more labour-saving ones.

As Europe seems to have become locked into a technological trajectory or growth pattern that is predominantly labour-saving, the employment intensity of growth is relatively low. For this reason, a policy supporting structural change in the direction of more R&D-intensive and less process innovation oriented sectors is called for more in Europe than in the United States and Japan. The present European trajectory will lead to increasing competition with Eastern Europe and advanced developing countries. This trend has continued for at least two decades without being corrected by market forces. There is thus a strong justification for considering policy intervention.

Government policy in this field should be thought of as a matter of emphasis between supporting process innovations and supporting product innovations. More specifically, policy can attempt to dissolve situations of lock-in into sectors dominated by process innovations and to facilitate (or support) structural change in the direction of sectors where product innovations dominate. Stimulating R&D-intensive and less process-oriented industrial sectors is important. Stimulating service sectors with a high level of product

innovation and those with relations to innovative manufacturing sectors is also important. Governments faced with an economy with an employment problem should consider these options.

2.3 Sub-Project 3.1.3: European Integration and National Systems of Innovation

Group in charge of sub-project: IKE. **Scientist in charge of sub-project:** Björn Johnson. **Collaborator 1:** STEP. **Task of Collaborator 1:** To carry out an overview study on public R&D policy and European integration. **Scientist in charge:** Keith Smith. **Staff:** Keith Smith.

2.3.1 Objectives

There were two main objectives in the ISE 3.1.3 sub-project: The first objective was to clarify in which areas and in which ways the National Systems of Innovation (NSI) in Europe are affected by the on-going process of European integration. The second objective was to explore the possible emergence of a European System of Innovation, partly as a consequence of the process of integration.

In continuance of the two research objectives, the sub-project discussed the resulting policy consequences in terms of new roles for and new balances between national and European innovation policies.

To realise the research objectives, a number of more specific research questions were raised:

- In which ways and in which respects can nation states be seen as an environment of innovation processes?
- How closely connected are the constituting elements of the NSIs? That is, how "national" are the production and knowledge structure of an economy. (This question is to be understood as a methodological one; quantitative answers can not be provided.)
- In which ways does the process of European integration affect NSIs and vice versa?
- In which areas is it possible to identify the emergence of a European system of innovation as a complement and/or as a substitute for NSIs?
- In which ways will the changing diversity of NSIs and the possible emergence of a European SI affect economic growth and international competitiveness in Europe?

- Which are the consequences of a changing diversity of NSIs and emergence of a European SI for national and European innovation policy?
- Which relationships are visible between national public technology programmes and the EU research programmes? Are they complements, substitutes, or are they integrated?

2.3.2 Progress

In accordance with the contract with the Commission, two papers have been delivered to the Commission:

- A policy paper: "European Integration and National Systems of Innovation" by Björn Johnson and Birgitte Gregersen. (79 pages)
- A task collaborator report: "Public R&D Policy, European Integration and European Innovation System" by Keith Smith. (37 pages)

Furthermore, three papers using material from ISE sub-project 3.1.3 have been published or discussed elsewhere:

- Gregersen, B. Johnson, B. (1997): "Learning Economies, Innovation Systems and European Integration", *Regional Studies*, Vol. 31.5, pp. 479-490.
- Johnson, B. (1997): "Implications of a system of innovation perspective on innovation policy in Denmark", paper presented at the International Symposium on RTD Policies in Europe in Jerusalem, 12–13 June 1997.
- Gregersen, B. and Johnson, B. (1997): "The role and the potential of diversity in the European integration process", paper presented at the International Conference on "Technology Policy and Less Developed Research and Development Systems in Europe", arranged by UNU-INTECH in Seville, 17–18 October 1997.

All research questions (listed in section 2.3.1) have been analysed and discussed in the reports delivered to the Commission. In addition, an analysis of the concept of the 'performance' of systems of innovation and a discussion of innovation policy in terms of interactive policy learning have been provided. This is important because innovation policy is still a less developed type of policy in terms of theoretical and practical foundations.

2.3.3 Methodology

The policy paper "European Integration and National Systems of Innovation" reflects theoretical literature and empirical studies of national systems of innovation, European integration and public policy. The main focus has been on a discussion of the core concepts diversity, learning economy, institutions, European integration, national systems of innovation, convergence and divergence, performance, and policy learning.

The second paper ("Public R&D Policy, European Integration and European Innovation System") uses available statistical data to examine variations in public R&D investments in Europe (with some comparisons with the United States and Japan where appropriate) against the background of the overall diversity between the national innovation systems which comprise the European economy.

2.3.4 Scientific Findings

2.3.4.1 The policy paper: "European Integration and National Systems of Innovation"

The policy paper uses a "vision" of a modern learning economy as a conceptual and analytical framework. European integration—which is defined as a process towards a common or mutually consistent institutional set-up for production, trade, and innovation within Europe—is looked upon as occurring between learning economies and as formed by different kinds of learning: technical learning, organisational learning, institutional learning, and policy learning. The report argues that understanding these processes of learning is a prerequisite to an analysis of the anatomy of and the change in innovation systems.

Integration affects innovation because there is both a tendency towards greater cross-border collaborative use of knowledge stocks and a tendency towards greater transdisciplinary complexity in technical innovation. As a consequence, institutional innovations are necessary to make use of such increased potentials for interactive learning across national borders. Changes in innovation processes are a driving force behind European integration, and integration can thus become an instrument to enhance the innovation performance in Europe.

The main idea of the concept of innovation systems is that the overall innovation performance of an economy depends not only on how specific organisations like firms and research institutes perform but also on how they interact with each other and with the government sector in knowledge production and distribution. Innovating firms operate within a common institutional set-up, and they jointly

depend on, contribute to, and utilise a common knowledge infrastructure. It can be thought of as a system that creates and distributes knowledge, utilises this knowledge by introducing it into the economy in the form of innovations, diffuses it, and then transforms it into something valuable, for example, international competitiveness and economic growth. In the perspective of innovations as resulting from interactive learning, a national system of innovation is to be regarded as a system of actors (firms, organisations, government agencies, consumers, etc.) who interact with each other in ways which influence the innovation performance of a national economy. The innovation system and its performance is influenced by five main sets of factors: the institutional set-up, the knowledge infrastructure, the specialisation pattern, the public and private demand structure (or consumer tastes in the broad sense), and the government policy.

Within the innovation systems research programme, the existence and importance of a wide diversity across Europe of national systems of innovation is increasingly recognised. Production structures, knowledge infrastructures, institutional set-ups, consumer demand structures, and innovation-related policies are all very different between countries. A central idea in this paper isthat the diversity of national innovation systems in Europe affects the innovation performance of both the individual countries and the European economy as a whole. Different kinds of diversity, both within and between national systems of innovation, influence the dynamic efficiency of European economies. To know more about how the process of integration affects different kinds of innovation systems and how this in turn affects the dynamic efficiency of European economies, it is necessary to describe and analyse the existing diversity of innovation systems as well as their past and present processes of change. Still, however, it is far from clear how to measure the extent of this diversity and the speed of convergence and divergence between different systems of innovation.

The paper concludes 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 whether they are losing out to systems on the European and/or regional level or not. We need further comparative studies of how the innovation performance of the European countries is influenced by specific parts of and the relations between the institutional set-up, the knowledge infrastructure, the specialisation pattern, the public and private demand structure, and the government policy. Also, the empirical evidence of an ‘autonomous’ European system of innovation is still, in a broad sense, rudimentary. For the time being, it is more reasonable to talk about an emerging European system of innovation in the narrow sense of the

term, that is, a system which only includes the specific knowledge-producing sector of the economy.

2.3.4.2 The task collaborator report: "Public R&D Policy, European Integration and European Innovation System"

The task collaborator report elucidates that European integration is occurring within a European economy characterised by significant diversity in industrial production structures, production segments, R&D investments, and technological specialisation. It concludes that continuing convergence in terms of productivity levels and real incomes does not appear to rest on any marked underlying convergence in technological capabilities and investments. At the same time, public R&D investment remains a major component of overall knowledge creation within the European Union Member States. Although such public investment has objectives which are, rightly, wider than the industrial innovation system, it is clearly a central component of innovation capability.

The data presented, however, suggests that such policy is aimed at relatively limited parts of the production system. In particular, the relatively low R&D-intensive industries, which account for the major part of European industrial output, appear to lie more or less outside the realm of public policy support in many countries. The effectiveness of public R&D for these low-R&D sectors thus appears to rest on the existence of system interactions—via user-producer links and flows of inputs—between such sectors and the high-R&D activities upon which much public support appears to be focused. This seems to be the case not only at the Member State level but also at the European level.

The existence of underlying system diversity poses important challenges for RTD policy at the European level; diversity implies that policy actions will have widely different effects according to the nature of innovation systems and production structures at national and regional levels.

2.3.5 Interdependencies Between Elements in Systems of Innovation

The policy paper emphasises interdependencies in systems of innovation. Interdependencies include the importance of many formal as well as informal links (interaction patterns) between firms, other organisations, and government agencies as well as interdependencies between the knowledge infrastructure, the production structure, the demand structure, policies, and most important, the institutional set-up. It is argued that these sets of factors interact with each other and determine the performance of national systems of innovation.

The broad definition of a national system of innovation should not be interpreted as if innovation performance depends on almost everything. Only some aspects of, for example, the institutional set-up, are really important for innovation performance; the trick is to identify these aspects. Likewise, only some of the connections between, for example, the production structure and the institutional set-up really matter. But this broad version of a national system of innovation provides a perspective—a way of looking at and understanding the determinants of the innovation performance of a national economy.

The concept of a national system of innovation in the broad sense paves the way for the very likely possibility that other types of policy than innovation policy—for example, education policy and social security policy—may affect innovation performance even more. This concept emphasises the possibility that norms of co-operation, habits of trust, collective and non-monetary incentives, etc., may influence innovation just as much as patent rights and tax incentives influence R&D. The concept provides new perspectives and reveals new places to search for the sources of innovation.

A national system of innovation is an open system in many ways: some of its firms are multinational, its technologies are mostly imported from abroad, it depends on international institutions, its innovation policies are influenced by international organisations, etc. It is also important to acknowledge that national systems of innovation may be more or less coherent. They contain many subsystems knitted together into rather loose structures. However, the institutional set-ups, the production structures, the knowledge infrastructures, the patterns of consumer demand, and the government policies of national systems of innovation have sufficiently clear national stamps on them and are sufficiently stable over time to motivate this level of analysis within the innovation systems approach to innovation studies. From this point of view, Europe may be looked upon as a diversity of national systems of innovation—a diversity which changes in the long run through convergence and divergence between the systems and through the relative strengthening or weakening of coexisting regional innovation systems, but which, nevertheless, has some stability and staying power over time.

The interdependencies between different national systems of innovation and, not least important, the interdependence between the emerging European system of innovation and specific national systems of innovation are discussed. It turns out that the development and implementation of specific parts of a European system of innovation, for example the framework programmes, may have very different effects on different national innovation systems.

2.3.6 ISE Coherence: Relations to Other Sub-Projects

Emphasising core concepts and theories related to the overall ISE theme on Systems of Innovation and European integration, this sub-project inevitably has links of various types and strengths to the other sub-projects. The importance and usefulness of a *systemic perspective* (based on interactions and interactive learning) in studying innovation processes is clearly illustrated in most of the sub-projects. Furthermore, the importance of *institutions and institutional change* for the anatomy of and the change in innovation systems fundamentally affects the analysis not only in the present policy report but in all three 'state-of-the-art' projects and most of the issue-oriented projects as well. In this way there are obvious and strong links to sub-projects 3.1.1 and 3.1.2 ("Systems Theories of Innovation: Policy Implications", and "Innovation. Employment and Growth"). This goes both for the more theoretical discussions based on the systems of innovation approach and the discussion on policy implications.

In various degrees, the present sub-project also is linked with the five issue-oriented empirical sub-projects. For example, the *institutional factor* is crucial in the project on corporate governance, which may be characterised as a discussion of the relation between innovation and one of the most important institutional characteristics of a national system of innovation.

The five empirical sub-projects all provide different evidence on the importance of *national* systems in influencing innovative activities. All studies show important European diversity of existing sub-systems: the financial system (sub-project 3.2.3), the types of corporate governance (sub-project 3.2.4), and the role and structure of technological diversification vs. new innovators (sub-project 3.2.5) all vary between national systems of innovation. At the same time, however, many of these studies also show certain tendencies of convergence within Europe within these sub-systems.

The importance of the structure of demand for the performance of national innovation systems is discussed in the report from sub-project 3.1.3 ("European Integration and National Systems of Innovation), and there is a link here to the crucial role of (national) public procurement as an innovation policy instrument which is addressed in sub-project 3.2.2.

In the same way, the importance for innovation performance of the structure of production (the pattern of specialisation), which is discussed in the present project, constitutes a link to the project on science-based technologies (3.2.1) and the project on technological entry (3.2.5).

2.3.7 Policy Implications

An innovation system perspective on economic policy implies, roughly, that policies should emphasise dynamic efficiency rather than static efficiency and explicitly try to improve the performance of the relevant systems of innovation. The performance of a system of innovation reflects how the system functions as an environment for the evolution of economically useful knowledge—how it produces, distributes, and utilises such knowledge. It reflects technical, organisational, and institutional learning, which are the main sources of innovation.

There are close connections between the performance of the different national systems of innovation and the European system of innovation. Since a European system of innovation still only exists rather selectively and in the narrow sense of the term, it may be premature to evaluate its performance. It should also be noted in this connection that an improvement in the performance of the European system of innovation primarily becomes evident through the improved innovation performance of the firms in the individual member countries and thus as improvements in the performance of national systems of innovation.

Innovation policy is here defined as those parts of economic policy that are concerned with improving the performance of systems of innovation. There are at least two characteristics of innovation policy to be taken into account. First, innovation policy should be regarded as a process of 'policy learning'. Continued weak macro-economic performance in many countries in combination with theoretical doubts about the efficiency of fiscal policy and new types of institutional restrictions on the policy options in Europe increasingly force innovation policies onto the agenda of economic policy. Gradually, and in interaction, the theories, practices, and institutions of innovation policy develop and become a permanent and "natural" part of economic policy.

Second, there is also "unintended policy" in connection to innovation. Policy decisions in the fields of labour markets, education, social security, income distribution, etc., as well as traditional fiscal and monetary stabilisation policies strongly—but in the form of unplanned side effects—influence the production and diffusion of new knowledge in the economy. The implication is that the policy-makers should be more aware of the important indirect effects their policies may have on innovation and that inter-ministerial co-ordination is necessary in connection to innovation policy.

In the report, five types of innovation policies are identified:

1. Policies to develop and strengthen the knowledge infrastructure.

2. Policies to develop some basic, formal as well as informal, institutions that affect interactive learning.
3. Policies to create specific organisations that support innovation activities.

Policy types 1-3 can be termed framework condition policies. They work indirectly by contributing to a better environment for processes of learning and innovation.

4. Policies directly and selectively supporting the development of science and technology (RTD policy).
5. Public technology procurement policy.

These policies are sensible from a systems of innovation perspective. They all potentially support different kinds of learning processes. However, they could be targeted much more directly at interactive learning than is the case today. Procurement policies could be used more systematically to shape patterns of user-producer interaction. Government support of R&D could be connected to organisational as well as technical learning and, especially, to the interactions between organisational and technical change. The knowledge infrastructure and intellectual property rights could be developed to support research and development co-operation, etc.

Today, the policy mix still puts too much weight on R&D subsidies and the idea of supporting nodal points and strategic patterns of interaction within systems of innovation does not yet seem to have been understood by policy-makers. Furthermore, all these types of policy could be systematically monitored from a policy learning perspective and they could be better co-ordinated and sometimes integrated with education policy, labour market policy, employment policy, etc.

In addition to these five types of “established” innovation policy, there are two yet unexplored innovation policy areas, which follow from the innovation systems perspective.

First, innovating firms interact with each other in complicated and changing networks of users and producers, of sources of labour skills, finance, knowledge and so on. It is an important task for innovation policy to identify and support important interconnections and nodal points in these networks.

Second, innovation policy should pay attention to the learning and innovation capability of firms. This implies giving organisational and management aspects increased attention. Further, it implies that policies to promote innovativeness of firms should be combined with policies which develop human resources and support changes in work content and the upgrading of skills and competencies of employees. Innovation policy-makers should recognise that what is required

are often combinations of technical, organisational, and sometimes, institutional innovation.

The policy implications above apply to national systems of innovation. What are the possibilities for an innovation policy learning process at the European level? What are the prospects for the five types of innovation policy?

- Policies to develop and strengthen the knowledge infrastructure can be fruitfully developed much further on the European level than is the case today.
- Policies to develop some basic institutions which affect interactive learning have been pursued for some time. Development and harmonisation of intellectual property rights, for example, are feasible fields for Community action.
- Policies to create specific organisations that support innovation activities take longer time to develop. There is more scepticism and resistance in different member countries to these kinds of somewhat more visible policy instruments. To build a completely new organisation will always raise questions about its necessity as well as its physical localisation.
- Policies directly supporting the development of science and technology (RTD) will probably continue to expand. However, the existence of underlying system diversity poses important challenges for RTD policy at the European level; diversity implies that policy actions will have widely different effects according to the nature of innovation systems and production structures at national and regional levels. The pursuit of policy programmes in this field leads to such strong inter-European informal network building that it will seem more and more natural to finance increasing amounts of R&D support over the community budget. The informal network building is thus an important effect of formally co-ordinated European research co-operation.
- Technology procurement policy is a less obvious community activity in the sense that European policy-makers probably will stick to rule-making and leave the actual procurements to member countries. By co-ordinating some very expensive procurement programmes at the European level, it may, however, be possible to avoid some unnecessary duplication of research activities. This concerns primarily *technology* procurement as opposed to off-the-shelf procurement.

All five kinds of community innovation policy discussed here will affect the member countries unevenly. This is a consequence of persistent differences between countries in terms of income levels, institutional set-ups, and specialisation patterns. Given the lack of convergence between European countries in these respects, it is impossible to design a European innovation

policy which is neutral in the sense that it does not favour some countries more than others. There is thus a risk of violating the principle of cohesion.

Finally, the report raises the question of different main directions in the process of policy learning. Which are the alternative "visions" and strategies that can be pursued in the development of a European innovation policy? Is building systems of innovation an option? In that case, should the policy support particular selected national innovation systems or should it try to support all of them? Or should the efforts be concentrated on building a European systems of innovation, maybe concentrated to particular aspects of it and maybe co-ordinated with particular national systems of innovation to form a kind of "system of systems" or a "co-ordinated system of innovation"? Questions like these follow naturally from the systems of innovation approach.

To formulate policy aims in relation to national and European systems of innovation raises all the difficulties inherent in the idea of planning for innovation. There is no such thing as an optimal system of innovation (and even less an optimal system of systems). The best one can do is to, step by step, develop common infrastructures and institutions: for example, co-ordinate R&D and education and training; strengthen different communication channels; increase the production and distribution of information; help build networks; take initiatives to establish institutions for discussion and exchange of information and ideas between different actors in the process of innovation (entrepreneurs, labour market organisations, researchers, policy-makers, venture capital organisations). Such an approach might be called "indicative planning in a European system of innovation", i.e. building and using information and interaction infrastructures and institutions, and is thus to be considered as a necessary part of a process of innovation policy learning.

3 PHASE 2: ISSUE-ORIENTED EMPIRICAL SUB-PROJECTS

The second phase of ISE involved five sub-projects. The work done here constitutes the bulk of the ISE project and involves the most important front-line, original empirical research. These five sub-projects built upon what we already knew conceptually and theoretically from phase 1.

3.1 Sub-Project 3.2.1: Science-Based Technologies and Interdisciplinarity

Group in charge of sub-project: FhGISI. **Scientist in charge of sub-project:** Thomas Reiss. **Staff:** Sybille Hinze, Ulrich Schmoch and Elke Strauss. **Collaborator 1:** Tema. **Tasks of Collaborator 1:** To carry out two case studies in Sweden: one on pharmaceuticals, one on new materials/chemistry. **Scientist in charge:** Charles Edquist. **Staff:** Ulf Sandström, Bo Persson. **Collaborator 2:** VTT. **Tasks of Collaborator 2:** To carry out two case studies in Finland: one on pharmaceuticals, one on new materials/chemistry. **Scientist in charge:** Tarmo Lemola. **Staff:** Christopher Palmberg. **Collaborator 3:** BETA. **Tasks of Collaborator 3:** To carry out two case studies in France: one on pharmaceuticals, one on new materials/chemistry. **Scientist in charge:** Patrick Llerena. **Staff:** Mireille Matt and Stefania Trenti.

3.1.1 Objectives

Recent studies of emerging technologies in several industrialised countries indicate that the characteristics of technological innovation are currently undergoing a series of changes. Trends include, among others, an increasing importance of science for technology and a growing significance of interdisciplinarity (Gibbons et al. 1994, Grupp 1994, Grupp and Schmoch 1992, Reger and Schmoch 1996 - for full references, see end of this sub-project report).

The main objective of this sub-project was to contribute to a better understanding of the evolution of science-based and interdisciplinary technologies. From a systems of innovation perspective, particular attention was given to the analysis of the evolution of interactions between different organisations of national and international systems of innovation in the context of knowledge generation. In particular, the following questions were tackled:

- What is the nature of knowledge that is produced during the evolution of science-based and interdisciplinary technologies?

- How does this knowledge evolve? How is knowledge generation organised in networks?
- Which are the major organisations in the particular systems of innovation to be considered?
- Which types of links (transfer channels) and interactions exist between different organisations of the innovation system (e. g. links between different firms, firms and universities, firms and other research institutions, different universities, different research institutions, and universities and research institutions)?
- How do these links evolve?
- Which incentives for establishing links do exist?
- Which differences or similarities between technologies and countries can be observed?

The sub-project touches on several policy implication areas. Mainly the following issues are included:

- The role of policy in the formation of links and interactions between science, technology, and markets.
- The role of policy in the creation of interdisciplinary networks.
- The relation between national and European policies during the establishment of international research networking systems.

These questions are analysed for two technological areas which are assumed to be interdisciplinary and science-based. The rational for this approach is that the project did not aim to analyse the significance of science-based and interdisciplinary technologies in general, which would certainly need a careful comparison with other technological areas that are assumed not to be science-based and interdisciplinary. Rather the focus of the project is on the analysis of the evolution of science-based and interdisciplinary technologies and on the policy implications, which can be derived from a better understanding of this phenomenon. Therefore, it was necessary to start with technological areas that were assumed to fulfil the criteria of being science-based and interdisciplinary. In particular, the following two technologies were analysed: autoimmune diseases as a sub-field within the pharmaceutical sector and electrically conducting polymers (ECP) as a sub-field of both the chemistry and the electronics sectors.

3.1.2 Progress

Basically, the sub-project succeeded in providing a detailed analysis of the two science-based and interdisciplinary technologies chosen. Clues and answers could be elaborated for all the research questions outlined above.

However, one principle limitation of the sub-project should be mentioned: two examples of technologies have been studied, which per se exhibit some peculiar specialties. Therefore, one should be rather cautious in trying to draw general conclusions from the specific scientific findings for the two technologies analysed.

An additional problem is related to one of the technologies—autoimmune diseases. In this case, health care systems and public health policies are important elements of the respective systems of innovation. These elements, however, and also related organisations could not be analysed in detail due to project limitations in time and budgets.

In line with the original work programme of the ISE project, the following papers have been submitted:

- Hinze, S.; Reiss, T.; Schmoch, U.; Strauss, E. (1997): Draft report on "statistical analyses of patents, publications and external trade in sub-fields of pharmaceuticals and new materials". March 1997.
- Hinze, S.; Reiss, T.; Schmoch, U.; Strauss, E. (1997): Statistical analyses of patents, publications and external trade in sub-fields of pharmaceuticals and new materials. June 1997.
- Hinze, S.; Reiss, T. (1997): Science-based technologies and interdisciplinarity - case study on autoimmune diseases. Draft report. August 1997.
- Hinze, S.; Reiss, T. (1997): Science-based technologies and interdisciplinarity - case study on electrically conducting polymers (ECP). Draft report. August 1997.
- Sandström, U.; Brenner, M.; Alm, H.; Persson, B.; Persson, O.; Tisell, A. (1997): Science-based technologies - the Swedish case. August 1997.
- Palmberg, C. (1997): Science-based technologies and interdisciplinarity from a small country perspective - the case of electrically conducting polymers and COMT-inhibitors for the Parkinson's Disease in the Finnish system of innovation. Draft report. August 1997.

- Llerena, P.; Matt, M.; Trenti, S. (1997): Autoimmune diseases (AI) - the French case. Preliminary version. August 1997.
- Llerena, P.; Matt, M.; Trenti, S. (1997): Electrically conducting polymers (ECP) - the French case. Preliminary version. August 1997.

The following scientific paper was published:

- Reiss, T.; Hinze, S. (1997): Patent trend profile: autoimmune diseases-knowledge generation and utilization. Exp. Opin. Ther. Pat. **7** (9): 1005-1013.

3.1.3. Methodology

Two complementary approaches were employed within this sub-project. The first part comprised a statistical analysis of scientific publications, patent applications, and trade flows for the two selected technological areas in the following countries: the United Kingdom, France, Sweden, Finland, Italy, Germany, Europe (EC 15), the United States, and Japan. The second approach comprised case studies in Sweden, Finland, France, and Germany.

The two methodological approaches used were complementary in the following way: as a result of part one, the statistical analysis, a broader picture of the evolution of science-based and interdisciplinary technologies on the macro level was derived. "Macro" in this context comprises the following dimensions:

- The development of a whole technological area
- Developments within the triad
- Developments on the EU level
- Developments on individual country levels

The case studies, on the other hand, focus more on specific innovations within a technological area, which are analysed in individual European countries.

The second complementary link between both approaches is associated with different types of information being gathered. The statistical data of part one will finally result in the formulation of hypotheses about the evolution of science-based and interdisciplinary technologies. These hypotheses in turn can be adopted during the second part of the sub-project—the case studies—and

serve as a starting point for formulating specific questions to be tackled during the case studies.

The statistical analysis was carried out based on bibliometric as well as on patent and external trade data. The differentiation between bibliometric and patent analysis was made because different indicators represent different aspects of science and technology and their development. It was assumed that bibliometric data and respective indicators can be used to reflect the activities in basic and applied research while patent data can be taken to analyse applied research as well as the activities based on experimental development (Schmoch et al. 1996, p. 118).

The bibliometric analysis was carried out using on-line databases. The bibliographic database Medline was used to analyse scientific activities and their development in autoimmune diseases. The investigations of electrically conducting polymers are based on data retrieved from the database Chemical Abstracts (CA).

In addition, co-operations were analysed using the Science Citation Index (SCI). The SCI data were also used to analyse the different disciplines contributing to knowledge production in the fields of autoimmune diseases and electrically conducting polymers.

Patent analyses were carried out using the on-line versions of the databases WPIL (World Patent Index Latest), EPAT, and EDOC. The analyses are based solely on patent applications at the European Patent Office (EPO). An exception was made in analysing the long-term development (since 1970) of the fields. Because the EPO was first founded in 1978, the years 1970–1977 could not be analysed using European patent data. Instead, we analysed patent applications for the German market and assumed them to be representative of the general overall trend of development in theEuropean market.

Activities per country were analysed beginning in 1987. To get an impression of the relative importance of the research activities on autoimmune diseases and electrically conducting polymers compared to the overall research activities of the countries, the specialisation indicator RPA (Revealed Patent Advantage) was calculated for the most recent period of time (1991-1994).

Relationships between science and technology, in particular the science base of the technologies, were analysed using the non-patent literature (NPL) indicator. The NPL indicator was constructed using citations of scientific articles in the official search reports of patents. These search reports document the state of the

art related to the legal claims of the patent application. The patent office examiners generally prefer to cite other patents, because technical features are more clearly described in patents than in scientific articles. But if they cannot find relevant patents, they also refer to publications. These "NPL" references are more frequent in science-based technologies, so this characteristic can be used for their quantitative definition (Schmoch et al. 1993, Schmoch 1997).

Furthermore, the disciplines contributing to knowledge generation in the field of electrically conducting polymers were investigated by analysing the classification codes of the International Patent Classification (IPC) assigned to the individual patent applications. Using a classification scheme for technology that consists of 30 different technological classes based on the IPC[1] (Grupp and Schmoch 1992) for all patent documents retrieved, the proportion of their respective IPC Codes were calculated to determine the relative importance of the sub-fields for the development of the field.

The analysis of external trade specialisation was carried out using the external trade statistics provided by the OECD. The OECD data are available on CD ROM and comprises trade data since 1961 classified according to the Standard International Trade Classification revision two (SITC 2).

For measuring the external trade specialisation, the world export share (WES) indicator was used. This indicator tells whether an economy holds higher shares of the world market within a certain product group or technology area compared to its overall exports. Positive indicator values in a certain area therefore point to a specialisation by a country in this area; negative values indicate underspecialisation.

All in all, eight case studies for the two technical areas—autoimmune diseases and ECP—were carried out by the project team:

- autoimmune diseases Germany: FhG ISI
- autoimmune diseases France: BETA
- autoimmune diseases Sweden: TEMA
- autoimmune diseases Finland: VTT
- electrically conducting polymers (ECP) Germany: FhG ISI
- ECP France: BETA
- ECP Finland: VTT

[1] For more details see Grupp and Schmoch 1992.

- ECP Sweden: TEMA

The case studies are based on structured interviews with experts from selected research institutions and firms who are actively participating in R&D related to the two fields under consideration. The following topics are discussed in the case studies:

- interrelation between knowledge generation and application-oriented R&D activities
- characteristics of the knowledge generated during the development of the fields
- characterisation of the major players involved in the process of knowledge generation
- organisation of interdisciplinary research
- characterisation of co-operation types during the knowledge generation
- analysis of R&D networks
- organisation of knowledge transfer

3.1.4 Scientific Findings

3.1.4.1 Autoimmune diseases

Both the statistical analyses of scientific publications and patent applications related to autoimmune diseases and the case studies confirmed the assumption—a criterion for sub-field selection—that the sub-field autoimmune diseases is a strongly science-based field. . It was found that its NPL indicator was about three times as high as the average value for all fields of technology. The science linkage within this sub-field was even stronger than it was for the pharmacy sector as a whole, which was already considered to be highly science-based.

Interdisciplinarity

R&D on autoimmune diseases is characterised by a high degree of interdisciplinarity. The spectrum of disciplines involved differs between different stages of the innovation process. The main differences could be observed between the experimental research stage and the clinical research and development stage. In the clinical stages, "small interdisciplinarity" plays a major role and concerns collaboration between different fields of medicine representing mainly different clinical indications. In the former case—experimental research during drug discovery—interdisciplinarity exhibits a different quality in the sense that disciplines with no common disciplinary base collaborate with each other. This "bigger interdisciplinarity" relates more fundamentally to the new paradigm of drug development and advances in biotechnology together with developments in synthetic technology (combinatorial approaches), computer-aided instrumentation, information technology. This type of interdisciplinarity is relevant not only for autoimmune diseases but for the pharmaceutical sector as a whole.

Interestingly, the autoimmune diseases scientific community seems to consider interdisciplinarity not as a completely new feature of the production of knowledge but as a natural and necessary way of working. In other words, the demand for new medicines to treat autoimmune disease phenomena requires an interdisciplinary approach.

The empirical analyses indicate that the organisation of interdisciplinary research is quite different between industrial organisations and academic organisations. Corporate research is often organised around projects, in which all the different disciplinary specialised people are working together. This project organisation allows intensive interactions between different disciplinary experts, facilitating the flow of knowledge between different disciplines, which is a prerequisite for the success of the project. Within the academic system these interdisciplinary links are less natural because of the institutionalisation of disciplines. These disciplinary organisations in the scientific community are strongly related to incentive structures for the establishment of interdisciplinary approaches.

Incentive Structures

In industrial organisations, innovation race and competition could be identified as important incentives for strengthening and broadening the interdisciplinary scope of research. In the pharmaceutical industry in general and also in the field of autoimmune diseases, the speed of the drug development process is decisive

for competitiveness. Since the new interdisciplinary approaches enable a faster track for drug discovery, there is a strong incentive for implementing such approaches. In academic organisations, no specific incentive structures could be identified; rather, interdisciplinarity is seen as being mainly a self-organising process.

Dynamics and country activities

The analysis of the long-term development has shown that development in the field of autoimmune diseases has been highly dynamical in the sense that, particularly since 1980, a strong parallel increase in publication and patenting activities can be observed. The time before 1980 was characterised by a rather long period of applications-independent knowledge production, indicated by the almost complete lack of patenting activities. The following parallel increase of publication and patent activities points to a more interrelated development of scientific and application-oriented activities. On the science side, looking at the activities of the triad, most scientific publications originated from the member countries of the EU followed by the United States and Japan. Within the EU, the United Kingdom is the most active country. On the application-oriented side, the United States are stronger than the EU countries. Again, Japan laggs behind. Within Europe in particular, Germany has outstripped the United Kingdom in recent years. Italy, which was very strong on the science side, was found to show less application-oriented activities. The patterns for Sweden and Finland are similar: relatively high publication activities face low patent activities. The only countries with above-average specialisation on the application-oriented side of the sub-field autoimmune diseases are the United Kingdom and the United States.

Organisations

The statistical analyses indicate that a considerable part (almost 50%) of research is being conducted in co-operation between different organisations. University hospitals especially focus on co-operative research, mainly with other hospitals, other research institutes, and industry. For industry, the university hospitals are the main partners in co-operation. Almost 40% of the co-operations identified are international and thus international relations might be seen as being highly relevant for the field. In particular, universities and industry perform about half of their co-operative research with international partners.

A more detailed mapping of organisations during the case studies led to further differentiations of the systems of innovation relevant for autoimmune diseases.

In each of the four countries analysed most types of players are the same: pharmaceutical companies, universities, research institutions, and hospitals. In addition, there exist some specialties in each country.

Basically, two types of industrial organisations can be differentiated. The first are the pharmaceutical companies, medium-sized as well as large ones, which are important players in all systems considered. The second are the small- and medium-sized specialised "dedicated biotech firms (DBFs)" that focus on providing R&D input for the development of treatments or diagnoses of autoimmune diseases. Even though there are many new developments throughout Europe, the United States are still leading in terms of number and competencies of DBFs. The American DBFs are important partners of European pharmaceutical firms in the field. Thus, American DBFs form a transeuropean link to the American systems of innovation.

Public research centres, universities, and hospitals are important organisations in each of the countries considered. Among the public research organisations, the French INSERM and CNRS and the German Max Planck Society in particular are noteworthy actors.

Organisations that support research on autoimmune diseases are very diverse from country to country. Basically, two types of funding schemes can be identified: basic-oriented and mission-oriented approaches. In autoimmune diseases as well as in other research areas related to specific diseases, an additional type of supporting organisation is important: foundations for different diseases that make considerable financial contributions to R&D. This holds true in particular for the French situation.

Among the supporting organisations transnational developments could also be observed, in particular the BioValley network between French, German, and Swiss organisations for the development of biotechnology, including research on autoimmune diseases. The organisations involved in the network comprise not only research organisations, universities, and industrial firms but also policy-makers and financing organisations. The second transnational element is some programmes of the EU. In particular, within the Biomed programme relevant research on autoimmune diseases is also covered. The role of this programme seems to be mainly that of a facilitator for European research collaboration.

Links between Organisations

Relations between these different organisations are both national and international. In general, personal links play a very important role in the process of forming and sustaining these networks. Between industrial companies, public research centres, universities, and hospitals, three types of links are relevant:

- Formal agreements on a contract basis like bilateral research contracts or common research contracts financed by public supporting organisations.
- Personnel dependent links like exchange of researchers, hosting of PhD students and postdocs or targeted recruitments from the academic system.
- Investments by the industry in research facilities and equipment.

In general, industry considers research in universities and research organisations to be a window to the research frontier. Collaborations can lead to co-patenting or co-publishing in scientific journals.

Among the links between industrial companies, co-operations between large pharmaceutical firms and small- and medium-sized biotech companies are most important. As already pointed out, the majority of these small- and medium-sized enterprises (SMEs)are located in the United States, which is one reason for the high relevance of international co-operations within the field. Biotech SMEs are also seen as important mediators between the academic sector and industry. It seems that these SMEs, which often had been founded as spin-offs of universities and research organisations, can cope with public research organisations more easily because of common routes in the same environment.

Other types of interfirm collaborations concern market entrance. Some of the important markets for pharmaceuticals in general and autoimmune disease drugs in particular are rather difficult to enter due to administrative and marketing barriers. This holds particularly true for the Japanese and US markets. Development and marketing co-operations with firms from the target markets are used as measures for coping with these problems.

Links between public research organisations are mainly organised in an informal way (co-publications, conferences, informal meetings, etc.) except for specific research programmes organised by national or European funding bodies.

Nature, evolution, and transfer of knowledge

In the early stages of the innovation process in the field of autoimmune diseases, mainly basic research activities were performed in universities and research organisations, resulting in the generation and accumulation of application-independent knowledge. The emergence of biotechnology led to a rethinking within the biology community; the potential for further applications of research results was increasingly considered by scientists.

The evolution of knowledge during the development of autoimmune disease innovations has been characterised by the following features: Increasingly, the accumulated tacit knowledge was transferred into codified knowledge like scientific publications, conference contributions or patents. In parallel, the field seems to be developing more and more towards medical applications. This is indicated by the growing importance of specific indication areas within the sub-field like cardiovascular systems and ophthalmology. Furthermore, pharmacology and pharmacy are increasing. Contrary to this trend, basic research areas are also becoming more important. This may be due to the fact that more emphasis is now being given to investigations directed to disclose the causal connections of specific syndromes.

As pointed out in the previous section, the flow of knowledge between the different actors is very complex and diverse. This knowledge concerns scientific theory ("know-why"), property studies, technical information (testing, screening), research skills ("know-how"), and knowledge of networking ("know-who"). Especially for the transfer of "know-how" and "know-who", the exchange of researchers, of PhD students, and personal contacts is very important.

3.1.4.2 Electrically conducting polymers (ECP)

Analgous to autoimmune diseases the underlying assumption that the sub-field ECP is science based could also be confirmed. The NPL index calculated is higher than the average for all technologies and also higher than for the polymer field as a whole although the sub-field ECP seems to be less strongly science-based than the sub-field autoimmune diseases.

Interdisciplinarity and incentive structures

Interdisciplinarity has played a significant role for the very origins as well as the evolution of research on ECP. The need to form interdisciplinary teams was present very early in this area. As a consequence, interdisciplinarity is not a new phenomenon but a natural and necessary condition to get results. What has evolved is the composition of the teams that try to integrate new disciplines due, for example, to new potential applications.

The analysis of the disciplinary affiliation of scientific publications related to ECP indicated changing patterns concerning the relevance of individual scientific disciplines. Increasingly, condensed matter physics, metallurgy, and physical chemistry as well as material sciences were of importance, while the proportion of the more general fields physics and chemistry was decreasing. Thus, research seems to focus on understanding the underlying phenomena of electrical conductivity as well as on the properties of the respective materials.

It seems to be important to distinguish between interdisciplinarity at the level of the organisation and at the level of the research team. Many universities and public research laboratories have physicists and chemists working in different teams that interact only occasionally and do not work together on a regular basis. In these cases of "external" interdisciplinary relations, incentives and project-accompanying assistance from, for example, public funding bodies are required. In addition, it seems to be inefficient simply to demand interdisciplinarity as a prerequisite for funding if no assistance is provided for managing the co-operation process.

Interdisciplinarity realised inside a research team, on the other hand, can be considered to be a self-evolving process that is working efficiently. In conclusion, it is not enough for a laboratory or organisation to acquire different competencies, rather interdisciplinarity has to be realised inside a team through strong interactions. A major problem of this interdisciplinary research is to create a common goal for scientists coming from different disciplines and to find the appropriate equilibrium between the different disciplines. Learning to communicate to exchange knowledge is crucial for achieving this goal.

The competencies and the training of the person in charge of an interdisciplinary team seems important for different reasons. He or she has to be able to understand, communicate, and judge the work of researchers inside the team coming from different disciplines to stimulate both the individual and collective work. Moreover, the cohesion of the group and the incentives to work in an interdisciplinary team, in an institutional context that does not support

interdisciplinarity (see below), strongly depends on the commitment of the head of the team.

In discussing incentives or disincentives, a differentiation between the industrial sector and academic organisations needs to be made. A general observation is that the only way industrial companies conduct research in ECP is within interdisciplinary research groups. Results leading to commercial success depend very much on the existence of interdisciplinarity and there seems to be no problem of incentives to work in such interdisciplinary teams. A different situation could be observed in academic organisations, namely universities. There, a much stronger tendency to configurate according to traditional disciplines seems to be prevalent. A main reason for this situation is the disciplinary orientation of academic career schemes.

There is evidence, however, that these disciplinary boundaries at universities are also being dismantled. Behind this, a mainly self-evolving process can be observed: if scientific problems occur that cannot be solved by traditional disciplinary approaches, missing disciplines are integrated into the research process to answer these research questions.

Dynamics and country activities

Until the end of the seventies, almost no publications or patent activities were found. Beginning in 1978, the number of scientific publications increased continuously until the end of the eighties. With a five-year delay, increasing numbers of patent applications could be detected beginning in 1983 with a peak in 1988 and a decline afterwards.

On the science side, Japanese researchers contributed most actively to knowledge production, followed by the United States and the EU, which are at the same level. Within the EU, Germany is the most active country in the sub-field. On the technology side, the EU is the most active member of the triad. Here, the United States and Japan follow at almost the same level of activity. Also on the technology side, Germany is the most active country within the EU although, in relative terms, Germany’s concentration of efforts on ECP is below average. Remarkable is the strong, above-average concentration on ECP by Finland.

Organisations

The following types of organisations are actively involved in R&D in the field of ECP: research groups at universities; research groups in other research organisations; large chemical enterprises; specialised medium-sized chemical firms; and on the user side, enterprises from the electronics sector. In general, the ECP community is rather small and specialised.

In addition to this general map of the ECP community, there are also country specifities, which need to be considered. A general observation is that industrial involvement in this field is limited to those countries where a relatively large chemical industry exists, Finland and Germany, whereas in Sweden and France, research has primarily been undertaken at public sector research organisations including universities. Differences in the national systems of innovation seem to explain some specific features of public sector involvement, namely in the case of Germany and France, where the role of public sector research organisations and national or European programmes in this field have been significant. In Germany, specific public research programmes have played an important role while in France, where there is no national specific programme to sustain ECP, the role of public funding is important in the sense that most of the researchers work in publicly funded laboratories.

Links between organisations

There exists a variety of different relations between the involved organisations. Very important are co-operative relationships between academic and industrial organisations. In some of the countries considered, these relations are a prerequisite for receiving public funding. Links are both national and international. In particular, at the European level a specific network has been established which, though not specialised for ECP, also covers important parts of ECP research. Within the industrial sector, producer-user interrelations are also significant. In these networks, some medium-sized specialised firms managed to occupy certain producer niches.

The initiation and early establishment of links depends to a large extent on social factors, personal relations and affinities. This is independent from the further evolution of links, be it in a more informal or a more formal way.

Nature, evolution, and transfer of knowledge

In the beginning of the development of ECP, R&D activities concentrated on the generation of basic physical knowledge concerning the electrical conductivity of polymers and on the chemical synthesis of conducting polymers. The aim was to synthesise new polymeric materials with high conductivity and high stability. Within a relatively short period, R&D activities became increasingly application oriented and thus, knowledge generation and application-oriented activities took place in parallel. During these stages, industry and, in particular, large chemical enterprises were involved in ECP R&D, also through publicly-funded joint research projects with academia.

Up to now the original expectations of new products based on ECP have been disappointing, and in addition, it became clear that ECP products are not targeting mass markets. An additional piece of evidence for ECP's continuing lack of market relevance is the observation that ECP patents are still anchored in the more basic chemistry and materials areas while application-oriented classes like telecommunications or information technology are still much less relevant. In conclusion, large industrial enterprises withdrew from their R&D engagement on ECP which is reflected, for example, in decreasing patenting activities. This was also the period where SMEs entered the field because it became obvious that niche markets might be more promising.

Knowledge transfer in the process of R&D concerning ECP is organised mainly informally. Personal contacts are essential for knowledge exchange between individuals and also between research teams. Conferences provide an important platform for establishing such personal contacts.

3.1.4.3 Comparison and Conclusions

All in all, the results confirm that both fields can be characterised as science-based and interdisciplinary. Thus, on a general level, the similar features of the two cases might be characteristics of the "new production of knowledge" (Gibbons et al. 1995). While autoimmune diseases are characterised by increasing scientific and application-oriented activities throughout the period considered, in the case of ECP a decline was found in application-oriented activities and strong fluctuations were observed in scientific activities.Nevertheless, in both cases a more or less parallel development of publication and patenting activities can be observed. Thus, the question arises whether it is a more general feature of science-based technologies that

knowledge generation—as indicated by publication activities—and application-oriented work—as indicated by patent activities—develop in parallel during the early stages of technology.

Common to both fields is that the spectrum of disciplines relevant for their development, and thus, the science base of these fields, seems to be broadening. These findings have clear implications for policy design: in particular, the question of a balance between broad and open policy instruments versus more focused approaches is relevant.

Both of the areas analysed point to the significance of strong interrelations between different phases of the innovation process. In the case of ECP, it could be concluded that decreasing scientific and technological output is due to a mismatch between characteristics and possibilities offered by the technology so far and market requirements and demand. To satisfy market requirements, scientific and technological activities have to be reoriented. It seems that the interrelation between the characteristics and possibilities offered by the technology at a certain stage of development and market requirements and demand are important factors in shaping science/technology development. In this context a dilemma of potential policy intervention becomes visible. On the one hand, programmes approaching the areas of interest broadly seem to be useful, also because industrial activities are usually more focused and thus potentially in danger of overlooking promising developments on the side. On the other hand, such broad public support for scientific and application-oriented development might conceal the mismatch between supply (science and technology) and demand (by the market), which becomes visible due to the feedback loops within the innovation process.

The interrelated and systemic development that in particular was observed in the case of ECP points to the significance of interdependencies between the different organisations constituting the relevant systems of innovation. Key actors in this context are not only universities, other research organisations, and industrial enterprises developing and producing these new materials but also industrial enterprises on the demand side utilising these new materials for certain purposes. As described, mismatches or disturbances of interdependencies, mainly between demand, on the one hand, and the organisations producing knowledge and ECP material, on the other hand, have been a crucial factor impeding the development of the field.

A great variety in the types of links between different organisations could be observed in both cases. While firm-firm co-operations usually are organised in a formal way on a contract basis, links between public research organisations or

universities are mainly of the informal type. In between these two patterns, co-operations between firms and public research institutes or between firms and universities are organised in both ways, formally as well as informally. The important point is that initiation, early establishment, and sustainment of the different types of links largely depend on interpersonal contacts. This situation may lead to a trade-off problem as described by Henderson et al. (1995) between efficiency of the system of innovation and fairness in the following sense: Only a few public research institutions are able to attract the best researchers, who in turn are crucial for establishing co-operative links with industry. This would lead to strong inequalities between research organisations, which, however, would be efficient. Fairness, on the other hand, would call for support of ‘weaker’ research organisations which are not able to compete with the key-person driven ‘champions’.

International interdisciplinary networks are significant in both cases. This leads to the question of the "division of labour" between national policies and European policies, in the sense that national policies are more deeply rooted in supporting disciplinary research while European policies tend to support interdisciplinary activities more intensively.

In both cases differences in the significance and organisation of interdisciplinary research could be found between industrial and academic research. Corporate research is frequently organised around projects where the different disciplines which are needed to accomplish the project goals are integrated. Academic research on the other hand is much more organised along single disciplines. These different interdisciplinary cultures can lead to mismatch problems in situations where close interdisciplinary co-operation between academic and industrial research would be needed.

This does not necessarily imply that academic research should become more interdisciplinary in general. Since strong disciplinary competencies are prerequisites for thinking and working in interdisciplinary contexts, disciplinary education and training cannot be substituted. However, learning to use and apply disciplinary knowledge to solve interdisciplinary problems is the main additional task needed in interdisciplinary fields like autoimmune diseases and ECP. The cases analysed indicate that this dimension of academic education and research is currently not developed well enough.

This sub-project provides empirical evidence for the nature and evolution of knowledge during the innovation process. In both of the cases studied, similar logical tendencies seem to have been followed. It starts with a period of accumulation of mainly tacit knowledge in universities and research

organisations. This knowledge is translated into a codified form, namely publications and patents. At this stage, industrial organisations develop their own in-house capabilities, which in turn lead to the accumulation of tacit knowledge in these organisations. By monitoring external sources of mainly codified knowledge, internal knowledge accumulation in industrial organisations proceeds. In addition, tacit knowledge is also incorporated through the relocation or hiring of key individuals. During this mutual process, publications and patents play a significant role in signalling the existence of distinct (tacit) knowledge, thus building the credibility needed to find partners in knowledge exchange (see also Meyer-Krahmer 1997). Another important point is the role of individuals, who have often played a key role in the formation of a network or technological community.

Knowledge production also has a spatial dimension. In general, domestic links are easier to establish than international ones. However, in both of the cases, these domestic links played a crucial role only in the rather early states. In the autoimmune case in particular, international links and international flows of knowledge became very important. The driving forces behind the formation of these international channels for knowledge exchange seem to be mainly the specific competencies of the involved organisations.

Another issue concerns the significance of "breakthrough" events, which could be substantiated mainly in the ECP example. This leads to the question of how these milestone events are perceived within the systems of innovation, or in other words, how does the system respond to such events? In the case of ECP, these breakthroughs did not occur somewhen in the innovation process but rather at the very beginning, and as the statistical data indicate, it obviously took some time until the system responded intensively. The question is whether there are ways which would enable a more efficient integration of these events into the relevant systems of innovation.

3.1.5 Interdependencies Between Elements in Systems of Innovation

The autoimmune case in particular points to several interactions and interdependencies between elements in systems of innovation. The main organisations in this particular system are multinational pharmaceutical companies, medium-sized pharmaceutical companies, small- and medium-sized biotechnology firms, universities, other research institutions, and hospitals. The pattern and significance of the links between these organisations changes considerably during the process of innovation.

In the early stages of drug discovery, research organisations and universities partly interacting with pharmaceutical firms are the main players. As time goes on, small- and medium-sized biotech firms specialised in genome analysis become increasingly integrated in these networks. In later stages, when drug candidates are being tested, multinational pharmaceutical corporations, hospitals, and specialised contract research organisations for clinical testing and evaluation become more important.

During this process of drug development different institutions like laws, rules, norms, and standards are important, as are additional organisations such as the respective authorities responsible for the implementation of these measures. This includes, for example, good manufacturing practice (GMP) rules for the production of drug candidates, good clinical practice (GCP) rules for testing and rules for application and approval of new drugs. Affected authorities include the national level as well as the European level. Since 1995 the European dimension has gained additional momentum through the foundation of the European Medicine Products Evaluation Agency (EMEA) in London.

The ECP example shows an additional interesting interdependence, which is illustrated by a so-called camel-shaped curve of science and technology development. The following hypothesis may explain these observations: After basic inventions prepare the ground for a new field, intensive inventing activities commence which are triggered by high expectations of the technological and commercial potential of the new field. However, after this early stage, new technological problems become obvious; in addition, the commercial potential cannot be realised as rapidly as expected. In consequence, technology development loses its speed after the initial take-off. After some time, a second take-off may occur which, however, is characterised by a different type of technology development, also based on different types of scientific knowledge, and more strongly oriented towards specific adaptations for commercialisation.

3.1.6 ISE Coherence: Relations to Other Sub-Projects

Sub-project 3.2.1 has quite obvious relations to sub-project 3.1.1 (”Systems Theories of Innovation: Policy Implications”). The organization of interdisciplinary research is particularly relevant. This includes the question of intervention versus setting frame conditions and also of appropriate incentives for interdisciplinary developments. Another issue is the relation between

supporting, linking or networking activities (e. g. "concerted actions") and the support of specific research organized, for example, in projects.

Science-based and interdisciplinary technologies pose new requirements for qualification. In particular, not only scientific technological knowledge is needed, but in addition and perhaps increasingly important, co-ordination and communication skills are required for facilitating interdisciplinary linkages and co-operations. Therefore the qualification issue in the context of innovations, employment and growth forms a link to sub-project 3.1.2.

Implications for sub-project 3.1.3 (”European Integration and National Systems of Innovation”) concern mainly the "division of labour" between national and European policies in the case of science-based and interdisciplinary technologies. The picture which seems to emerge is that national policies are more deeply rooted in supporting disciplinary research due to the disciplinary orientation of important elements (in particular universities) of the national systems of innovation while European policies tend to support interdisciplinary activities more intensively.

Relations to the procurement sub-project (3.2.2) arise from the parallels which exist between the requirements for an effective procurement policy and the kinds of relationship which support effective organisation of interdisciplinary research and university-firm relationships. In both cases, the acquisition of not only technical and economic but also organisational competence by the involved individuals is an important issue.

A different type of link exists with sub-project 3.2.5 (”Technological Entry: Diversification vs. New Innovators”). Both sub-projects share a common methodology (patent data, technology classification based on the international patent classification, indicators such as the RPA), which has been implemented through close co-operation and information exchange between the responsible research groups.

3.1.7 Policy Implications

The following policy implications can be drawn from the analysis in this sub-project:

1. During the development of the two science-based areas analysed the science base of the fields broadened in the sense that more scientific disciplines became involved. To support this development, broad, open and flexible policy instruments seem to be adequate. In addition, this observation raises the general question of the relation between policy instruments supporting linking and networking activities and policy instruments supporting fundamental research activities. The challenge is to design the optimum ratio between these two types of instruments for the respective science/technology area.

2. The statistical data point to strong interrelations between the different phases of the innovation process leading to different patterns of development in the two cases. In particular, the interrelation between the characteristics and possibilities offered by the technology at a certain stage of development and market requirements and demand seems to be an important factor in shaping science/technology development. This points to a dilemma of potential policy interventions: On the one hand, policy instruments supporting a broad approach towards the technological areas of interest seem to be useful. On the other hand, such a broad support and approach might conceal the discussed feedback mechanisms.

   This leads to the more general question of significance, timing, and interrelation between the following elements: creation of variation, selection of best-suited options, shift towards exploitation. Questions of variations and selection in particular are able to influence the innovation process. On the one hand, very strict selection processes can lead to a lack of progress and innovation while too weak selection can lead to inefficiency because of too much experimentation.

   In terms of policy implications, this indicated the need of having a mix of instruments available which allows these systems' elements to be tackled in an optimum way. A crucial issue in this context is the question of direct intervention versus setting frame conditions. It should be pointed out that this discussion does not necessarily mean that intervention (direct or indirect) is the only option. No intervention may turn out to be the best option in certain cases. Similar problems are relevant within large pharmaceutical companies. During the process of drug development, the focus of activities has to switch

at a certain point from more exploratory research activities to concentrated testing and developing of a particular drug candidate. A key success factor for pharmaceutical companies is to find the optimum balance between these two types of activities. Therefore, selection mechanisms are of paramount importance.

3. During the development of the science-based technologies considered here, there is a significant overlap, not only between different research stages but also between different stages of the process as a whole. Policy instruments are needed which target different phases of the whole process. Since quite often there is a rather clear division of responsibilities among policy-makers, the question of interrelation and co-ordination between the different policy responsibilities is important. In addition, within a certain responsibility different types of instruments may be needed, leading again to the question of co-ordination and interrelation between the policy actors responsible for the different types of instruments.

4. With respect to the question of national versus European policies at least two issues need further discussion: i) The results point to the significance of international interdisciplinary networks. This brings up the question of whether it is possible to identify a type of "division of labour" between national policies and European policies, in the sense that national policies are more deeply rooted in supporting disciplinary research while European policies tend to support interdisciplinary activities more intensively. This would indicate the importance of the role of European policies for the development of science-based and interdisciplinary technologies. ii) On the other hand the international design of policies could also become a certain impeding factor for innovativeness. The argument is as follows: if the original source for innovative ideas is linked mainly to individual players, then the need to form international R&D consortia could lead to a certain levelling out of individual innovative forces.

5. Interpersonal links and social networks play an important role in initiating and sustaining interdisciplinary co-operations. The question is whether and how policies could support the formation of such social networks. Direct approaches seem to be very difficult since they require a profound knowledge of "know-what", "know-why" and "know-who" which is hardly accessible from outside the research community. Indirect approaches like providing fora for dialogues between the actors or supporting mobility and exchange of researchers might be easier to follow.

6. There seem to be inherent and pronounced differences in the patterns of development of science-based and interdisciplinary technologies. This points to the notion that it would be very difficult to define best practice policies for science-based technologies.

7. As an impeding factor for interdisciplinary research networks, the disciplinary-oriented career schemes in public organisations in general and in universities in particular have been identified in some of the analysed countries. Therefore in those cases, integrating interdisciplinary components into academic career schemes is an important policy issue.

8. Public procurement seems to be a difficult policy instrument in interdisciplinary and science-based technologies. At least the two cases studied here indicate that both the technologies per se and the organisational context, in which innovations take place, are extremely complex. Under these conditions, public procurement instruments must be able to draw on a strong expertise in the technologies under consideration and their organisational contexts, which might be a difficult challenge.

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3.2 Sub-Project 3.2.2: Public Technology Procurement as an Innovation Policy Instrument

Group in charge of sub-project: Tema. **Scientist in charge of sub-project:** Charles Edquist. **Staff:** Mats Fridlund, Leif Hommen, Thomas Kaiserfeld. **Collaborator 1:** VTT. **Scientist in charge:** Tarmo Lemola. **Staff:** Christopher Palmberg. **Collaborator 2:** ARCS. **Scientist in charge:** Fritz Ohler. **Staff:** Fritz Ohler and Martin Husz.. **Collaborator 3:** BETA. **Scientist in charge:** Patrick Llerena. **Staff:** Mireille Matt and Stefania Trenti. **Collaborator 4:** CFS. **Scientist in charge:** Lena Tsipouri. **Staff:** Lena Tsipouri.

3.2.1 Objectives

This sub-project addressed government technology procurement as an instrument for innovation and industrial policy. It had three parts:

Part 1: Public (technology) procurement was related to various innovation theories, particularly those of relevance for a systems of innovation approach, e.g. those of a user-producer interaction kind.

Part 2: A number of cases of public technology procurement in five European countries were intensively analysed. The objective was to learn about technology procurement (which is very poorly documented in the literature), to

learn positive and negative lessons from the cases, and to examine whether the national level really is no longer relevant for procurement in some fields.

Part 3: On this basis problems and prospects related to public technology procurement in the future were discussed—at a national as well as at a European level.

3.2.2 Progress

According to the contract with the European Commission, this sub-project should result in two papers, namely a theoretical discussion of about 40 pages and a report on the national case studies of about 60 pages.

A draft of the theoretical paper (Charles Edquist and Leif Hommen: ”Public Technology Procurement and Innovation Theory” [142 pages]) was presented at the ISE Workshop in Athens in March 1997. Martin Husz has also written a short paper on auction theory to show its relevance for the analysis of tender processes. It was later included in the theoretical paper (with clear reference to Martin Husz). After revision, the theoretical paper was submitted to the Commission in June 1997. This version, however, was also discussed at the ISE Workshop in Vienna in September 1997.

At the ISE workshops, ten case study papers were discussed. On the basis of these discussions, the papers were revised and later submitted to the Commission. The case studies concerned Austria, Greece, Finland, France, Italy, and Sweden, and had the following authors and titles:

- Edquist, Charles; Hammarqvist, Per; and Hommen, Leif: ”Public Technology Procurement in Sweden. The Case of High Speed Trains”.
- Fridlund, Mats: ”Shaping the Tools of Competitive Power: Government Technology Procurement in the Making of the HVDC Technology”.
- Fridlund, Mats: ”Switching Relations: The Government Development Procurement of a Swedish Computerized Electronic Telephone Switching Technology”.
- Husz, Martin: ”Implementation of the Austrian Computerized Digital Switching System (OES)”.
- Kaiserfeld, Thomas: ”A Case Study of the Swedish Government Technology Procurement Project: ‘The Computer in the School’ (COMPIS), 1981-1988”.

- ◊ Llerena, Patrick; Matt, Mireille; and Trenti, Stefania: ”Government Technological Procurement: The Case of Digital Switching Systems in Italy”.
- ◊ Llerena, Patrick; Matt, Mireille; and Trenti, Stefania: ”Government Technology Procurement: The Case of Digital Switching Systems in France”.
- ◊ Ohler, Fritz and Jörg Leonhard: ”Public Procurement as Collective Action: the Case of the Austrian Low-Noise Rail Programme”.
- ◊ Palmberg, Christopher: ”Public Technology Procurement in the Finnish Telecommunications Industry”.
- ◊ Tsipouri, Lena: ”Procurement of Public Switching Centres by OTE, the Greek Telecommunications Operator”.

On the basis of the theoretical work (Part 1) and the case studies (Part 2), a paper analysing, comparing, and drawing conclusions of the case studies was written by Charles Edquist, Leif Hommen, and Lena Tsipouri. It was entitled: ”Scientific Findings and Conclusions of the Procurement Case Studies”.

In addition to the above, we are also planning to put together an edited book from this sub-project. The book will include a revised and shortened version of the theoretical work mentioned above, the case studies (shortened into book chapters), a chapter analysing the case studies, and an additional chapter on policy implications. In that paper the problems and prospects related to the use of government technology procurement in the future (Part 3) will also be discussed—at a national and at a European level.

3.2.3 Methodology

In Part 1 of the sub-project, the methodology was to analyse critically the existing literature, particularly the theoretical literature, dealing with issues of interaction between organisations within a systems of innovation perspective and with public technology procurement. In particular, we tried to illuminate theoretical issues which could be of policy relevance.

All the case studies in Part 2 followed a similar structure (which was outlined in detail in the April 1997 ISE Progress Report). All the case studies addressed all the issues in this structure to make comparisons possible. To deal with these issues, written sources and other public material were normally not enough. It was also necessary to include interviews with key actors on the user side, the supplier side and representatives of organisations surrounding these. Archives

were also visited in some cases. Part 3 used Parts 1 and 2 as the basis for the analysis.

3.2.4 Scientific Findings

3.2.4.1 Conceptual issues

Public technology procurement occurs when a government agency places an order for a product or system which does not exist at the time, but which could (probably) be developed within a reasonable period. Additional or new technological development work is required to fulfil the demands of the buyer. In contrast to public technology procurement, 'regular' public procurement occurs when government agencies buy 'existing' products such as pens and papers—where no R&D is involved. Only price and performance of the (existing) products is taken into account.

Public technology procurement has been used extensively in many advanced industrialised countries during the Post War period. Procurement policies differ in relation to the institutional and economic national contexts and in relation to different policy traditions and approaches to public intervention in general and innovation policy in particular.

The United States, during the Post World-War II period, has developed one of the most well-known models of public technology procurement policy. Based on the central role played by the US defence programmes, the federal government has awarded important large contracts to large and small organisations (mainly firms and university departments) for the development of specific technologically advanced defence items. Two elements have characterised this model. First, contracts have been awarded not only to well-established organisations but also to new ones (like new, high-tech-oriented SMEs) and in many cases to firms interested in also developing new products for non-military commercial markets. And second, the public agencies have played an important role in promoting the dissemination of the new knowledge to the industrial community.

Western European policies have developed different models. In Sweden and other European countries the public technology procurement instrument has been used to develop tight relationships between government agencies and large technologically-oriented firms in strategic sectors. The role of defence

procurement has been important in Europe, but not as dominant as in the United States. In Europe, public agencies specifically devoted to civilian technology development have also acted as procurers. A final difference between the European model and the US one has to do with the less explicit efforts in Europe to force contractors to diffuse research results.

There is a growing awareness among European national policy-makers that public technology procurement is an important instrument for enhancing technological capabilities. There are, however, different national models for defining such policy instruments and different types of technology procurement. In the theoretical paper of this sub-project we distinguished four modes following two dimensions:

- Procurers as end-users vs. procurers as catalysts
- 'Development-oriented' and 'adaptive' procurement

Procurers as End-Users vs. Procurers as Catalysts

The classical public technology procurement policy, including technology-oriented interventions, is based on the role of the government as a leading user. In areas such as defence, or transport and telecommunications infrastructures, the government agency is both the buyer and end-user of the product or system procured. The agency simply uses its own demand to trigger innovation.

An alternative role of a procuring agency is to work as an intermediary for the final user of the new product. In other words, the agency is not the final destination of the procured product (as with PTTs or public railway companies) but an agency specifically designed to promote technologically advanced products for specific economic, social, or environmental purposes.

This is the case of the Swedish Board for Industrial and Technical Development (NUTEK). NUTEK established a division with the purpose of fostering the creation of more energy-saving products through the use of new technological knowledge. An example is the procurement of new refrigerators in the early 1990s. The requirement was that much less freon - which damages the atmosphere's ozone layer—should be used in production and that the refrigerator's energy use should be considerably lower than that of earlier designs. A bidding contest was announced where the prize—which was an order of at least 500 refrigerators to be used in apartments—went to the company which could best satisfy the demands. A design which could meet the

demands was presented by Electrolux within a relatively short time. This example illustrates that innovation policy through technology procurement can have other objectives besides economic ones.

'Development-Oriented' and 'Adaptive' procurement.

The cases mentioned so far refer mainly to examples of 'development-oriented' technology procurement with some specific technological and socio-economic objectives. This means that results from bidding contracts have been innovative globally speaking, producing results that enhance the knowledge-creation process through new findings.

Another type of technology procurement is focused on adaption, seeking to introduce a product or production process that already exists into the country. In this case, this instrument was designed specifically to foster the adaption and transformation of the national industrial base using new technological developments that have originated elsewhere. 'Adaptation-oriented' procurement includes R&D activities on the part of the producer, focusing on the adaptation of these new products or systems to national conditions. An example of this might be the adaptation of software products.

3.2.4.2 Scientific Findings Based on Case Studies

The comparison of case studies offered further insight into the distinction between 'developmental' and 'adaptive' procurement. Some of the difficulties involved in making this distinction are analytical -- for example, the period of time over which a procurement process is studied. But there are also empirical factors determining whether or not a given procurement will be primarily 'adaptive' or 'developmental'. These include the strategic orientation guiding the procurement, the extent of co-ordination with complementary policy instruments, the degree of 'fit' between formal and informal institutional arrangements, the relative maturity of the technology being procured, and the 'state of advance' of knowledge.

The comparison of cases thus indicated that public technology procurement should proceed with a planning perspective that takes into account not only market opportunities and technological possibilities but also the historical and political-economic context within which procurement intervenes. Since 'developmental' procurement is often the culmination of longer-term processes of collaboration involving both 'adaptive' and 'regular' procurement, it should not be regarded as an isolated economic event—rather, "history matters", as demonstrated by the crucial importance of issues related to timing, competence, institutions, and interaction.

Findings related to 'The Dimension of Time' indicate that timing is of strategic importance to the procurer. Early and sophisticated demand for new technologies is a main determinant of success, defined in terms of the maximisation of economic benefits. Consequently, user competence, based on systematic search and learning about markets and technologies, is of key importance. At the same time, the high risks involved in the selection of new technological trajectories indicate that, in early stages of development, more than one trajectory should be supported. In the later stages of a technology's development, the identification of new market opportunities becomes particularly important to the procurer's ability to acquire the technology on advantageous terms. Benefit can be increased by making 'time' an explicit consideration in planning and by anticipating problems that might delay implementation.

Findings related to 'Competence and User-Producer Interaction' indicate that competence is essentially *relational* in character. Accordingly, relations between users and producers have a decisive influence in processes of public technology procurement. Effective public technology procurement requires

broad organisational competence as well as more specific technical and economic competencies. The requisite competences, moreover, vary greatly from case to case.

Thus, what is most fundamental is the creation of institutional frameworks and organisational forms that will enable users and producers to acquire the necessary competence. 'Focal' organisations capable of developing 'poles of competence' (i.e. organised 'pools' of knowledge and expertise) and co-ordinating the R&D efforts of users and producers are needed. To act effectively, however, they also require the markets within which they operate to be organised, through frameworks such as those provided by producer associations, in a manner that supports learning based on recurrent interaction.

Institutional frameworks that facilitate the transfer of relevant knowledge, work—over the longer term—to create balance and complementarity between the competencies of 'buyers' and 'sellers'. At the same time, they operate as selection mechanisms that provide stabilising influences by reducing uncertainty. This dual effect is, for example, accomplished through supplier firms' participation in standard-setting by public agencies charged with technology procurement. Like technical standards, moreover, other institutions and organisational forms evolve over time. As technologies mature, the pace of development quickens, and competitive forces make implementation and commercialisation imperative, procurement relations tend to become more tightly integrated, more specifically focused, and more formalised, taking commercial interests into explicit account. The balance between formal and informal institutions changes.

Findings related to 'Political Influence and Levels of Intervention' indicate that the architecture of formal institutions, including the design of administrative structures and regulatory regimes, best promotes successful public technology procurement when it accomplishes several related purposes.

The first purpose is to provide for a central focus on 'innovation policy' (altering the speed or direction of technical change, or increasing technical diversity) rather than 'industrial policy' (enhancing the competitive position of domestic firms). This can be accomplished through market regulation encouraging public agencies to pursue innovation on the basis of self-interest. The second purpose is to ensure that the public agencies charged with carrying out technology procurement have sufficient autonomy and responsibility to conduct technological initiatives informally during earlier stages of development. This means that higher level political decision-makers are

confined primarily to acting in a supportive capacity at later stages, resolving conflicts through formal, institutional means.

A third, and closely related, purpose is to develop differentiated formal institutional arrangements allowing governments to act on immediate priorities without sacrificing longer-term undertakings. A fourth and final purpose, closely connected with the second and third, is to take informal institutions into account as important channels for initiatives that can counter-balance the 'pragmatism' of public agencies and political decision-makers. This requires the inclusion of all relevant interests in decision-making, leading to greater transparency and legitimacy of the decision process and a higher level of co-operation in implementing the decisions reached.

Findings related to the 'Interaction Environment' concern the structure and dynamics of markets with public buyers. They indicate that monopsonistic power on the part of buyers need not act as a brake on innovation. Monopsony is often the basis of leverage by which producer firms can be induced to enter new technologies and markets. Both monopsonistic public agencies and their suppliers, however, require adequate incentives to make such transitions. For the former, these incentives can come from pressures to provide improved services at lower cost. For the latter, such incentives can come from competitive pressures on either domestic or international markets or both.

Monopsonistic public agencies can develop relations with producers that are conducive to innovation when they are forced to by the challenges posed by their lack of competence in new technologies. These conditions can lead to the formation of alliances with suppliers and the creation of new organisational forms supporting interactive learning. Alternatively, similar results can be achieved under conditions that give public agencies a competitive interest in forming strategic alliances with key suppliers. Firms can be induced to enter into such relations through market incentives, secured through a variety of policy instruments geared to address the different types of firms and positions in producer markets. Thus, effective Public Technology Procurement will depend critically on effective policy co-ordination.

3.2.5 Interdependencies Between Elements in Systems of Innovation

As a matter of fact, public technology procurement *is* a matter of the interaction between (public) procurers and potential suppliers, i.e., it is a matter of interaction between organisations that constitute elements of the system of innovation. The point of departure is a perceived socio-economic problem or a socio-economic need that is not solved or mitigated by private market actors. In other words, someone has to formulate a long-term 'vision' which can serve as the basis for the procurement.

An important conclusion of ISE research on public technology procurement—involving a wide range of empirical case studies—is that the development of competence is crucial both within the procuring organisation as well as in the supplying one. Otherwise, the interaction between them will not be able to constitute a learning process of an interactive kind.

In the procuring organisation, the competence concerns the formulation of functional specifications of the system or product wanted. In the supplier it is a matter of techno-economic capability to fulfil these specifications. These partly different kinds of competencies must be relational and reciprocally modified by the potential user and the supplier.

3.2.6 ISE Coherence: Relations to Other Sub-Projects

The procurement sub-project has several links to the other sub-projects:

- In relation to the sub-project on policy implications of the systems of innovation approach, government technology procurement is highly relevant since it is actually a special case of interaction between users and producers in product development.
- In the sub-project on employment and growth, the crucial role of product innovation for these variables was stressed. This is also what is in focus in discussions of government technology procurement where public agencies act as demanding customers in the development of new products and systems.
- One sub-project deals with the relations between national systems of innovation and the European one. One conclusion in the procurement sub-project is that the scope for technology procurement has decreased at the national level, but that there are considerable opportunities to increase its use at the European level. This applies in particular to the kind of

procurement where the public agency takes the role of a catalyst rather than representing final demand.

- Technology procurement is more relevant for the science-based industries than for others. Procurement projects also normally include more than one discipline in their knowledge base. Therefore the links to the sub-project dealing with science-based technologies and interdisciplinarity are obvious.
- Financing issues are important in technology procurement; hence there are links to the sub-project on financing of innovation.
- Since government technology procurement involves complicated decision-making processes in public agencies and firms, the sub-project on governance is highly relevant in this context.
- Finally, since one important function of public technology procurement is to open up new product trajectories, procurement can play an important role in processes of diversification and of the entry of new firms.

3.2.7 Policy Implications

Most of the innovation policy instruments available refer to the supply side of technological change, such as R&D subsidies, the improvement of the technological infrastructure, or the encouragement of innovation networks. However, developing demand-side policy instruments is equally relevant for European and for national innovation systems. Examples of such instruments are public technology procurement, laws, regulations, standards, and related institutions which help to shape the demand for technological solutions.

Public technology procurement as an innovation policy instrument is poorly documented in the policy literature and therefore poorly understood by most policy-makers. There is a lot of ignorance about this subject. Therefore, the theoretical work (part 1) and the case studies (part 2) that constituted elements of this sub-project were designed to provide a more firm basis for discussing the policy aspects of public technology procurement.

Public technology procurement can have different purposes, such as:

- economic purposes, e.g. the enhancement of the technological base in an area of important technological and industrial potential for the innovation system, or the satisfaction of a socio-economic need that is not satisfied or mitigated by private market actors.

- ◊ Environmental purposes, such as the case of NUTEK's objectives, e.g. the reduction of energy use in electric items and the non-use of freon.
- ◊ Military purposes.

Public technology procurement is, of course, only applicable when the problem or need can potentially be solved or satisfied through technical change.

Despite the wide use of technology procurement, many European governments do not have a specific strategy for technology procurement. This results in a lack of explicit instruments and agencies for this purpose. Then, innovation policy tends to follow traditional supply side and linear conceptions of public intervention, where the demand side is systematically underestimated. An innovation policy which aims to tackle the complexities and interactivity of the innovation system needs to integrate public technology procurement policy, as a valuable demand-side-oriented instrument, and relate it to the other available instruments.

Public technology procurement requires public organisations with substantial anticipatory, strategic, and technological competencies to identify and foresee the potential benefits of specifically designed tenders. These organisations must have a 'vision'. These characteristics are equally needed in the two dimensions of policy action mentioned earlier, namely, when agencies act as end-users or catalysts, and when the procurement is development-oriented or adaption-oriented.

A relevant policy question is whether or not most European national systems of innovation are too small to handle procurement in some technological areas. (We might, for example, not need fifteen high-speed train systems in Europe, but perhaps only three or four.) If so, there might be arguments for using technology procurement more efficiently at the EU level in these areas. It might be a new policy option for the EU.

In particular, it is important to investigate whether and in what ways technology procurement can be efficiently used as a policy instrument within the 5th Framework Programme. This is a relevant issue for the following reasons. The earlier framework programmes have been almost exclusively supply-push oriented. Various evaluations have indicated that this approach has not been very successful. This might be a reason why the discussions of the character of the future 5th Framework Programme have a more problem- and demand-oriented character, seeking to change the largely technology-push emphasis of the past. If this, in the end, proves to be not only rhetoric, the new emphasis means that an availability of demand-pull-oriented policy instruments is

important. Government technology procurement is one of the—rather few—demand-side innovation policy instruments available.

In the 'classical' case of government technology procurement, the government uses nothing but its own market demand to induce technical innovation. It simply acts as a demanding buyer. This is the case in the defence sector (which is not studied in this project) and in infrastructure (like telecommunications and trains) when government agencies are the final user of the technology or system. In other cases, the government acts as a co-ordinator and catalyst for user-induced technical innovation. It co-ordinates the 'catalysing' demand and needs of other users. (This is the form of government technology procurement practised by NUTEK in Sweden in fragmented markets where there are many small buyers.)

Since the Commission does not represent final demand for goods, systems, and services to any considerable extent, it is likely that the kind of procurement most relevant at the EU level is the one where EU organisations serve as catalysers and co-ordinate the demand for new products and services of organisations at the national and regional levels. In, for example, the cases of high-speed trains and civilian aircraft, it would be a matter of co-ordinating the efforts and requirements of a limited number of national and regional operating train and flight companies.

Two main dimensions of EU policy—and national government policy—regarding public procurement and its effects on public technology procurement conducted at the level of individual member states can be identified:

- The first of these dimensions concerns the regulatory aspect of policy—i.e. the creation of rules governing public procurement, including public technology procurement. Here a relevant question is how the new EU procurement regulations affect the role of national agencies involved in technology procurement.
- The second dimension concerns the strategic aspect of policy—i.e. the actual practical use of public technology procurement as an instrument of innovation policy.

Before discussing the results of the ISE sub-project on public technology procurement in relation to these two policy dimensions, we will briefly outline some of the most salient characteristics of EU policy regarding public procurement. The intention is to provide a brief overview of the recent history of policy development and the main features of existing policy that are relevant to the present discussion.

The current system of EU procurement rules and their enforcement were developed in the early 1990s, as a result of both the establishment of the single European market and the need to rationalise and enforce effectively previously existing EU procurement regulations. The objectives were to eliminate artificial barriers to trade and reduce unnecessary differences in regulations. The regulations apply to all kinds of public procurement, technology procurement as well as regular 'off-the-shelf' procurement. In practical terms, the EU procurement regulation contemplates three possible procedures for tenders: namely, *open*, *restricted,* and *negotiated* procedures.

The *open* procedure is one of unrestricted tendering according to established rules of advertisement, closed bidding, and contracting. It applies primarily to the purchase of existing, standardised supplies, works, and services. Contracts can be awarded on the basis of 'the most economically advantageous offer'—a criterion that takes into account not only cost but also technical merit, the reliability of the tendered, and what might be termed transaction costs.

Under the *restricted* procedure, development projects are more likely to be dealt with. This allows for invited tendering and provides more latitude for procurers (particularly utilities) in processes of pre-qualifying prospective suppliers and advertising contracts. It is justified by a need to maintain a balance between contract value and procedural costs and by the specific nature of the goods to be procured.

Finally, there is the *negotiated* procedure, which is highly exclusive and is most likely to be pursued in highly innovative development projects. Innovation is, in fact, one of its primary justifications. The negotiated procedure can also be used for technical or artistic reasons or to protect exclusive rights when the goods can only be provided by a particular supplier. Additionally, its use can be justified in cases of extreme urgency or where a change of suppliers would not be feasible for technical reasons.

Despite the fact that these regulations are designed in general terms for all kinds of public tenders, the third procedure, namely negotiated procurement, seems to *allow for* innovative development projects. This possibility, however, does not per se mean that the EU has an explicit *strategy* or *policy* to develop public technology procurement as an instrument of innovation policy in a systematic or consistent way.

'Open' tendering is the normal procedure to be followed according to EU regulations. 'Restricted' and 'negotiated' tendering—respectively, the second

and third of the procedures described above—can only be used under special circumstances, which must be justified to the appropriate regulatory authorities and, ultimately, to the European Commission. The use of these procedures is thus closely circumscribed. In particular, the negotiated procedure—i.e. the one most appropriate to highly innovative development projects—is applicable only under exceptional circumstances.

The mechanisms for implementing these regulations follow the decentralised pattern of other EU legislation, whereby member States' administrations are in charge of enforcement. This means that the role of the European Court of Justice is to solve litigations when the national jurisdictional process has been exhausted, establishing EU-wide interpretations of EU legislation. This is supposed to result in the gradual adaptation of national regulations and practices and in a clearer definition of the open-ended European legislation in this field. (The EU directives on public procurement are 'open-ended' in the sense that they provide a framework of general principles and guidelines rather than highly prescriptive regulations.)

A final relevant aspect of the EU regulations on public procurement concerns the *scope* and *character* of action that they allow public agencies in the use of public technology procurement as a means of initiating innovative development projects. Regarding *scope*, there has clearly been a diminution over time of the number of sectors in which public agencies at the national level can undertake public technology procurement without observing the restrictions of EU regulations. Regarding the *character* of the actions these agencies are allowed to undertake, the EU directives have clearly made 'arm's-length', anonymous 'market' relations the norm (as under the first of the three procedures described above). Interactive relations with suppliers, which are more conducive to innovation, are only allowed for after justification with reference to special circumstances (as under the second and third of the three procedures described above).

Over the past decade, EU legislation in this area has progressively widened the application of the directives on public procurement to cover many formerly 'excluded' sectors. This includes the energy, transport, and telecommunications sectors. These are infrastructural sectors that have, in the past, tended to constitute 'natural monopolies', usually subject to management by public agencies and closely regulated by national authorities.

Markets of this kind are, of course, precisely those in which specifically *public* technology procurement has played an important role at the national level. They have also tended to be highly protected markets, in which there has often been

nationalistic purchasing for strategic reasons. The EU's unambiguous purpose in 'opening up' the excluded sectors and bringing them into the 'Single Market' has been to break down protectionist barriers around these sectors. The rationale has been to provide for international competition for supply contracts that will lead, over time, to the restructuring of the affected supplier industries on a 'European' scale. This approach to creating economies of scale in the supplier industries thus depends on restricting the scope of action with respect to strategic purchasing by public agencies operating at the national level.

As the EU directives on public procurement are introduced in the formerly excluded sectors, they make 'open' tendering—the first of the three procedures described above—the normal procedure to be followed by the responsible public agencies in awarding contracts to suppliers. Overall, the EU procurement directives encourage public agencies to conform to a norm of *non-interactive*, arm's length market relations in public procurement and other dealings with their suppliers. In this way, the character of strategic purchasing by public agencies is also affected.

Thus, the general trend in the public procurement activities of public agencies in member states of the EU is towards international competition (within the bounds of the EU), and away from (national) protectionism. The trend is also away from close relationships with specific suppliers and towards arm's-length dealings with a broader range of suppliers. These developments conform with the European Union legislation on public procurement. There is still, however, a considerable margin of manoeuvre at the national level with regard to public technology procurement. The framework nature of EU legislation in this area does not prevent the development of national strategies to encourage technologically-oriented procurement actions. The existence of the three different forms of tendering procedures introduces a certain degree of flexibility, and all of them do not *a priori* exclude the use of public tenders for the stimulation of sophisticated demand for new products and systems with clearly defined socio-economic, environmental, or military objectives. Nevertheless, EU legislation has definitely restricted both the scope and character of innovative public technology procurement.

The research conducted by the ISE sub-project on public technology procurement as a policy instrument provides the basis for developing a critical perspective on current EU policy regarding public technology procurement. The theoretical and research literature reviewed, together with the analysis of the case studies, indicates that successful examples of 'developmental' public procurement aimed at achieving important technological innovations typically

build on and bring to fruition longer-term innovation trajectories involving *close collaboration* and *interactive learning* between users and producers.

To establish such trajectories, a number of important preconditions must be met, through a variety of policy instruments. Market regulation, competition policy, industrial policy, and the mandates of public agencies must combine to produce a competitive environment providing strong incentives for both public agencies, as users, and private firms, as producers, to invest in the development of new technologies. Through policies supporting scientific research and technological development, 'poles of competence' have to be brought into existence in economic sectors of major importance. Further, through the sectoral organization of firms and public agencies that can function in relation to industry as 'focal organisations', 'frameworks for learning' have to be established that will allow for the development of balance and complementarity between user and producer competence in the new technologies.

In this connection, moreover, regulatory regimes and administrative structures must be designed to provide adequate administrative and executive autonomy for the development of longer-term innovation trajectories. They should minimise disruptive 'political interference' and maximise the inclusion of relevant economic interests to assure co-operation based on transparent and accountable decision-making processes. Finally, but not least important, all of these conditions point to the need for public authorities to possess a long-term strategic orientation ('vision') that develops a central focus on innovation and to use this perspective to design appropriate institutional frameworks and mechanisms for policy co-ordination.

We can relate the findings and conclusions from the ISE case studies on public technology procurement to the current EU policies on public procurement by referring to the two dimensions of policy that were introduced and explained at an earlier point in this discussion. The first of these dimensions was identified as the regulatory aspect of policy . This concerns the rules governing public procurement, including public technology procurement. The second dimension was identified as the strategic aspect of policy. This involves the use of public technology procurement as an instrument of innovation policy.

Applying this perspective to the relevant EU policies, it can be fairly stated that EU legislation on public procurement has been largely concerned with the regulatory dimension. The EU has paid considerable attention to the establishment of competitive market conditions affecting the technology procurements of public agencies. Competition has been strengthened through EU interventions aimed at the reduction of protectionism, the imposition of

procurement rules requiring more transparent tendering procedures in formerly 'excluded' sectors (water, energy, transport and telecommunications), and complementary initiatives aimed at the liberalisation of public goods markets.

The EU has not, however, addressed the 'organisational' requirements of innovation in the context of public technology procurement, except in a negative way. Specifically, it has diminished the number of sectors in which public technology procurement can be readily used as an instrument of innovation policy. Generally, the focus of EU procurement policy has persistently been limited to the objective of achieving public sector savings and possibly bringing about private sector economies of scale through measures designed to increase competition in the procurement of existing goods and services. The EU's 1997 'Green Paper' on public procurement forcefully restated the regulatory policy orientation described above. It made no specific reference to the strategic role of public technology procurement as a vehicle for technological innovation. As a matter of fact, EU procurement policy has avoided promoting the use of public technology procurement as a stimulus for innovation except to a limited extent in the energy field.

The findings of the ISE sub-project on public technology procurement indicate that innovative public technology procurement relies on institutional and organisational arrangements that allow for close relationships and interactive learning between public agencies and their suppliers. Interactive learning is fundamental to innovation in the context of public technology procurement. Some clear policy implications follow from this basic and centrally important finding. Most concern the regulatory dimension of policy, but there are also some related considerations about the strategic dimension.

With respect to the regulatory dimension of policy, the main lesson to be drawn from the findings of the ISE sub-project on Public Technology Procurement is clear. The rules and laws designed—by national governments and the European Commission—to govern the relations between procurers and suppliers must allow for close interactive learning between them. They must certainly not be confined to arm's-length market relationships. This has radical implications with regard to existing regulation at the European level, which currently does not recognise the need for such interaction, except in a negative way.

Present EU legislation merely *allows* such interaction to take place—and only in special cases. Under EU procurement legislation, collaboration between firms and public agencies aimed at the development of new technologies with the ostensible goal of increasing public benefit has only been tolerated as a 'necessary evil'. Implicitly, the EU legislation regards interaction between

procurers and suppliers as an aberration—a deviation from the legalised norm of autonomous 'market' relationships. Accordingly, it has restricted both the fields of economic activity in which such interaction will be allowed to occur and the circumstances under which it will be allowed to proceed. National rules must be compatible with EU procurement directives and therefore have the same character. In other words, possibilities for interactive learning have been diminished because of EU regulation.

EU procurement rules have, it is true, allowed for the continuation of user-producer interaction in public goods markets through certain special tendering procedures, allowable exemptions from the regular procurement rules, and a flexible regime of enforcement. This has been done, however, without an explicit policy rationale—only the implicit understanding that these are necessary accommodations of national and sectoral interests. Hence, for the benefit of innovation, the regulations should be changed. In a positive way, *the regulations should be changed to encourage, stimulate, and spur interaction between procurers and suppliers in fields where public technology procurement is appropriate*.

The EU has neglected the strategic dimension of public technology procurement; it has so far been pursued mainly at the national level. At the EU level, there are no systematic initiatives with the intention of using public technology procurement as an instrument of innovation policy to solve socio-economic problems in sectors of key importance to the competitive advantage of Europe as a whole.

Pursuing this kind of policy objective in a systematic way would require a long-term strategic perspective on innovation-based economic growth. This perspective, in turn, would have to be translated into specific priorities. Within sectors or areas of economic activity designated as having such priority, implementation would require the creation of 'poles of competence' and 'frameworks for learning' between public agencies and firms. Maintaining at least an indirect role for the EU would require these activities to be carried out through co-ordinating mechanisms, administrative structures, and programmes that would operate across national boundaries.

More direct EU action in public technology procurement could have two objectives. In the first place, it could help in co-ordinating and catalysing (well or weakly articulated) national actions. A decided EU action in this sense could have the benefit of avoiding duplication of efforts undertaken at national levels, as discussed earlier (i.e., the 15 train systems).

A second role for direct EU involvement in this area could be to complement the actions already undertaken under the EU innovation policy strategy. EU innovation policy has been criticised on several occasions for being too supply-side-oriented. The introduction of EU-wide technology procurement tenders would certainly stimulate technology development in some concrete technological areas with large potential for European industry as a whole. Needless to say, the role of a hypothetical EU agency for that purpose should be based on the idea of working as a catalyst, with a strategy combining development-oriented and adaptation-oriented tenders, and encouraging cross-European co-operation among firms as a requisite for obtaining the contract.

3.3 Sub-Project 3.2.3: Financing of Innovation

Group in charge of sub-project: IKE. **Scientist in charge of sub-project:** Björn Johnson. **Staff:** Jesper Lindgaard Christensen. **Collaborator 1:** STEP. **Tasks of Collaborator 1:** 1: To provide background material to this report. **Scientist in charge:** Keith Smith. **Staff:** Keith Smith.

3.3.1 Objectives

In the Green Paper on Innovation of The European Commission of December 1995 it was pointed out that finance is a crucial obstacle for innovation in Europe. Furthermore, it was claimed that the efficiency of the European innovation system critically depends on the ability of financial systems in Europe to support investments in innovation. A major concern of policy-makers throughout Europe is now how to alleviate financial constraints for innovation. Even in textbooks on industrial economics we begin to see discussions on this issue.

The aim of this sub-project is to add to the existing pool of knowledge on innovation financing in a way that may contribute to the design of effective means of improving this process. More specifically, we need to know more about actual trends in the dynamics of the institutional environment of innovation financing. In other words, in which direction are the financial systems of the European Union moving, and what are the driving forces behind this development?

The performance of important, current institutional features of financing innovation is also investigated, especially the venture capital industry and

government support for financing innovations. Furthermore, recent research on the innovation process has shown that innovation differs according to firm size groups and across industries. We need to know if financing of innovation is closely linked to such differences. In other words—is the financing of innovation as different across sectors and firm sizes as the innovation process itself?

3.3.2 Progress

The ISE Workshop in Athens in March 1997 pointed to the following three tasks for the ensuing six months:

1. More work on the importance of firm size and sector as constraints on financing innovation should be carried out.

In this matter, frequency analyses were supplemented with more rigorous tests of variables which could explain financial constraints on innovation. Moreover, a general discussion on firm size was developed and the discussion on sector specific constraints extended to include innovation intensity in addition to pure sectors.

2. A typology of capabilities of financial systems should be developed and used.

Such a typology was specified in more detail and the data in the report is interpreted in a context of capabilities of financial systems to support different types of investments. One word of precaution is given in the report: a larger EU project with exactly the goal of bench-marking innovation financing in 12 member states has been initiated. That project has the potential to reach a level of detail and range of indicators that exceed what would be possible in this ISE report. Furthermore, our work on this issue was supposed to be based partly on results from interviews in the financial sector conducted by Collaborator 1 (STEP). Because of the risk of duplicating other EU work and because the above-mentioned interviews were not conducted in time for integration in the financing of innovation report, chapter 9 on this issue in the report builds on other material.

3. The policy implications of the analysis should be specified out in more detail.

Extensions and details of the policy implications were made. A selection of these is specified in the separate section on policy implications.

Compared to the original work programme, all the tasks specified were fulfilled except for one minor change. This change concerns the Pavitt taxonomy, which was not found appropriate for investigating industry differences. It was emphasised in the work programme that the qualitative aspects of borrower—lender relationships would be dealt with in detail. This is done in the report by way of additional chapters on formal and informal venture capital.

Papers and Reports

The main output of this sub-project is a major report by Jesper Lindgaard Christensen of IKE entitled "Financing Innovation".

In addition Keith Smith wrote a report entitled ”Public Policies for Finance of Innovation in Europe” that constituted background material and input for chapter 6 (on public policies for financing of innovation in Europe) in the report mentioned above.

Parts of the results generated in this ISE sub-project have also been presented elsewhere. This applies to two conference papers:

- Christensen, Jesper L. and Drejer, Ina (1997): "Finance and Innovation - System or Chaos?", Paper for DRUID Conference, Copenhagen, 8-10 January.
- Christensen, Jesper L. (1997): "A two-sided view on financing innovative, small firms", paper for The Second International Stockholm Seminar on Risk Behaviour and Risk Management, Stockholm, 9-12 June 1997.

The chapter on informal venture capital is planned to be used in an article on this subject. This article will include new empirical evidence on the quantitative and qualitative role of business angels in Denmark. It will also be considered whether other chapters could be transformed into articles.

In a report for the Danish Ministry of Industry on the Danish Innovation System selected parts of the results of this ISE sub-project will also be used. This report is due at the end of May 1998.

3.3.3 Methodology

This sub-project is mainly based upon existing literature and data sources, although the collaborator STEP collected some new data. More specifically, data from the Community Innovation Survey, from EVCA, and from the OECD Financial Statistics was used as well as a range of other data sources.

The balance between theory and empirical work is clearly on the empirical side. This is not only because of a great need to develop the empirical knowledge in this field but also because financial theory is largely inadequate for our purpose. Therefore, the theoretical basis is innovation theory rather than looking at innovations from the point of view of financial theory.

Both micro and macro issues are dealt with in the sub-project. This is based on a belief that there is an interaction between analyses on these two levels of aggregation. It is consequently the approach to first make clear what are the macro conditions for financing, and what are the dynamics of changing these. Then the level of aggregation shifts to micro and meso issues.

The criteria for selection of research topics has been a combination of on the one hand what is needed in terms of displaying the basic driving forces in financing innovations and on the other hand what are policy relevant issues of research.

3.3.4 Scientific Findings

Financial systems are challenged by the increasing need for investments in intangible assets and innovations. But precisely what type of financial system does Europe need if this challenge is to be met? Is there a "best practice", or should financial systems entail several of the features of both market-based and credit-based systems to improve the dynamics of the system? How do important organisations for financing innovations in Europe perform? Do barriers to innovation need to be alleviated in certain industries, in certain types of firms, in certain countries? These are some of the main research questions addressed in the report. In this section we will summarise some of the results.

3.3.4.1 There is no best solution of an organisational set-up for financing innovations

It is argued in the report that financial intermediaries are apparently better suited for financing innovations than markets, their main advantage being the

ability to reduce future uncertainty by learning from past experience. It was found that one constraint in relation to financing innovations concerns the competence in screening and monitoring the projects. This constraint is often mitigated if financial organisations and firms enter close relationships, the effect being that both parties learn from the interaction for the benefit of similar future situations.

The ability of the system to develop in order to preserve and stimulate such links between financiers and firms and diffuse generated knowledge is a substantial characteristic of a national financial system able to support technical innovations. Financial systems are generally regarded as distinct in their ability to generate and use such learning processes.

The ability of the financial system to meet financial requirements and develop/take advantage from productive learning processes depends on the flexibility and specialisation of the financial organisations. The establishment of standard operating procedures within financial organisations could be a response to the fundamental uncertainty in investment projects and especially in innovation projects. In an era of stable, predictable technological change this may be an appropriate method of risk assessment.

These procedures, however, may create problems if they are maintained when technology is changing rapidly and the life cycle of products and processes becomes shorter. When the size and diversity of loan applications increase, bankers may face a situation of inadequate operating procedures compared to the needs for credit. Innovation projects rarely fit a schedule-like set of rules to allocate credit and select among projects, because of the generic diversity in the sample of innovation projects put forward to a potential lender. In such cases of the establishment of inadequate routines, the market method of financing may be a better solution.

3.3.4.2 There is convergence between European financial systems but there are limits to this trend

To investigate if financial systems are converging or if they are still mainly national in character, a statistical analysis of developments in the main indicators of financial systems in Europe, the United States, and Japan was undertaken. In the analyses we found that data for Japan and Sweden are consistently and significantly indicating that these countries are characterised by a credit-based system. This is in accordance with our expectations. Similarly

we find clear and consistent indications of a market-based financial system in the United Kingdom, the United States, and the Netherlands. Again, this is what we would expect, although the Netherlands has not been investigated in this manner before. The above-mentioned countries are the only ones to show clear patterns in most of the indicators. We would expect Germany to be categorised as credit-based but the lack of data for this country prevents us from assessing if this label is appropriate.

Another interesting pattern is that the southern European countries show remarkably similar structures. This is in accordance with the view of some observers who claim that these countries (France, Spain, Italy, Greece, Portugal, Austria) have a special form of credit-based financial system where the state plays a dominant role (e.g. Tylecote, 1994, p.4).

There are also some signs of differences due to the size of the country. The smaller countries show weak tendencies towards a reduction in the importance of long-term bank credits and towards a higher degree of internationalisation of the banking sector through cross-border bank credits.

The above analyses show that even though there are remnants of two distinctive types of financial systems, it is becoming increasingly more difficult to use quantitative statistics to classify the orientation of national financial systems as that of either market transactions or bank credit. Both these means of raising funds are present in all countries, and there is a tendency for the importance of credit to increase in traditional market-based systems as well as for the importance of market transactions to increase in traditional credit-based systems.

In the literature on financial systems, there have been two basic views. One is that there are no essential differences between financial systems (e.g. Edwards and Fischer, 1994). The other thesis is that there are indeed important differences between financial systems (e.g. Porter, 1992). Even though there are clear signs of convergence between national financial systems we can conclude, along the lines of the OECD (1993, p. 46), that globalisation has not eliminated important international, structural differences in the way industrial activities are financed. According to the OECD, these differences exist, not because globalisation has not yet wiped out the differences but because there are also inherent, cross-country entry barriers for financial organisations.

It is obvious that all the statistical analyses of financial systems in the report are not directly aimed at innovation financing. In fact, the financial systems serve many other purposes than financing innovations, and the link between financial

systems and innovation financing is therefore indirect. A natural exercise following these conclusions is to be somewhat more specific on some of the important organisations specifically aimed at financing innovations in the EU countries. Those selected were the formal venture capital organisations, informal venture capitalists and government financing of innovation.

3.3.4.3 The bulk of formal venture capital funds in Europe is not available for small, innovative firms

Venture capital is expected to be well suited to financing innovations. Venture capital originated as risk capital supplemented with extended competence on the investor side. According to its original definition, venture capital is the most early and most risk-willing capital invested in firms, and it is most often invested as equity capital. Venture capitalists are often characterised in the literature as financing new, fast-growing firms, as well as participating actively in managing the firms.

The analyses in this report show a very heterogeneous European formal venture capital market. There are large differences between countries with regard to size of the venture capital market, average investment size, investment stages, sectoral distribution of investments, etc.

Also the functions of the venture capital organisations differ, even if the quantitative data may not reveal the differences. As an illustration, venture firms in Japan engage heavily in lending. (70% of all venture capital firms; 3.6 times the investment balance - actually much of what is characterised as venture capital in Japanese statistics on venture capital activity is long-term debt). This illustrates that even though the statistics on financial systems show convergence between nations, there may still be differences in the functioning of financial markets and financial systems. Even equity organisations in credit-based financial systems may have features stemming from the nature of the credit-based financial system.

Similarly, there is an effect upon the kinds of financing firms demand. For instance, in Germany the market for small- and medium-sized firms and for technology financing is heavily influenced by the large banks, although these do not specialise in equity support for technology investments. This makes the German venture market rather small by Anglo-Saxon standards. But an additional aspect of this is that firms in general do not tend to favour venture capital. Even if credit makes the firm less financially flexible, most firms prefer

credit to equity. This lack of equity financing culture makes start-up financing particularly difficult in Germany (Gerke, 1996, p.73).

A general conclusion from this could be that the proportions of formal organisations in a financial system do not necessarily reflect the way the system works. It may be equally important that the right informal/cultural environment is present cf. the above-mentioned lack of equity culture in Germany. Another example is that, in Japan, individual investors are simply "not popular" (Yasui, 1996, p.83).

The point made above has policy implications as well, although on a very general level: the cultural constraint may limit the speed and effect of institutional change. Yasui (1996, p.84) even claims that

> However, because of the differences in social systems, cultural backgrounds, national characteristics, etc., it is unrealistic to expect the emergence of the United States type venture capital firms in Japan.

In spite of the differences even amongst European countries, one characteristic is common to all, and that is the small amount of funding going to early stage investments in high-tech sectors, together with the lack of internationalisation of the venture capital market. The first element is contrary to the common perception of venture capital as high-risk capital directed towards early-stage, technology-based firms, while the second element is more in accordance with general beliefs.

An important aspect is that there may be a lock-in effect in investments. Investors mostly interested in later stage financing/buy-outs will probably not redirect their investments towards earlier stages if attractive buy-outs are not available. Thus, it is generally not possible to make funds specialized in later-stage replacement financing to be made available to new, technology-based firms. Rather, it is important to see them as two separate activities.

In addition, formal venture funds typically only make relatively large investments and their investment criteria are often too strict to be met by small, new firms.

The size of the market indicates that venture capital is most developed in the United Kingdom and Ireland, but when the size of the original target group of venture capital is considered, these countries are among those with only a minor focus on early stage investment. The smaller, less developed markets have a

larger focus on the early stage. There seems to be no solid connection between the main sources for venture capital and the focus on early stage and high-tech investment.

According to the analysis above, formal venture capital as a major source for high-risk innovation financing in early-stage businesses is not typical in present day Europe. Thus, as far as the formal part of venture capital goes the established definition of venture capital does not fit.

3.3.4.4 Informal venture capital seems to entail both quantitative and qualitative potentials

In contrast to formal venture capital, informal venture capital is relatively under-researched, with the exception of the United States and the United Kingdom. However, increased interest has been recently shown, both by researchers and policy-makers.

Every estimate of the actual size of the informal venture capital market and its potential size indicates that it is of major importance. Although estimates naturally are rather rough and vary a lot, these estimates show that the importance of this source of financing is much greater than that of formal venture capital funds.

There are many commonalties in the informal venture capital business, but there are also indications that business is not homogeneous across countries. A comparison of the informal venture capital business in the United Kingdom, Sweden and—more limited in information—Denmark, as compared to the United States, illustrates that informal venture capital has, to a much higher degree than formal venture capital, kept to the original definition of venture capital in their activities.

A useful distinction in this connection is the one made by Bygrave and Timmons (1992). They define "classic venture capital" as focused on early-stage, hands-on, patient investments where investors are typically adding value to the formation of the firm in terms of entrepreneurial skills. Conversely, "merchant" venture capital comes primarily from institutional investors and is focused upon larger, latestage investments with a shorter time horizon. Know-how in financial engineering, transaction crafting, and fee generation are some of the important skills in this type of venture capital. Whereas there has clearly been a shift from classic to merchant venture capital in the United States, there is some debate on whether there has ever been classic venture capital in Europe

at all. At least for some countries in Europe which experienced an upswing in the venture capital industry in the mid-1980s, the picture is one that focuses on early stages and small investments. But these investments were made by investors who primarily had financial skills, and generally, the necessary hands-on aspect of such investments were underestimated.

One of the major, generic differences is that formal venture capitalists administer other people's money whereas the informal venture capitalist deals with his own money. This makes a difference with respect to requirements to due diligence, supervision from authorities, and responsibilities towards funding sources. Informal investors tend to rely on their own judgement, are more willing to invest in early stage and to make smaller investments. In contrast, formal venture capital funds are forced by their higher fixed cost structures to concentrate on larger investments with lower risk.

In general, informal venture capitalists require fewer formal documents and are able to decide within a short time horizon. This helps reduce the costs for the applicant firm. Informal venture capital is also a flexible form of finance encompassing both equity, loans, debt-equity arrangements etc. Finally, traditional, formal venture capital firms tend to be concentrated in certain geographical areas. In contrast, informal investors are dispersed throughout the countries and not concentrated in certain regions to the same extent .

Coupled with the finding that formal investors invest within a limited distance from their home, we arrive at an additional rationale for promoting this type of financing: as formal investors re-circulate wealth within a region, there is also a regional development argument.

The benefits of informal venture capital vis-à-vis organisational venture capital should, however, not stand alone. Several disadvantages could be mentioned. One is the malfunctioning and invisibility of the market, which makes it difficult to use efficient policy measures. Another disadvantage is that informal investors are less likely to make second-round investments. A third is that the investors often expect to have substantial influence on the strategy of the firm—often more influence than the share of capital could justify.

The differences between the two forms of financing do not, however, indicate that they should be seen as rivals. On the contrary, informal investors should be seen as an important brick in the division of labour in a row of financing options for innovative firms. Thus, there may be a complementary relationship between informal investments and formal venture financing in the sense that informal investors may be more appropriate sources of financing in the early

stages when the firm is preparing for growth than in a later stage which often requires additional capital in an amount more adequate for formal venture firms.

3.3.4.5 There is extensive government experimentation with support for innovation financing because secure knowledge of the financial aspects of the innovation process is generally lacking

Although there appears to be wide agreement among policy-makers that financial obstacles to innovation is a serious issue, there appears to be no real consensus on how such issues should be approached by governments. The empirical overview presented in this report suggests a wide variety of potential actions, although this may reflect differences in specific circumstances. There may, for example, be differences in the institutional structure of the national and regional innovation systems involved. There is also the possibility that the differences are ad hoc, reflecting contingent factors.

In a wide range of policy fields—like diffusion policy, infrastructures, business strategies and planning, and so on—policy-makers are clearly experimenting at the present time and, moreover, learning from experience. In the broad area of non-R&D policy initiatives, there is certainly some degree of consensus on the need for such initiatives and, to some extent, convergence in the types of broad policy action being undertaken. But diversity and variety remain the hallmarks of policy in this field, no doubt reflecting the continuing lack of secure or agreed knowledge on financial aspects of innovation, which this report noted at the outset.

3.3.4.6 Financing constraints on innovation are linked to innovation intensity

In general, firms claim that they meet many obstacles when they try to innovate. This reflects not only that lack of finance is the obstacle most often quoted by respondents but also that those who experience lack of finance are also hampered by other obstacles, and this is valid not only for the economic ones. This tells us that the innovation process is very complex with many requirements for successful completion and, consequently, great uncertainties. In policy terms, it also indicates that policy measures should not concentrate on alleviating one barrier only. Rather it should be multifaceted (as it indeed is in most countries).

Several variables were investigated in the report. Results for innovation intensity confirm that highly innovative firms are more likely to be hampered by

lack of finance. There is less clear evidence that belonging to a high-tech sector can in itself explain financial constraints. Even though there are tendencies of sector-specific constraints, the results suggest that highly innovative firms can be found in all sectors, and this is more likely to be an explanatory factor in constraining innovation financing.

3.3.4.7 Small firms are often finance-rationed due to inherent characteristics

Research on the development and importance of small firms has above all shown that this is an extremely heterogeneous group. In contrast, we have tried to come to some general results on small firms, for example on the fragility of their development and other disadvantages. Ideally, financiers should be able to differentiate within the group of small firms because, of course, they do not all suffer from all the disadvantages. Only a minority of financiers, however, are able and willing to consider carefully the special features of the single, small firm. The bulk of financiers are unwilling to finance small firms, even if they do not suffer from traditional small-firm disadvantages, because the generic characteristics of small-firm financing actually reflect how they are used to think about small firms.

The discussion in this chapter leads us to conclude that not all small firms need support, but generally they do suffer from characteristics which justify that public initiatives and incentives for promoting innovation financing may be targeted on small- and medium-sized enterprises.

3.3.5 Interdependencies Between Elements in Systems of Innovation

Both in practical and theoretical discussions on innovations there is a tendency to focus upon visible, new products or processes. This sub-project has emphasised that an important part of an innovation system is to select innovations. Part of the system is to prevent some suggestions for innovation to be pursued. One such important selection mechanism is the financial system. Financial organisations may deny firms external financing of innovations thereby acting as a selection mechanism.

The design of this selection mechanism differs across nations and time. This reflects the fact that the purpose of most financial organisations is wider than that of serving to promote innovation. This fact could be generalised to the cases of other organisations as well. Therefore, systems of innovation are

intertwined with other "systems" like the broader production system and the governance system.

The report has indicated the co-existence of factors enhancing convergence trends and factors hampering convergence between systems. It is an important part of a systems approach to take into account this at first sight, apparently conflicting duality.

Several times in the report it was emphasised that organisational structures and the actual functioning of the systems, although important for the functioning of the system, may be masked by the statistics. For example, venture capital in the United States may be very different from that in Japan. The difference may to a large extent be explained by historical and cultural differences. It is important in a systems approach to supplement quantitative statistics that describe the systems with information that describes the function of the system and the interaction between actors and organisations—in this report most often called the borrower and the lender.

3.3.6 ISE Coherence: Relations to Other Sub-Projects

Issues discussed in this sub-project are closely related to what has been discussed in a more general manner in the ISE sub-project European Integration and National Systems of Innovation (sub-project 3.1.3), which pointed to five main factors affecting learning and innovation in a national system of innovation:

- The knowledge infrastructure
- The production structure
- The institutional set-up
- The consumer demand structure
- Policies

With respect to financial systems, some of the most important reasons why there are limits to the convergence process resemble these general arguments. Thus we highlight some of the basic properties of and changes in financial systems in the past decade to investigate if there is a similar integration process with respect to financial systems. The general belief is that many European countries

have moved towards the UK/US-mode of financial system. In other words, the trend is for a convergence of financial systems.

When discussing some of the prime forces which cause financial systems to converge or diverge, the process has involved specification and exemplification of results derived in a theoretical, general way in the sub-project on integration and innovation systems in Europe.

In addition, the analyses are relevant for the ISE sub-project on science-based industries (sub-project 3.2.1) as well as for the one on employment and growth (sub-project 3.1.2). But the most obvious link to the other sub-projects is to the sub-project on corporate governance (sub-project 3.2.4). Relationships between firms and financial institutions are often linked to the character of the market for corporate control, at least for the large firms. In fact, some observers claim that the low debt-equity ratios in the Anglo-Saxon countries could be explained by the fact that exactly these countries have a developed market for corporate control and more frequent hostile take-overs.

3.3.7 Policy Implications

3.3.7.1 Development of Skills in Assessment of Intangible Investments Should be Encouraged

In The Green Paper on Innovation of The Commission (Dec. 1995), actions to promote innovation financing were proposed at both a national and a Community level. For example, it was suggested that the banks should establish partnerships with expert bodies in appraising innovation projects, i.e. expanding the banks' competence in relation to innovation financing. Related to this, the OECD (Gonenc, 1996, p.4) points to a dual development between an increase in technological, operational, and marketing uncertainties in innovation projects on the one hand, and increased requirements for sophisticated skills and techniques in screening, selection and management of R&D and innovation projects on the other hand. This issue will be even more important in the future because the importance of intangible assets in production over the past few years has increased and should be expected to do so in the future. Current experiments to include knowledge assets in established accounting procedures should therefore be encouraged.

3.3.7.2 Radical Changes are Necessary to Change the Existing Venture Capital Market

In Europe today, almost all countries try to boost their venture capital markets, recognising that a lack of equity for innovation is a major constraint to innovation in small- and medium-sized firms. This study indicates, however, that existing venture funds are unlikely to shift to financing small, technology-based firms. Too high fixed costs; lock-in with respect to competencies etc. are some of the reasons. In itself this leads to the policy conclusion that the intention to boost the venture capital industry must either involve institutional reform—new funds—or involve very strong incentives/measures to redirect existing venture funds towards new, technology-based, small firms. In our view, it could, however, be seen in connection with a second suggestion which has to do with informal venture capital.

3.3.7.3 In Europe informal venture capital should be put on the agenda as a major policy issue for promoting financing of innovation.

There are several arguments for this suggestion. As far as the empirical evidence goes, informal venture capital is more directed towards small, early-stage investments. Informal venture capital also tends to be geographically widespread whereas formal venture funds are concentrated in certain geographical areas. Further, formal venture capital has to a large extent shifted its focus from early-stage, high-tech (and high-risk) investments; this type of financing is often a gateway to other types of financing—bank financing, government support programmes, and other equity investments. The hands-on character of the investment often provides the firm with an upgrading of competencies, especially with respect to management skills. Initiatives supporting the functioning of the informal venture capital market are unlikely to suffer from dead-weight effects. The cost per job created easily compares with that of other initiatives. Displacement effects, the redirection of activity from equivalent or otherwise economically beneficial activities, is likely to be low (there are, of course, also drawbacks).

It was pointed out that, at least in the U.S, there may be complementarity between informal investors and formal venture capital firms. Whether such complementary relationships exist elsewhere than in the United States is, however, uncertain. But if they do, the policy implications are immense. The most obvious implication is that current attempts to boost formal venture capital markets in Europe—now seen in many countries—may seem successful in the short run. But long-term efficiency is accomplished only if dual initiatives are taken to promote both the informal and the formal venture capital industry and

in particular the interplay between informal and formal investments. In fact, coupling formal venture funds with informal investors could be a method to redirect some of the formal venture funds towards "classic" venture investments. The advantage would be that private investors may contribute substantially to management expertise and partly to monitoring, thus reducing fixed costs for the formal venture capital firm.

Policy formulation and research should go hand in hand on this issue. One of the things to explore is the specific way informal venture capital markets could be developed in accordance with the specific national or regional context. Business angel networks and other policy options are sensitive to such national and regional contexts.

3.3.7.4 Financial Organisations Should Be Involved in Network Policies

A number of policies throughout Europe have focused upon initiatives to establish or enhance networking between private firms and organisations specialised as consultants on technological development and diffusion. Also, at the EU level these policies have attained interest. It has generally not been the case, however, that financial organisations have had a formal role in these networking policies. It should be considered if and in what way financial organisations—including EU funding sources like the European Investment Fund—could contribute.

Obvious benefits are improved knowledge of the markets and possible synergies with other firms and financial organisations (one financial organisation may be the gateway to other financial organisations or markets). Involvement of financial organisations in different types of network policies may thus alleviate some of the problems of assessing and trusting not only the technology in question, but especially the persons and firms involved.

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3.4 Sub-Project 3.2.4: Corporate Governance and Innovation Performance

Group in charge of sub-project: STEP. **Scientist in charge of sub-project:** Keith Smith. **Staff:** Keith Smith, William Lazonick, and Mary O'Sullivan. **Collaborator 1:** CESPRI. **Tasks of Collaborator 1:** To carry out a study of governance in state-owned enterprises in Italy. **Scientist in charge:** Franco Malerba. **Staff:** Stefano Brusoni and Luigi Orsenigo.

3.4.1 Objectives

Despite the completion of the internal market and increasing European integration, there remain a number of key institutional differences in Europe that play a central role in structuring system differences. The objective of this project was to map one of the most important of these institutional differences: it sought to develop conceptual and empirical analyses of the ways in which differences in the innovative performance of European firms are shaped by differences in national methods of corporate governance.

This ISE sub-project defines corporate governance as the general system of policies and regulations by which companies are owned, directed, and controlled. The basic hypotheses of this project were (1) That there remain major differences in corporate governance systems among European economies, and between European economies, the United States, and Japan. THese differences are visible despite processes of increasing economic integration. (2) That these differences are significant in explaining innovative differences and differences in the ability to exploit technological opportunities.

The point of departure of this project is a critical perspective on the existing policy and theoretical approaches to corporate governance, and it is important to emphasise that the project takes a radically new view of corporate governance as an issue for public policy. There is an extensive literature on the problem of ownership and control of firms. Most analyses of corporate governance, however, see the problem in very narrow terms. Corporate governance is usually seen in terms of controlling managements who are not themselves owners of firms; we call this the ‘shareholder value’ approach to corporate governance. By contrast, this project analysed corporate governance, not in terms of returns to shareholders or other stakeholders, but in terms of how the institution of corporate governnance affects the ability of management of large firms to invest in and to create the assets necessary for innovation.

3.4.2 Progress

This project had three major components. They were:

- First, a study of the historical evolution of corporate governance systems in the United States, Europe, and Japan. This study aimed, as the work programme put it, to produce ‘a detailed and extensive comparison of the

US, Europe and Japan, from the point of view of the historical evolution of corporate governance systems'.

- Second, a detailed review of policy issues related to corporate governance debates at the present time in Europe, specifically looking at the impact of governance rules on innovation.
- Third, a study of the issues of corporate governance in publicly-owned firms, focusing on the modern history of Italian State Owned Enterprises (SOEs).

This project completed the three major reports that comprise the project as a whole. These are:

- Governance of Innovation for Economic Development, by William Lazonick and Mary O'Sullivan.
- Corporate Governance and Innovation in Europe: a Review of the Issues, by Mary O'Sullivan.
- State-Owned Enterprises and Managerial Structure: the Italian Experience in Steel and Oil, by Stefano Brusoni and Luigi Orsenigo.

The project had one failure, in terms of our ability to gather empirical information via interviews. These turned out to be unsuccessful, and a lesson here would be that specialised forums are necessary for informed discussion of these issues on a company level.

The project produced one further report, however, discusssed at the Helsinki meeting, on policy issues for Europe with respect to corporate governance. This paper focused specifically on policy issues. It is:

- Corporate Governance and the Innovative Economy: Policy Implications of ISE Research, by William Lazonick and Mary O'Sullivan.

3.4.3 Methodology

This project was primarily aimed at clarifying conceptual issues from a historical perspective. The project was therefore a combination of critical reviews of theoretical literature combined with a historical methodology using a wide range of source materials.

3.4.4 Scientific Findings

In this section we describe results of each of the four major papers of the project.

Governance of Innovation for Economic Development (William Lazonick and Mary O'Sullivan).

This substantial report explores the historical evolution of corporate governance systems in the United States, Europe, and Japan. This paper covers most of the issues listed on page 34 of the work programme, in particular paragraphs a) and b) of the description of how we intend to proceed. It is, as the work programme puts it, 'a detailed and extensive comparison of the United States, Europe and Japan, from the point of view of the historical evolution of corporate governance systems'.

The recognition that, for the sake of innovation and sustained economic development, it matters who makes investments decisions, what types of decisions they make, and how returns generated by these investments are distributed, gives national policy-makers an interest in the governance of the business enterprises on whom their economies rely to invest in productive resources. This report defines business governance as the social process that determines the strategic allocation of resources and returns in business enterprises. Business governance influences who has control over productive resources and what their incentives are in allocating these resources, as well as who appropriates the returns from investments and what their incentives are in allocating these returns.

This report analyses evidence from the comparative development of large advanced economies such as Germany, Japan, and the United States that who, what, and how cannot be answered in abstraction from the social organisation of the particular national economy in question and the major business enterprises, or groups of business enterprises, within that economy. National policy-makers who view sustained economic development as a goal thus require an intellectual orientation and an analytical framework for asking who, what, and how.

As the analysis of who, what, and how suggests, neoclassical economics, by fundamental assumption that the business enterprise can only respond to existing investment opportunities, systematically ignores the innovation process. Yet a recognition of the centrality of the innovation process to economic development makes imperative the analysis of the changing social organisation of the economy over time and in different places. Neoclassical

economics performs their feat of omission by positing as the ideal an economy organised by perfect markets and by then construing all real-life deviations from this ”ideal” as market imperfections. Yet, even though it ignores the central issues concerning the wealth of nations, neoclassical economics currently exerts a pervasive influence on national policy formulation.

This report, and the body of empirical research and theoretical formulation on which it is based, introduces national policy-makers to a more rigorous and relevant approach to understanding the operation and performance of the economy. In sharp contrast to neoclassical theory, the theory of innovation and economic development that guides the analysis in this paper rejects the notion of an economy organised by perfect markets as ideal precisely because *such an economy is one in which innovation and economic development would not, and could not, occur*. From the perspective of this report, those real-life phenomena that neoclassical economists depict as market imperfections often reflect the social organisation of innovative enterprises, regions, and nations. The point then is not to rid the economy of these so-called ”imperfections” or to optimise taking these ”imperfections” as constraints. The point is rather to use this social organisation to generate innovation and economic development.

The report outlines a perspective on economic development for national policy-makers who want to design policies that can encourage the nation’s business enterprises to engage in innovation rather than adaptation. It examines the theoretical and empirical weaknesses of the standard analysis of national economic performance that neoclassical economists use in trying to account for economic growth over time and across nations. It argues that what is missing from the neoclassical analysis of growth is a theory of economic development as well as a methodology for analysing the process of economic development in, and changes in economic leadership among, the advanced national economies over the past century.

A comparative-historical analysis of the social foundations for economic development and leadership in the economies of the United States, Germany, and Japan is presented. It highlights the importance of the interaction between national institutions (particularly the educational system, the financial system, and the legal system) and the social organisation of business enterprises in fostering the innovation processes that provide the technological foundations for economic development and leadership. The report therefore elaborates a theory of innovative enterprise that can be used to assess the extent to which national economic activity is innovative or adaptive. Finally the report draws on the empirical and theoretical analyses to consider how national policy can influence business governance—the strategic allocation of enterprise resources

and returns—to promote innovation and economic development.

Corporate Governance and Innovation in Europe: a Review of the Issues (Mary O'Sullivan).

This paper is based on the revised proposal presented 6.12.96 and subsequently agreed with the ISE Co-ordinator. It contains a detailed review of policy issues related to corporate governance debates at the present time, specifically looking at the impact of governance rules on innovation. The paper gives a critique of the current mainstream positions in corporate governance, which mainly address the issue in terms of ownership and control (that is, in terms of principal-agent problems) rather than in terms of the long-term investment and innovation impacts on firms. The aims were to give the project a more immediate policy focus and to contribute to the discussion of this issue within the European Commission, where such issues are now under active debate.

In recent years there has been an on-going debate about the appropriate response of the EU member countries to the realities of international competition and technological change. On the one side are those that argue that the model of the "social market economy" pioneered in Europe in the post-war period must be preserved, even at the cost of high unemployment. From the other side come calls to redress the imbalance in many EU countries between protection for those at work and opportunities for those out of work. Advocates of such a rebalancing of prosperity tend to argue for greater "deregulation" of labour and financial markets. They point to the economic experiences of the United States and the United Kingdom to support their contention that such institutional change would allow new jobs—even if they are lower paid jobs—to be created.

The report argues that an economy's capacity to achieve sustainable prosperity is closely related to the process through which corporate revenues are allocated. The fact is that corporate strategists control substantial financial and productive resources that permit them to make strategic choices in the allocation of resources. Retained earnings—undistributed profits and capital consumption allowances—have always provided, and continue to provide, the financial resources that are the foundation of investments in productive capabilities that can make innovation and economic development possible. How major corporations allocate their vast revenues are matters of strategic choice, and the strategic choices of corporate decision-makers can have profound effects on the availability and viability of stable and remunerative employment opportunities. To understand what has happened and what will happen to employment

opportunities and income levels in Europe, therefore, we have to understand strategic decision-making within Europe's major corporations and how and why that process changes over time.

The strategic investment process that shapes an enterprise's innovative capabilities is influenced by a combination of institutionalised practices generated by the unique organisational history of an enterprise and the social and political history of the economy in which it has grown and continues to operate. The social institutions that influence the process of strategic investment in corporate enterprises—who makes investment decisions in corporate enterprises, what types of investments they make, and how returns from successful investments are distributed—can be characterised as a system of corporate governance.

The problem of corporate governance and industrial development is not resolved by simply advocating that industrial corporations be run for other "stakeholders"—especially employees—besides shareholders. The danger is that different groups who can lay claim to shares of corporate revenues will, as has increasingly been the case of shareholders, extract corporate revenues, whether or not their contributions to the generation of these revenues make these returns possible on a sustainable basis. The result of the creation of a "stakeholder society" might be to increase the propensity for major industrial enterprises and the economy in which they operate to live off the past rather than invest for the future. If sustainable prosperity is the objective, proposals to reform the corporate governance system must be based on a theory of the innovative enterprise.

Without such a theory, stakeholder arguments run the risk of encouraging other groups, besides shareholders, to become claimants to a given, and even diminishing pool of returns. To avoid such a political and economic stalemate requires a conception of how investments in people working together in organisations can generate the returns in international competition that make sustainable prosperity possible. To make constructive contributions to the corporate governance debate, economists must shed the shackles—both methodological and ideological—of an economic theory that was never designed to understand how an economy develops and build their own capabilities for analysing the processes of industrial innovation, international competition, and the social foundations of sustainable prosperity.

State-Owned Enterprises and Managerial Structure: the Italian Experience in Steel and Oil (Stefano Brusoni and Luigi Orsenigo)

This report addresses issues of corporate governance in publicly-owned firms. It gives an interpretation of the history of the Italian State Owned Enterprises (SOEs) in terms of unresolved conflict among competing goals. SOEs are considered to be joint stock companies characterised by the separation of property and control and whose particularity is given by the peculiar nature of the owner: the State. Therefore, management and ownership are characterised not merely by different objectives, but by different efficiency criteria—based on market feedbacks for the former, upon political consensus for the latter.

The paper argues that the balance between them cannot be seen as a process of intrafirm market bargaining within the framework of a well defined choice set. The key variable focused on is the managerial structure, which is interpreted as the interface between political and entrepreneurial functions. On one side, it represents the channel through which the political systems directly interact with the economic sphere. On the other, it transfers economic and technological constraints into the policy-making. The report analyses the goals formation processes and the routines of co-ordination and control determined by such an interaction.

Corporate Governance and the Innovative Economy: Policy Implications of ISE Research, William Lazonick and Mary O'Sullivan

This report draws on earlier studies suggesting that cross-national comparisons of organisational learning in specific industries show systematic variations in:

- the *hierarchical integration* of personnel with different levels of responsibility and authority in the learning process.
- the *functional integration* of personnel with different types of technical specialisations within the learning process.
- the *strategic integration* of those managers who make strategic decisions concerning the allocation of corporate resources and returns into processes of organisational learning.

This conceptual framework for understanding the innovative enterprise provides the basis for considering the types of national and EU policies that will support innovation processes in particular and the innovative economy more generally. To promote sustainable prosperity and social equality, the goal of corporate governance policy is to contribute to the creation of a broad and deep skill base

within the EU. The allocative strategies of corporate enterprises will be an important determinant of the extent to which this goal is achieved. The prime foci for corporate governance policy are the reform of:

- *corporate governance institutions* so that they support the innovation process better.
- *corporate governance processes* so that, within the framework of these institutions, they encourage corporate strategies that entail allocations of resources and returns to broader and deeper skill bases that can engage in organisational learning.

We can identify four different types of corporate governance institutions based on different relations with the locus of decision-making power over the allocation of corporate resources and returns.

- *Executive institutions* determine the responsibilities and qualifications of those people engaged in decision-making over the allocation of resources and returns within the corporation.
- *Supervisory institutions* determine to whom executive decision-makers are directly responsible and the rights of these supervisors to influence, and intervene in, the process of executive decision-making.
- *Consultative institutions* determine the parties (unions, stockholders, enterprise groups, industry associations, government agencies) with whom, and the procedures by which, executive decision-makers consult in gathering information and gaining support for their allocative decisions.
- *Regulatory institutions* determine the laws and rules that enable and proscribe corporate decision-making over the allocation of corporate resources and returns.

Government policy should seek to structure the institutions of corporate governance to encourage a strategic decision-making process for the allocation of corporate resources and returns that

- seeks the influence of and is accountable to those people engaged in organisational learning within units of strategic control.
- reallocates both people and money from existing enterprises to new units of strategic control that can engage in organisational learning.
- encourages the integration into processes of organisational learning of groups of producers within enterprises, districts, nations, and regions who

have previously been segmented or excluded from organisational learning processes.

Toward these ends, policy reform of:

- *executive* institutions should make corporate executives responsible for maintaining and extending the organisational learning capabilities of their enterprises and establish qualification criteria for those who occupy corporate executive positions that will exclude those who are not able or willing to allocate resources and returns to organisational learning.
- *supervisory* institutions should mandate the inclusion on a corporate supervisory board of representatives from organisations of employees, enterprises, communities, educational institutions, financial institutions, and public agencies that can demonstrate (and reconfirm on a periodic basis) that they have a direct interest in ensuring that the corporation allocate resources and returns to organisational learning processes.
- *consultative* institutions should encourage the creation of interactive structures as part of the normal operation of the enterprise that links employees and subsidiary enterprises with executive decision-makers for the purpose of sharing information and opinions concerning the technological and market orientation of corporate strategy, sharing the skill bases that will be required to implement these strategies, and evaluating the enterprise's innovative performance.
- *regulatory* institutions should aim at transforming corporate law and related regulatory practices to reflect an awareness of the dependence of an economy and society on the innovative performance of corporate enterprises, while at the same time, through executive, supervisory, and consultative institutions, ensuring the autonomy of the enterprise as a unit of control that integrates allocative strategy with organisational learning.

3.4.5 Interdependencies Between Elements in Systems of Innovation

Within a systems approach to innovation, we often speak of the importance of institutional differences between countries, meaning differences in the 'rules of the game' under which firms operate. Yet, although they are often referred to, these institutional differences and their effects are relatively under-analysed in the innovation literature. Corporate governance is, in our view, one of the most important areas of such institutional differences. As such, this project connects with a number of elements of the 'systems' approach: with financing issues,

with the effects of ownership structures, with debates on regulation and political frameworks, and so on.

3.4.6 ISE Coherence: Relations to Other Sub-Projects

This project has a wide set of links to other elements of the overall ISE project. The project is aimed not simply at an analysis of institutional factors, but seeks to connect the institutional structure with innovation performance and, through that, to long-run trends in economic development. As such, it links up with those parts of ISE which seek to explore overall impacts of system structures, growth processes, and trends in the process of economic integration. Particularly important are links with the following sub-projects:

- 3.1.1 Systems Theories of Innovation: Policy Implications
- 3.1.2 Innovations, Growth, and Employoment
- 3.1.3 European Integration and National Systems of Innovation

More specific links can be found between this sub-project and sub-project 3.2.3 (”Financing of Innovations”), since one of the key themes of this sub-project is that the conditions under which firms can externally and internally finance innovation are central to system performance. The main difference is that the corporate governance project focuses on large firms, whose innovation efforts are largely financed by retained earnings (and where distributional issues are therefore central to the capacity of managements to invest), whereas the project on financing of innovations focuses on the external banking and venture capital systems.

3.4.7Policy Implications

One of the arguments of this project is that policy towards corporate governance is a key factor governing innovation and economic growth performance and deserves greater attention from policy-makers. One of the conclusions which is likely to emerge from this project is that there should be a more significant European level in shaping corporate governance systems and in deciding their content. Specific policy implications from the project are discussed above, in the fourth paper of this project. More generally, the policy implications are as follows.

‘Corporate governance’ refers to the systems of law, regulation, and accountability that provide the institutional framework within which corporations are managed and controlled.

Corporate governance is normally seen in terms of the problem of making managers responsive to shareholder interests. This project seeks to place the general issue of corporate governance into the much wider framework of economic development and growth. In the conventional framework, corporate governance is seen in terms of how to secure the interest of owners when corporations are in effect directed by professional managers; this is approached in terms of principal-agent problems, in which the market for corporate control secures the ultimate interests of owners and in which freely functioning equity markets—which place strong short-run profit objectives on managers—are a central economic mechanism and policy instrument. This project sees the problem in terms of innovation: how do corporate managers secure the powers and authority to organize firms and commit resources to learning (that is to make long-term intangible investments), and thus generate innovation-based growth? What are the long-run effects of different solutions to this question, and what are the policy implications?

The approach of the project is to offer a comparative-historical analysis of economic development and international competition in the large advanced economies, in particular making a triadic comparison of Europe (meaning the United Kingdom and Germany in this case), the United States, and Japan. Against this background, it suggests two fundamental conditions that characterise the social organisation of innovation. One fundamental characteristic, which in the project is called organisational integration, is that the people involved in the process of organisational learning be willing and able to make their skills available and efforts to the pursuit of organisational goals. The other fundamental condition, which in the project is called financial commitment, is that the business enterprise have sufficient access to financial resources to sustain both the innovation process until it can generate returns and the business organisation so that it can engage in continuous innovation.

The project argues that the different systems for meeting these conditions have very different long-term outcomes and play a large part in explaining different development trajectories for the countries concerned. The project suggests that this type of approach opens up the possibility for market-oriented policies that affect innovation capabilities and performance without direct intervention. However there remain strong differences between countries in terms of these systems at the present time, and harmonisation of corporate governance rules is already an issue in the EU. The main policy recommendation of this project will

be that such harmonisation, which is both inevitable and desirable, should occur on the basis of conceptions of corporate governance which are founded on real, long-run innovation performance and not on the maximisation of short-run returns to stockholders.

Many aspects of public policy—including especially the operation of stock markets and their impacts on mergers and acquisitions activity—over the past decade have in effect been aimed at changing systems of corporate governance. These changes, however, have not taken the organisational and innovation capabilities of companies into account. Policy-makers have not considered how policy measures aimed at improving efficiency (that is, market efficiency) might affect long-term asset building. This is a pressing problem because long-term asset accumulation is essential to develop organisational and innovation capability.

From an innovation perspective, the basic criticism of the 'Anglo-American model' of corporate governance is that it inhibits the creation of the intangible assets needed for good innovation performance. It forces managements into maximising *short-term* rates of return. In particular, managers do not have incentives for investing in workforce skills, R&D resources, design and engineering development and so on. These might be important in the long run, but in the short run they are current costs which reduce current profitability. The German and Japanese systems have placed more emphasis on growth, on human capital development and on acquiring market share—short-term profitability has been seen as less important than long-term viability. The German and Japanese systems have been more focused on creating value; the Anglo-American system is more focused on extracting value from the firm. The choice between these types of corporate governance system will be a key issue for Europe in the future.

3.5 Sub-Project 3.2.5 Technological entry: Diversification vs. new innovators

Group in charge of sub-project: CESPRI. Scientist in charge of sub-project: Franco Malerba. **Staff:** Stefano Breschi, Stefano Brusoni, Francesco Lissoni, Luigi Orsenigo. **Collaborator 1**: Tema. **Tasks of Collaborator 1**: To carry out a case study of technological diversification and two (2) case studies of technological entry by new innovation. **Scientist in charge**: Charles Edquist. **Staff**: Maureen McKelvey, Francois Texier and Hakån Alm. **Collaborator 2**: FhGISI. **Tasks of Collaborator 2**: To carry a study of technological distance using patent data. **Scientist in charge**: Thomas Reiss. **Staff**: Sybille Hinze.

Collaborator 3: VTT. **Tasks of Collaborator 3**: To carry out a case study of technological diversification and two (2) case studies of technological entry by new innovation. **Scientist in charge**: Tarmo Lemola. **Staff**: Christopher Palmberg.

3.5.1 Objectives

The purpose of this ISE sub-project was to analyse entry into new technologies during the 1990s. In particular, the analysis aimed at assessing differences in the entry rates across technologies, examining the balance between technological entry by new innovators and through diversification by established firms, and describing how large established firms handle the technological diversification process.

The project distinguished between sectoral entry and technological entry. Sectoral entry refers to new firms entering a given sector while technological entry refers to entry by new innovators (which are not necessarily new firms) in a given technology.

The key questions to be answered by this specific sub-project were the following:

1 What is the relevance of sectoral entry of new firms in Europe?

2 What is the relevance of technological entry in Europe during the 1990s?

3 On average, is technological entry in Europe higher or lower as compared to the United States and Japan?

4 Are there differences across technological fields?

5 What is the rate of success of technological entry?

6 Which mode (technological diversification vs. new innovators) are European national systems following to enter new technologies?

7 Are there differences in terms of new innovators and technological diversification across European countries? and between Europe, Japan, and the United States?

8 From which technologies do diversifying firms come?

9 How can a firm effectively master the diversification process?

3.5.2 Progress

According to the contract with the European Commission, this sub-project should result in two research papers: one on the patterns of technological entry, diversification, and new innovators in Europe, the United States, and Japan; the other on the problems and issues faced by large established firms in their diversification process. They were to total 60-70 pages.

The participants in this sub-project have been CESPRI, VTT, TEMA, and FhG-ISI. At the Athens and Vienna Workshops, drafts of the papers of this sub-project were discussed. At the Helsinki Workshop, the final drafts of the papers were discussed.

The papers produced in the sub-project are the following:

1 "Patterns of Technological Entry and Exit: Evidence from France, Germany, Italy, and the UK" by Franco Malerba, Stefano Breschi and Francesco Lissoni (CESPRI) (77 pages of text plus 25 pages of tables).

2 "Technological vs. Industrial Dynamics: Evidence from Telecommunications, Audiovisual and Information Technology" by Franco Malerba, Stefano Breschi and Francesco Lissoni (CESPRI) (28 pages).

3 "Knowledge proximity and technological diversification: an analysis of the determinants of technological diversification in Europe, United States and Japan" by Franco Malerba, Stefano Breschi and Francesco Lissoni (CESPRI) (37 pages).

4 "Statistical Analysis on the Distance between Fields of Technology" by Sybille Hinze, Thomas Reiss and Ulrich Schmoch FhG ISI (20pages).

5 "Nokia as a related diversifier: Nokia's entry into cellular phone technologies and markets" by Tarmo Lemola and Christopher Palmberg VTT (48 pages).

6 "The Dynamics of High Technology Industry: Swedish Firms Developing Telecommunications Systems" by Håkan Alm, Maureen McKelvey and Francois Texier TEMA (70 pages).

Each paper addresses a different set of questions, all of them taken from those listed above in Section 1. In particular, question 1 was answered from secondary sources and existing literature and is dealt with in part 1 of Paper 1. Questions from 2 to 9 have been examined at a quantitative level by Papers 1, 2, 3, and 4 and at a qualitative level by Papers 5 and 6.

3.5.3 **Methodology**

The quantitative analysis is based upon CESPRI's database on patent applications to the EPO (European Patent Office) from 1978 to 1994. This database is quite useful for research purposes because it includes firm-level data and covers all the patents granted by EPO to firms both inside and outside of the EU. In some of the papers in this sub-project patent data were used in an innovative way because they were merged with economic data at the firm level.

Three different lines of enquiry were pursued.

First, an overall description of *technological entry* in Europe, the United States and Japan has been produced. It provides a general picture of the relevance and main features of the phenomenon. This line of enquiry is addressed mainly by Paper 1. Here the International Patent Classification (IPC) has been aggregated into 30 technological classes to simplify the analysis and allow sensible measures of "technological distances" covered by diversifying firms (both the classification and the methodology for calculating technological distances are discussed in Paper 4).

Second, the relationship between *sectoral and technological entry* was investigated by means of a very detailed analysis of entry flows in 12 technological "micro-classes" from the fields of telecommunications, IT, and audio-visual technologies. This line of enquiry is addressed mainly by Paper 2. Micro-classes are sub-samples of the 30 technological classes. They are small in size (both in terms of patents and patent applicants) to allow a search for information on the applicants' age, size, and fields of economic activity.

Third, the determinants of *technological diversification* were more deeply analysed in Paper 3, where great emphasis is placed on technological distance (measured in terms of frequency with which different technologies—i.e. IPC classification codes—occur together in the same patent document) as a key concept to be used when mapping choices of diversifying firms.

The qualitative analysis developed case studies of firms which were identified as representative of successful attempts of entry through technological diversification. All the case studies are from Scandinavian countries and deal with both large and small-medium enterprises, such as Nokia and Ericsson (see Papers 5 and 6 respectively) and a cluster of small Swedish firms involved in telecommunications (Paper 6).

3.5.4 Scientific Findings

In **Paper** 1, the existence of clear patterns in the dynamics of technological activities were identified. Technological activities present a very high degree of *turbulence* in terms of firms (i.e. entry of new and exit of old innovators), but *stability* in terms of patents (i.e. some key large innovators are present in all countries and technologies).

In addition, striking similarities emerge between the patterns of technological activities from patent data and the patterns of industrial dynamics. The existing research on industrial demography (both the census-based and the life-cycle-based ones) clearly suggests that entry is linked to innovation. At the very least, several firms which enter a given industry do so on the basis of some technology they have developed. In general, one may suggest that late entrants enter through product innovations to overcome the increasing disadvantage they face against incumbents.

Our findings on patent data in Paper 1 are closely consistent with this line of reasoning. New innovators enter with some knowledge about technologies and markets whose features they need to test, and eventually quit after discovering that this is not good enough for survival. At the same time, patenting is very unlikely to be a random phenomenon, since very few firms are discontinuous innovators. Firms either patent once and then exit, or keep patenting for a considerable amount of time, building upon their initial expertise and strengthening their hopes of survival as technologically active firms. We have also shown that persistent innovators are indeed the most diversified ones. In Paper 3 we also show that the choices of technological diversification follow a logic related to knowledge proximity.

All the technologies we examined are characterised by *a core-fringe dichotomy* —i.e. by few large established firms which are persistent innovators and by small new innovators who may exit innovative activities quite soon. Technologies differ in terms of the relative weight of the core and the fringe, and of the speed at which late entrants build upon their initial share of patents, thus eroding that of the core. Core innovators' key characteristic is their persistent efforts to diversify. Fringe innovators' problem, on the contrary, is survival, and it remains so for a long while. The contribution of the two kinds of firms to the overall progress of a technological field differs widely among technologies. At the same time, there is a correlation between the ability of a country to develop a core of innovators in a given technological field and the degree of specialisation and competitiveness it can achieve in that field.

In Paper 1, *clusters of technologies and clusters of countries* were identified. These groups share the same knowledge base (technologies) and country characteristics. A set of summary statistics was produced by means of principal component analysis. They help classifying technologies according to the key variable *Stability*, which is a function of the characteristics of the knowledge base and the technological strength of the country. The relationship between stability and technological strength means that the development of a core of large and stable innovators is necessary to achieve international technological leadership.

The results in Paper 1 were deepened in two companion papers, one examining the link between technological entry and sectoral entry in specific electronic technologies (Paper 2) and one identifying the main features and driving forces of technological diversification (Paper 3). These papers refer to the general framework discussed in Paper 1 and focus on specific aspects of that paper.

Paper 2 examines the links between firms' *technological activities* and firms' *survival.* Its aims were to identify differences in the way national systems of innovations affect entry and to compare empirical results coming from recent contributions in the realm of the industry life cycle. It tried to answer the following questions. Are new innovators also new firms? Do firms which cease to patent also abandon their markets? Is there any correspondence between patent growth and size growth?

In an innovative way, Paper 2 merged two datasets which are very different both for contents and sources. The first one is the EPO-CESPRI database on patents and patenting firms. The second one is the result of a collection of company information in the realm of telecommunications, information technology, and audiovisual technology. In particular, information on the age and the economic activity of innovators was obtained and differences between new innovators and diversifiers were taken into account. Core innovators with a technological leadership were also specialised. In addition, technological leaders in these fields (the United States, Japan, and, to a lesser degree, Germany) host a large number of first-movers, who later become core innovators. Nevertheless, differences in national systems of innovation also emerged with the United States standing out as being the host of an exceptionally large number of entrants, some of which grow rapidly and enter the innovators' core.

In **Paper 3** ISE research examined the extent to which large innovators *diversify technologically* and whether they may move gradually to technologies close in terms of knowledge to the ones currently developed. The analysis of

technological diversification is quite important to understand the processes of transition and structural change that systems of innovations go through when moving out of existing technologies and into new technologies. In particular, technological diversification refers to innovators enlarging the range of the existing technologies they master and eventually exiting established technologies. It must be kept in mind that most large- and medium-sized firms are multitechnology corporations, even if they are specialised in one line of business. In addition, technological specialisation and diversification is stable over time, particularly among large firms. Finally, the diversification of large firms exhibits some degree of coherence, i.e. the technologies in which diversified firms are active are related in specific ways.

Paper 3 shows that *technological diversification* in France, Germany, Italy, the United Kingdom, the United States and Japan (based on the analysis of patents applications by firms from 1978 to 1994) is a widespread phenomenon. Diversificators are persistent innovators. Major differences in the relevance of persistent innovators exist among European national systems of innovation. Most firms are small innovators which diversify into two technological classes. Very few firms are diversified in most of the classes: they are very large innovators. This means that, over time, persistent innovators become major innovators and accumulate a lot of patents in several technologies. On the other hand occasional innovators do not have many patents and disappear from the innovative scene quite soon. Germany and Japan are among the most persistent countries while Italy and the United Kingdom are less persistent. More than 50% of firms are present in two technological classes, and around 20% in three. Most of these firms are small innovators: they hold less than 15% of total patents. Few firms are diversified in most of the classes: they are very large innovators.

In summary, a process of technological growth takes place over time among persistent innovators, with firms continuously entering new technologies and exiting old ones. This also means that, in their innovative process, most firms have to master and integrate different technologies.

Using a measure of knowledge proximity, ISE research has found that firms diversify into technologies that are close in terms of knowledge to the ones currently developed. This has been shown both in terms of single technological classes and in terms of macro-technologies. **Paper 4** provides a measure of distance among technological classes in terms of co-occurrence of technological codes (Individual Patent Codes [IPC]) assigned to individual patent documents. This measure is a key tool for the analysis of technological diversification.

Using this measure, Paper 4 shows that the distance between technological classes is relatively invariant across countries.

While the first part of sub-project 3.5.2 was quantitative, the second part (Papers 5 and 6) was qualitative and through two case studies it entered in detail into the processes of technological and productive diversification of large established firms. These case studies refer to mobile phones.

The first case study, **Paper 5**, is on the *Finnish mobile telephone industry*. It focuses on the process of technological and productive diversification by an established innovator (Nokia) and the technological fortunes of a small number of new innovators, who entered the field alongside/closely related to Nokia. They include Insele-Lauri Kuokkanen Oy (rf-filters for mobile phones), Micronas (semiconductors) and Benefon (mobile phones for niche markets). The basic questions that the case study tried to answer are the following: Why did the firms move into a new technology? What type of technological and market knowledge (as well as organisational change) was necessary? How was this knowledge obtained (especially in-house R&D vs. external sourcing)? What type of national and international supporting network did the firms have?

In the case of Nokia, the diversification process was analysed in terms of why and how the firm developed competencies to enter the fields of first NMT cellular phone technologies, then TACS and AMPS, and later GSM standards and markets (roughly in the period 1975–1992). This process has meant a process of entry into new technologies and markets with different demands, and also a major organisational change.

Some lessons emerge from the case study. Diversification has been characterised by a wide and changing scope, with the aim of searching for new business opportunities. There was coherence in Nokia's diversification, but the process was characterised by trials and errors, and a continuous alternation of broadening and refocusing in specialisation. Knowledge proximity was an important drive, but a big push also came from the low profitability of the previous core business in which Nokia was involved (consumer electronics). In addition, a set of mergers and acquisitions with innovative Finnish producers as well as co-operation with technologically progressive international companies allowed the rapid entry of Nokia into mobile phones.

Close co-operation with several public and private actors of the Finnish telecommunications sector played a major role in Nokia's diversification process. In particular the role of the lead user in terms of the publicly controlled national telecommunications operator was of great importance. In addition, the

birth of the Nordic Mobile Telephone (NMT) standard opened a fairly big and advanced market. Finally, Nokia took advantage of a local innovation system in terms of universities, research institutes, local suppliers, national technology programmes, and financial aid.

The second case study, **Paper 6**, examines technological and productive diversification in the *Swedish mobile telephone* industry. It shows that the history of mobile telecommunications in Sweden is to a large extent the history of Ericsson and its relationship to the Swedish PTTs as well as to other small firms. The mobile telecommunications industry in Sweden emerged at the end of the 1970s under the push of the Nordic PTTs through the creation of the NMT standard. Three technologies were key components for the setting up of a mobile telephone system: the switches (connecting the telephone lines), the radio-base station (receiving and sending radio signals), and the handsets. Throughout the 1960s and 1970s, the radio laboratories of Televerket (the Swedish PTT) were very active in trying to develop a mobile telecommunication system for professional users (such as firemen or doctors on call). The management of Ericsson was not interested in developing technologies for mobile telecommunication since their main activity was fixed telecommunication. This lead to the development (in co-operation with Televerket in a joint venture called Ellemtel) of a new switch for the fixed network, the AXE system (see the ISE sub-project on Public Technology Procurement for a more detailed discussion). However, Svenska Radio AB (SRA) (a firm jointly owned by Ericsson and the British company Marconi) was developing radio-based stations and phones for the mobile network in collaboration with Televerket's Radio Labs.

Convincing the top management of Ericsson of the promises of the new technology in mobile telecommunication was not easy for people at SRA. When the NMT standard was finally operational in 1982, it was still not clear that the fixed telecommunication side of Ericsson should provide the switches for the radio communication side. It was difficult to persuade the internal hierarchy that Ericsson should become a system provider, and not just a seller of separate elements of the system. The vision of the top management of the firm was very different and very much in line with the vision of other firms in the telecommunications industry as well as in the computer industry: move to the "paperless office". However, Ericsson failed in its venture and thus focused on the mobile telephone business.

Ericsson Radio System (ERA) was created in 1982, and, similar to Nokia, acquired small specialised firms to access the competencies they lacked in radio communication. The first one (Magnetic, bought in 1983) was specialised in

military radio equipment as well as in radio transmitters for television. The second firm (Radiosystem, bought in 1988) provided competencies in components for radio-based stations.

The competencies in switching could be found in-house with the use of the AXE system in a way that it could handle the different functionality required by mobile telecommunication systems. At the same time analogue standards were made operational and research had started on digital technologies to improve the quality of the system.

Collaboration with universities proved important in the diversification process. Joint research started between the main technical universities in Sweden and Ericsson as early as 1974.

Ericsson entered on all three major standards in the United States, Japan, and Europe (GSM). From 1990, the policy of Ericsson became oriented towards high investments in R&D and a focus on mobile telecommunication systems.

3.5.5 Interdependencies Between Elements in Systems of Innovation

This sub-project highlights several interdependencies between elements in a system of innovation.

First, from the analysis of technological entry and diversification and from the case studies of growth and transformation of large multitechnology corporations, it became evident that innovation systems go through processes of *transition and structural change* characterised by a change in the relevance of old and new technologies, the emergence and growth of new innovators and the diversification of existing firms.

Second, from the analysis of diversification it has been highlighted that contemporary innovation systems may span *a large variety of technologies and sectors*. The understanding of how these links are generated and change over time is a key part for any analysis of the dynamics of sectoral systems.

Third, this sub-project shows the *systemic link* between type of technologies, firms' competencies and strategies, and market structure. It has been shown both at the quantitative and at the qualitative levels that the type of technology, the growth and modifications of competencies (as seen from our patent analyses

and case studies) and the structure of the market (in terms of core and fringe firms) coevolve over time.

Fourth, institutions such as *government and public policy* play a major role in affecting innovation and firms' entry into new technologies, as the case studies of Ericsson and Nokia show.

Finally, *national systems of innovation* do play a role in affecting the rate of entry and the patterns of diversification of firms into new technologies. The analyses of the various European countries show that even for the same technology, national systems of innovation shape the features of innovative activities.

3.5.6 ISE Coherence: Relations to Other Sub-Projects

This sub-project presents links with the other seven sub-projects. These links are summarised as follows.

All papers (but especially papers 1, 2, 5, 6) have policy implications and, as such, they are strongly connected to sub-project 3.1.1 (”Systems Theories of Innovation: Policy Implications”). Particularly, the findings of Paper 1 stress the role that technology-specific as well as country-specific factors have in determining the observed patterns of technological activities, in terms of the role of new innovators vs. diversifying innovators, importance of persistent innovators, the survival of new innovators, and so on. These findings provide further evidence to support the idea that national systems play a major role in affecting the way innovation is developed and diffused within the economy.

The importance of a systemic perspective in studying innovation processes also emerges rather clearly from Papers 5 and 6. They show how the successful entry of Finnish and Swedish firms in the mobile communications business depended on a rather peculiar interaction between three major sets of actors: government, large oligopolists, and a restricted number of small firms. In particular, the key role played by government intervention early on in the development of the new industry strongly supports some of the theoretical arguments put forward in the papers of sub-project 3.1.1.

Paper 1 is also linked to sub-project 3.1.3 (”European Integration and National Systems”). In fact, it provides quantitative evidence on the patterns of convergence among European countries in the rates of innovative natality and

mortality and on the continuing importance of national systems in influencing innovative activities.

Papers 1, 2, and 3 can be linked to sub-project 3.2.1 (”Science-based Technologies and Interdisciplinarity”). In particular, Paper 2 examines and compares industrial dynamics and patterns of technological activities within new science-based technologies. In this respect, the paper complements many of the findings of sub-project 3.2.1 by analysing the relevance of new firms’ entry vs. technological diversification as a main mode of entry into new science-based technological fields. In this respect, Europe shows more limited entry than the United States. But the analysis has to be made technology specific, because relevant differences emerge among technologies.

Papers 4 and 5 show strong links with sub-project 3.2.2 (”Public Technology Procurement as a Policy Instrument”). Both papers forcefully point out the crucial role that public procurement policies and standards played in favouring the successful development of strong technological capabilities in the new mobile communications business. In this respect, both papers have several policy implications that could fruitfully integrate the policy conclusions of sub-project 3.2.2.

Papers 3 and 5 highlight the relevance of technological entry, but also the high mortality rates of several new innovators. This is closely related to sub-project 3.2.3 (”Financing of Innovations”). In fact, several new innovators face the problem of finding appropriate financing for their new products. In this respect, venture capital plays a major role in the support of new firms.

Finally, papers 3, 5, and 6 show several links to sub-project 3.2.4 (”Corporate Governance and Innovation Performance”). In particular, Paper 3 points out quantitative differences across countries in the extent and directions of technological diversification, implicitly suggesting that such differences could be related to differing corporate governance systems among European economies and between the European economies, the United States, and Japan.

3.5.7 Policy Implications

The policy implications derived from Papers 1, 2, and 3 are the following.

The first policy implications derive from the findings that *major differences* among technologies exist in the dynamics of transition. These differences are

closely related to the main characteristics of technologies or sectors. In certain technologies or sectors, the type of knowledge base and the specific conditions of opportunity, appropriability, and cumulativeness of innovation (the so-called "technological regime") led to a major role played by large firms diversifying into new technologies. In other technologies, new firms and new innovators represented the driving force of change.

Thus policies of support for a rapid transition should take into account these differences. In the first case, policies targeted to support the large established firms in their transition process may be inappropriate because they may run into antitrust and competition problems. Policies of human capital formation or standard setting, however, could be appropriate. On the contrary, in the case of transition with a major role played by new firms, policies that support entry may be appropriate. In this case, however, it has been shown by ISE research that a top policy priority should be to help new innovators to overcome key obstacles after innovative entry has occurred. These obstacles take place during the first years after entry has occurred and are related to problems concerning assets that are complementary to technology and innovation (such as financing, human capital, and management).

Second, the other policy implications derive from the findings of an interaction between *technology specific factors* ("technological regimes", rather invariant across countries for a specific technology) and *national innovation systems* (similar for all technologies in a specific country). Here, policy has to assess the specific role of the institutional setting and the national innovation system in the modification of the patterns of sectoral innovative activities (in terms of relevance of new innovators, large established firms, and so on) along the way most adapt and tuned to the specific technological regime. When policy-makers try to modify the patterns of sectoral innovative activities, they need to periodically asses the specific roles of the institutional settings and the national innovations system so that, over time, they adapt and stay tuned to the developments in the different technological regimes.

Third, the existence of *strong relationships* between technological innovation and industrial dynamics suggests that policies which aim at affecting the natality and mortality rates of firms should take into account the role of *technology and innovation* in firms' survival. Whenever governments aim to increase the entry rates within a given industry (or to enhance small firms' survival probabilities), the best policy target is not gross entry rates (which is always very high), but net entry rates (which depend upon new entrants' survival probabilities in the short run). Since such probabilities are critically affected by firms' capabilities of developing technologies up to a viable level, a

top policy priority should be to help new innovators (e.g. firms which enter the market and soon register a patent) to overcome major obstacles when they try to build upon their initial innovation.

Fourth, some implications also refer to innovation and diffusion policies for SMEs. These policies should recognise that firms are highly heterogeneous, with only a few ones being likely to survive in the medium and long run, as a consequence of their different technological bases and skills. This implies a high degree of heterogeneity in firms' responsiveness to innovation and diffusion policies. Therefore *generalist* policies (i.e. policies which aim at increasing the degree of innovativeness or the adoption of new technologies by all firms in a country, region, or industry by means of non-selective mechanisms for financing innovation efforts or providing technical assistance) may end up channelling a large amount of resources towards firms which would be doomed to fail anyway. S*elective* policies (i.e. policies which target a small number of beneficiaries) would on the contrary face the problem of selecting a priori the most promising firms (i.e. firms with the better technological capabilities or the most promising growth and survival probabilities). This task, however, would require an advanced level of competence which rarely can be found in any policy body. Thus, a *trade-off* between the two kinds of policies can be envisaged. It is very difficult to find ex-ante an effective solution to this trade-off. The variables that the policy-maker should consider include the specific features of the technologies or sectors mostly affected by these policies, the amount of available resources, the age and entry dates of the SMEs, and the competencies of the policy bodies.

Fifth, whenever resource scarcity necessitates a choice between policies aimed at large established innovators -the core- and policies aimed at new innovators -the fringe-, this choice has to considers the specificities of the technology. In fact, the findings of this sub-project have shown that the relative contribution of core and fringe firms to innovation differs widely from technology to technology. If the policy objective is the overall growth of national expertise in a given technology, then the type of firms to support is closely related to the specific features of that technology. On the contrary if the policy objective is to support a specific type of firm (either large established firms -the core- or new entrants -the fringe-) then specific technologies have to be selected. These technologies are the ones where either the importance of the core is great or the survival probabilities of the fringe firms are high.

However, the papers also found that all countries which develop a major international strength in a given technology host a relatively *large core of innovators*. The opposite happens in countries which are weak in a technology.

This observation suggests that technologically weak countries should focus their efforts on building up and consolidating a core of innovators. At the same time however, our research shows that technological and industrial dynamics is to a large extent irreversible: the growth of a core of innovators depends crucially upon the date on which firms started developing competencies in a technology. This last observation is strengthened by papers 5 and 6. They show the relevance of policy for the development of a strong technological base (and the growth of two core firms such as Ericsson and Nokia) in the mobile telephone industry in Sweden and Finland. At the same time, though, they show how these efforts occurred very early in the history of the industry, this being a key of their success.

Thus a major policy question is related to the way *technologically weak countries* should develop their core of innovators in specific technologies. This process being long and cumulative, timing and the amount of resources devoted to this goal are very important. This may be quite difficult for latecomers and small countries.

Sixth, policies aiming to support new innovators—the fringe—should take also into account the specific *relationship between large and small firms* in different technologies and different countries. Following the above discussion about the interaction between sectoral specificities (cross-countries sectoral invariances due to technological regimes) and national specificities (due to national systems of innovation), this relationship may differ from country to country as a consequence of the characteristics of the industrial structure, the competitiveness of large firms and the institutional setting. For example, given the fact that new innovators are very important in biotechnology, the relationship between new innovators and large firms is quite different in the United States and in Europe, and the policy implications have to take these differences into account.

Moreover, in many cases small innovators do not exit the market because of failure, but because they are *acquired* by large core innovators. In many cases this is a sign of success. This suggests then that being absorbed by the core innovators may be one of the main long run objectives of a SME. This observation adds further support to *selective* policies rather than to generalist policies. *Selective policies* are better equipped to identify the causes of disappearance of individual firms and to take them into account when their purpose is to support small firms' survival.

Seventh, a final suggestion refers to *policy and policy capabilities.* The policy-maker's choices and actions to support or direct firms' efforts is characterised

by trial-and-error and by success and failure. No public body holds a "superior" knowledge which may channel firms' innovation strategies in the "right" direction. False starts and dead ends are common. This implies both the need to evaluate policy results in the long run, and the need to pursue more technological options at once.

4 PHASE 3: SYNTHESIS AND POLICY IMPLICATIONS OF ISE

Group in charge of sub-project: Tema. **Scientist in charge of sub-project:** Charles Edquist. **Staff:** **Collaborators:** Representatives of the other contractors.

The synthesis and policy implication work within ISE was discussed at the meeting with the ISE Steering Committee at the Vienna workshop in September 1997. It was decided that the steering group members would together carry out this work. The members of the Steering Committee are Charles Edquist (co-ordinator), Björn Johnson, Tarmo Lemola, Franco Malerba, Tomas Reiss, and Keith Smith. They are also the leaders of the research groups constituting the 'contractors' of ISE. The co-ordinator was assisted by Leif Hommen from Tema in this work.

Phase 3 of ISE resulted in two things. The first was the summary of the scientific findings and policy implications reported in the present report ("The ISE Final Report"). The target groups of this report are our research colleagues and interested policy analysts.

The second result was a policy position paper entitled "The ISE Policy Statement—The Innovation Policy Implications of the 'Innovation Systems and European Integration (ISE)' Research Project". It constitutes a more integrated synthesis of the policy implications of ISE and was specifically written for policy-makers and politicians.

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