EUROPEAN
COMMISSION

Community research

EU SOCIO-ECONOMIC RESEARCH

Sectoral Systems in Europe:
Innovation, Competitiveness & Growth

ESSY

Sectoral Systems in Europe: Innovation, Competitiveness & Growth — ESSY

PROJECT REPORT

EUR 21039

EUR 21039

Interested in European research?

RTD info is our quarterly magazine keeping you in touch with main developments (results, programmes, events, etc). It is available in English, French and German. A free sample copy or free subscription can be obtained from:

European Commission
Directorate-General for Research
Information and Communication Unit

B-1049 Brussels
Fax : (32-2) 29-58220
E-mail: research@cec.eu.int
Internet: http://europa.eu.int/comm/research/rtdinfo/index_en.

EUROPEAN COMMISSION

Directorate-General for Research
Directorate K – Social Sciences and Humanities
E-mail: rtd-citizen@cec.eu.int

EUROPEAN COMMISSION

EU RESEARCH ON SOCIAL SCIENCES AND HUMANITIES

Sectoral Systems in Europe: Innovation, Competitiveness & Growth ESSY

Final report

Project SOE1-CT98-1116
Funded under the Targeted Socio-Economic Research Programme (TSER)
Directorate-General for Research

Report issued in February 2002

Edited by:
CESPRI Bocconi University Franco Malerba

Coordinator of project:

CESPRI Bocconi University, 20136 Milan ITALY Franco Malerba CESPRI home page: http://www.cespri.uni-bocconi.it

Partners:
CREII -Centre for Research in Industrial and International Economics, Paris-France, Benjamin Coriat.
CRIC - Centre for Research on Innovation and Competition, University of Manchester-UK, John Stanley Metcalfe.
SSSA - Scuola Superiore S. Anna, Pisa - Italy,Giovanni Dosi.
SPRU - Science Policy Research Unit, University of Sussex, Brighton - UK, Edward Steinmuller.
TEMA - Department of Technology and Social Change, University of Linköping - Sweden, Charles Edquist.
WZB - Social Science Research Centre, Berlin -Germany, David Soskice.
IKE - Department of Business Studies, Aalborg University -Denmark, Bent Dalum,
ISI - Fraunhofer Institute for Systems and Innovation Research, Karlruhe - Germany, Jürgen Wengel.
PF - Department of Economics and Management Universitat Pompeu Fabra, Barcelona - Spain,Walter Garcia-Fontes.

Directorate-General for Research
2005 Citizen and governance in a knowledge-based society EUR 21039

EUROPEAN COMMISSION
RESEARCH

Commissioner: Janez Potocnik

Directorate-General for Research
Director General: Achilleas Mitsos

The Directorate-General for Research is responsible for implementing EU level policies and activities in view of the development of the European Research Area. It initiates and implements the necessary Community actions, in particular the RTD Framework Programmes in terms of research and technological development. It also contributes to the implementation of the "Lisbon Strategy" regarding employment, competitiveness at international level, economic reform and social cohesion within the European Union.

The Directorate " Social Sciences and Humanities; Foresight", Directorate K, addresses key societal, economic and S&T challenges for Europe. It identifies and analyses major trends in relation to these challenges and examines them in the light of the principal EU strategic objectives and sectoral policies. The overall context for its work is the transition towards the knowledge based economy and society in Europe.
Within this overall framework, the Directorate provides a policy relevant research based capability executed through the promotion and management of research activities in the areas of social sciences, humanities and foresight, the exploitation of their results and its own analyses. In this way, the Directorate offers knowledge for policies (including RTD policies) while supporting the formulation of policies for knowledge.

Scientific Officer: Ronan O'Brien

Ronan.O'Brien@cec.eu.int

http://www.cordis.lu/fp6/citizens.htm, for information on Priority 7 – 'Citizens and Governance in a Knowledge Based Society' under the 6th Framework Programme.

http://improving-ser.jrc.it/default/, the database of socio-economic projects funded under the 4th and 5th Framework Programme.

http://europa.eu.int/comm/research/social-sciences/index_en.html Social sciences and humanities in Europa

Europe Direct is a service to help you find answers to your questions about the European Union

Freephone number:
00 800 6 7 8 9 10 11

Cataloguing data can be found at the end of this publication.

Luxembourg: Office for Official Publications of the European Communities, 2004

ISBN 92-894-7571-4

Printed in Luxembourg

PRINTED ON WHITE CHLORINE-FREE PAPER

Preface

Within the Fourth Framework Programme of Research and Technological Development, the Targeted Socio-economic Research Programme (TSER) had as main objectives to increase European knowledge across three targeted areas – evaluation of science and technology policy options, research on education and training and on social exclusion and social integration. Research was undertaken through the funding of translational research networks of high quality, which were sought to provide policy relevant findings that could have an impact on the social and economic development of Europe.

The insights and information that the reader will obtain in the following pages constitute the main scientific findings and the associated policy implications of the research project "Sectoral Systems in Europe: Innovation, Competitiveness and Growth"

This project brought 10 research teams in a collaborative endeavour lasting 36 months.

The abstract and executive summary presented in this edition offer to the reader the opportunity to take a first glance on the main scientific and policy conclusions, before going into the main body of the research provided in the other chapters of this report.

The research reported in this publication should not be viewed in isolation. Over 300 research projects and thematic networks in the wider area of the social sciences have been funded under the Fourth and the Fifth Framework Programmes of Research and Technological Development. These collaborative research efforts involving more than 2000 European research teams have made significant advances to knowledge, support policy-making in Europe and have laid the foundations for the development of a European research community in the social sciences.

The Sixth Framework Programme, through Priority 7 'Citizens and Governance in a Knowledge Based Society', is building on the progress already made and aims at making a further contribution to the development of a European Research Area in the social sciences and the humanities.

I hope readers find the information in this publication both interesting and useful as well as clear evidence of the importance attached by the European Commission in fostering research in the field of social sciences and the humanities.

Table of contents:

Abstract

The ESSY Project is the result of the research work of ten research groups in seven European countries. The overall purpose of the project was:

1. to build a research methodology which focuses on sectoral systems,

2. to understand the functioning and evolution of six major sectoral systems in Europe,

3. to study the determinants of the European performance in these six sectors,

4. to develop new policy options and implications on this basis.

Three summary reports have been produced in ESSY. The reader interested in the sectoral system methodology and on the evolution of the characteristics of six European sectors is advised to read WP4-RP11 - Sectoral Systems in Europe: Summary and Conclusions. *Franco Malerba.* The reader interested in the determinants of the performance in the six European sectors is advised to read WP4-RP12 - The performance of Sectoral Systems in Europe. *Benjamin Coriat, Franco Malerba and Fabio Montobbio.* The reader interested in the policy issues is advised to read WP4-RP13 - Sectoral Systems: Implications for European Technology Policy*, by Charles Edquist, Franco Malerba, Stan Metcalfe, Fabio Montobbio, Ed Steinmueller.*

Overall ESSY has produced 39 deliverables. In accordance with the contract with the Commission, 31 papers have been delivered to the Commission. Eight extra papers have also been delivered.

The ESSY final report describes and summarises the scientific findings and the policy implications of each of the 13 Research Projects (RP) in ESSY. The RPs were clustered in four Work Packages as follows:

WP1 - LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK: Basic definitions, a literature review and the conceptual background for the whole research.

WP2 - SECTORAL SYSTEMS IN EUROPE: The six case studies of specific sectoral systems in Europe: Services (Retailing, Airports, and Medical services) (RP1). Software (RP2). Telecommunications hardware and services (RP3). Pharmaceuticals and biotechnology (RP4). Machine tools (RP5). Chemicals (RP6).

WP3 - NATIONAL INSTITUTIONAL FRAMEWORKS AND SECTORAL SYSTEMS: the role played by national institutional frameworks in the evolution of sectoral systems. Patterns of national institutional framework (RP7), Organisation of R&D (RP8), Corporate governance (RP9), The financing of innovation(RP10).

WP4 - THE IMPLICATIONS FOR EUROPEAN INTERNATIONAL PERFORMANCE AND PUBLIC POLICY a synthesis of both WP2 and WP3 and the policy implications: Sectoral systems in Europe (RP11). A comparison of the structure, evolution and performance of sectoral systems in Europe, US and Japan (RP12). Policy implications (RP13).

Information and results of ESSY are available on the Web site: *http://www.cespri.uni-bocconi.it/essy*. On this site, information about the ten ESSY partners, the work programme, the 5 progress reports, the 39 deliverables can be found. It is possible to download the working papers, the project work programme, the progress reports and past workshop agendas.

1. Background and Objectives

Background

This project starts from the evidence provided by a great amount of recent economic literature and enhanced by the previous ISE TSER project (Innovation Systems and European Integration, n° SOE1-CT95-1004)), that the innovation activity, interpreted in a broad sense to encompass economically significant forms of innovation activity, is affected by a wide array of institutional and organisational variables. In particular ESSY recognises that sector-specific conditions are very important in innovation and production and that they influence the growth potential and the competitive advantages of each country and of Europe as a whole.

In order to understand the innovation dynamics in different sectors and the evolution of sector specific institutions and organisation and their impact on innovation ESSY decides to to move away from the traditional concept of "industry" towards the refinement and use of the notion of "sectoral system".

Sectoral systems are broader than industries because, in addition to firms, they encompass non-firm organisations (government, universities and financial organisations) and institutions (education, labour markets, intellectual property rights), networks of firms and vertical as well as horizontal linkages with related technologies, firms, suppliers and customers. Moreover the idea is to provide a methodology to select variables for the empirical analysis and case studies to take into account the dynamic co-evolution of these factors, institutions and demand in the innovation process.

Objectives

The project is aimed at analysing the salient features of some key European sectoral systems and to understand their differences and similarities, their dynamics and co-evolution, and their links to European growth and competitiveness. The issue is understanding the role of non-firm organisations and of the specific character of the European demand and how this affects the co-evolutionary process among technology, firms' organisation and strategies and institutions. ESSY focuses on six important sectors in order to study the factors conducive to European international leadership, European catching up or European persistent lack of success at the international level. These factors depend upon the co-evolution of firms and institutional variables and therefore upon the interplay between a set of sector-specific variable and nation-specific variable.

This project contributes to the above mentioned issues analysing six different sectors in a comparative way across European countries and to some extent, US and Japan. In particular ESSY analyses the structure and the most important features of some services, telecom, pharmaceutical, chemical, software and machine tool sectoral systems in Europe in terms of technological, knowledge and productive boundaries; demand conditions; links and interactions among firms, non-firm organisations, and institutions. ESSY points also at identifying for each sectoral system the main geographical boundaries, the differences across European countries, the degree of European integration and convergence. It is aimed at evaluate the factors conducive to European innovative and commercial international leadership, European catching up.

Finally ESSY is aimed at analysing the role of public policy in sectoral systems, shedding new light on the dispute between advocates of government support for particular "strategic" industries and services and critics that argue against any type of activist or

"targeted" policies. The project is aimed at providing a wide range of benefits for policy makers, firms, non-firms organisations and scholars: a deeper understanding of the processes leading to sustained innovation, countries' competitive advantages and international leadership in relation with the generation and diffusion of knowledge and new technologies at the sectoral level; a better knowledge of sectoral differences and their role in the European economic development; a deeper understanding of the sector-specific interaction and co-evolution between firms, non-firm organisation and institutions - such as universities, labour market and financial organisations; an explicit comparison with Japan and the United States. This will enable policy makers to define the different levels of intervention (regional, national, European) and appropriate tools (infrastructures, formation, R&D financing, intellectual property rights, industry protection, forms of co-operation and technological alliances etc.) for the different sectoral systems.

Work Content

ESSY is composed four work packages (WP), three of which will include a number of research projects (RP). The following chapters will therefore maintain the ESSY structure outlined below:

WP1 LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK: Basic definitions, a literature review and the conceptual background for the whole research.

WP2 SECTORAL SYSTEMS IN EUROPE: The six case studies of specific sectoral systems in Europe.

RP1 Services (Retailing, Airports, and Medical services)

RP2 Software

RP3 Telecommunications hardware and services

RP4 Pharmaceuticals and biotechnology

RP5 Machine tools

RP6 Chemicals

WP3 NATIONAL INSTITUTIONAL FRAMEWORKS AND SECTORAL SYSTEMS: the role played by national institutional frameworks in the evolution of sectoral systems.

RP7 Patterns of national institutional framework

RP8 Organisation of R&D

RP9 Corporate governance

RP10 The financing of innovation

WP4 THE IMPLICATIONS FOR EUROPEAN INTERNATIONAL PERFORMANCE AND PUBLIC POLICY a synthesis of both WP2 and WP3 and the policy implications.

RP11 Sectoral systems in Europe

RP12 A comparison of the structure, evolution and performance of sectoral systems in Europe, US and Japan

RP13 Policy implications

The WPs are organised according to *a matrix-like structure*, where **six case studies** of specific European sectoral systems (WP2) will be cut across by general **horizontal themes** regarding firms, institutions and policy (WP3 and WP4).

2. Scientific Overview: Methodology And Results

WP1: Literature Review and Conceptual Framework

Co-ordinator: CESPRI

Partners: SSSA

Research Team: Franco Malerba (CESPRI), Fabio Montobbio (CESPRI), Stefano Breschi (CESPRI), Francesco Lissoni (CESPRI), Giovanni Dosi (SSSA), Giulio Bottazzi(SSSA).

Progress

In accordance with the contract with the Commission, five papers have been delivered to the Commission. Two extra papers have also been delivered. An extra papers by SSSA which complements and completes its first deliverable and an extra paper by CRIC.

- Sectoral Systems of Innovation and Production, *F. Malerba.*
- National Innovation Systems. A Critical Survey. *F. Montobbio.*
- Sectoral Systems, National Systems and International Technological and Trade Performance. *F. Malerba, F. Montobbio.*
- Modeling Industrial Dynamics with Innovative Entrants. *G. Winter, Y.M. Kaniovski, G. Dosi.*
- Geographical Boundaries of Sectoral Systems. *S. Breschi, F. Lissoni.*

The two additional papers are:

- Distributed Innovation Systems and Instituted Economic Processes. *B. Andersen, J.S. Metcalfe, B.S. Tether.*
- Modes of Knowledge Accumulation, Entry Regimes and Patterns of Industrial Evolution. *G. Bottazzi , G. Dosi, G. Rocchetti.*

Methodology

WP1 provides a review on the existing literature on systems of innovation, discusses the definition, structure and dynamics of sectoral systems and their geographical boundaries. It assesses empirical differences among sectoral systems in innovation and performance, using quantitative indicators. Finally it develops modelling exercises in order to provide a benchmark for the empirical analyses of the dynamics of sectoral systems. Seven working

papers have been presented at the Second Workshop in Manchester on October 22 and 23 1999 and at the third Workshop in Berlin on June 1-3, 2000. Five working papers were indicated in the work programme. Two additional papers have been delivered by CRIC and SSSA to contribute to the methodological and theoretical discussion.

The seven papers have different methodological approaches:

- a survey of the existing literature on systems of innovation (by Fabio Montobbio: CESPRI);
- a conceptual discussion paper on the concept, definition and evolution of sectoral systems (by Franco Malerba: CESPRI);
- a conceptual discussion paper on the geographical boundaries of sectoral systems (by Stefano Breschi and Francesco Lissoni: CESPRI);
- an econometric analysis on the differences among sectoral systems based on the current available data (by Franco Malerba and Fabio Montobbio: CESPRI);
- two modelling theoretical exercises on industrial dynamics under different regimes of knowledge and learning (by Giovanni DOSI: SSSA, with S. Winter and Y. Kaniovski).
- a discussion of the concept of system of innovation and its relation with the evolutionary perspective (by B. Andersen, S. Metcalfe, B. Tether: CRIC)

Scientific Findings

The *first paper* is a survey: it assesses critically the theoretical background and the empirical relevance and the normative implications of the recent literature on national systems of innovation. The role of a wide set of institutional and economic agents from which innovative firms draw knowledge and competence is considered. In particular the mechanisms through which the national and the regional specificity affects firms' organisation and firms' external interactions are emphasised. The impact on innovation of institutions and non-firm organisations such as universities, research institutes and government policies together with specific forms of market and non-market interactions among firms (including the financial systems) are analysed. The way globalisation affects the role of supporting institutions and firms' interactions is also considered. Differences and complementary features between different approaches are singled out and implications in terms of technology policy are drawn.

The *second paper* 'Sectoral System of Innovation and Production' aims at examining the *main dimensions of sectoral systems.* It discusses concepts and methodology regarding the analysis of sectoral systems. The paper starts from a definition of sectoral system as composed by a set of heterogeneous agents carrying out market and non-market interactions for the generation, adoption and use of technologies and for the creation, production and use of products that pertain to a sector ("sectoral products"). It points out that sectoral systems have knowledge and a technological base, and have key links and dynamic complementarities among products, knowledge and technologies. The agents composing the sectoral system are individuals and organisations (both firms and non-firm, such as universities, financial organisations, and so on), as well as organisations at lower or higher levels of aggregation. These agents are characterised by specific learning processes, competencies, structures and behaviours. They interact in a market and non-market way through various processes, and

their interactions are shaped by institutions. A sectoral system changes over time through co-evolutionary processes.

The paper emphasises that sectoral systems may prove a useful tool in various respects: for a descriptive analysis of sectors, for a full understanding of their working, dynamics and patterns of change, for the identification of the factors affecting the performance and competitiveness of firms and countries and finally for the development of new public policy indications.

The novelty of this approach has to be confronted, on the one hand, with the industrial economics literature dealing with industries and, on the other, with the systems of innovation literature dealing with innovation and change. With respect to the first one, the sectoral system approach differs significantly from econometric industry studies, the structure-conduct-performance tradition, the transaction costs approach, sunk cost models and game theoretic models of strategic interaction and co-operation, which emphasise differences across industries in the contexts in which economic agents act. First of all it pays a lot of attention to the knowledge base and the learning processes of agents. Second, it focuses on within-sector heterogeneity of agents in terms of learning, competencies, organisation and behaviour. Third, it pays a lot of attention to non-firms organisations and sectoral institutions. Fourth, it stresses the role of dynamic complementarities. Finally, it focuses on change and dynamics of the whole system through co-evolutionary processes.

With respect to the system of innovation literature, the differences regard mainly the focus on sectors rather than on technologies or countries, and the inclusion of production in addition to innovation. The concept of innovation systems in the literature is very broad and encompasses a wide variety of topics and issues. Other more focused concepts have either a technological dimension or a geographical one. The first include *technological systems,* in which the focus is mainly on networks of agents for the generation, diffusion and utilisation of a technology. The second include the studies in the *national systems of innovation* literature tradition. Here the focus is on national boundaries and on non-firms organisations and institutions, with the inclusions of a wide variety of sectors. A tradition closer to sectoral systems is the studies on *regional or local systems:* very often in fact a local system overlaps with a sector (see for example the studies of industrial districts and the machinery industry).

The *third paper* discusses the *geographical boundaries*. The theoretical development on this issue is still in its infancy. However, this part of WP1 addresses the questions such as the spatial boundaries of sectoral systems and their relationship with national systems; the effects of the nature of the knowledge base and the mechanisms of knowledge transmission on the geographical boundaries of that system; the coexistence of different spatial boundaries (e.g. local and global boundaries) within the same sectoral system. The paper on the "geographical boundaries of sectoral systems" should contribute to build up the conceptual framework for the more applied WPs in the project. It targets a key methodological issue, such as how to define the boundaries of systems to be studied, and at the same time deals with a fast-growing literature within industrial economics.

The late 1980s, and even more the 1990s have witnessed a growing interest in the economics of industrial clustering. While initially fuelled by the popularisation of a number of success stories of regional and urban booms or revitalisation, this new wave of studies has increasingly focused on *innovation as a possible determinant of localisation.* Even mainstream economists, once renowned for their neglect of the geographical viewpoint, now concur fully to this research agenda.

In particular, international trade theorists, growth theorists and industrial economists seem to have re-discovered Marshallian agglomeration forces, such as economies of intra-

industry specialisation, labour market economies and localised knowledge spillovers, and to have been fascinated by the last one.

In fact, although the most up-to-date contributions to the economics of technological change suggest that localised innovation advantages may be caused by any of the above-mentioned agglomeration forces, it is localised knowledge spillovers that have attracted most research efforts, dominated much of the debate between economic geographers and economists and fascinated many policymakers.

This dominance may be explained by the possibility, once recognised that knowledge spillovers exist, to look for them not just within the realm of industrial activities (production, marketing and broadly defined "innovation"), but also in between the two worlds of university research and corporate R&D. More precisely, if proximity can induce knowledge spillovers among firms, why not thinking about the possibility to see knowledge flowing *from* university departments, public R&D labs, and other research institutions *to* firms.

In this paper the authors conduct a sceptical enquiry on the relevance of knowledge spillovers as an agglomeration force. The authors devote most efforts at challenging the evidence on localised spillovers between academic and public research institutions and firms, but the authors will also look at some recent evidence which run against former simplistic accounts of knowledge spillovers among firms. Then the authors highlight a few crucial logical contradictions in much recent literature on the geography of innovation and in particular a *de facto* failure to move away from a *linear* view of technical progress, and to absorb the most recent advances in the economics of innovation. From this critique, one can move on and examine sceptically many policy measures, which have become increasingly fashionable in the past few years.

The *fourth paper* conducts an *econometric* analysis of sectoral systems for the advanced countries. The analysis points at a fine sectoral disaggregation and to international comparability of the data in order to assess the relevance, dynamics and performance of the main sectoral systems. The starting statement is to test whether the international technological specialisation and the international trade specialisation of countries in a specific technology/product are affected by the specific structural variables of sectors. This paper tests whether there is a significant relationship between these structural variables and the international technological and commercial specialisation of countries or whether this relationship is mediated or even overpowered by the nation-specific variables. The empirical analysis is conducted for 132 technologies/products and six countries (G6) in the period 1989-1994 with the OECD Foreign Trade by Commodities dataset and the EPO-CESPRI dataset for patents.

(i) First, the authors test whether for all the 132 technologies/products, some 'structural and organisational' variables, like concentration and degree of entry (which could be related to sectoral systems as well as to national systems), are able to explain international specialisation. Panel data analysis allows an econometric treatment of country and sector specific effects.

(ii) Second, the authors show that these 'structural and organisational' variables differ in terms of presence and combination across broad groups of technologies/products. The authors construct few clusters of technologies/products groups related to different specific combinations of these 'structural and organisational' variables. Thus typologies of sectoral systems are identified.

(iii) Finally, the authors test whether the intensity of the specific 'structural and organisational' combination of sectoral system variables for a group of technologies/products affects the international specialisation of that group of technologies/products (i.e of that sectoral

system) or whether 'national' variables related to national systems of innovation (that cut across sectors) are more important for international specialisation.

The paper gives the macro-picture on cross-country common characteristics of sectoral innovative activities and on the determinants of export and technological specialisation of countries for each technology/product. Moreover it is a useful tool to single out differences across sectoral systems in the relation between technological, structural and institutional variables and export and technological specialisation and provides a background picture for the qualitative and in-depth analysis of the sectoral studies.

Finally *the fifth and the sixth* papers are *theoretical.* These modelling exercises point at the formal exploration of the dynamic properties of different sectoral regimes of innovation. They open a dialogue between theoretical questions and empirical research. The general task is to develop a quite general formal framework in order to account for some stylised and "archetypical" forms of knowledge accumulation – i.e. *technological regimes* -, and, to map them into *regimes of industrial evolution.* Building upon (Winter, Kaniovski, Dosi, A Baseline Model of Industrial Evolution, [1997]), the SSSA has completed a specification of the model corresponding to an entry-driven learning process (often defined as the "Schumpeter Mark I" Regime). Quite robust properties – derived via both analytical methods and simulation exercises – have been presented in (Winter, Kaniovski, Dosi, Industrial Dynamics with Innovative Entrants, [1999]) at the Manchester meeting.

Different "regimes" are characterised by a) specific stochastic processes describing the arrival of firm-level innovations; b) different mechanisms of access to the above by entrants and incumbents; and c) different selection dynamics determining the growth and survival of firms. On the grounds of such framework, one is able to assess (i) the properties of learning and industrial dynamics that are, so to speak, "generic" – i.e. they hold irrespectively of the specificity of the sectoral innovation system -, vs. (ii) regime-specific features (e.g. in terms of the long term role of entrants, survival probabilities, size distribution of firms, industrial concentration, etc.).

The S.Anna Unit researches explore with its extra paper the interplay between entry, selection and innovative learning as determinants of industrial evolution. We propose a model, mainly derived from the formal framework proposed in Winter, Kaniovski and Dosi (2000), aimed to capture the essential features of learning and competition as drivers of the dynamics. Using both analytical and numerical techniques, we are able to disentangle possible generic properties which robustly hold for a wide range of parameterizations. In particular, we identify different generic ``evolutionary archetypes" in turn defined by characteristic interactions between entry/exit regimes, learning and industrial structures.

A *seventh paper* has been provided by CRIC's research team. They have produced a survey of the innovations systems literature entitled, "Distributed Innovation Systems and Instituted Economic Processes". This paper provides an important background to the empirical work CRIC is undertaking, as it establishes the connections between evolutionary and systemic perspectives on the innovation process. They used the paper to summarise various systems approaches to innovation, to relate these to systems thinking more generally, and to identify what is distinctive about the systemic approach. From this the authors have been able to identify a number of new themes which form the background to CRIC's empirical work. The three most important of these are:

- a focus on the dynamics of the co-development of the innovation systems and service delivery

- an assessment of the consequences of the systemic dimension for the observed pattern of innovation taking into account successes and failures

- the development of a systemic failure perspective on innovation policy as an alternative to the market failure perspective.

WP2: Six Sectoral Systems in Europe

WP2 represents the core of the project in which six sectoral systems are examined. Each sectoral study addresses a common set of questions which are built around six major topics: knowledge base and learning processes; firms, non-firm organisations, networks and institutions; geographical boundaries; long term dynamics of the sector and co-evolutionary processes; public policy and international performance. Each sectoral study examines these issues in different ways and different depths according to the specificity of the sector and also guarantees uniformity and comparability across sectoral studies. Each sectoral study is developed in a flexible way. It follows its own methodology with a specific number of countries or geographical areas upon which the study is based. Such freedom of research is required in order to deal with the heterogeneity of each sectoral system.

In what follows we describe the analysis of the research carried out in the different research projects of WP2. Each research project corresponds to a sectoral study and has been carried out by a research team which brings together researches from different centres in different countries.

RP1: SERVICES

Co-ordinator: ESRC Centre for Research on Innovation & Competition, University of Manchester (CRIC).

Research Team: Prof. Stan Metcalfe, Dr Bruce Tether, Dr. Mark Harvey, Mr. Andrew James (from 1.6.99).

Progress

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

- Emergent Innovation Systems and the Delivery of Clinical Services: The Case of Intra-ocular Lenses. *J S Metcalfe and Andrew James*
- Horndal at Heathrow? Co-operation, Learning and Innovation: Investigating the Processes of Runway Capacity Creation at Europe's most Congested Airports. *Bruce Tether, Stan Metcalfe.*
- Deep Transformation In The Service Economy: Innovation And Organisational Change In Food Retailing In Sweden And The Uk. *M Harvey, A Nyberg and S. Metcalfe*
- Innovation Systems & Services. Investigating 'Systems of Innovation' in the Services Sectors – An Overview. *Bruce S. Tether, J. Stan Metcalfe and Ian Miles.*

Methodology

The analysis of services answers the general questions posed in the WP2 objectives, by conducting both direct research (interviews) and by drawing on research conducted by CRIC. The RP1 focuses its study on a number of European countries. The primary research method is case studies based investigation supplemented by national statistics.

Scientific Findings

The RP1 addresses three service sectors, which CRIC considers to be representative of the considerable diversity of service activity, namely *Airport Services, Retailing Services and Medical Services.* In addition a summary paper addresses the peculiarities of innovation and industrial dynamics in services vs. manufacturing, with special reference to the services chosen for the case studies. Three papers on three separate service sectors, medicine, retailing and airports have been prepared and presented at the ESSY meetings.

The study of innovation systems in medicine has focused on the advancement in intraocular lens technology (IOLs). Such systems, it is argued, are constituted by elements at multiple levels, transnational and national, sectoral and regional. What matters most for the actual course of innovation is their micro systemic element. To understand how these processes work we need a far more detailed understanding of micro innovation systems and how they are constructed around connected problem sequences. National organisations, in the form of health care systems and their differences have certainly framed the development of IOLs but the framing is weak and contingent. More constraining are the sectoral attributes that lie within particular branches of ophthalmic practice and the links between surgeons and major ophthalmic companies. However, these sectoral constraints spill over national boundaries and change over time as the innovation is diffused within different healthcare systems.

A second study is on innovation in a low-tech, backward economic activity: food retailing. This is a comparative analysis of its development in the UK and Sweden where different national markets and their instituted attributes have resulted in widely different patterns of innovation based change. Food retailing in the UK has changed dramatically since the early 1960s as new forms of organisation have interacted with new technologies in relation to information technology, packaging and display, transport and logistics, and food manufacture. The economic space is defined in terms of the relations between five distinct classes of economic agent: Primary producers, Food manufacturers and processors, Distributors and intermediary markets, Retailers, Consumers. It is argued that what differentiates Sweden from the UK are the specific configurations of the relationships between these classes of economic agent, and, within each of them, the specificities of business models (and for consumers, the consumption styles and shopping strategies). Both in Sweden and in the UK there have been different 'deep transformations' of these relations over time. There is an innovation system that had to be created to match the new model of food retailing, that is not naturally determined by national institutional factors and that changes as the constraining problems change. The dynamics of innovation is coupled to a dynamic of the underpinning innovation system. In fact the supermarket retailers are 'constructing' their own micro innovation systems as an element in their competitive strategies. Innovations resulting from collaboration with one supplier, say logistic services, become available to other retailers operating in the same business mode. In effect, while competing individually, they are also competing as a group against the traditional business

model of retail activity. Thus competition at the level of the market is underpinned by the differential ability to create a productive innovation system.

The study on airports emphasises that services are not (normally) engaged in the production of tangible products, but cover a huge range of diverse activities, associated with various types of transformation - i.e., transformations of people (physically and mentally), things and information. Studying services brings to the fore the relationships between business models, organisational forms, technology and outputs to a greater extent than studies of manufacturing (which tend to focus on the product produced). Studies of services also highlight the significance of knowledge forms other than, or complementary to, technological knowledge (and R&D). In particular the significance of market knowledge and procedural knowledge is highlighted. 'Sectors' or 'sub-sectors', as these are conventionally defined, do not bound the systems of innovation. Instead, the systems involve a wide range of agents from many different 'sectors' (including both different manufacturing sectors and different service 'sectors').

An interesting feature of these systems is that the agents involved (and the inter-relationships between these agents) can change over time: thus the boundaries are not fixed but are dynamic. Systems of innovation can be considered to develop around identifiable problems (or opportunities), which are themselves framed by a number of contingencies (including the regulatory, cultural and technological context). In this way, the problem or opportunity at the heart of the 'system of innovation' becomes the focusing device around which it is developed.

In some cases the problem / opportunity is obvious – such as in the case of airports and the problem of insufficient runway capacity to meet demand, and in the case of seeking a remedy to failing eyesight due to cataracts. In other cases the problem / opportunity is not so obvious – as in the case of retailing – and in such cases the problem / opportunity becomes a matter of interpretation that may need to be constructed, negotiated and even institutionalised. In UK retailing, the problem / opportunity might be interpreted as being how to gain and maintain primary access to consumers (against direct and indirect competitors). Notably, this has been achieved through the centralisation and control of distribution functions.

Importantly, the problem / opportunity is often contingent, not only on the technological fundamentals (and past sunk investments), but also on the regulatory and institutional constraints. For example, at airports such as Frankfurt and London Heathrow the problem of inadequate runway capacity would not exist (or at least would be very different) if (as in the case of Paris Charles de Gaulle) they were permitted to build new runways. It is because they have not, that the pattern of innovation at these airports has followed a different road.

As there are several sectoral systems of innovation and production in manufacturing, so there are several sectoral systems in services. Although it is difficult to generalise, it is possible to identify, as in the papers by Thether-Metcalfe-Miles (2001), some general features of sectoral systems in services. These features and dimensions are present also in manufacture, but in services they have a often prominent place. The services examined in the ESSY project represent a first exploration of these main features, dimensions and dynamics of the service sectoral systems.

The first point is that in services *products are closely related to processes*. The emphasis on processes and on the actors and institutions that are active in these processes, makes the concept of sectoral system even more useful. Often innovation has restructured the sectoral system of innovation by creating markets for specialised equipment and supplies, such as the one related to clinic based delivery of the surgical service in the case of medical services-

intraocular lenses. In this case the delivery of the removal of cataracts combined with the implantation of an artificial lens was achieved by the change in procedure from the one requiring one single surgeon with craft techniques within capital intensive contexts to a routinised procedure which could be done in a local medical centre (Metcalfe-James,2001 in ESSY).

Second, great emphasis is given to *knowledg*e embodied in equipment and in people and to *changes in the domain* of this knowledge related to the diffusion of information and communication technologies, as well as to instrumentation and other devices. Thus, the link with manufacturing (and the related transformation of knowledge domain that have taken place recently) is quite relevant in most services. In airports, the case of runway capacity extensions shows a move away from direct operating experience and observations towards the use of sophisticated information technologies support tools (such as the final approach separation tool that allows spacing between arriving aircraft). This was also associated to the use of new type of knowledge (such as mathematical modelling, computer science, and so on) and the pressure to change the use of integers as units of distance in order to better measure minimum distance separations. On the contrary, R-D is less relevant for services than for high-tech manufacturing, except in sectors such as software or telecommunication services.

Third, actors such as suppliers (of equipment) and users play a major role. Interaction is particularly important in services. As the case of air traffic services in airports and the creation of runway capacity show, the innovation process is usually the outcome of the interaction of the service provider and the service user. Actually, this co-production is much more relational than in manufacturing, in which the manufacturer may change unilaterally the organisation of production, and may involve both joint operation and the search of mutually acceptable solutions (Thether-Metcalfe,2000 in ESSY). In retailing, the actors involved include food suppliers, logistics companies, retailers and consumers (Harvey-Nuberg, 2001 in ESSY). On the contrary, universities and research centres have less relevance in services than in manufacturing. Thus, as in manufacturing, demand is particularly important for innovation and the process of construction of demand is central to the emergence and growth of specific sectoral system of innovation. The close interaction with users is quite relevant in the formation of new services (and consequently new sectoral systems).

Fourth, institutions play a great role both in terms of procedures and mechanisms (think of the mechanisms of airport slots discussed by Thether-Metcalfe,2000 in ESSY), and in terms of formal regulations, standards and privatisation. Procedural change plays a major role in services. In the air traffic service case, procedural change related to the bunching of aircraft away from the first come first serve basis, and the usual of dual glideslope, is negotiated between the service provider (air traffic control) and the users (airlines). In the case of medical services- intraocular lenses- innovation results from the interaction between clinicians and the different national ophthalmic health systems, connected by international networks of clinicians and transnational health companies. Various practices and theories within ophthalmology played a major role (Metcalfe-James,2001 in ESSY). In the case of embedded software, efforts to assure safety involve considerable potential for displacing own-production in favour of specialised embedded software 'system' producers which can invest the resources necessary for 'robust' systems by serving many different clients (see also Steinmueller 2001, in ESSY RP2).

Fifth, services are less international than manufacturing, and are usually produced locally. However new technologies are allowing a more extensive division of labour that has also geographical dimensions, such as the decentralisation of back office functions (routine operations) and centralisations of control functions and of value added services (core control functions). Thus internationalisation of services in terms of spatial division of labour has been taking place, with certain function being internationalised with the diffusion of information

and communication technologies. These tendencies are observable in enterprise resource planning software markets where the generic systems produced by SAP and the American competitors Oracle and Microsoft rely upon international markets for achieving the necessary investment in platform development and an international supplier network for accommodating user needs for specialised 'modules' to customise the platform for specific applications (see also D'Adderio 2001, in ESSY RP2).

Sixth, services show continuous change and transformation over time, and not always necessarily in favour of a greater convergence and alignment. First of all, services have all been affected by ICT, which has triggered major changes at all levels. Second, they have become more and more characterised by professional management. Third, as just said, major geographical division of labour has taken place. The paper by Harvey-Nyberg (2001, in ESSY) for retailing shows the major transformation of grocery distribution in terms of leading actors from global food manufacturers to retailers and supermarkets, and from production of generic products with the exploitation of economies of scale to the differentiation of areas and stores and a major attention to consumer interface. Here however national differences due to historical starting conditions and contexts, have affected the specific path of transformation. In the UK for example retailing is an integrated business and the retailer orchestrate the business. Also in Sweden retailers have a leading role, but the cooperative movement tradition led to a federation of end-retailers and to a more decentralised pattern of local and small scale production.

The previous example indicates that countries differences in organisation and performance raise some interesting issues for services. First, as shown in the case of retailing, differences in organisations of sectoral systems may be due to the major local content of services. The case of intraocular lenses show the role that differences in ophthalmic health systems played a major role in affecting international competitiveness of countries. The internationalisation of some of the services (or parts of them), the spread of professionalisation and the role of multinational companies may introduce various levels of analysis, which encompass both local and international dimensions. The case of intraocular lenses have also shown that differences in ophthalmic health systems and the role of major ophthalmic multinational have greatly shaped the system in various countries. Second, and related, the interaction of these elements has major consequence for performance. Again in the case of intraocular lenses, the interaction of national health systems and multinational ophthalmic corporations led to the leadership of the United States, after an early predominance of Europe, and particularly of the UK. However, the international performance of various countries in services may be difficult to assess in a clear and uniform way, because the value of services may be difficult to measure and because services may be organised in different ways in different countries. In general, however, as Tether-Metcalfe-Miles(2001 in ESSY) mention, the Unites Sates have adopted new technologies more rapidly and more widely and have applied scientific management and commercial logic to processes in services than Europe has.

Finally, public policy considerations stress different aspects than the ones for manufacturing: skilled labour training (a key element for services), advanced regulations and standards for the professionalisation and the responsiveness to change of services (see for example the case of GSM), diffusion of information technologies in the provision of high quality services (and eventually support of small and medium enterprises in some advanced services such as knowledge intensive business services -KIBS). (Thether-Metcalfe-Miles,2001 in ESSY).

RP2: SOFTWARE

Co-ordinator: SPRU

Partners: WZB

Researchers: W. Edward Steinmueller (SPRU), Luciana D'Adderio (SPRU), Mark Lehrer (WZB.)

Progress

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

- The European Software Sectoral System of Innovations. *W. Edward Steinmueller.*
- From Factor Of Production To Autonomous Industry: The Transformation Of Germany's Software Sector. *Mark Lehrer*
- The Software Sectoral Innovation System: Open Source Software and the Alternatives. *W. Edward Steinmueller*
- Embedded Software:European Markets and Capabilities. *W. Edward Steinmueller*
- The Diffusion of Integrated Software Solutions: Trends And Challenges. *Luciana D'adderio.*

Methodology

The analysis of software answers the general questions posed in the WP2 objectives, by conducting both direct research (interviews) and by drawing on the research of the two Centres dealing with horizontal themes. The RP2 focuses mainly (but not exclusively) on the major European countries. A particular attention is also placed on government policy which affects the performance of the European software industry through a variety of paths. Both TAP and ACTS are 4th Framework RTD programmes and current indications are that RTD activities in these programmes can be combined in the 5th Framework. The implications of such developments for each of the sub-sectors are therefore examined in this research project. Government policies that have an effect on the European software industries are, however, not limited to RTD policy. An important part of the research effort on government policies affecting the European software industry is to enumerate and examine the importance of these other influences of government policy.

Scientific Findings

Software spans over several other sectors, ranging from computers, to consumer electronics and so on It is also embedded into several products. In software the context of application is relevant for innovation as well as the vertical and horizontal division of labour among different actors. The role of large computer suppliers in developing integrated

hardware and software systems has been displaced since the early 1980s, with the spread of networked computing, the Internet, the development of open system architectures and the growth of web-based network computing. A lot of specialised software companies innovate either in package software, or in customised software. Here the role of the university has become important because it plays a role in the open source domain.

But the analysis of innovation in software has to be differentiated because many subsectors are present, each of which has different types of products, firms and capabilities. IPR play a major role in innovation and competition. *In the integrated enterprise software sub sector* for example a tension between higher generalisation and higher specialisation in the knowledge bases was identified. Both large integrated software and small niche software producers draw from the knowledge made available by local as well as global networks of users in order to improve on their existing and create new products. There is effectively a trend towards co-development between user and producers whereby both have to find the most appropriate balance between generality and specificity. For example, producers aim to build increasingly generic systems that can be applied to a greater range of users, while at the same time attempting to make their modules specific enough to appeal to individual customers or user sectors. Customers instead aim to fully draw the benefits of adopting a standardised package and at the same time demanding a product that better fits their idiosyncratic requirements and local settings (D'Adderio in ESSY 2001). Standard setting alliances support common standards in order to facilitate the diffusion and adoption of large integrated systems (i.e., by supporting the modularisation of software and by ensuring the compliance and interoperability of specialised niche and legacy applications with the generic system's platform).

In particular the papers in RP2 deal with the following issues:

First of all SPRU is delivering a paper (*The European Software Sectoral System of Innovations, Ed Steinmueller*) with the findings from the analytical and empirical work on the European software sector conducted for the ESSY project. This paper provides a synthesis of the main issues and findings as well as a collection of policy recommendations and areas for further investigation. Moreover it provides a thorough description of the software sectoral system of innovation in Europe.

This paper has pointed at the tension between two major alternative co-ordinating mechanisms, the role of technological standards and the role of dominant competitors in specific segments of the software industry. European firms tend to rely upon the co-ording mechanism of foreign companies or on the emergence of open standards. The nature of competition in the software industry ('winner takes all') tends to benefit the dominant competitors and the companies that are located geographically closer. This disadvantages European firms and suggests to increase the scope for 'open standards' and 'open source' software'.

Internal development of software is a major source of employment for software professional in Europe. The principal problem with improving the sectoral system of innovation for this type of software is the dispersed and situated nature of the development efforts. European companies such as SAP and Software AG have had considerable success at a global level in the Integrated Software Solutions market. It involves the creation of a 'network' of related firms co-ordinated by the producer of a platform application. Supporting these companies involves the policy advice to strengthen the ability to found and build small and specialised software companies.

The Diffusion of Integrated Software Solutions: Trends and Challenges (Luciana D'Adderio). This paper examines the evolving market of enterprise software focussing on Product Data Manager (PDM) and Enterprise Resource Planning (ERP) software applications, two of the

largest categories of enterprise software. Key findings of the paper include: Europe is the home of one of the largest producers of such type of software –SAP- as well as a growing number of smaller companies. There is a growing tension between the extension of generic capabilities of the main products and the emergence of smaller 'niche' producers. The extension of generic capabilities reduces the scope for entry of specialised 'niche' companies.

Despite these developments, the market for specialised entry remains strong although it appears that the degree of specialisation is increasing and therefore the relative size of specialised companies may fall further. Despite the importance of European players such as SAP and BAAN, the extent of US participation is increasing with Oracle and Microsoft adopting similar strategies in organising specialised suppliers.

Embedded Software: European Markets and Capabilities (W. Edward Steinmueller). This paper analyses the embedded software industry on a global level with special attention to European producers and markets. Key findings of the paper include: despite the importance of embedded software for European manufacturing companies, Europe has created a much weaker infrastructure for the support of embedded software than the US. This situation is of particular concern because this area of software is in transition and moving towards a greater dependence on new scientific theories for the design of such software systems. The new theories are becoming increasingly necessary for meeting the safety, reliability, and complexity requirements of modern embedded systems. Among the reasons for the difficulties of European producers in this area are the continuing emphasis on in-house development by large companies, the separation of research and production activities, and the disciplinary specialisation of European computer science and informatics departments. The latter makes is a poor fit for the inter-disciplinary activities required for advances in knowledge in this area.

The Software Sectoral Innovation System: Open Source Software and the Alternatives (W. Edward Steinmueller). This paper examines a key development in the software industry, the open source software movement. The open source movement is part of the Internet-related segment of the European software system. This paper examines the rationale and development of the open source movement and points to some of the benefits that the movement may provide for European companies and society. A leading innovation of the open source movement, the Linux operating system, was produced in Europe and many European software engineers have contributed to other open source products, including Apache, the leading Internet server application. Open source software provides an important international strategy for linking the efforts of computer programmers and can contribute to increasing the cohesion of the European Research Area. Open source software development requires a pre-existing working conception and model for the software project, preferably a working software program that needs enhancement. The development of 'seed' projects for open source development depends upon the diversity of activities in the software field so that university activities in software development are important potential sources of 'seed' material.

Open source software development requires a new kind of entrepreneur; it is important to enhance the social structures that give rise to the involvement of this sort of individual. Substantial opportunities exist for open source software development in areas outside the operating system and operating system utility markets where efforts have, so far, been principally located. Exploiting these opportunities will require rethinking the 'commercialisation'-oriented policies now governing European research investments in the software field. Research examining other Internet-related software in the area of multimedia indicates the relatively greater importance of distribution channel development over technological issues in this area. This suggests that this area will not warrant the same treatment as the other three sectors that we have been considering.

Finally a paper by WZB focuses on the comparative characteristics of Germany's software industry. It looks at the business segments that German software firms specialize, examines the nature of their various business strategies; and considers the components of Germany's "national system of innovation" in regard to software: education and training, government policy, and organized interest formations. All three aspects of the German software industry are in a state of rapid transformation, as reflected in the current German high-tech boom and the growth of the Neuer Markt. Hence the characterization of the German software sector is very much that of an industry in transition.

In the traditional world of mainframe computers, much of German software development by done by user companies themselves without recourse to external software markets. Government programs to support software development regarded software engineering largely as a technological factor of production and was little concerned about influencing the software industry *qua* industry, as an arena of competing firms. This was reasonable for as long as software development was accomplished without market transactions. In the meantime, however, Germany's software sector is organizing itself increasingly according to market principles - including the market for political influence (lobbying). For policy-makers this means putting a greater emphasis on improving the efficiency of market mechanisms for creating and disseminating software know-how alongside the traditional emphasis on funding software R&D as a public good.

The diffusion-orientation of Germany's public support programs deserves to be continued. But in the future it will no longer be only a question of creating the conditions for new knowledge creation, but of nurturing *innovation markets* in the area of software (which increasingly overlaps with the entire information and telecommunications sector). Software innovations in Germany will not only arise at universities, technical colleges, and the typical joint industry-university research projects subsidized by government, but will emerge increasingly out of interactive market processes and the dynamics of competition. If Germany can position itself as the world's second most important national innovation market for software and software services - a goal that is eminently reachable and perhaps already attained -, then global software players will see Germany not only as a market to sell to, but as a strategically important market for innovating in and for developing next-generation products and services.

This means that future public policy for software should rest on multiple pillars so as to be equally attentive to the needs of scientific, entrepreneurial, and service-oriented developers of software. The increasing importance of software *markets* implies the need for institutions of higher-learning and research to position their educational curricula and contract research in a more strategic way. *In fine*, dynamic market processes will lead to an increasingly differentiation and specialization of software knowledge requiring an analogous differentiation and specialization of such knowledge in Germany's public institutions.

RP3: TELECOMMUNICATIONS HARDWARE AND SERVICES

Co-ordinator: TEMA

Partners: CESPRI, IKE

Research Team: Charles Edquist (TEMA), Leif Hommen (TEMA), Esa Manninen (TEMA), Bent Dalum (IKE), Gert Villumsen (IKE), Nicoletta Corrocher (CESPRI).

Progress

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

- The Fixed Internet and Mobile Telephony Sectoral System(s) of Innovation: equipment production, access provision and content provision *Charles Edquist*:
- The Internet services industry: Sectoral dynamics of innovation and production and country-specific trends in Italy and in the UK. *Nicoletta Corrocher.*
- Fixed Data Communications – Challenges for Europe. *Bent Dalum, Gert Villumsen.*
- Three Generations of Mobile Telecommunications Systems & Services: European standards, 1970 to 2000. *Leif Hommen, Esa Manninnen.*
- Data Communication - The Satellite and Tv Subsystems. *Bent Dalum.*

Methodology

RP3 examines the dynamics in the telecom sectoral system by stressing the interplay between hardware and services, the role of large firms and new entrants and the impact of the body of regulations on the structure of the telecom sector. The analysis of telecommunications hardware and telecommunications services aims at answering the general questions posed in the WP2 objectives, by conducting direct research and by drawing on the research of the two Centres dealing with horizontal themes. The study of the telecommunication sector is based on interviews and field analyses as well as from material available from organisations such as the OECD, the EU and the IDATE. The telecommunications sector has been the subject of numerous studies and reports by both national and international organisations (UIT, WTO etc.). Several studies of a more academic nature are also available, and contain analyses of changes in the regulations as well as the strategies of the firms and other players in the sector.

Scientific Findings

Telecommunication hardware and services is a very large sector, with converging technologies and segments, with several sub-sectors and segments and a wide variety of different specialised and integrated actors involved in innovation, ranging from the large telecom equipment producers to the new telecom service firms. The increase in the number of actors is due to the process of convergence of previously separated sectors such as telecom, computers, media, and so on, and by the process of privatisation and liberalisation that occurred in Europe since the mid 1980s. In this broad sector innovation is very much affected by the institutional setting and by standards. Internet is becoming a major part of the telecommunication industry. The main scientific findings form the telecom ESSY research project can be emphasised as follows.

In *telecommunications hardware and services* the knowledge base has been quite diversified because the sectoral system examined in this project is quite large, expanding rapidly and

encompassing both fixed communications (Dalum-Villumsen,2001 in ESSY), satellite communications (Dalum,2001 in ESSY), mobile phones (Hommen-Manninen, 2001 in ESSY) and internet services (Corrocher,2001 in ESSY). All these subsectors present different features, but they are technologically related. Moreover, this broad sectoral system has been recently affected by the processes of convergence between information and communication technologies and between ICT and broadcasting-audio-visual technologies. Until the advent of the Internet, the telecom service industry did not experience major technological and market discontinuities (Dalum-Willumsen,2001 in ESSY). With the internet and its open network architecture, modular components and distributed intelligence, both the knowledge base and the types of actors and competences have changed significantly (Corrocher,2001 in ESSY).

The process of convergence has generated the entry of several new actors coming from various, previously separated, industries, each one emphasising different sets of competencies. For example, in telecommunication equipment and networks firms may range from incumbent telecom equipment suppliers and incumbent network operators, to new entrants telecom operators, cable TV operators and alternative network providers (Dalum-Villumsen, 2001 in ESSY). In Internet services, firms may range from Internet service providers, to Internet content providers, e-commerce companies and software and Internet specialised consulting companies. Specialised competencies and specific knowledge have increasingly become a key asset for firms survival and growth, but even more important in the new telecom environment is the combination of existing and new competencies - software programming, network management, content provision - which traditionally belonged to different companies (Corrocher,2001 in ESSY). Also in this sector networks among a variety of actors, not only firms, but also standard setting organisations and research organisations, are relevant. Demand plays a key role not just in terms of user-producer interaction, but also in terms of emerging characteristics. This is particularly true in the Internet services sector, where the changing requirements of the final users - from standardised services like Internet access and e-mails, to more complex applications such as Intranets, Extranets and platforms for electronic commerce - have stimulated firms to upgrade the quality of services.

Networks for example played a role in the case of GSM. The GSM success could be ascribed not only to the strategies of few innovative producers, but also to the role played by a variety of quite different actors: PTO/PTT, standard setting organisations and research organisations. In fact GSM was introduced by a Nordic consortium formed by national PTO/PTT with the major involvement of key producers such as Ericsson and Nokia. These firms were inserted in a regional consortium which was based on a historical close collaboration between Nordic producers and the Nordic PTO or PTT. These public sector actors had been already key to the development of the first generation standards NMT. These PTO/PTT co-operated within a formal organisational framework provided by CEPT (European Conference of Posts and Telecommunications). This regional Nordic consortium then became a Pan European Standard, ratified by ETSI (European telecom standard institute). ETSI (standard development organisation) membership consists of PTO and PTT, telecom manufacturers, public research organisations and telecom service providers (300 members). The shift from CEPT to ETSI was marked also by a shift from closed to open approach to standard development. Public research organisations also had a major role in the development of GSM (while they did not have a role in the development of NMT). For example, in Sweden Ericsson co-operated with universities. In addition COST (European co-operation in the domain of technological and scientific research- a European intergovernmental agreement for promoting research by supporting public research organisations), heavily funded the development of GSM and made he results available to ETSI. (Hommen-Manninen, 2001 in ESSY)

In sum, regulations, liberalization/privatisation and standards have played a key role in the organization and performance of the sector. As discussed in Dalum-Villumsen (2001, in ESSY) liberalization and privatisation has had major effects on the behaviour and performance of incumbents and has transformed the structure of the industry. An example of the role of institutions is given by GSM. As previously discussed, standards have played a major role in innovation and in the success of GSM in Europe. In particular, concerted standard settings, European and open standards have proven a major driving force. Originally, GSM was the result of the old regime of protected national telecommunication markets and public sector monopolies (GSM generation phase). The liberalization and the entry of new network operators with the new policy regime introduced in Europe with the EC Green Paper on Telecommunications (1987) helped GSM in the diffusion phase. Thus in the case of GSM we had a balance between coordination in the development phase and competition in the diffusion phase. In general, over time there has been a shift in terms of key actors from multipurpose monopolistic organizations (POT/PTT and major equipment producers) to a new division of labour in which roles are more widely distributed (SDO, specialized PTO/PTT, and so on) (Hommen-Manninen, 2001 in ESSY). In internet services, local regulation (such as legislation on interconnection fees for the diffusion of internet and the one regarding taxation with respect to electronic commerce) as well as social and cultural factors have shaped the supply of internet services differently across European countries (Corrocher,2001 in ESSY).

In *telecom* hardware and services the early separation of the radio spectrum for use in one-way broadcasting and two-way telephony has given rise to the oligopolistic structure of the industry that persisted for quite a long time (Dalum-Villumsen,2001 in ESSY). The convergence between within ICT and between ICT and broadcasting-audio-visual and the emergence of internet has originated a more fluid market structure with a lot of different actors with different specilisation and capabilities, and new types of users. This in turn has greatly expanded the boundaries of the sector by creating new segments and new opportunities, and also national differences in the organization of innovation. Moreover, the emergence of internet has generated more pressure in favour of open standards and has led to the rise of new actors such as ISP and content providers.

In telecommunications, hardware has to be kept separated from software and services. In *telecom hardware* European countries have a similar market structure with respect to American in equipment. Here the coexistence of large global players and specialized firms has been associated with the global dominance of mainly Americans firms (Dalum-Villumsen, 2001 in ESSY). On the contrary, in *Internet service industry* national features strongly influence innovation and the rate and the direction of technological change. In the various European countries the characteristics of local markets differ greatly, as the case of the UK and Italy show (Corrocher,2001 in ESSY). Also between Europe, United States and Japan major differences exist.

In Internet services, in Europe the advent of free service has seriously undermined the position of ISPs, while strengthening the position of content and network providers. The process of standardisation of the protocols for mobile communication has also played out in a quite different way in Europe and in the US and it partly explains the leadership of the European countries in this market. In markets with a well-developed network and with a high level of competition – US and Japan, but also UK and the Scandinavian countries - the incumbents and the new entrants compete both on traditional communications services and on more enhanced services over the Internet. In those countries, the development of new access technologies and of increasingly efficient transmission protocols stimulate the introduction of value-added services, which can be customised to the specific requirements of users. On the other hand, countries such as Italy, Spain and France have a less developed

Internet market, not only in terms of diffusion of services among the potential users, but also in terms of infrastructure and competition among providers. Those countries generally do not have a wide installed base of cable TV infrastructure. In terms of institutional framework, the Internet sector greatly benefited from the process of liberalisation. Technological and market developments may anticipate and thus constrain regulators' decisions. This process is very much dependent upon country-specific characteristics. As we have seen, the UK and Italy have had two different experiences: in the first case, the technological progress has anticipated the changes in the regulatory framework, while in the second case the liberalisation of the market has followed the process of technological convergence, without stimulating the development of innovations.

In telecommunications, Europe has a major success: GSM. GSM has been the result of the interplay of several factors: the presence of large capable and innovative firms, the increase in external cooperative links, a regionally based consortium with close collaboration among actors, the move to a pan European standard ratified by European standard organizations (Hommen-Manninen,2001 in ESSY). GSM success could not be ascribed only to the strategies of few innovative producers, but to the collaboration of a variety of quite different actors: PTO/PTT, standard setting organizations and research organizations. One could say that European past success in GSM will not necessarily be replicated in the third generation mobile telephony because some of the conditions of the success of the first generation and second generation no longer apply. In particular, liberalization has reduced the central role of monopolistic PTO/PTT, so that close interaction and large sheltered domestic markets are more difficult to obtain from the start for new products.[1]

As Casper-Soskice(2001 in ESSY) noticed, recently in the telecommunication sectoral system some of the institutional features that characterize the Swedish national framework (such as the long term relationships between firms and employees) have been modified in order to take into account the new characteristics of the innovation process in mobile phones. Ericsson recognized that wireless technologies require open standards and the full exploitation of network effects. Thus in the late 1990s Ericsson decided to make its last system integration language open rather than proprietary, and sponsored the formation of new start ups which are spin-offs from Ericsson and which aimed to develop products compatible with Ericsson's new generation of wireless technologies. While introducing this new policy of open standard and support of networked new firm formation, Ericsson maintained some of the features of the Swedish system by allowing engineers leaving Ericsson to return if their start up fail.

[1] The European success in GSM took place while in the United States rival standards competed. They included the D-AMPS supported by the US Cellular Telephone industry association (CTIA) and CDMA, which emerged later but attracted more operators. Neither of the two standards were directly compatible with each other. Contrary to the European decision on GSM, CTIA opted for backward compatibility with first generation analogue systems, so that an incremental shift could take place. In addition the FCC (Federal Communication Commission) ruled in 1988 that there would not be a national digital standard, but only compatibility among different standards. These two decisions were going to have profound effects on the competition between GSM and American standards, because they reduced the speed of transition from the first generation to the second generation mobile phone. Thus no single standard came to dominate the US market. CDMA was technically superior to D-AMPS in terms of capacity gains. But CDMA had limited availability of terminal equipment and was implemented differently by each operator. So the slower diffusion of digital systems in the US was due to the presence of two standards and a weaker migration from the first generation to the second generation due to backward compatibility. In addition, in Europe the structure of tariffs on mobile services was different and roaming and caller pay issues were resolved much earlier (Hommen-Manninen,2001 in ESSY).

RP4: PHARMACEUTICALS AND BIOTECHNOLOGY

Coordinator: CESPRI (Luigi Orsenigo).

Partners: SSSA, TEMA, WZB

Research Team: Giulio Bottazzi (SSSA); Steve Casper (WZB), Elena Cefis (CESPRI), Maureen McKelvey (TEMA), Hannah Kettler (WZB), Nicola Lacetera (CESPRI), Luigi Orsenigo (CESPRI), Fabio Pammolli (SSSA), Massimo Riccaboni (SSSA); J Owen-Smith and Woody Powell, University of Stanford, collaborated to RP4.

Progress

In accordance with the contract with the Commission, four papers have been delivered to the Commission. Three extra papers were delivered by CESPRI and SSSA.

- Pharmaceuticals as a Sectoral Innovation System. *M. McKelvey and L. Orsenigo*
- Does Co-location matter? Knowledge Collaboration in the Swedish Biotechnology- Pharmaceutical Sector. *M. McKelvey, H. Alm and M. Riccaboni.*
- A Comparison of US and European University-Industry Relations in the Life Sciences. *J. Owen-Smith, M. Riccaboni, F. Pammolli, W. W. Powell.*
- National Institutional Frameworks and the Hybridization of Entrepreneurial Business Models: The German and UK Biotechnology Sectors. *S. Casper, H. Kettler.*

The extra papers are:

- Firms' Growth in the Pharmaceutical Industry. *E. Cefis, M. Ciccarelli and L. Orsenigo.*
- Innovation and corporate growth in the evolution of the drug industry. *G. Bottazzi, G. Dosi, M. Lippi, F. Pammolli, M. Riccaboni.*
- Corporate Governance and Innovation in the Pharmaceutical Industry: Some Further Evidence, *N. Lacetera.*

Methodology

The analysis of pharmaceuticals and biotechnology answers the general questions posed in the WP2 objectives, by conducting both direct research and by drawing on the research of the two Centres dealing with horizontal themes. The project is based on the simultaneous use of different methodologies, with a comparative and dynamic approach.

Historical analysis are used to reconstruct the structure and evolution of knowledge, the biomedical research systems and the main policy regimes (e.g. property rights regimes, price controls, and reimbursement policies) across countries. Interviews with research institutions, scientists, companies, public officers (e.g. regulatory agencies) are used to analyse the interactions among the multiple actors that define the system of innovation in this industry. Also standard statistical and econometric techniques are used on a database on firms' R&D expenditures, new chemical entities and sales (both at the level of therapeutic classes) and patents for the 100 largest world pharmaceutical companies over a period of around 20 years.

Scientific Findings

In the *pharmaceutical and biotechnology sector* several different actors are the protagonists of innovation: large firms, new biotech firms (NBF) and small firms. They interact with a lot of different agents: universities, public agencies, venture capital and physicians. In this sector regulation, IPR, national health systems, and demand play a major role in the innovation process. The dynamics of the sector could be interpreted as a process of adaptation to major technological and institutional shocks. Change has been dramatic. In the early stages of the industry (1850-1945), pharmaceuticals were close to chemicals, very little formal research was done until the 1930s and licenses were widely used. Later on in the "random screening period" (1945-early 1980s), R-D became extremely important, and search took place through the random screening of natural and chemically derived compounds. Few blockbusters were discovered every period, but each one had a very high growth. Patents have been widely used. The industry structure became rather stable, with large pharmaceutical firms doing most of the R-D. Increases in final demand were due to the process of increasing collectivisation of health care. Finally, the molecular biology revolution in the late 1970s and early 1980s again caused major changes. Now, a wide variety of science and engineering fields are continuing to play important roles in renewing the search space for this sector. New biotech firms have entered into the sector, competing as well as co-operating (or being bought up) by the established large pharmaceutical firms. More recent changes in regulation and demand are also squeezing the profitability of firms and opening up new opportunities in generic drugs.

Consequently in the *pharmaceutical industry* the knowledge base and the learning processes have greatly affected innovation and the organization of innovative activities. Nowadays no individual firm can gain control on more than a subset of the search space. Innovation increasingly depends on strong scientific capabilities and on the ability to interact with science and scientific institutions in order to explore the search space. (McKelvey-Orsenigo,2001 in ESSY, Henderson-Orsenigo-Pisano, in Mowery-Nelson,1999)

The change in the knowledge base discussed above led to a different organization of innovative activities within and across firms. Division of labour took place between NBF which lacked experience in clinical testing and established companies that (with time) adopted molecular biology. Networks of collaborative relations facilitated by the science base and by the abstract and codified nature of knowledge generated by the NBF, emerged in the sector. Also mergers and acquisitions allowed established firms to obtain complementary knowledge for the development of innovative products. As of now, the pharmaceutical-biotechnology sectoral system has a structure of innovative actors which includes large firms, NBFs, small firms, and single individuals (such as scientists or NBF entrepreneurs). In addition, a very rich set of non-firm organizations and institutions greatly affect innovation, ranging from universities to the public and private research systems, the financial system and venture capital, the legal system and IPR. Demand channelled through agencies, physicians and the health system, and institutions such as regulation have played a significant role in the

diffusion of new drugs. Nowadays no individual firm can hope to gain control of more than a subset of the search space. Even the innovativeness and competitiveness of the largest pharmaceutical firms depends on strong scientific capabilities and on the ability to produce and interact on one side with science and scientific institutions (in order to explore such a complex space) and on the other with specialized innovative firms (in order to develop new products). (McKelvey-Orsenigo,2001 in ESSY)

National health systems and regulations have also played a major role in affecting the direction of technical change, in some cases even blocking or retarding innovation. (Lacetera-Orsenigo,2001) In addition, the form of corporate governance is closely related to the country of origin: the outsider system in UK and insider system in Germany, with France in between. (Geoffron-Rubinstein,2001, in ESSY). Finally patents have played a major role in the appropriability of the returns from innovations. European countries exhibit differences in terms of national institutions, demand, networks of knowledge acquisitions, etc., and such national differences have appeared to historically affect the national firms (McKelvey-Orsenigo,2001 in ESSY). Over time, the markets for knowledge as well as the markets for products are becoming increasing international, as are regulations and scientific and technological knowledge flows. Nevertheless, national institutional arrangements appear to influence not only the number and types of biotechnology firms started but also their specialization into different areas, as evidenced by differences between Germany and the UK (Casper-Soskice, 2001 in ESSY). In Sweden, firms tend to engage in collaboration for knowledge areas at the intersections of biotechnology-pharmaceuticals to a large extent with international partners - especially American and British ones. In Sweden local interactions among firms in order to formally collaborate to develop new knowledge has been uncommon, while interaction among small firms and local universities has been more likely - if the firms had any interactions with universities (McKelvey-Alm-Riccaboni,2001 in ESSY).

The interaction between knowledge and technological factors and the institutional and country-specific factors have shaped the evolution of the system of innovation. On the one hand, changes in the knowledge base and in the relevant learning processes of firms have induced deep transformations in the behaviour and structure of the agents and in their relationships among each other. On the other hand, the specific way these transformations have occurred across countries has been profoundly different, due to details of the institutional structure of each country. Thus, in addition to supply and demand, also institutions and incentives have influenced demand, supply and knowledge development. For example, the nature of the processes of drug discovery and development in the second epoch had an important impact on the patterns of competition and on market structure. The innovative R-D intensive companies were profitable and competitive. The overall market competition and market structure were in turn dependent on the strategies and fortunes of individual companies, which were linked to different national contexts and/or international phenomena. Firms have diverse reactions in order to try to increase their fit and to survive in their particular environment. These environments keep changing, not least due to innovations and choices made by all the constituent competitors: while these environments could previously be said to be national, the defining characteristics are increasingly international. (McKelvey-Orsenigo,2001 in ESSY)

In this sectoral system knowledge, actors' competencies and institutions have coevolved continuously. As an example, product approval regulations inserted an incentive towards more innovative strategies, at least for those firm and countries which had the capabilities to invest in the new technologies. Similarly, weak patent protection induced imitative strategies, but this effect was much less important for firms and countries which had developed strong technological and scientific capabilities (as for example Germany until the advent of the molecular biology revolution). Conversely, the introduction of stronger patent

protection might have contributed to the practical disappearance of the Italian industry, which was until the mid-Seventies one the most successful producer of generics. As a final example consider how the molecular biology revolution, by creating new competencies and a new technological regime, induced deep changes in the incentive structures within firms, universities, etc.. (McKelvey-Orsenigo,2001 in ESSY). In this process of adaptation and change, different dynamic processes lead to differential patterns of competition and performances.

In sum the contribution of each paper in this Research Project can be outlined as follows. First, CESPRI and TEMA (Maureen McKelvey and Luigi Orsenigo) have produced a paper discussing the evolution of the bio-pharmaceutical sectoral system of innovation over the past 25 years and examining and discussing the interplay between technological, institutional and policy actors in shaping the dynamics of the industry in the USA, Europe (and partly Japan).

Second, SSSA (Fabio Pammolli and Massimo Riccaboni) have performed an analysis of the network of collaborative relations. They have conducted an econometric analysis of the determinants of the probability of establishing agreements and have analyzed the structure of university-industry relations in Life Sciences, in collaboration also with J Owen-Smith and Woody Powell, University of Stanford.

TEMA's contribution to the bio-pharma group, has resulted in the paper (jointly with Massimo Riccaboni) 'Analysing Collaboration for Knowledge Development in the Swedish Biotechnology-Pharmaceutical Sector'. This paper analyses interactions involving at least one Swedish actor in biotechnology-pharmaceutical. Using different databases including a new one developed through this project, the paper analyses how, why, and when interactions occur and the effects on innovation. Interesting trends about the changing patterns of interaction and about the quite different groups of firm strategies are identified.

Steve Casper and Hannah Kettler (WZB) have written a paper on the institutional factors shaping the evolution of the biotechnology industry in Germany and the UK. This work involved final interviews with UK and German companies, government, and finance representatives as well as extensive literature reviews and meetings with biotech consultants. The project raised some important questions about policy, especially for the UK case.

A third stream of research, conducted by CESPRI and SSSA, has concentrated on the analysis of the patterns of industrial dynamics. Making use of the quite unique PHID database - which allows also the longitudinal study of market dynamics at quite high levels of disaggregation – the SSSA research unit has pursued the analysis of:

- corporate growth processes - in particular with reference to the possible dependence of growth shocks on corporate size; the distribution of the shocks themselves and their autocorrelation over time;

- the process of arrivals of innovation;

- the patterns of corporate diversification across 'micro' markets.

The results of the analysis are presented in Bottazzi et al. (2000). Also the paper by Elena Cefis and Luigi Orsenigo (CESPRI) investigates some properties of the patterns of firms' growth in the pharmaceutical industry, using somewhat different statistical techniques than the usual ones (a Bayesian approach that takes into consideration heterogeneity at the firm level) Results suggest that there seems to be strong evidence against Gibrat's law (on average) and that previous results are probably incorrect because they are based on models that do not control for potential heterogeneity in the slope coefficient. A more "structural"

model of the processes of firms' growth is then estimated, examining in particular the role of innovations, persistence of innovative activities and stocks of accumulated knowledge.

Finally, a CESPRI extra paper by Nicola Lacetera on corporate governance in pharmaceuticals has been done. It suggests an original interpretation of some organizational dynamics, that have characterized pharmaceutical industry in the last thirty years, like the increased importance of skilled scientists within firms and the development of inter-organizational alliances for the division of scientific labor, as affecting the governance structure and the innovative effort of firms. Preliminary empirical support is provided, concerning a panel of large US pharmaceutical companies.

RP5: MACHINE TOOLS

Coordinator: Jürgen Wengel, Fraunhofer ISI

Partners: Phil Shapira, School of Public Policy at GeorgiaTech

Progress

In accordance with the contract with the Commission, one paper has been delivered to the Commission:

- Machine Tools: The Remaking of a Traditional Sectoral Innovation System?, *J. Wengel, P. Shapira.*

Methodology

The analysis of machine tools answer the general questions posed in the WP2 objectives, by conducting both direct research and by drawing on the research of the two Centres dealing with horizontal themes. The RP5 combines quantitative data, in order to describe and analyse the overall performance and development of the sectoral system in machine tools, with a qualitative approach, in order to understand the particular forms of co-operation and innovation between machine tool manufacturers, its customers and the respective innovation infrastructure. The focus is on the major suppliers of machine tools in Europe, with a particular focus on Germany, Italy and the UK, compared to Japan and the United States. For the quantitative approach general databases (like Eurostat, CIS, and the general Delphi surveys in Germany and Japan) and sector-specific surveys are used. Such surveys exist in several countries, including the US (US Census Bureau; Performance Benchmarking Service; Georgia Manufacturing Survey) and Germany (FhG-ISI survey "Innovations in Production" 1995 and 1997). A comprehensive review of relevant literature and empirical research on the machine tool sector complements the quantitative data processing. Particularly relevant here is the recent studies of the Ifo-Institute in Munich for DG III. The qualitative approach focuses on the regional clusters of machine tool manufacturers. Studies here can provide insights into changing sectoral boundaries, networking, co-evolution and the impact of innovation infrastructure and support schemes.

Scientific Findings

ISI focus is the machine tool industry. It examines :

- the influence of the regional innovation system elements through the reference to existing studies highlighting the regional aspects,

- the impact of the national innovation system via comparison between countries (Germany, reference to other European countries, US and Japan)

- technological specificities by including analysis of three 'technology areas': Teleservice, Dry Processing and manufacturing processes for Mobile Fuel Cells.

It uses these analyses to advance three principal hypotheses about sectoral innovation systems in machine tools.

1. The sectoral boundaries of the innovation system in machine tools have significantly shifted in recent years.

2. The sectoral scope of innovation in machine tools has broadened.

3. The sectoral form of innovation in machine tools has evolved at the leading edges of the industry, from tacit systems to strategic partnerships.

The country, company, and technological examples described by the study illustrate that established systems of innovation in the machine tool industry are undergoing change and partly dissolution, while at the same time new relationships are being forged. Today, the outline of the emerging sectoral system of innovation, as characterized by the case studies, appears as characterized by: more openess, partnerships, regional to international in scope, new technology-based, information-intensive, linkages with research centers, producers, and users, and increased codified knowledge. These shifts are not always complete. For example, while international linkages for innovation development have emerged, regional and national systems continue to have strength in this sector. That said, that there are shifts and changes is undeniable.

A key critical factor in the further development of the European machine tool industry certainly is the continuous re-building of the knowledge base. Germany at least has been facing shortages of qualified labour, both on the shop-floor and with engineers, which is feared to become an inhibiting factor to growth. Apparently, work in manufacturing has to be made more attractive. In this respect, there seems to be room for modernisation of work organisation and processes in the European machine tool industry. A strength of the industry always was the integration of theory and practice or of manufacturing and design (not least due to the fact that the industry is among its own best customers). Increasing relevance of science and subsequent increasing distance of the R&D and design processes from the production area may threaten this strength. Entries do not play an outstanding role in the industry. However, the cases of Italy and of the United States and their success in parallel with some volatility of the number of companies indicate that the entry-exit issue is worth more consideration.

In machine tools incremental innovation is quite common and R-D plays a less relevant role than in other sectors. Horizontal innovative co-operation is not common, while links with users are very important. Thus, demand has played a major role as a stimulus for innovation. Skilled personnel on the shop floor level and applied technical qualification play major roles in new product design and development. Products are increasingly being modularised and standardised. Thus, suppliers of components get the chance to involve themselves in innovation making use of generalised defined requirements. Regional clusters

are very important. Thus localised user-producer interaction, learning spillovers across producers, national differences in the structure of demand led to international differences in the rate and direction of the new technology.

In machine tools innovation has been mainly incremental and now becomes increasingly systemic. Knowledge about applications is very important, and therefore user-producer relationships as well as partnerships with customers are common. The knowledge base has been embodied in skilled personnel on the shop floor level with applied technical qualification and in design engineers not necessarily with a university degree but with long-term employment perspectives in the company. Internal training (particularly apprenticeships) is quite relevant. However, knowledge building and maintaining in this way is challenged by economic/financial pressure from the one side (as could be observed in the recent crisis) and by labour market restrictions (currently represented by a strong competition on experts) from the other. In small firms R-D is not done extensively and R-D cooperation is not common. Recently, the knowledge base has shifted from purely mechanical to mechanical as well as microelectronic based and information intensive, with an increasing codification and an increasing use of formal R-D. Products have increasingly being modularised and standardised. A key role is also played by information flows about components among producers of different technologies, such as lasers, materials or measurement and control devices. In sum, the sector is characterized by local skills, user-producer interaction, national differences in the structure of demand (which has in turn led to international differences in the rate and direction of technical change). But it should not be overlooked that many large machine tool companies operate already on an international basis making use of specific knowledge sources at their different firm sites. And that they complement internal training and local skill with professional recruitment strategies. (Wengel-Shapira, 2001 in ESSY; Mazzoleni, in Mowery-Nelson, 1999).

In machine tools firms are highly specialised, and often focussed on specific vertical segments. Networks here differ from country to country, because the types of products and the different users and demand structures have led to different sectoral systems, each of which has been innovative in its own way. In any case, local financial organisations and vertical links with users play a major role. In addition, it seems that any nation with a relevant machine tool industry sought in the past to strengthen these "providers of productivity" by public, partly indirect measures, for example the German Manufacturing Technology Programmes or the US Manufacturing Extension Partnership. Thus, organisations and networks engaged in technology transfer in a broad sense developed. Though the almost exclusiveness of earlier programmes to manufacturing equipment producers has now been abandoned. While "old" actors (industrial and professionals' associations, specialised university and research institutes, prime user firms, producers, traditional suppliers, etc.) still dominate, "new" actors occur on the horizon (share market with the increase in going public, "communities" related to specific technological shifts (fuell cells, nano technologies)). Market mechanisms increasingly show up in yet "non-market" relationships, such as the co-operation in industrial/professional associations, or special customer-supplier interactions in the machine tool sector. And industry public-private consortia increasingly complement the latter. (Wengel-Shapira,2001 in ESSY)

In machine tools, internal and regional labor markets and local institutions (eg. local banks) have played a major role in influencing international advantages of specific areas. There have been differences in this institutional base. For example, in the UK and the US, formal and informal institutional support for machine tool companies has typically been "thinner" than in Japanese, German, and Italian regions. Trust based, close relationships on the regional level have obviously over a long time ensured a sufficient financing of the innovation and expansion plans of the mostly family businesses in Germany and Italy. The

consequence being that other more restrictive, risky or expensive ways were rarely used and that more radical changes took seldom place. In Germany vocational training has greatly fostered the development of skills in the machine tools industry. The "Maschinenbau-Ingenieur" (mechanical engineer) in the German higher education system went along with the pre-dominance of mechanical innovation. Rather stable employment conditions and company employment strategies (internal labor markets) formed the background for cumulative knowledge building and incremental innovation (Soskice 1997). Standards are an easily overlooked institution in the machine tool sector as standardisation seems generally a routine activity with a long tradition not only with respect to health and safety but also with respect to economies of scale. They built a basis for the share of development tasks between the machine tool makers and the suppliers of components and periphery equipment. This adds again to a predominantly incremental innovation regime. The EU machine directive was fundamental for the realisation of the Common Market, particularly in the machine tool industry. And the way it was shaped probably influenced the development of the industry and the respective success of certain companies (and member states). The "self certification" or relatively open definition in the directive turned out in favor of the already internationally more competitive companies rather than to open up competition. (Wengel-Shapira,2001 in ESSY)

Machine tools are often local in the organisation of supply although they are global in terms of demand and outputs. Data from the Fraunhofer ISI manufacturing innovation survey 1999 in Germany on the average regional distribution per firm in mechanical engineering of the input and the output underpin that. While the input comes to almost one third from suppliers within 50 kilometers only little more than 10 percent of the output is delivered to customers within the region. Similar figures will be observed when the border is set at the national level The same variety holds for knowledge flows, which could range from very local to very global (see Breschi-Lissoni,2000 in ESSY). The recruitment of skilled shop-floor personnel is usually a local activity. For higher education the strategies are increasingly international and the VDMA lobbies for an extension of the German "green card". At the same time, re-location of production or acquisition of firms abroad in order to fulfil local content expectations, to reach customers, or to round-up the product range is to be observed. Particularly larger firms in the sector make use of specific regional capabilities in the distribution and specialisation of their sites. The competitive strength of leading companies in the sector builds less and less on the regional clusters they are in. Many institutions relevant to the sector are national (such as the educational system), while others mainly European (though with strong national forces such as standards). (Wengel-Shapira,2001 in ESSY)

In machine tools a major driving force for coevolutionary processes is the demand from advanced customer sectors, namely the automotive, aeronautics and defense industries. The main trends in the last decades here may be summarized as follows: slight disillusionment from high automation (CIM, manless factory), engagement in new production concepts ("lean production", teamwork, TQM, etc.), growing environmental concerns, steady incremental innovation in the products but no major technological shift, globalisation of production (transplants). As a consequence, in the machine tool sector incremental innovation remained dominant, some internationalisation of production took place, the user-relationships became more market-like and much discussed technological concepts (eg. flexible manufacturing systems, "automatic" CAD/CAM) never really made it, while the offer of product accompanying services became more and more crucial. However, there are obvious challenges for the machine tool sectoral system. For instance the fuell cell and electrical motor as the basis of the power train in automobiles involves new actors and sectoral cooperation. Another coevolutionary process can be observed in the context of technological developments, namely in electronics but also with respect to new materials,

micro or nano technologies. Electronic devices have increasing shares of the value of machine tools and IT technologies (PC, operating systems, internet) often determine technical solutions on how to control machine tools and on how to integrate them in company production systems. As a consequence, besides electrical engineers computer scientists have partly replaced mechanical engineers in the design departments of machine tool manufacturers and brought with them other ways of working. Some firms have followed strategies of outsourcing or of separating such units. On the shop-floor level a related change in required qualifications took place. New apprenticeships were developed (eg. "Mechatroniker") others are disappearing. However the institution of the "Facharbeiter" in Germany do not seem at risk. Links to basic research are now looked for and patenting had been growing strongly in the last years. Sector-specific associations start cross-sectoral activities and joint organisations.

RP6: CHEMICALS

Co-ordinator: University Pompeu Fabra (UPF), Barcelona – Spain.

Research Team: Walter Garcia-Fontes, Alfonso Gambardella, Fabrizio Cesaroni (from 1.10.1999).

Progress

In accordance with the contract with the Commission, one paper has been delivered to the Commission:

- The Chemical Sectoral System. Firms, markets, institutions and the processes of knowledge creation and diffusion. *T F. Cesaroni, A. Gambardella, W. Garcia-Fontes, M. Mariani.*

Methodology

The analysis of chemicals answers the general questions posed in the WP2 objectives, by conducting both direct research and by drawing on the research. The methodology is analytical, with a strong *historical* flavour. The RP6 starts looking at the historical evolution of the European chemical industry since the end of the XIX century, and it compares that with the evolution of the industry in the US and partly in Japan. The analysis then focuses on the most recent period. The RP6 also focuses on the trends in R&D and innovation, and their role in shaping the present structure of the industry, its patterns of specialisation and division of labour, and its different competitive advantages. The RP6 assesses this trend using industry level data and science & technology indicators, and draws corresponding implications for the competitiveness and growth of the European chemical industry. This latter task of the RP6 is also linked to another TSER project ("From Science to Products: A Green Paper on Innovation in the Chemical Industry", Contract N. SOE1-CT97-1059). The RP6 focuses on some aspects of the co-evolution of institutions, markets, organisations, and companies that are not analysed in detail in the other TSER project. At the same time that the RP6 uses

databases and other quantitative and qualitative information produced in that project to support some of the arguments made in this task.

Scientific findings

The description of the chemical sectoral system of innovation and production has been afforded by focusing on several aspects that characterise the sector and make it different from any other. Explicitly, first, the general boundaries of the chemical sectoral system have been defined, in terms of its dimension, its tradition in innovation and R&D activities, the linkages between this sector and downstream sectors, the innovative patterns existing in this industry, and the evolution of the industry organisation. In doing so, RP6 provided the bases for understanding the role of knowledge and the mechanisms for knowledge creation and diffusion. Second, RP6 explored the phase of knowledge development. By means of a patent analysis, RP6 compared the firm and the cluster as different organisational modes for producing innovations. Third, RP6 focused on the processes of technology diffusion and licensing, after innovations have been developed. And, finally, after having discussed the conditions that brought to the upsurge of a market for technologies in chemicals, RP6 provided some empirical evidence of the latter, and highlighted the role of firms' licensing behaviour in the development of such a market.

The chemical sector is a large and heterogeneous sector with a lot of different products from bulk chemicals to specialty chemicals. Internal R-D has been complemented with external links and the absorption of external sources of scientific and technological knowledge. The major innovators have shown great continuity in their innovativeness. Economies of scale and scope, cumulativness and path dependence, as well as research and commercialisation capabilities, have characterised chemical firms (Chandler,1990; Arora-Gambardella-Rosenberg 1999). The interaction among agents has greatly changed over time and so did the organisation of innovation. At the beginning of the industry firms developed links with universities and with users, while later on industry-university relationships have increased. Now vertical networks between chemical companies and engineering contractors are quite widespread, and specialised engineering firms are a major source of process innovation. In the sector, three types of networks are present: interfirm, university-industry, user-producer (downstream specialty sectors).

One of the main findings of the study is that the history of the industry can be characterised by the presence of a series of big discontinuities. The dyestuff model, the development of polymer chemistry (i.e., the science of chemical products), and the chemical engineering (i.e., the science of chemical processes) were major changes in the knowledge sphere. The shift from coal to petrochemicals in the years before the Second World War had strong consequences on regional leadership in chemicals, and allowed the American chemical industry to catch up with Europe. The emergence of specialised engineering firms (SEFs) made it easier the outsourcing of process technologies and allowed a growing division of labour at the industry level between SEFs and chemical companies. The world demand decrease during the 1980s induced a process of industry restructuring. Contrasting with this view, the history of the chemical industry can also characterised by a big continuity in companies' life, which were able to evolve and compete over time. BASF, Bayer, Hoechst, ICI, Agfa, ICI, i.e. some of the leading chemical companies nowadays, have more than one hundred years history and have been top chemical producers during all this period. This means that between small and large companies, markets, research institutions and other organisations there has been a process of co-evolution, with firms playing the central role within the chemical system.

Then, RP6 paid greater attention to the role of knowledge, by focusing on the mechanisms for knowledge generations and for knowledge (technology) diffusion. As far as knowledge generation is concerned, RP6 compared the firm and the technological cluster as organisational modes for producing innovations. In this respect, the results confirmed a major role for large firms. However, for smaller companies there exists a comparative advantage of being located in a technological cluster, for it typically features a good deal of different and complementary competencies inside the same territorial area. From a comparative viewpoint, geographical proximity in a technological intense region plays a more important coordination function for companies that lack the internal scientific competencies and the organisational capabilities needed to coordinate the R&D collaborations. In this sense, geographical proximity is a good substitute for the organisational proximity.

Finally, our study evidenced a greater role of large chemical companies also once the technology has been developed. In this case, the traditional managerial literature has considered large companies as the locus where the phases of technology development and use are naturally integrated – i.e., large companies develop new technologies mainly for internal production needs. In the last years, however, large firms in chemicals have enlarged the spectrum of strategic options, and have increased their propensity to license out proprietary technologies to other firms. In so doing, they can be considered one of the main actors of that market for (process) technologies that begun with the appearance of the specialised engineering firms during the 1960s in the US.

Information used in the empirical analysis have been drawn from three different databases: a) Chem-Intell, a database on more than 36,000 chemical plants existing world-wide, produced by Reed Elsevier Publisher; b) Chemical Patents, from the European Patent Office (EPO); and, c) S.D.C., a database on the external relationships (Mergers and Acquisitions, Joint Ventures, and other Strategic Alliances) promoted by companies from different sectors over the period 1985-97. The database is produced by Securities Data Company.

The ChemIntell database has been used to study the process of knowledge diffusion, Explicitly, information at the plant level allow to define the source of the technology used in the plant setting-up, and to study the relationships between chemical producers and technology suppliers. It was possible to assess the characteristics and the dynamics of the vertical relationships in the industry, and the technological strategies implemented by chemical companies.

Complementary analyses have been performed by using information drawn from SDC. RP6 explored the characteristics and dynamics of the external relationships promoted by chemical firms in the last decades, and to highlight existing trends in the restructuring process. In so doing, RP6 compared the behaviour of European vis-à-vis US firms.

Finally, by using information from the European Patent Database, RP6 analysed the processes of knowledge creation. In the chemical industry usually patents result from the collective work of several researchers. By looking at the inventors listed in each patent it has been so possible to describe the formation of networks of inventors for the development of innovations, to address questions related to the patterns of knowledge diffusion, and to analyse the existence of knowledge spillovers among firms and sectors.

In chemicals learning processes based on formal search processes have been present since the beginning of the history of the industry [2] with the diffusion of the "synthetic-dyestuff model" (which introduced a scientific base to innovation), and later on with the

[2] After the early origin of the industry centered on inorganic chemicals -soda, soda ash and blench- in the first half of the XIX century

development of organic chemistry (related to the understanding of the chemical structure of new molecules and the possibility of exploiting economies of scope in knowledge for the development of different organic products). This has led to the presence of firms with large R-D departments (some of which active since the beginning of the industry) and to a greater role of universities and other scientific institutes.

Second, changes in knowledge and learning processes have been accompanied by the development of new products which were quite different from previous ones, and by the emergence of different actors and organizations. Let's take the second major change in the industry, polymer chemistry (1920s), based upon the idea that materials consist of long chains of molecules –polymers- linked together by chemical bounds. This change led to the development of materials by design, in which the scientific understanding of chemical composites is the base for different product applications. Polymer chemistry provided a common technological base for developing applications and product differentiation in five distinct markets: plastics, fibres, rubbers, surface coatings and adhesives. The other major change in the industry, the development of chemical engineering and the concept of unit operation (1915) (introduced by A.D.Little at MIT), broke down chemical processes into a limited number of basic components, common to many product lines. This development became the general purpose technology of the chemical sector. It allowed the separation of process innovation from product innovation: process innovation became a commodity that could be traded. In general, one could claim that these changes led to a transformation of firms' learning processes away from trial and error procedures to a science-based approach to industrial research.

Third, advances in chemical disciplines such as polymer chemistry and chemical engineering have created the base for greater codificability of knowledge. In the same time firms' behaviour has enhanced the transferability of chemical technologies. Separability and transferability made possible the transaction of technology in the chemical industry and the emergence of new markets for engineering and process design services for chemical plants.

Fourth, this type of knowledge base has implied that internal R-D has been complemented by external links and knowledge. Nowadays in chemicals innovation requires the interaction between R-D capabilities and external sources of scientific and technological knowledge. (Cesaroni-Gambardella-Garcia-Fontes-Mariani,2001 in ESSY; Arora-Gambardella,1998, Freeman 1968, Rosenberg,1998).

Fifth, technogical knowledge in chemicals is related to strict links between chemical companies and university research. This was certainly true in the past, but university-industry relationships are important even today, especially in some specific and emerging fieds. A recent study by Geuna and Malo (2000) tried to analyse the importance of distance in the process of knowledge transfer from public research to industrial innovation. In particular, they tried to understand whether the knowledge produced by public research institutes and universities is viewed by industrialists as important to the process of innovation in the chemical and pharmaceutical industries, and, given the fact that public research is valued, how the distance from the public research institute or university affects this perception and the use that is made of the research. The results of the analysis carried out in this study highlight the fact that there are significant differences in the degree of importance assigned by industrialists to university and publicly funded research, and that localisation matters both in this regard and in relation to the channels through which its results are obtained.

In chemicals, the structure of the sectoral system has been centred around large firms, which have been the major source of innovation over a long period of time. Large R-D expenditures, economies of scale and scope (Chandler,1990), cumulativeness of technical

advance and commercialisation capabilities have given these firms major innovative and commercial advantages (Arora-Gambardella-Rosenberg, 1999).

The changes in the knowledge base discussed above have affected the types of actors and networks. As mentioned previously, with the diffusion of the synthetic dyestuff model firms scaled up their R-D departments and the role of universities increased. The introduction of polymer chemistry (1920s) affected the structure of the industry because knowledge about the characteristic of different market segments became important so that firms had to develop extensive linkages with downstream markets. The other major change related to the development of chemical engineering and the concept of unit of operation led to an increasing division of labour between chemical companies and technology suppliers, with the rise of the specialized engineering firms (SEFs), which developed vertical links with chemical companies. In this period, university research continued to be important for the development of innovations, and links between university and industry increased. In addition, advances in chemical disciplines and the separability and transferability of knowledge increased the transferability of chemical technologies. Thus there has been a greater role of licencing also by large firms, which in turn increased knowledge diffusion It must be noted that also large firms licensed process technology and that SEFs did not develop radically new processes. Rather, they acted as independent licensors on behalf of other firms' technology.

The increasing reliance on external links for complementary scientific and technological knowledge led to the emergence of networks of three types: interfirms, university-industry and user-producers in specialty segments. However, the relevant networks have changed in relation with the type of knowledge base. In the synthetic dyestuff model firms developed links with universities, and with users. In polymer chemistry and with the diffusion of chemical engineering, networks between producers and users, industry-university networks, and vertical networks between chemical companies and engineering contractors have bee common, with the use of mergers and acquisitions to related and unrelated sectors in order to acquire capabilities (Cesaroni-Gambardella-Garcia-Fontes-Mariani ,2001 in ESSY). In general however, the inventive capacity of a country heavily depends upon the strength of the underlying universities and public research institutes. In this sense, the innovation process of firms relies to a great deal upon research carried out by universities and by public research centres of their own country.

One further type of networks in chemicals is the network of inventors. As described in Cesaroni-Gambardella-Garcia-fontes-Mariani,2001 in ESSY), it is possible to compare geographical proximity among inventors (i.e. physical proximity) as a coordination mechanism for fostering research collaborations with effectiveness of the affiliation of the inventors to the same firm (i.e. organisational proximity). The comparison between the large firm and geographical cluster as mechanisms for inducing collaborations among inventors shows that the larger the firm is: a) the lower is the probability that inventors are co-localised, in the sense that a lower percentage of patents is produced by inventors located in the same place; b) the larger is the network of inventors that collaborate to produce a patent; c) the higher is the number of supplementary classes listed in the patent. Hence, compared to the geographical proximity in a technological cluster, organisational proximity in large companies enhance international networks of inventors, induce a greater number of inventors to collaborate and produce more interdisciplinary or "general" patents. At the same time, smaller firms might have comparative advantages of being in a technological cluster compared to large multinationals. The technological cluster, like the large company, typically features a good deal of different and complementary competencies inside the territorial area. Therefore, firms localised in a technological cluster have limited need for finding these competencies outside the region. Although both small and large firms take advantage from being in a technological cluster, smaller companies rely on the external scientific and technological

environment more heavily than large multinationals. Geographical proximity in a technological intensive region plays a more important coordination function for companies that lack the internal scientific competencies and the organisation capabilities needed to coordinate the collaborations. In this sense, geographical proximity is a good substitute for the organisational proximity.

In chemicals institutions play and have played a critical role concerning two different situations, named restructuring processes and patent policy. Concerning industry's restructuring processes, already in the past (during and after WWI), national governments allowed or promoted the creations of cartels and national giants. Germany and Great Britain are clear example in this direction. While in Germany the presence of chemical trade associations made it easier to create a link between the government and the individual firms, in Britain the absence of such associations imposed a deeper intervention by State authorities. The British State took control over large parts of the economy, and reorganised the chemical industry (traditionally independent of Government) to supply chemicals for the war needs. As a consequence of this "forced" co-ordination, the leaders of the largest chemical firms came to know one another. Both in Britain and in Germany different trade associations and alliances among firms emerged. In Britain, the chemical industry organised itself in the Association of Chemical Manufacturers. In Germany, the eight largest dyes producers formed a "quasi-cartel". The interesting aspect of this situation is that, apart from their role in the wartime, the stronger interaction among chemical firms had a deep influence in defining the structure of the chemical industry in the inter-war period. Since 1980s, the chemical industry has entered a new phase of restructuring, in which public policy has played a role as well. In that period, governments managed the restructuring process to a good extent, especially in France and Italy.

The second important role of institutions in chemicals is related to patent policies. These are especially relevant to small firms. Indeed, proper forms of intellectual property rights and strong enough patent protection supported the activity of smaller technology-based firms. In turn, this created the bases for a division of labour between technology suppliers and users, and allowed the development of markets for technology. This pattern was particularly evident in the US, where patent protection was properly defined earlier. By contrast, European markets for technology are far from being developed, and this requires policy support for their formation, firstly – but not only- in terms of policy for intellectual property rights.

The chemical sectoral system has always been global, and for many years the industry has shown considerable flows on international investments, and systematic flows of engineering and process licenses. While up to the 1980s foreign investments were to a large extent confined to first world countries, in the recent decades there has been an increase in the flows towards the developing countries as well. As a matter of fact, chemical investments in these countries have become a critical strategy of the major multinational chemical firms from the advanced world, and to some extent the ability to invest in these countries has become a major factor in enhancing their competitiveness, and more generally an important element for competition in the industry. Moreover, apart form foreign direct investments in plants, the developing countries have become important areas for inflows of process licenses and engineering services. Again, the competitiveness of the chemical firms in advanced countries is often related to their ability to operate and invest in these markets, as well as on their ability to complement these investments with related technology flows through licenses or engineering services. Analyses of investment flows (Arora, Garcia-Fontes and Gambardella, 1998) show that the European chemical industry has moved abroad its investments. However, the same can be said for the American and Japanese chemical industry. This means that there has been an increasing globalisation process for this industry,

that can be translated into a significant increase in the number of chemical plants built in Asia, coupled with a decrease of the domestic share of Japanese of the domestic share of Japanese firms in Japan, American firms in the US and European firms in the European Union. In general, it can be said that there is a trend toward the location of plants near the customers and the fast-growing regions, where the demand and consumption may be stronger. This trend might be related to an increase in product differentiation and customisation of plants, together with an increased concern on reducing transport costs. However, as far as the European dimension is concerned, there is some evidence that the process is stronger for the chemical firms from the European Union. These firms have been major actors in the increase in investments in Asia, and in the reduction of shares for domestic firms in the US and Japan. Indeed, the trend for the location of European firms in North America, Japan and Asia is stronger than the trend of American and Japanese firms locating in Europe.

In chemicals, processes of coevolution of technology, demand, markets, agents and institutions have also been present. One interesting example of coevolutionary process in chemicals is related to the environmental issue. The chemical industry has often been accused of being highly responsible for pollution, and chemical firms, before others, have been highly committed to solve environmental problems. Some relevant accidents (e.g. Seveso, Bhopal) have contributed to generate a diffuse suspicion against chemical firms and the industry as a whole. This greater attention paid by consumers to pollution and environmental problems resulted in three different, but related consequences.

First, with some differences in terms of intensity, all developed countries have assisted to the rise of new markets for environmentally-safe, less pollutant products. Second, governments have paid greater attention to pollution, and have subsequently tried to impose regulations and define appropriate control measure, in order to reduce waste production and pollution. Third, as a consequence of both forces, chemical firms had to develop and adopt new production technologies (environmental technologies, green processes), and new products (e.g., less polluting solvents and paints). Moreover, rigid environmental standards and strong public pressure have a positive influence on the environmental innovative rate of chemical firms. Indeed, another consequence of the growing attention to environmental issues, has been the birth of an intermediate market for environmental technologies and engineering services related to environmental technologies. Similarly to the birth of SEFs providing process technologies in chemicals, new environmentally-related SEFs have started to operate (especially in the US), and a new market for environmental technologies and engineering services is about to emerge (Arduini- Cesaroni, 2001).

WP3: The Interplay between National Institutional Frameworks and Sectoral Systems

WP3 examines the interplay between national institutional frameworks and sectoral systems by analysing the role of national systems of innovation and of a set of specific institutions that cut across sectoral systems in an "horizontal" way. Some general themes are contained already in the sectoral studies such as the role of users and suppliers, universities, and so on. For the horizontal themes we have chosen to focus on four key issues that require closer scrutiny, because they affect significantly the innovation process and the performance of European firms and countries. They are:

- Patterns of National Institutional Framework and Sectoral Systems (RP7)

- The organisation of R-D (RP8)
- The form of corporate governance (RP9)
- The financing of innovation (RP10)

All Research Projects in WP3 will draw information and knowledge from the RPs in WP2 through ESSY workshops, research papers, personal contacts and, when appropriate, special meetings. The degree of matching between the two Work Packages can vary according to sectoral system specificities and the characteristics of the horizontal theme.

RP7: PATTERNS OF NATIONAL INSTITUTIONAL FRAMEWORK AND SECTORAL SYSTEMS

Co-ordinator: WZB

Research Team: David Soskice, Steven Casper (WZB),

Progress

In accordance with the contract with the Commission, one paper from WZB has been delivered to the Commission. Moreover an extra paper has been delivered by CREII:

- Patterns of Innovation and Varieties of Capitalism: Explaining the Development of High-Technology Entrepreneurialism in Europe. *S. Casper and D. Soskice.*

The extra paper is:

- National institutional framework, institutional complementarities and sectoral systems of innovations. *B. Coriat , O. Weinstein.*

Methodology

By means of an analysis of the literature, direct research related to the ESSY sectors, qualitative data and research from ESSY sectoral studies four hypotheses are investigated.

H1. A null hypothesis: sectoral systems impose no requirements on national institutional frameworks (NIFs).

H2. A strong hypothesis: the fortunes of sectoral systems depend closely on NIFs so that each sector tends to "fit" a particular NIF.

H3. A weaker hypothesis: within the same broadly defined sector (e.g. pharmaceutical-biotech or machinery) there are sub-sectors or product group with different institutional requirements.

H4. The behaviour of multinational corporations: Those companies, which need to innovate across all sub-sectors of broadly defined sectoral systems, will base their location strategies on the different institutional requirements of each sub-sector.

Casper and Soskice report is organized into three core sections. First, Casper and Soskice present a broad overview of the national innovation system across different European economies.. Patent statistics show dramatic differences in patterns of industry specialization across Germany and the United States. Casper and Soskice suggest that these differences are caused by variations in national institutional frameworks across the two countries, and briefly discuss why they advantage different firm-level innovation strategies. The next section then draws on this analysis to examine more carefully the challenges facing entrepreneurial technology firms in Germany, Sweden, and the United Kingdom. Drawing from this analysis, the final section assesses different scenarios for the continued evolution of the European innovation systems within the context of supporting new technologies, including the role of public policy.

Scientific Findings

The national institutional framework of the United States economy has proven favorable to the expansion of high-technology industries. Since the early 1980s, the US political economy has evolved to support a dramatic expansion in biotechnology, software, and a variety of other fast-moving high-tech activities with close links to basic science. In particular, the institutional framework of the US has evolved to provide ever more venture capital to high-risk start-up companies, to encourage new links between university scientists and companies, and to encourage, or at least not hinder the reorganization of large companies for exploiting commercial opportunities in high-tech. In Europe firms and policy-makers are anxiously experimenting with their own institutional structures in an attempt to better support science-based high-tech innovation in their own country.

This research project explores the influence of national institutional frameworks on the evolution of high-technology industries, focusing in particular on recent public policy and private sector initiatives to foster larger numbers of entrepreneurial technology start-up firms in Europe. Casper and Soskice analysis draws on extensive field research within the biotechnology and internet software, two of the most important new technologies in which the creation of entrepreneurial start-ups is most important. The paper elaborates and then applies well-known "varieties of capitalism" arguments to examine the development of high-technology in Europe, focusing in particular on entrepreneurial technology firms.

Casper and Soskice evidence supports arguments suggesting that in recent years innovation systems within Europe have embraced important reforms that allow it to systematically foster the development of entrepreneurial start-up firms that are widely seen as critical for long-term success in many high-technology sectors. However, Casper and Soskice evidence also indicates that the vast majority of new technology firms in Europe's largest economy, Germany, are significantly different from their Anglo-American brethren. Casper and Soskice also find unexpected problems within the UK biotechnology sector, which institutional explanations predict should be excelling. Finally, Casper and Soskice found unexpected sources of technology vibrancy within Sweden, a country with a "coordinated" pattern of economic institutions long associated with more incremental innovation trajectories.

Policy-makers across Europe and East Asia, eager to promote the formation of entrepreneurial internet firms, have sought to implant key institutions to support entrepreneurial business models. This has particularly been the case with venture capital. Following Germany's lead in the mid-1990s, most European economies as well as Japan and

South Korea have created "public venture capital" programs to promote the development of high-risk finance. Venture capital subsidies have generally complemented initiatives to create new high-risk stock markets modelled on the Nasdaq, as well as a variety of tax and corporate governance reforms aimed at promoting equity-based financial schemes and employee remuneration.

In Casper and Soskice view, the availability of high-risk finance, preferably associated with sophisticated technical oversight, might be a necessary precondition for the establishment of entrepreneurial technology firms, but is not sufficient. While "technical" expertise in positioning firms is less critical, most application layer firms are also funded by venture capitalists. The business model risks associated with application layer firms, combined with a lack of capital assets, tends to preclude bank loans as a financing mechanism, necessitating venture capital as a primary source of funds. In this respect, government policies to promote the creation of stronger private sector venture capital institutions could influence the formation of application layer start-ups.

However, the availability of venture capital does not "solve" the key competency dilemmas facing either middleware or application layer firms. Core problems facing technology firms relate to human resource and knowledge management dilemmas, not finance. A core conclusion of Casper and Soskice analysis is that different sub-sectors of biotechnology and internet software are associated with dramatically different technology regimes, corresponding different constellations of organizational risk. From a public policy perspective, this suggests that multiple pathways exist. Initiatives to mimic the "Silicon Valley Model" and its associated practices will not breed success in all areas of the new economy. In fact, institutions facilitating "competency preserving" commitments between managers and software engineers are core to the success of application layer firms. The German case in particular shows that biotechnology and internet software firms can thrive within largely "organized" institutional environments.

Ironically, there is a risk that efforts to sponsor increased entrepreneurrism within traditionally "organized" economies might produce more harm than good. Technologically intensive therapeutics and middleware software firms, while best served by liberal institutional environments, tend to develop in technology hubs, often in close conjunction with the activities of network layer firms. The deregulation of labor markets within Continental European economies, to take an oft discussed example, could undermine the long-term viability of firms coping with firm-specific knowledge management programs, while not necessarily spurring an increase in more technologically intense middleware activities. Furthermore, The development of Stockholm's wireless technology hubs shows that more flexible labor market flexibility can emerge within normally regulated labor markets. However, it was not state intervention that has created strong technical communities of engineers and software developers working within wireless technologies, but a series of personnel and technical initiatives by Ericsson, the dominant player within Sweden's telecommunication sector.

The UK biotechnology case also poses a strong challenge for national institutional approaches. Why have a relatively large number of firms embedded within the "right" institutions consistently failed to innovate? To examine problems within the UK biotechnology sector, Casper and Soskice used the varieties of capitalism perspective to understand the credible orchestration of competencies within high-risk biotechnology firms, then demonstrate that a series of small problems within UK institutions may be systematically dampening the ability of UK firms to perform well. Casper and Soskice suggested that while economy-wide institutional environments to support entrepreneurial firms exist within the UK, these institutions have not congealed into a sectoral support system (Mowery and Nelson 1999) capable of systematically supporting entrepreneurial biotechnology firms.

Public policy initiatives within the UK should differ from those in Germany or other "organized" economy. While German policy-makers must manage the hazards of integrating new institutions supportive of new economy industries within the overarching context of an "organized" political economy, the UK government must develop instruments to fortify the orchestration of competencies within generally "correct" institutions. Ironically, the UK government has recently attempted to mimic some aspects of German technology policies – for example through trying to introduce a variety of new regional venture capital subsidies. Within the UK there is little evidence of a "venture capital gap"; rather there are difficulties in creating the mix of technical and commercial expertise needed to govern existing venture capital funds effectively. Similarly, the government has attempted to bolster the development of technology infrastructures through a variety of cluster policies, again modeled loosely on the German model (see Cooke, 1999). While less controversial, again it is not clear that, within the UK's strongly market oriented economy, "markets" cannot do most of the job of providing incentives for patent lawyers, incubator labs, consultants, and other support services to emerge.

Within the UK, policies might more effectively aim to strengthen the development of markets for both scientists and engineers and basic research more generally. Within the biomedical area, it is likely that issues such as the overall funding of basic research could be crucial. While funding has remained strong, UK public and private funding of biomedical research has trailed the staggering investments made in basic research by the NIH and private foundations in the United States. These investments have dramatically subsidized the US biotechnology industry through providing relatively cheap technology and helping to train vast pools of high quality research scientists. Within the UK basic biomedical research funding has remained relatively constant. In addition to creating labor market shortages has the size of public and private sector biomedical research employment has increased, the "pool" of technology potentially available to UK firms has not grown. Recent Wellcome Trust statistics report a massive gap between the US and all other nations in the quality of biomedical research; the UK has performed well, but has declined relative to Germany and Japan in recent years (see Kettler and Casper, 2001). Policies to increase the size and quality of the UK biomedical research establishment might have a far greater effect on the ability of UK biotechnology firms to succeed than cluster policies. Again, these initiative should be viewed within the general context of the UK's liberal market economy.

Overall, while a variety of capitalism perspective cannot provide precise explanations of why particular firms fail, through focusing on the development of credible institutions to support firm-level competency orchestration, it provides a strong investigative lens. A frequent criticism of varieties of capitalism research is that it is a static theory, incapable of explaining change. Casper and Soskice agree that some versions of national institutional framework theory presuppose a "cookie cutter" approach (Kogut, forthcoming), artificially limiting the autonomy of actors within the economy to craft unique organizational solutions, even when facing massive new market opportunities such as those posed in recent years by biotechnology and the internet. Casper and Soskice argue that varieties of capitalism theory, through focusing more carefully on firm-centered micro-foundations, can avoid some of these pitfalls. Viewing institutions as "tool kits" available to managers, scientists, and other actors, Casper and Soskice analyze more carefully how firms engage institutional frameworks to acquire and orchestrate competencies.

The evidence presented here suggests that the types of company organizational structures and investment strategies needed to excel in segments of entrepreneurial technology sectors firms specialized within in Germany, Sweden, and the UK provide a close "fit" with the incentives created by both long-standing institutional frameworks and more recent technology policies and private market reforms. In fact, Casper and Soskice analysis

leads to the prediction that, in at least some segments of high-tech, German firms could develop comparative advantages compared to firms located within the United States in solving certain organizational and financial problems that are crucial to success. Casper and Soskice suggest that while government policies in Europe are unlikely to alter the country's general pattern of industry specialization, framework policies can expedite the process by which firms identify and enter favorable market segments within high-technology industries.

The report of Coriat and Weinstein is aimed at providing some analytical tools to better understand how national institutions influence innovation practices and trajectories, and more specifically at the sectoral level. To achieve this goal they first have tried to better define what should be regarded as an institution and how it shapes the behaviours of the agents. They define institutions as both 'rules of the games' and 'non-market organisation' dedicated to provide the agents with the tangible and non tangibles resources required for their market activities.

Three sets of institutions have been particularly emphasised:

- institutions which provide the basic scientific and technological knowledge and the rules of the game allowing firms to benefit from their involvement in innovation;
- institutions which organise the financing of innovation andthe corporate governance mechanisms,
- institutions which provide human resources and industrial relation systems.

To highlight the sectoral dimension of this framework , Coriat and Weinstein have turned to the analysis of institutional complementarities. They put forward the hypothesis that some complementarities may arise between the three sets of institutions described above. Two alternative models are sketched. First an 'Open Science' model with "Open technology" (where appropriability is based on tacit, non codified knowledge), strong Internal markets and corporate governance systems dominated by Insiders. Conversely there is a 'Patent' model with a strong complementarity is achieved between a strong IPR's regime, a fluid and efficient External Market and corporate systems dominated by Outsiders.

Confronted with real, existing national economies, this opposition may provide useful tools to better characterize the functioning of given national systems. It is thus easy to note that the patent model is quite at odds with the main traits of US innovation system, relatively more conducive to specialisation in sectors like biotech, internet and new segments of IT. The 'open science' model is very close the "rhein" capitalism (ie: Germany of Japan) with a relatively stronger specialisation in mass production and on classical science based industries like Chemical and Aeronautics.

Coriat and Weinstein point out that Europe does not seem to face special difficulties in the sectors organised around the 'open science' principles. However this is not the case for a set of new emerging science based activities. No institutional complementarities have emerged able to provide the type of institutional framework able to favor the launching at large scale of the new activities. This clearly is one of the major challenges confronting the European economies.

RP8: ORGANISATION OF R-D AND SECTORAL SYSTEMS

Co-ordinator: CREII

Research Team: Benjamin Coriat, Olivier Weinstein

Progress

In accordance with the contract with the Commission, one paper has been delivered to the Commission:

- The Organization of R&D and the Dynamics of Innovation A "Sectoral" View. *B. Coriat , O. Weinstein.*

Methodology

RP8 has produced a threefold analysis concerning:

- Internal organisation: different research and development structures at the firm level.
- External organisation: modes of inter-organisational relations in research and development and research networks.
- The extent and nature of government involvement in R-D.
- Main sources will be direct research related to the ESSY sectors, the available literature, standard databases on R&D expenditures and results from the ESSY research on sectoral systems.

In a first section Coriat and Weinstein try to identify the key dimensions of R&D organization and present and discuss some basic models of organization; in a second section they present a sectoral typology integrating of R&D organization.

Scientific Findings

The process of "institutionalization" of innovation and research (Chandler, 1977, Noble, 1977; Mowery and Rosenberg, 1998) and the development of organized structures of industrial research have been a central dimension in the evolution of industrial economies since the end of 19th century. The creation of the industrial research laboratory has been, in particular, one of the major organizational innovations in the history of capitalism. R&D had thus become a central dimension of industrial and innovation systems. And it is not only the volume of expenditures devoted to R&D that became more and more important, but also the complex forms of organizations and institutions that affect R&D efficiency and firm's competitiveness.

It is possible to underscore some general characteristics and tendencies in the principles of organization of R&D, nonetheless there is a great variety of organizational forms, and more particularly a sectoral variety related to the features of technological regimes and the environments of selection (Dosi & alii., 1992, Malerba and Orsenigo, 1996). It seems reasonable to conjecture that the design of a new type of shoe does not raise exactly the same

problems, and does not involves the same procedures that the design of an electronic device, or the creation of a new drug. The Kline and Rosenberg's Chain-Linked Model (1986) allow, for example, to distinguish different organizational patterns according to the modes of coordination of activities and of information diffusion, and the importance given to research, i.e. the favored modes of learning and knowledge creation. Thus Coriat and Weinstein explore the relations between the modes of organization of R&D and the specific characteristics of sectoral regimes of innovation.

This paper aims at highlighting the main characteristics of the organization of R&D proper to different "Sectoral Systems of Innovation", notably to those put under study by the ESSY program. The basic hypothesis underlying this analysis is first that *the "sectoral" dimension – at least to a certain extend- does matter*. To put it in other words Coriat and Weinstein hypothesis is that *sectoral peculiarities contributes to the understanding of the choices made as regards R&D organization, as well as the dynamics of innovation proper to different sectors*. The second basic hypothesis underlying this paper is that institutions play a key role in the determination of organizational forms and their evolution, in particular at the sectoral level.

In particular Coriat and Weinstein analyze the *different functions that any given system of R&D should achieve* to satisfy the requirements of the production of innovation. Coriat and Weinstein then take into account the *sectoral specificities* allowing to explain the specific features of R&D organization, inasmuch the nature of the constraints shaping innovation process and the hierarchy of targets can differ according to sectoral characteristics.

At the empirical level, Coriat and Weinstein concentrate on the organizational and institutional forms *prevailing in the SSI's defined in the ESSY program*. It is the reason why, Coriat and Weinstein lean above all, on materials supplied by the sector-based studies produced under the ESSY program, by completing them as much as need, by materials coming from complementary sources.

Coriat and Weinstein have proceeded in three steps:

1. The identification of the key dimensions and key functions of R&D organizations. Using the theoretical and applied literature on R&D, Coriat and Weinstein have considered the complex function of industrial R&D, and the way to characterize the forms of organization of R&D: modes of division of labor, modes of coordination and modes of governance and incentives.

2. The investigation of the new forms of R&D organization, considering the deep changes in organization during the last fifteen years. Coriat and Weinstein consider some general tendencies : decentralization inside firms, development of externalization of R&D and of alliances and cooperation in R&D, between firms as well as with university or public laboratories, new modes of governance and incentives. Coriat and Weinstein consider also the relevance of the specificities of national systems of innovation.

3. Three basic "models" of R&D organization have been identified:

A first one is focused on the organization of product development across functional integration and project teams structures.

A "Technical integration", or *"Science-based I"* model which concern sectors where on one side technological performance is imperative for competitiveness, and technologies evolve at a rapid pace, in direct relation with progress in research, and on the other side, the design of products and production processes make use of highly diversified scientific and technological knowledge.

The "Science-Oriented Discovery", or *"Science-based II"* model which define a new mode of innovation involving major organizational change in R&D, involving a leading role of basic research . It has been observed mainly in the biotech sector.

In a second phase, Coriat and Weinstein attempt to introduce more explicitly the institutional dimension, in order to underscore the way institutions influence the processes of innovation and affect their forms of organization. Coriat and Weinstein consider, on one side, fundamental and general institutional forms (intellectual property rights, forms of corporate governance, characteristics of labor markets…), and their functions in various sectoral contexts; and, on the other side, sector-specific institutions (regulatory agencies in telecom or pharmacy for example).

This investigation, combined with the consideration of the three models of R&D organization, give us a general framework to explore the links between sectoral systems and R&D organization and characterize some sectoral systems of R&D organization. Coriat and Weinstein explore the application of this framework to different sectors: Scale intensive (as a useful reference) ; Machine tools; Software; Telecom equipment; Chemicals; Biotechnology.

RP9: CORPORATE GOVERNANCE AND SECTORAL SYSTEMS

Co-ordinator: CREII

Research Team : P. Geoffron and M. Rubinstein

Progress

In accordance with the contract with the Commission, one paper has been delivered to the Commission:

- Sectoral Systems of Innovation and Production. *P. Geoffron, M. Rubinstein.*

Methodology

More theoretical and empirical research is needed in this area to achieve clearer definitions of alternative models of corporate governance and has been carried out in this RP. Main sources are direct research and interviews related to the ESSY sectors, the available literature and results from the ESSY research on sectoral systems.

Scientific Findings

This report is intended to highlight the transformation of the *corporate governance systems* of Europe. This question is important as corporate governance mechanisms are not neutral: they weigh on production choices and, more broadly, on the design of national and sectoral systems of innovation.

For that reason, Geoffron and Rubinstein objective is to define the impact in terms of innovation and certain sector-based aspects of these alterations. With regard to the Essy program, Geoffron and Rubinstein analyse the new balance between *non market and market interactions* in corporate governance and to emphasize some *coevolution mechanisms* between sectoral and corporate governance systems.

Geoffron and Rubinstein report is composed of four sections:

I) Corporate governance in Europe: Towards the disappearance of insider models? (*Patrice Geoffron*)

II) Which type of corporate governance structure is most conducive to innovation? (*Marianne Rubinstein*)

III) Corporate governance and innovation in the pharmaceutical industry (*Marianne Rubinstein*)

IV) Telecommunications sector : the impact of UMTS on the corporate governance of European firms (*Patrice Geoffron*)

Corporate governance is viewed as a major aspect of firms' performance and economic growth of nations. In the context of the American recovery and the Japanese crisis, since the beginning of the 90's, many have the temptation to attribute the American success to its shareholder/outsider system and the Japanese failure to its stakeholder/insider system.

This debate raises in the context of the transformation of the European insider systems. If the resulting process does not automatically entail the convergence of national systems in Europe towards the outsider case, it calls into question the former coherence of those systems. It is tempting to envision a 'best of both worlds' coherence, but the studies on path dependence show that the local systems generate checks on such a mix and that, in addition, the coherence of the systems is far from guaranteed. The complexity of the insider systems renders them little suited to confront an environment of global competition; the multiplicity of shareholders, the greater reliance on mutually consistent and stable expectations make them less adapted to globalisation than outsider systems.

In this context, it is urgent to shape more precise and explicit links between corporate governance and efficiency. As innovation appears to be a driving force of firms' performance and growth, the determination of the type of corporate governance structure, which is most conducive to innovation, emerges as a very important issue. Any attempt to address this relationship needs to distinguish the organisational and the institutional level of analysis. At the organisational level, the economic literature doesn't give any response, as theories of the firm focusing on governance issues (whether it is shareholder or stakeholder model) fail to take into account the innovation process. At the institutional level, Geoffron and Rubinstein will argue that the «short-termism bias» of outsider systems is not a convincing argument in favour of insider systems and that these two different corporate governance structures may help or hinder different types of innovations and investments**.**

Geoffron and Rubinstein two sectoral studies about pharmaceuticals and telecommunications provide additional arguments in favour of cautiousness concerning the supposed effects of corporate governance on innovation and firms' performance. The pharmaceutical sector is R&D-intensive and dependant on external finance. This type of sector is supposed to be enhanced by outsider/shareholder system. As many M&A occurred in the sector, one can assess that they would allow the firms to converge towards the best corporate governance principles. However, the large European pharmaceutical companies have varied profiles in the area of corporate governance. These profiles are quite consistent with the national typologies, notably the existence of an outsider system in the United

Kingdom and an insider system in Germany, with France occupying an intermediate situation. These profiles show that in the European pharmaceutical sector, the country of origin is a pertinent variable for explaining the diversity of the forms of corporate governance. This heterogeneity in the choice of corporate governance, largely determined by the company's country of origin, may be contrasted with the homogeneity of R&D expenditures which, regardless of the company considered, may be situated at 15 to 17 percent for pharmaceutical products. Thus, beyond the form of corporate governance, it seems that in recent years a standard has emerged for the portion of turnover (in percentage of sales) to be allotted to R&D in order to ensure the group's long-term growth.

Like Pharmaceuticals, Telecommunications is R&D-intensive and dependant on external finance. Unlike Pharmaceuticals, it offers us the example of a sector with rapidly homogenising corporate governance practices. The characteristics of corporate governance are being aligned with the expectations of the minority shareholders constituted by the Anglo-American institutional investors. The transformations under way are going rather clearly and quickly in the direction of the 'good governance' standards in the line of the shareholder/outsider system, despite of some inertia of the capital structures. In this sector, the introduction of UMTS plays the role of accelerator. The introduction of UMTS, by increasing the operators' dependency on the stock markets, is undoubtedly contributing to the acceleration of this trend, which emerged with the deregulation of the sector and the privatisation of its players during the 1990s. In addition, since UMTS is not a standard limited to Europe (unlike GSM), the players' potential markets are more widespread, thus giving rise to a spate of mergers or acquisitions. One result of these operations is the confrontation of the corporate governance practices of companies with different national regimes.

The comparison between the two sectors is meaningful. If there is not doubt that corporate governance matters in firms' performance and innovation, one has to be very cautious about the definition of «best principles», regarding the process of innovation and more broadly, firms' performance. Firstly, the superiority of the shareholder/outsider system has not been yet demonstrated (Rubinstein and Weinstein, 2000). Secondly, the effect of «corporate governance principles» is probably far from mechanic and depends on others institutional aspects. Therefore, if trying to copy in Europe the shareholder/outsider system is not neutral, it is, however, unrealistic (following the path-dependency assumption) and probably an inefficient process.

RP 10: THE FINANCING OF INNOVATION

Co-ordinator : CREII- University of Paris 13

Research Team : Dorothée Rivaud-Danset, Emmanuelle Dubocage

Progress

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

- The Financing of Innovation and the Venture Capital, the National Financial and Sectoral Systems. *D. Rivaud-Danset.*
- The Financing of Innovation by Venture Capital in Europe and in the USA: a Comparative and Sectoral Approach. *E. Dubocage.*

Methodology

It focuses on questions such as who invests capital and how much, and how is the capital allocated on a sectoral basis. Following this, the research examines the causes and the effects of the high cost of project evaluation and monitoring, the reasons for intense sectoral specialisation and the risk of lack of liquidity of the investments even when the firm is performing well. The study also focuses on the relative importance of the financial and non-financial services offered by risk capital and on the ways in which the potential risk of lack of liquidity can be dealt with. RP10 based on a review of the theoretical and empirical literature and on discussions with risk capital and other firms. Main sources are direct research and interviews related to the ESSY sectors, the available literature and standard databases and results from the ESSY research on sectoral systems.

Scientific Findings

The first part of the report by Rivaud-Danset is untitled '*The financing of innovation in manufacturing and services sectors*'. It focuses on the impact of the financial obstacle over innovative firms. It provides evidence that when the industry is mature and/or large firms are the key element of innovation strategies, capital constraints become lighter, although the amount of financial resources required to fund innovation strategies may be very high. In fact in the manufacturing sectors, in the European Union countries investment is often self-financed. Firms meet low capital constraints, as several external financial sources are available (see Nokia case). Therefore, observed differences across sectors or countries in financial patterns do not matter much as regards the financing of innovation issue. This is not the case for the start-ups of the high tech sectors (biotechnology, software industries) where classic financial resources are expected to be hardly available, thus capital constraints are very high, even if the level of financial resources is not so important.

Evidence supports the key arguments of the study of D. Rivuad-Danset. The financing innovation issue is problematic for a set of firms - small, new-comers in services and knowledge-based sectors -, but not for the total set of innovative firms. Banks do not finance R&D, they do not finance innovation, but they do finance innovative, large and incumbent firms, as long as they perform as expected. Banks do favour innovative firms because higher performances have been observed and are expected. Banks do not finance small knowledge-based firms which are new comers operating in an unstable environment. In most cases, finance is not a hampering factor *per se* but correlates with economic risk and cost, and an innovative project, selected as a priority by managers, will be financed. Hence the financial power is located inside the firm.

However, in computer services and more generally in the knowledge-based economy, an innovative project, even if its viability appears high, is expected to lack of appropriate forms of finance, and if it is financed by equity, shareholders have a power on the

entrepreneur. Venture capital is a new financial institution, which is the first one to be orientated towards innovative firms. The second section of the work of Rivaud Danset is entirely dedicated to it (*Venture Capital: the birth of a new financial institutions orientated towards innovative start-ups*'). It develops the idea that venture capital is a new and specific financial intermediary which enforces international norms and is strongly influenced by the US model

Venture capital is the first institution orientated towards innovative firms and, precisely, towards the set of firms for which the lack of appropriate fund is the first factor which limits innovative projects. It supplies not only equity but also non-financial support, venture capitalists having scientific skills which allow them to practice a new corporate governance, which is unique in the history of finance and industry, the availability of venture capital is undoubtly much higher in the US than in Europe. This last point is documented by Emmanuelle Dubocage's survey in ESSY backed by an important quantitative work.

This second part of the report is, first, an attempt to define, very briefly, venture capital. Secondly it shows that the behaviour of venture capitalists follows international rules. Finally it points three issues: the new corporate governance with strong relationships between investors and entrepreneurs, the new division of R&D expenses between large and small firms, and the 'equity gap'.

In Europe, from 1970 which can be considered as the birth of venture capital, to 1995, venture capital remained under-utilised as a financial mean, while, innovative SMEs themselves were failing to achieve their innovative potential. The resultant imbalance is often termed the 'equity gap', i. e. an excess of demand with under-utilised supply. It makes consensus within venture capitalists, operating in France, that in 2000, this equity gap disappeared. A cross-country study done by Harding gives the following conclusions: The U.K. is unique in the nature of its equity gap. In countries where a venture capital industry has effectively been created through policy …, the equity gap is catered for by structures within the risk capital system (Harding, 2000, p. 29). Dubocage's survey provides evidence which supports this view.

Nevertheless, other problems have to be mentioned: venture capitalist are highly selective, and aim to finance a limited percentage of innovative SMEs, as a consequence, there are entrepreneurs who consider that they are constrained by a shortage of capital, even if investors do not meet any more a lack of good projects, in the continental European countries. Not all the innovative projects may lead to outcomes linked to large markets or to an emerging industry and where private equity funds are not available, it indubitably limits the growth of the high-technology firms.

Secondly venture capital fund managers, like other investors, have a tendency to over-accumulate in some industries. Indeed, financial investors' tendency to concentrate investment in the same industries is well-known. Cyclical behaviour is more likely if the venture capitalists lack skill and, therefore, are more sensitive to the dominant opinion. They do so because of a "fashion effect" and because each thinks that the investee-firm may perform better than the other newcomers. Venture capitalists tendency to invest on the same market segments favours over-investment. Although they are aware of this tendency, each wants to participate because he or she thinks that he or she can pick the first comer who will be the to-morrow's winner. Excess of funds generates an excess of new comers and amplifies the level of competition in this market segment. Examples are numerous in the computer industry in the U.S. (Aoki, 1999, p. XI-5), whereas in the European countries, start-ups specialised in B to C (trade on Internet) are often quoted as an example of over-investment. Where this market segment a cluster with large technology-based companies which, from their own sides, develop competition among their sub-contractors, the venture-backed start-up high failure rate is becoming less surprising. Between the lack of funds which slows down

the innovation process and the excess of funds, producing a highly competitive environment with a high rate of failure, the frontier is not so large, especially for new activities.

To sum up, for high technology firms with high potential of growth, venture capital is a key factor, both because of the inadequacy of traditional financial intermediaries, and because of the mode of governance promoted by this new financial institution. Venture capital participates in the shaping of new relationships within the non-financial actors and has a power which is unique in the relationship between finance and industry. It is a key factor in the new labour division between innovative large and small enterprises and it favours the development of new knowledge-based industries which need IPR to be profitable. Venture-capital is an active member contributing to the development of an uncertain and competitive market environment. A good understanding of the venture capital industry non-financial rules and norms is important for public policy makers, as, in several western countries, they have undertaken public programmes to bolster innovative start-ups through venture capital promotion.

This line of argument is underpinned by the second report of the RP10. It is untitled *The financing of innovation by venture capital in Europe and in the USA: a comparative and sectoral approach*. It provides a statistical comparison of venture capital activity data between Europe and the USA, and within a small number of European countries (the UK, France, Germany and Italy). Insofar as the financing of innovation covers very different realities according to the sector concerned, it also deals with the financing of innovative enterprise in sectors related to biotechnology and the New information and Communication Technologies (NICT).

An analysis of the statistics for the venture capital industry reveals that compared with the USA, this is a very recent activity in Europe. The gap is a substantial one, with a 4:1 ratio for capital under management, venture capital raised, and venture investment in the broad sense of the term. The ratio is 3:1 for early-stage investment (venture capital in the strict sense). In the USA, the late 1990s featured a trend toward megafunds and megaprojects. The average amounts involved were two and a half times higher than in Europe.

Another striking feature of American venture capital is the historical role played by the pension funds as providers of funds to venture capital organizations, although their relative importance declined sharply in 1999. Another specific characteristic of the USA not found in Europe is the concentration of the industry in limited geographical areas (cf. Silicon Valley).

In sectoral terms, in both the USA and Europe, the preferred sectors for investment are the New Information and Communication Technologies and, to a lesser extent, biotechnology. The late 1990s were affected by the Internet boom and a marked preference on the part of investors for the Internet sector. Venture capitalists are attracted by the speed of the returns on NICT investments compared with those in life sciences.

Very few differences are visible in the breakdown of investment by development stage. Where exits are concerned, and the realization of capital gains, it is noteworthy that IPOs are a more frequent outcome in the USA than in Europe. NASDAQ is a far bigger than its European equivalents (Euro-NM and EASDAQ). The high percentage of divestment by trade sale and the growing importance of corporate venturing in both the USA and Europe is revelatory of the positioning of large corporations in the wave of innovation for which start-ups are currently the vehicles.

In this third part of her paper, Dubocage looks at the venture capital industry in four European countries: Germany, France, Italy and the United Kingdom. Dubocage limits her analysis of European venture capital here to these four countries since they are the most

developed where this activity is concerned, and they account, taken together, for a large proportion of European venture investment.

The concept of a national system expresses a degree of coherence where the functioning of venture capital in the various countries is concerned. In the United Kingdom, as Dubocage has seen, the national features of its system of financing are the source of a number of handicaps for venture investment. Conversely, in Germany, the characteristics of the national system offer a number of benefits. This set of favourable and unfavourable factors is part of a continuum with the institutional framework of which it is part. Dubocage has interpreted them with that in mind.

Nevertheless, it would be rash to establish any link between the national system for the financing of innovation (a concept based on the distinction between credit-based and market-based systems) and the more or less dynamic character of venture investment. This is so because her statistical analysis of venture capital in European countries casts doubt on the hypothesis that a market-based system will create a favourable environment: the German venture industry is dynamic despite the fact that its national system of financing is close to the credit-based system, whereas the British venture industry finds it difficult to develop although the national system of financing is close to being market-based. An approach based on national systems for the financing of innovation is inadequate insofar as it is too general and too deductive. It assigns, in her view, too important a role to finance, postulating that finance shapes technological trajectories. Conversely, in line with its systemic approach, in which emphasis is placed on institutional factors, it underestimates the part played by players' expertise. Dubocage has already seen that in an environment which is in principle conducive to venture capital activity, a lack of skills other than financial on the part of fund managers may be a crucial impediment to the venture industry's development.

Venture capital organizations (VCOs) tend to adopt a risk diversification strategy by spreading their investments over more than one sector, although certain VCOs do manifestly specialize in certain sectors. An infatuation with certain sectors can be seen periodically. The unbridled enthusiasm of investors for a given sector stems from the fact that venture capitalists are a closed group of networked professionals. This is conducive to crowd-following behaviour and self-fulfilling prophecies. The views expressed in promoting the advantages of investing in such and such a sector will have a real impact on the distribution of investment by sector and the market capitalization of listed firms. For example, Dubocage witnessed in 1998-99 an infatuation with Net-economy investments, and especially B-to-C (Business-to-Consumer) enterprises. Conversely, investment in companies in the life sciences was considered unattractive. During the first half of 2000, in the face of market downturns for companies with limited technological content, investors turned massively away from this category of enterprise, and became obsessed with B-to-B (Business-to-Business). In the part of this study which follows, Dubocage analyses the role played by large corporations in different sectors and countries, highlighting the specific features of venture capital investment according to the domain in which it is operating. In the first section, Dubocage looks at how biotechnology is funded in the USA and Europe, and how NICT companies are funded in USA.

Empirical analysis shows that while the venture industry has expanded very substantially since the end of the 1990s in Europe, the United States is still undeniably in the lead. Analysis of the industry in the various countries of Europe has highlighted the diversity of both the players involved in financing innovation and the institutional environments. Far from being an activity that is uniform at the international level, major national particularities are apparent. Behind the figures, the institutional framework, the role of local networks between investors and firms and social factors need to be taken into account. For this reason, an approach which combines non-financial and financial factors can be productive. The

expertise of venture capitalists has developed in a non-uniform manner in the various European countries. Dubocage has seen that within Europe, the United Kingdom and Germany are the two most important countries as far as venture activity in the broad sense is concerned. Behind this fact, Dubocage has seen that these two countries show very different patterns. It is particularly interesting to note that Germany is the country where the banks have a traditionally important role in the financing of SMEs (in other words, the financial system can be described as credit-based) and it is also the country where venture capital in the strict sense can be seen to be most dynamic. Conversely, the United Kingdom, whose financial landscape is the closest to the American model, with an important role played by the equity markets and financial and institutional investors such as pension funds, is encountering difficulties in developing early-stage venture capital investment. This casts doubt on the notion that a market-based system will create a VC-favourable environment.

The final part of this paper sets out the advantages in adopting a sector-based approach. A distinctive feature of biotechnology companies is the length and cost of their R&D phase. They are financially particularly vulnerable. The nature of the uncertainty, or at least its intensity, differs according to sector. In the case of biotechnology for example, the uncertainty is above all technological in character and relates to product feasibility. In that of NICT, the most marked uncertainty is commercial, and technological risk is less intense.

3 Conclusions and Policy Implications

WP4: The Implications for European International Performance and Public Policy

Work Package 4 provides the conclusions of the ESSY project, draws a synthetic view of the sectoral system approach based on the cases of WP2 and o the horizontal studies in WP3. In particular it provide an attempts to assess the similarities and common patterns across sectoral systems in Europe and to single out the relevant differences in sectoral systems within Europe and between Europe, United States and Japan. Moreover it assesses the international performance of European Sectoral Systems, the role of public policy and European-specific institutions in affecting the structure, boundaries, co-evolution of Sectoral Systems in Europe.

In particular WP4 is composed of three Research projects:

RP11: *Sectoral Systems in Europe: Synthesis and Implications for Europe International Performance.*

This part draws the conclusions from the sectoral studies of WP2 and from the horizontal themes discussed in WP3. In fact, the empirical results from our analysis help in providing some evidence on some of the factors affecting performance and competitiveness in the six sectoral systems.

Rp12: *A Comparison of the Performance of SSs in Europe, Us and Japan.*

This part of the ESSY project takes place in collaboration with the *CCC Matrix project* led by Richard Nelson (Columbia University) and by David Mowery (Berkley University)

which has examined the sources of industrial leadership in several high technology industries. Nelson and Mowery participated to the last ESSY meeting in Milan and gave important insight and feedback. This RP examines the result of the sectoral case studies and compares them with the *CCC Matrix Project*. Particular attention is devoted to the localisation of industrial leadership and on the process of European catching-up. Finally this comparative analysis, in some cases, is able to point at policy factors that may have been conducive to successes and failures in different sectors.

Rp13: *Policy Implications.*

A major goal of the ESSY project is to provide an evaluation of industrial and S&T policy records in Europe and to formulate new policy options and directions on the basis of the historical analyses of the European sectoral systems. RP13 addresses many policy issues, which are briefly summarised by the following points: How to cope with *sectoral diversity*? The European policy maker needs to know the differential impact of "horizontal policies". Does sectoral specificity point to the need for *targeted* (i.e. industry-specific) *industrial* and *S&T policies*? What lessons for the future of targeted policies in support of strategic industries can be drawn from the past record of activist industrial and innovation policies in Europe?

RP11: SECTORAL SYSTEMS IN EUROPE: SYNTHESIS AND IMPLICATIONS FOR EUROPE INTERNATIONAL PERFORMANCE

Co-ordinator: CESPRI

Research Team: Franco Malerba (CESPRI).

Progress

In accordance with the contract with the Commission, one paper has been delivered to the Commission:

Sectoral Systems in Europe: Summary and Conclusions. *Franco Malerba.*

Methodology

This part draws general conclusions from the sectoral studies of WP2 and from the horizontal themes discussed in WP3. The co-ordinator Franco Malerba is in charge of RP11 and provides a paper linking the conceptual framework to the main results of the ESSY projects.

Scientific Findings

ESSY has put sectors - an analytical category often forgotten by most of the current tradition in industrial economics - at the centre of the attention for analyses in the realm of innovation and production. It claims that sectors should become again a major object of economic inquiry and a major concern for policy makers. In doing that ESSY has proposed an analytical framework for organising industrial economic research on sectors that departs

from usual concepts of industry in industrial economics, and that could be used for comparative work on sectors. ESSY proposes the concept of *sectoral system of innovation and production* and focuses on three broad dimensions that affect the generation and adoption of new technologies and the organisation of innovation and production at the sectoral level:

- knowledge (and the related boundaries)
- actors and networks
- institutions

These factors have been considered singularly and then together and co-evolution has been analysed.

The empirical results coming from the ESSY conceptual framework and the ESSY analytical cut reach conclusions (see RPs above) that studies in the current industrial organisation tradition and using traditional tools of industrial economics such as game theory, structure-conduct-performance or transaction cost economics have not obtained in the analysis of the same sectors. These results are key for an understanding of the working, dynamics and performance of a sector. Thus, the concept of sectoral systems may prove a useful tool in various respects: for a descriptive analysis of the structure, organisation and boundaries of sectors, for a full understanding of their working, dynamics and transformation, for the identification of the factors affecting innovation, commercial performance and international competitiveness of firms and countries and for the development of new public policy indications.

Here it is summarized the main conceptual points on sectoral systems (discussed more in details in Malerba, 2001 in ESSY) and to present the major empirical results obtained from the study of the six sectors. RP11 is also linked to two other RPs of the concluding Work package (Coriat-Malerba-Montobbio, 2001 in RP12 and Malerba-Edquist-Metcalfe-Montobbio-Steinmueller,2001 in RP13) dealing more explicitly on the issue of international performance and public policy.

Sectoral Systems of Innovation and Production

This project focuses the attention of scholars and policy makers on the sectoral dimension of innovation and production. The concept of *sectoral system of innovation and production* tries to provide a multidimensional, integrated and dynamic view of sectors, that takes into account a lot of the factors and dimensions mentioned above and proposes a methodology for the analysis of sectors which could allow for comparability.

The notion of sectoral system of innovation and production departs from the traditional concept of sector used in industrial economics because it examines other agents in addition to firms, it places a lot of attention on knowledge and boundaries, on non market as well as on market interactions, and on institutions. Moreover, the sectoral system of innovation approach recognises that firms are active actors who shape their technological and market environments and not passive automata for the transformation of inputs into outputs in response to market price signals.

A sectoral system perspective a sector is composed by three main building blocks:.

1-Knowledge and technological domain

2-Actors and networks

3-Institutions

1. *Knowledge and technological domain.* Any sector could be characterised by a specific knowledge base, technologies and inputs. In a dynamic way, the focus on knowledge and the technological domain places at the centre of analysis also the issue of sectoral *boundaries,* which usually are not fixed, but change over time.

2. Actors and networks. A sector is composed by heterogeneous agents that are organisations and individuals (e.g. consumers, entrepreneurs, scientists). Organisations may be firms (e.g. users, producers and input suppliers) and non-firm organisations (e.g. universities, financial institutions, government agencies, trade-unions, or technical associations), including sub-units of larger organisations (e.g. R-D or production departments) and groups of organisations (e.g. industry associations). Agents are characterised by specific learning processes, competencies, beliefs, objectives, organisational structures and behaviours. They interact through processes of communication, exchange, cooperation, competition and command.

Institutions. Agents' interactions are shaped by institutions, which include norms, routines, common habits, established practices, rules, laws, standards and so on, that shape agents cognition and action and affect the interactions among agents. They may range from the ones that bind or impose enforcements on agents to the ones that are created by the interaction among agents (such as contracts); from more binding to less binding; from formal to informal (such as patent laws or specific regulations vs. traditions and conventions). A lot of institutions are national (such as the patent system), while others are specific to sectoral systems, such as sectoral labour markets or sector specific financial institutions.

The previous analysis allow to broadly characterise the five sectors in terms of knowledge, actors and networks and institutions. For detailed accounts of the results of each sectoral study see the appropriate research projects above. We spend more lines on the issue of services which arise particular issues in this framework of analysis.

Bio-pharma: science; networks and division of innovative labour; key role of universities, venture capital and national health systems

In the *pharmaceutical and biotechnology sector* several different actors are the protagonists of innovation: large firms, new biotech firms (NBF) and small firms. They interact with a lot of different agents: universities, public agencies, venture capital and physicians. In this sector regulation, IPR, national health systems, and demand play a major role in the innovation process. The dynamics of the sector could be interpreted as a process of adaptation to major technological and institutional shocks. Change has been dramatic. In the early stages of the industry (1850-1945), pharmaceuticals were close to chemicals, very little formal research was done until the 1930s and licenses were widely used. Later on in the "random screening period" (1945-early 1980s), R-D became extremely important, and search took place through the random screening of natural and chemically derived compounds. Few blockbuster were discovered every period, but each one had a very high growth. Patents have been widely used. The industry structure became rather stable, with large pharmaceutical firms doing most of the R-D. Increases in final demand were due to the process of increasing collectivisation of health care. Finally, the molecular biology revolution in the late 1970s and early 1980s again caused major changes. Now, a wide variety of science and engineering fields are continuing to play important roles in renewing the search space for this sector. New biotech firms have entered into the sector, competing as well as cooperating (or being bought up) by the established large pharmaceutical firms. More recent changes in regulation and demand are

also squeezing the profitability of firms and opening up new opportunities in generic drugs.

Telecom hardware and services: convergence; knowledge integration and combination;production specialisation

Telecommunication hardware and services is a very large sector, with converging technologies and segments, with several subsectors and segments and a wide variety of different specialised and integrated actors involved in innovation, ranging from the large telecom equipment producers to the new telecom service firms. The increase in the number of actors is due to the process of convergence of previously separated sectors such as telecom, computers, media, and so on, and by the process of privatisation and liberalisation that occurred in Europe since the mid 1980s. In this broad sector innovation is very much affected by the institutional setting and by standards. Internet is becoming a major part of the telecommunication industry.

Chemicals: continuity of large multinational firms through R-D, scale and scope; emergence of vertical division of labour

The *chemical sector* is a large and heterogeneous sector with a lot of different products from bulk chemicals to specialty chemicals. Internal R-D has been complemented with external links and the absorption of external sources of scientific and technological knowledge. The major innovators have shown great continuity in their innovativeness. Economies of scale and scope, cumulativness and path dependence, as well as research and commercialisation capabilities, have characterised chemical firms (Chandler,1990; Arora-Gambardella-Rosenberg 1999). The interaction among agents has greatly changed over time and so did the organisation of innovation. At the beginning of the industry firms developed links with universities and with users, while later on industry-university relationships have increased. Now vertical networks between chemical companies and engineering contractors are quite widespread, and specialised engineering firms are a major source of process innovation. In the sector, three types of networks are present: interfirm, university-industry, user-producer (downstream specialty sectors).

Software: highly differentiated knowledge base; several quite different sub-sectors, firms innovative specialisation; user-producer interaction; global as well as local innovation and production systems; advanced human capital mobility

Software spans over several other sectors, ranging from computers, to consumer electronics and so on It is also embedded into several products. In software the context of application is relevant for innovation as well as the vertical and horizontal division of labour among different actors. The role of large computer suppliers in developing integrated hardware and software systems has been displaced since the early 1980s, with the spread of networked computing, the Internet, the development of open system architectures and the growth of web-based network computing. A lot of specialised software companies innovate either in package software, or in customised software. Here the role of the university has become important because it plays a role in the open source domain.

But the analysis of innovation in software has to be differentiated because many subsectors are present, each of which has different types of products, firms and

capabilities. IPR play a major role in innovation and competition. *In the integrated enterprise software sub sector* for example a tension between higher generalisation and higher specialisation in the knowledge bases was identified. Both large integrated software and small niche software producers draw from the knowledge made available by local as well as global networks of users in order to improve on their existing and create new products. There is effectively a trend towards co-development between user and producers whereby both have to find the most appropriate balance between generality and specificity. For example, producers aim to build increasingly generic systems that can be applied to a greater range of users, while at the same time attempting to make their modules specific enough to appeal to individual customers or user sectors. Customers instead aim to fully draw the benefits of adopting a standardised package and at the same time demanding a product that better fits their idiosyncratic requirements and local settings (D'Adderio in ESSY 2001). Standard setting alliances support common standards in order to facilitate the diffusion and adoption of large integrated systems (i.e., by supporting the modularisation of software and by ensuring the compliance and interoperability of specialised niche and legacy applications with the generic system's platform).

Machine tools: application specific knowledge base; firms specialization; user-producer interaction; local innovation and production systems; in-house experienced human capital.

In *machine tools* incremental innovation is quite common and R-D plays a less relevant role than in other sectors. Horizontal innovative cooperation is not common, while links with users are very important. Thus, demand has played a major role as a stimulus for innovation. Skilled personnel on the shop floor level and applied technical qualification play major roles in new product design and development. Products are increasingly being modularised and standardised. Thus, suppliers of components get the chance to involve themselves in innovation making use of generalised defined requirements. Regional clusters are very important. Thus localised user-producer interaction, learning spillovers across producers, national differences in the structure of demand led to international differences in the rate and direction of the new technology.

Sectoral Systems In Services.

As there are several sectoral systems of innovation and production in manufacturing, so there are several sectoral systems in services. The taxonomies by Soete and Miozzo (2001) and Sundbo and Gallouj (200) show how different services are, and how rich and differentiated a taxonomy of sectoral systems in services could be. Although it is difficult to generalise, it is possible to identify, as in the papers by Thether-Metcalfe-Miles (2001), some general features of sectoral systems in services. These features and dimensions are present also in manufacture, but in services they have a often prominent place. The services examined in the ESSY project represent a first exploration of these main features, dimensions and dynamics of the service sectoral systems

The first point is that in services *products are closely related to processes*. The emphasis on processes and on the actors and institutions that are active in these processes, makes the concept of sectoral system even more useful. Often innovation has restructured the sectoral system of innovation by creating markets for specialised equipment and supplies, such as the one related to clinic based delivery of the surgical service in the case of medical services-intraocular lenses. In this case the delivery of the removal of cataracts combined with the implantation of an artificial lens was achieved by the change in procedure from the one

requiring one single surgeon with craft techniques within capital intensive contexts to a routinised procedure which could be done in a local medical centre (Metcalfe-James,2001 in ESSY)

Second, great emphasis is given to *knowledg*e embodied in equipment and in people and to *changes in the domain* of this knowledge related to the diffusion of information and communication technologies, as well as to instrumentation and other devices. Thus, the link with manufacturing (and the related transformation of knowledge domain that have taken place recently) is quite relevant in most services. In airports, the case of runway capacity extensions shows a move away from direct operating experience and observations towards the use of sophisticated information technologies support tools (such as the final approach separation tool that allows spacing between arriving aircraft). This was also associated to the use of new type of knowledge (such as mathematical modelling, computer science, and so on) and the pressure to change the use of integers as units of distance in order to better measure minimum distance separations. On the contrary, R-D is less relevant for services than for high-tech manufacturing, except in sectors such as software or telecommunication services.

Third, actors such as suppliers (of equipment) and users play a major role. Interaction is particularly important in services. As the case of air traffic services in airports and the creation of runway capacity show, the innovation process is usually the outcome of the interaction of the service provider and the service user. Actually, this coproduction is much more relational than in manufacturing, in which the manufacturer may change unilaterally the organisation of production, and may involve both joint operation and the search of mutually acceptable solutions (Thether-Metcalfe,2000 in ESSY). In retailing, the actors involved include food suppliers, logistics companies, retailers and consumers (Harvey-Nuberg, 2001 in ESSY). On the contrary, universities and research centres have less relevance in services than in manufacturing. Thus, as in manufacturing, demand is particularly important for innovation and the process of construction of demand is central to the emergence and growth of specific sectoral system of innovation. The close interaction with users is quite relevant in the formation of new services (and consequently new sectoral systems).

Fourth, institutions play a great role both in terms of procedures and mechanisms (think of the mechanisms of airport slots discussed by Thether-Metcalfe,2000 in ESSY), and in terms of formal regulations, standards and privatisation. Procedural change plays a major role in services. In the air traffic service case, procedural change related to the bunching of aircraft away from the first come first serve basis, and the usual of dual glideslope, is negotiated between the service provider (air traffic control) and the users (airlines). In the case of medical services- intraocular lenses- innovation results from the interaction between clinicians and the different national ophthalmic health systems, connected by international networks of clinicians and transnational health companies. Various practices and theories within ophthalmology played a major role (Metcalfe-James,2001 in ESSY). In the case of embedded software, efforts to assure safety involve considerable potential for displacing own-production in favour of specialised embedded software 'system' producers which can invest the resources necessary for 'robust' systems by serving many different clients (Steinmueller 2001, in ESSY).

Fifth, services are less international than manufacturing, and are usually produced locally. However new technologies are allowing a more extensive division of labour that has also geographical dimensions, such as the decentralisation of back office functions (routine operations) and centralisations of control functions and of value added services (core control functions). Thus internationalisation of services in terms of spatial division of labour has been taking place, with certain function being internationalised with the diffusion of information and communication technologies. These tendencies are observable in enterprise resource planning software markets where the generic systems produced by SAP and the American

competitors Oracle and Microsoft rely upon international markets for achieving the necessary investment in platform development and an international supplier network for accommodating user needs for specialised 'modules' to customise the platform for specific applications (D'Adderio 2001, in ESSY).

Sixth, services show continuous change and transformation over time, and not always necessarily in favour of a greater convergence and alignment. First of all, services have all been affected by ICT, which has triggered major changes at all levels. Second, they have become more and more characterised by professional management. Third, as just said, major geographical division of labour has taken place. The paper by Harvey-Nyberg (2001, in ESSY) for retailing shows the major transformation of grocery distribution in terms of leading actors from global food manufacturers to retailers and supermarkets, and from production of generic products with the exploitation of economies of scale to the differentiation of areas and stores and a major attention to consumer interface. Here however national differences due to historical starting conditions and contexts, have affected the specific path of transformation. In the UK for example retailing is an integrated business and the retailer orchestrate the business. Also in Sweden retailers have a leading role, but the cooperative movement tradition led to a federation of end-retailers and to a more decentralised pattern of local and small scale production.

The previous example indicates that countries differences in organisation and performance raise some interesting issues for services. First, as shown in the case of retailing, differences in organisations of sectoral systems may be due to the major local content of services. The case of intraocular lenses show the role that differences in ophtalmic health systems played a major role in affecting international competitiveness of countries. The internationalisation of some of the services (or parts of them), the spread of professionalisation and the role of multinational companies may introduce various levels of analysis, which encompass both local and international dimensions. The case of intraocular lenses have also shown that differences in ophtalmic health systems and the role of major opthalimic multinational have greatly shaped the system in various countries. Second, and related, the interaction of these elements has major consequence for performance. Again in the case of intraocular lenses, the interaction of national health systems and multinational opthalmic corporations led to the leadership of the United States, after an early predominance of Europe, and particularly of the UK. However, the international performance of various countries in services may be difficult to assess in a clear and uniform way, because the value of services may be difficult to measure and because services may be organised in different ways in different countries. In general, however, as Tether-Metcalfe-Miles(2001 in ESSY) mention, the Unites Sates have adopted new technologies more rapidly and more widely and have applied scientific management and commercial logic to processes in services than Europe has.

Finally, public policy considerations stress different aspects than the ones for manufacturing: skilled labour training (a key element for services), advanced regulations and standards for the professionalisation and the responsiveness to change of services (see for example the case of GSM), diffusion of information technologies in the provision of high quality services (and eventually support of small and medium entreprises in some advanced services such as knowledge intensive business services -KIBS). (Thether-Metcalfe-Miles,2001 in ESSY).

The Challenges Ahead

The approach centred on sectoral systems emphasises that sectors should be examined as systems in which different agents have links and interact within an institutional

context. More specifically, in this framework, knowledge and learning processes are important explanatory factors of the working and organization of sector, and they greatly affect the type of actors and networks that are active in a sector. Institutions shape and are shaped by innovative activities: some of these institutions are national, others local, other sectoral. Major coevolutionary processes take place in the long run evolution of sectoral systems, and affect knowledge, technology, actors, networks and institutions. Finally, the international performance of firms and countries in a sector is greatly affected by non-firm organizations, networks and institutions

One remark has to be advanced about the impossibility of identifying "optimal" structures and working for sectoral systems. In reality some coherence among the various elements of a sectoral system may occur and develop over time as a result of both conscious design and unplanned processes. And mismatches among the various parts and variables of sectoral systems could be identified and eventually eliminated. But the actual coherence is far from being "optimal". Thus sectoral systems may take different features in different countries, and in different times, due to continuously changing environments and coevolutionary processes.

Future research on sectoral system should move along four lines. First, it should examine in detail some key variables and aspects of sectoral systems that are still rather unexplored: demand, boundaries, networks, coevolution and interaction between sectoral variables and national institutional frameworks.

Second, *taxonomies* of sectoral systems have to be constructed. Here comparative work is particularly relevant. These taxonomies should group sectoral systems in terms of elements, structure and dynamics, so that regularities could be identified among sectors and a general description of the features could be proposed. Pavitt's taxonomy (Pavitt,1984) is a useful starting point as far as the sources of innovation, the appropriability means and the industrial structure are concerned. The same holds for the Schumpeter Mark I and Schumpeter Mark II distinction, with the related types of technological regimes (Malerba-Orsenigo, 1996). The work by Marsili(2001) of extending Pavitt taxonomy goes in this direction.

Third, *conceptual and theoretical* work has to be carried out on the basic relationships among the elements of a sectoral system, the emergence and persistence of firms heterogeneity, the basic processes of variety creation and selection, and coevolution. Here both theoretical models of industry dynamics and history friendly models can be useful. In the best evolutionary (and innovation system) tradition, this work should go hand in hand, and be continuously confronted with, empirical work.

Fourth, analyses of *international performance* should be developed by taking into full account the role played by the various elements of a sectoral system. This is what Coriat-Malerba-Montobbio (ESSY 2001) aim to do. Similarly, *public policy* implications have to be developed, along the lines suggested by Edquist-Malerba-Metcalfe-Montobbio-Steinmueller (ESSY 2001).

RP12: A COMPARISON OF THE STRUCTURE, EVOLUTION AND PERFORMANCE OF SSS IN EUROPE, US AND JAPAN

Co-ordinator: CESPRI

Partners: CREII

Research Team: Franco Malerba (CESPRI), Fabio Montobbio (CESPRI), Benjamin Coriat (CREII).

Progress

In accordance with the contract with the Commission, one paper has been delivered to the Commission:

The performance of Sectoral Systems in Europe. *Benjamin Coriat, Franco Malerba and Fabio Montobbio.*

Methodology

ESSY partners in the fourth ESSY meeting in Brighton decided that Franco Malerba, Fabio Montobbio (CESPRI) and Benjamin Coriat (CREII) were in charge of this RP12. Particular attention has been devoted to the determinants of industrial leadership in Europe. The ESSY project co-operates with the *CCC Matrix project* led by Richard Nelson (Columbia University) and by David Mowery (Berkley University) which examined the sources of industrial leadership in several high technology industries. Nelson and Mowery participated at the final workshop in Milan, November 2001..

Scientific Findings

This paper aims at analysing the determinants of European industrial strength in a selected number of sectors *vis à vis* US and Japan. We take a comparative bottom-up approach, presenting a series of results from the analysis of six sectors (Chemicals, Pharmaceutical and Biotechnology, Telecom, Chemicals, Software, Machine tools and three sub-sectors in services) within the ESSY research project. The case studies adopted a sectoral system methodology (Malerba, 2001 in ESSY). We enquiry whether the case studies display major differences in the structure and working of sectoral systems across countries, whether these differences affect the international performance of countries and finally, which characteristics of the sectoral systems have been comparatively key factors for industrial leadership in each sector.

Chemicals.

In parallel with the major steps of transformation of the technological knowledge base, leadership shifted. In particular, passing from production related to coal to petrochemicals, in the years before the Second World War, US firms caught up with Europe. They became leaders in organic chemicals using US rich oil resources and the size of the domestic market. The emergence of SEFs was mainly a US phenomenon, linked to the US strength in oil refining because competition in this industry, having less scope for product diversification, started to be based on cost saving processes.

German and Swiss firms remained behind, moving to pharmaceutical, dyestuff and synthetic fibres. Later in the 70s and 80s, the oil shocks and tougher competition from Europe and the developing countries, which profited from the market for technologies

promoted by SEFs, began jeopardising the US leadership (Arora et al., 1999; Cesaroni-Gambardella-Garcia-Fontes-Mariani, 2001 in ESSY).

In sum the factors affecting leadership n the Chemical sectoral system revolve around the following interrelated issues. The Chemical industry has got increasingly oligopolistic and the ability of large multinational firms to perform R-D, to build efficient network (with universities or with specialized suppliers), to expand and to adapt to the changing knowledge base. Accordingly their location depends upon regional characteristics including local demand and technological and scientific research capabilities. Finally patent policies have been particularly important in support of the activity of smaller technology-based firms. In the US this created the bases for a division of labour between technology suppliers and users, and allowed the development of markets for technology. By contrast, European markets for technology are far from being developed, and this requires policy support for their formation, firstly – but not only- in terms of policy for intellectual property rights.

Pharmaceuticals and Biotechnology

The main factors affecting industrial leadership in the pharmaceutical and biotechnologies industries are a dynamic combination of many aspects: a strong science base created upon a high quality and efficient organization of research and education (for scientists, entrepreneurial scientists and managers), a tradition in the university-industry relationships and transfer, the presence of a market for technologies within a clear institutional (patent legislation) and regulatory frameworks conducive to higher level of efficacy and innovation. The size of the domestic market, its degree of competition and integration are also important in an industry with high fixed cost in R&D and possibly low marginal costs. The size and the integration of the market are also important because facilitate the creation of alliances between small and big firms and an efficient division of labour.

US was able to become leader in biotechnology at the end of the 70s and beginning of the 80s thanks to the excellence of its scientific base and to firms start-ups. These were the combination of university spin-off, scientists, professional managers, venture capital. Geographical proximity played a major role (Genentech, Inc. was founded in 1976 by Robert A. Swanson, venture capitalist in S. Francisco, and biochemist Dr. Herbert W. Boyer, professor at the University of California, San Francisco). It is interesting to note that in UK there are most of the necessary factors conducive to the expansion of biotech outlined above. Nevertheless, despite being the first to develop in Europe, UK biotechnology is stagnating and only one firm has been able to launch a therapeutic product in the market. Lack of expertise at the level of scientists, managers and also technology transfer offices in universities seem to be one of the main constraining factors.

However, in Europe, as Casper-Kettler (2000 in ESSY) and Casper-Soskice (2001 in ESSY) show, European countries may end up specializing in *subsectors* of biotechnology. Germany biotechnology firms have specialized into platform technologies that are then sold to other research laboratories (for example consumable kits to rationalize common molecular biology laboratory processes). These technologies are more generic and more cumulative than the standard therapeutic products, often relate to the development of equipment for pharmaceutical firms, have library of core technologies that are then customized for customers in specific market niches.

These features fit better than the standard therapeutic products with the German institutional framework (characterized by "insider" corporate governance, internal long term relationships between firms and employees, investments in firms specific knowledge). On the other hand, firms in the United Kingdom specialized in standard therapeutic products, related

to the standard products developed by the dominant American industry (Casper-Kettler,2000 in ESSY, Casper-Soskice,2001 in ESSY).

Software

In Europe, many sectors of the packaged software industry suffer primarily from the first mover effects stemming from the personal computer revolution and the effects of network externalities in software. Federal government, military and social security system investments played also an important role stimulating research in universities, creating infrastructures and enhancing the supply of skilled personnel. In Europe fragmented markets were a significant constraint and the industrial, university and public research systems displayed feeble support to the development of personal computer applications.

Those segments that are markedly less affected by these factors are also ones where there are closer and more important ties to local content or business practice (integrated system software and multimedia software as well as the large 'hidden' sector represented by in-house development and related system integration and consulting businesses). Open source software is an emergent area of European participation and expertise, which offers considerable promise in revitalising European systems integration and consulting activities. Of all of the software sectors examined for the ESSY study, the embedded system software market appears to show the clearest signs of a dysfunction as a sectoral system of innovation in Europe and presents the clearest case for intervention in the form of new interdisciplinary research programmes and a dialogue with industry concerning their future needs.

Telecommunication equipment and services

In ICT in general and in telecom equipment the European performance is weak. In other telecom segments like mobile phone and some internet services European firms are performing reasonably well. It is in the world of "proprietary standards" (namely in services) that the European firms are facing their major difficulties. The good performances of some European countries are the results of specific demand conditions and of historically contingent procedures of standard setting backed by national telecommunications providers (then public monopolies). Since a large market is created European firms can retain an advantage through learning effects and innovation on the production side. In order to do so they should have the appropriate level of skilled human resources.

However, as Casper-Soskice (2001 in ESSY) noticed, recently in the telecommunication sectoral system some of the institutional features that characterize the Swedish national framework (such as the long term relationships between firms and employees) have been modified in order to take into account the new characteristics of the innovation process in mobile phones. Ericsson recognized that wireless technologies require open standards and the full exploitation of network effects. Thus in the late 1990s Ericsson decided to make its last system integration language open rather than proprietary, and sponsored the formation of new start ups which are spin-offs from Ericsson and which aimed to develop products compatible with Ericsson's new generation of wireless technologies[3].

Finally liberalisation and European integration (with an active competition policy) have improve innovative and economic of European firms. This could be not sufficient if this

[3] While introducing this new policy of open standard and support of networked new firm formation, Ericsson maintained some of the features of the Swedish system by allowing engineers leaving Ericsson to return if their start-ups fail.

is not coupled with the development of critical mass in terms of network of cooperating and competing firms at the European level.

Machine Tools

In the XIX century the machine tool industry is characterized by British leadership. Mass production had a big impact on the American industry, which became the leader for most of the XX century and performed the early R&D activity that transformed machine tools from mechanical devices to numerical and computer-controlled systems. In the US, machine tools producers have been highly dependent on the defence and automotive sectors. Demand from high end users led American machine tools producers to develop machine tools for manufacturing operations with high stringency requirements. After WWII they produced numerically controlled machines. Later on Japanese firms became leaders licensing products from US, stimulated by MITI and protected by trade tariffs. Differences in domestic demand were a crucial determinant here. Japanese protected home market was characterized by small general purpose machine tools for flexible and labour-saving processes (automobile and general machinery industry). As a result there was a rapid application of numerically controlled machines. Large volumes of standardized machine tools were adopted. Fanuc of Fujitsu (NC lathes and machining centers) became a world leader. Standardization and concentration on the supplier side helped users and builders, which saved on post-processor programming. In turn Fujitsu could invest in development of modular design easier to be customized. Conversely US firms thought that the control choice was a prerogative of the customer, and that they could maintain high market also because buyers had sunk specific investment about particular control systems. However this provided the basis for success of Japanese firms in the US: with the help of the downturn in 1975, restructuring firms in US started buying low-cost general purpose-NCMT from Japanese firms (Mazzoleni, 1999).

Overall, linkages with research centres, producers, and users, and increased codified knowledge are increasingly important and the role of strategic partnership is increased. In Europe in front of the transformation of the knowledge bases and the increased level of international competition, a critical factor is the continuous upgrading of labour and engineering skills. Germany seems to face shortages of qualified labour, both on the shop-floor and with engineers. A strength of the industry always was the integration of theory and practice, manufacturing and design. Italian firms have greatly upgraded their human capital in terms of external formal training. The greater focus on human capital has been associated with a larger number of employees dedicated to technological innovation. The increasing relevance of science and subsequent increasing distance of the R&D and design processes from the production area may threaten this strength (Wengel-Shapira, 2001). In this respect, it is interesting the double effect of niche user-supplier interaction. On the one side it helped preventing strong competition from standardized low cost general purpose technologies. This was particularly true in EU. On the other side it prevented the growth of a market leader. This is recognized as one of the major cause of the US decline in these industries. For EU it can be worthwhile asking if this pattern is stable or not if there are risks of loosing the positions of leadership and which are the possible outcomes of the process of economic integration (Mazzoleni, 1999).

As a final remark it can noted that a well established and to some respects efficient sectoral systems may be overcome by developments elsewhere. The US experience in post-war and Italian case can be an interesting example. In US firms managed to invent the R&D based NC machines but Japanese had a better environment for applications. In Italy despite a stable, hard working and dedicated labour force the machine tool industry may be jeopardized by increased standardization based upon different knowledge bases and international

competition. The rise of new producer locations, such as China, Taiwan, and Korea, adds new global complications to the mix, particularly since these emerging producers are developing stronger capabilities in research and innovation and augmenting their human capital capabilities in machining sectors. Strong regional sectoral linkages and a close coupling of regional production complexes with users will likely to continue to be key elements in competitive advantage in machine tools, as in the past. However, increased investments in system integration, innovation and emerging technologies, public-private collaboration, formal training systems, technology and market intelligence, and international partnerships and linkages are also likely to characterize the most successful elements of the sector in future years.

The specific co-evolution between firms' capabilities and the knowledge bases, actors and networks and institutions of a sector.

The determinants of industrial leadership are determined by the specific co-evolution of knowledge bases, actors and networks and institutions of a sector. This emerges quite clearly from all the sectoral studies. ESSY has tried to stress in detail the interactions between these elements. In addition, we may single out some factors of success.

Technological and scientific research capabilities

In some ESSY sectors technological and scientific research capabilities and education were major sources of industrial leadership. Success stories are a combination of the ability of creating new products opening up new disciplines and markets and, at the same time, of integrating research, teaching and the industrial needs. Importantly the construction of a solid knowledge and scientific base in specific fields has often benefited from different forms and levels of public investments in their early stages (i.e. pharmaceutical, biotechnology and software), above all in US.

Moreover the integration between in-house research and advancements in the relative transfer sciences (chemical engineering, automation and robotics, computer sciences, biotechnology, microbiology, pharmaceutical chemistry) helped firms to be ahead of their competitors product and process technologies. Not only the quality of the research systems and the ability to shift and transform the technological knowledge bases provides firms with exploitable technological opportunities, but also the sector specific integration between specific applied disciplines, technological change and commercial exploitation.

Demand and interactions with sophisticated users

Close and continuous interactions with sophisticated users is particularly important in the case of Machine Tools and Chemicals (and in some segments of Software and Biotechnology). In Machine Tools and Chemicals also co-location supported the innovative performance of firms. However the mechanisms connecting demand to economic success are different according to the sector. Demand can be important in terms of level (size of the market: Chemicals, Pharmaceuticals, Packaged Software), in terms of quality (Machine Tools in Europe, Chemical Engineering in US), in terms of composition (Software and Machine Tools in Europe), in terms of specific requirements (Machine Tools in US and Japan, Chemical Engineering, Telecom), in terms of government share (Biotech in US and Telecom in US).

Size of the market

The size of the market and its degree of integration was a conducive factor of US success in many sectors. EU seems to be penalised by fragmentation in some sectors with low marginal costs (packaged software and pharmaceuticals), and increasing returns to users adoption (segments of packaged software). In these cases fragmentation of markets leads often to different monopolies or vertical integrated separate structures that obstructed the development of technologies (see software, biotech, chemical engineering). At the same time , according to the characteristics of the industry, different markets and heterogeneous users helped European firms which are able to be ahead of their competitors thanks to their ability to create customised product and process technologies (Machine Tools and Integrated Software Solutions).

Technology and innovation policies

Technology and innovation policies played an important role in affecting the industrial, institutional and organisational settings and the rate of innovative activities. In most of the ESSY sectors, agents have drawn incentives and opportunities from different types of institutional packages: IPR systems, specific norms and laws, types of standards, product approval, government support and corporate governance. Patent policies have been particularly important in support of the activity of smaller technology-based firms and university licensing (particularly in Biotechnology and Chemicals). In the US this has created the bases for a division of labour between technology suppliers and users, and allowed the development of markets for technology. Finally standardization has affected the mobile telephone industry. In particular, European firms widely benefited from the European decision of adopting GSM technology.

A qualitative investigation of the domains and sub-sectors in which European products are recognised in the world for their quality and image provides a list of three series of activities.

A group of diversified industrial products covered by strong 'brand names'.

This is the case of products and sectors like top-of-the-line luxury cars (e.g. Rolls Royce, Bentley, BMW, Mercedes, Ferrari, Saab) and machine tools (German, Italian or Swiss) (not to speak of top-of-the-line products in diversified traditional sub-segments like 'Haute Couture', select jewellery, watch-making industry, fashionable clothing, shoes or cosmetics…) (see for example the case of machine tools discussed by Wengel-Shapira,2001, in ESSY);

ii) Another domain of 'European Excellence' covers a number of sub-segments of short production runs of customised products, integrated complex systems and prototypes.

These types of products are centred on projects based on high-tech (often complex) product systems, where competitiveness depends less on price than on quality. These activities are dependent on high levels of technology and skilled labour force. They include aeronautics (Ariane-Espace, Airbus, etc.), key segments of telecommunications (for example digital exchanges equipment); 'key in hand' delivery of different types of complex product systems – networks of high-speed trains (French, German or Italian…), nuclear power

stations, services of water management, etc. (see for examples the cases discussed by Dalum-Willumsen,2001 in ESSY, Coriat 2000c, Dosi, Hobday and Marengo 2000);

iii) More recently (and perhaps more unexpectedly) Europe has demonstrated a proven ability to assert itself *in some markets of mass-produced products in high R&D-intensive industries*. This is the case of mobile telephony. As it has been argued above, during the last few years, Ericsson and Nokia (the latter now the world market leader, ahead of the American firm Motorola) demonstrated a European capacity to achieve a dominant share of the world market in small high-tech products. Also in the semiconductor industry, after many failures, SGS-Microelectronics has gained a significant presence in world markets for some customised products (see for examples the cases discussed in Edquist,2001 and Hommen-Manninen,2001 in ESSY).

Notwithstanding the variety of sectors which they incorporate, the activities listed above do share some common denominators. A common characteristic of the products mentioned is the relative advantage gained by products and services that are *vertically differentiated* and which involve a number of different partners and competencies . Whether it be a seemingly 'simple' product (e.g. a luxury perfume), or a more complex one (an airplane), European competitiveness results from a capacity to combine different know- how's along the chain, which converge in the delivery of the final product. The later result from complex arrangements which combine: institutional dimensions, large and complex organisational networks (between firms and connecting them to different institutions and regulatory agencies -e.g. high-speed train systems, management of Utility Networks, etc.). In most of these domains, coordination between complementary activities is a key condition underlying the production of quality. Thus, specific networks of agents based on a highly skilled diversified labour force and competencies seems to be a crucial dimension of the European distinctive capabilities.

This paper provides an attempt to assess how differences in sectoral systems affect the international performance of countries and to point at the specific characteristics of sectoral systems that have been comparatively key factors for industrial leadership in each sector.

We have found that in the sectoral systems examined in ESSY (Chemicals, Pharmaceuticals and Biotechnology, Software, Telecom, Machine Tools and some segments of Services) major differences exist across sectors and that these differences have greatly affected the determinants of countries international performance. We have also identified some common factors affecting the international performance of European firms.

A major policy implication, derived from the ESSY studies and supported also by the study of automobiles (Coriat,2000d) relates to latecomers, and could be summarised in the statement: "innovate, not replicate". In automobiles, for example, the Japanese car makers, even if they were late comers (most of the companies -including Toyota- started their business in the 1950's), were very successful in "catching" up with the Western companies. But these companies were able to "catch up" because they were able to innovate and to follow their own paths towards the state of the art in the sector (in this case : mass production of standardized products marketed at lower and lower prices). Basically through a series of organizational innovations they were able to build their own competitive advantages and find their access to world markets. This was achieved through the systematic implementation of the "just in time" protocols and routines. Just in time allowed the Japanese car markers to catch up with the state of the art (mass production) whilst offering to clients larger options in terms of variety and product differentiation. Thus they introduced a new

"dominant architectural design" as regards the organization of the sector envisaged as a whole.

Finally, a provocative and may be controversial interpretation based on the ESSY studies could be advanced as a way of conclusion. It can be claimed that European firms performed less well in those sectors characterised by a complementarity between a strong IPR regime, an efficient external market and corporate systems dominated by outsiders. This type of institutional setting creates favourable environments for activities based on the commercial exploitation of science discoveries, and more generally for activities living commercially from the exploration of the state of the art. The existence of a property right regime protecting scientific discoveries through patents, provides firms specialized in R-D activities with intangible assets (patents on discoveries). These intangible assets, and the perspective to capture the innovation rents, are used in financial markets, designed to finance risky, but potentially highly profitable, firms. Some specific devices of the corporate governance mechanisms are also required to give the sufficient confidence and control to financial investors. Thus, the existence of an outsider corporate model is very favourable to this type of activities. Finally since the activity itself (research and development in very specialized and moving fields) imposes to be able to quickly recruit the right highly skilled people required at different stages of the R-D process, the existence of an efficient external labour market is the final conditions that guarantees the success of this activities. This typology can represent the case of *biotechnology*, some segments of *software*, and *telecommunication equipment* where new "start ups" built on IPRs are put on the Nasdaq and recruit staffs of researchers in the external market.

Conversely European firms have been relatively stronger in sectoral systems where internal markets are relatively more important and corporate governance systems are dominated by insiders. In this case the institutional setting exhibits the following features: there is a relatively more "open technology" which allows to capture freely (at zero or low costs) the benefits of the discoveries, and many of the technological advances made in the field. Each new entrant (follower) can benefit at no or very low costs from the innovations of the previous innovator, adding its own contribution, which, in turn, is made available for the follower. This sectoral typology could be sustainable because appropriability is based on specific capabilities and internal learning of the firms. Strong internal markets are needed and firms core capabilities are built mainly on organizational learning. Finally such a model does not require a strong and specialized financial markets, as in the previous case. Even if the companies operating in these sectors are publicly owned, there is no need to give to outsiders any strong control and power; on the contrary insiders models are more convenient to monitor and guide the strategy of the firms. These are "scale intensive" and "specialized suppliers" sectors (e.g. *automobiles, machine tools* and some segments of *software*).

RP13: POLICY IMPLICATIONS

Co-ordinator: CESPRI

Partners: CRIC, SPRU, TEMA.

Research Team: Franco Malerba (CESPRI), Fabio Montobbio (CESPRI), Stan Metcalfe (CRIC), Ed Steinmueller (SPRU), Charles Edquist (TEMA).

Progress

In accordance with the contract with the Commission, one paper has been delivered to the Commission:

Sectoral Systems: Implications for European Technology Policy*, by Charles Edquist, Franco Malerba, Stan Metcalfe, Fabio Montobbio, Ed Steinmueller.*

Methodology

All ESSY partners are participating at the development of the policy implications of the ESSY research which draw on all the ESSY RPs. In particular Franco Malerba (CESPRI), Fabio Montobbio (CESPRI), Charles Edquist (TEMA), Ed Steinmueller (SPRU) and Stan Metcalfe (CRIC) have written this summary paper on the policy issues raised by ESSY.

Scientific Findings

The sectoral system of innovation approach can be used as a framework for designing specific innovation policies. A necessary condition for public intervention in processes of innovation is that a 'problem' - which is not automatically solved by markets and firms - must exist. Substantial analytical and methodological capabilities are needed to identify these 'problems'. The important insight in the sectoral systems approach is, that innovation systems are constructed and operate at multiple levels in an economy and that they to various degrees interact within and across national economies and technologies. The sector becomes the focusing device to identify the intersection of these different levels and scales of analysis.

Sectoral production systems and their related markets are important because it is within these systems that sequences of innovation problems are defined and 'solved' by firms. The problems are specific to the sector but the solutions typically draw on a more extended division of labour that goes beyond the production/market system narrowly defined. Thus, nations and sectors support what can be called bundles of innovative capabilities and resources of a general kind. Firms in the pursuit of competitive advantage stimulate the application of these resources to specific innovation problems, and the context in which firms interact with the wider innovation milieu depends on the nature of the sector. Notice here the important role of the firm to act as the combinatorial locus for the many different kinds of knowledge typically required to innovate. Innovation requires more than knowledge of science and technology, it also requires knowledge of organisation and market and the latter are exclusively the province of firms, or more precisely, business activities in sectoral contexts.

The importance of the sectoral system is that it forms the locus of intersection of numerous networks generating particular kinds of knowledge. A typical 'technologist' in a firm may interact with other technologists in the relevant disciplinary community, with industry and government groups establishing standards and regulations, with technologists in rival firms and with academic researchers in supporting fields. Each of these networks has different members and different purposes but all contribute to innovation. Indeed, innovative ability may depend on the ability to participate in and manage these network relations. Thus, the wider significance of the sectoral perspective to identify the complex of networks and the dynamics of their birth growth and even decline in relation to innovation performance.

Of course Sectoral Systems of Innovation are quite *different* from each other, e.g., with regard to knowledge base, resources spent on R-D, firms' characteristics etc. In addition, organisations and institutions constituting elements of the sectoral systems may have different roles in different countries. For example, research institutes and company-based research departments may be important organisations in one country (e.g. Japan) while research universities may perform a similar function in another (e.g. the United States). Institutions such as laws, norms, and values also vary considerably across countries.

In our project, we emphasise than that Sectoral Systems are different and that within each sector there are important regional and country specificities that affect the different trajectory of industrial development. We would like to bring to the fore the importance of a sound, empirically driven comparison between sectoral systems and within sectoral systems across countries. Without such comparisons, it is difficult, as mentioned earlier, to single out 'problems', missing functions, organisations and institutions. Comparisons are therefore the most important means for understanding the relationships within sectoral systems and their impact on the performance of firms.

Genuinely empirical and very detailed comparisons can be performed between existing systems (geographically or historically). They are similar to what is often called 'benchmarking' at the firm level. Such comparisons are crucial for policy purposes. They can identify the 'problems' that should be subject to policy intervention and are necessary to know the causes behind the problems identified – at least the most important ones - in order to be able to design appropriate innovation policy instruments.

Within a system of innovation framework, an identification of the causes behind the problems is the same as identifying deficiencies in the functioning of the system. It is a question of identifying those systemic dimensions that are missing or inappropriate and which lead to the 'problem' in terms of comparative performance. Let us call these deficient functions '*system failures*'. When we know the causes behind a certain 'problem' – for example weak technological transfer between university and industry - we have identified a 'system failure'.

Not until they know the character of the system failure can policy-makers know whether to influence or change organisations or institutions or the interactions between them – or something else. Therefore, an identification of a problem should be supplemented with an analysis of its causes as a part of the analytical basis for the design of an innovation policy. Benchmarking is not enough.

In terms of policy, it is possible to state the principal contributions of the sectoral system approach.

1. A sectoral system approach provides a new methodology for the study of sectors and therefore for the identification of variables which should be the policy targets.

While up to now industrial economics and industrial organisation have focussed on dimensions such as structure-conduct-performance, strategy in a game theoretic way, transaction costs or sunk cost and the bounds approach, the approach suggested here is that sectoral analyses should focus on systemic features in relation to knowledge and boundaries, heterogeneity of actors and networks, institutions and transformation through co-evolutionary processes. As a consequence, the understanding of these dimensions becomes a prerequisite for any policy addressed to a specific sector.

In fact, one of the problems that governments may face is the inability to understand the specificity of the sector, the technology or the institutional setting in which policy has to take place. For example, in very general terms, policies that try to correct for lock ins and variety failures by promoting entry should pay considerable attention to the type of sectoral system. In an entrepreneurial (Schumpeter Mark I) regime, characterised in principle by high entry rates, policies promoting entry would be very much in tune with the organisation of innovative activity of a sector characterised by high turbulence. In a routinised regime (Schumpeter Mark II), characterised by strong rivalry among a core group of innovators, exploiting economies of scale and scope in R-D, policies favouring small firm entry would risk to disrupt the inner innovative dynamics of the industry. In this case, rather than entry promotion, a policy of basic research or "technology vision" addressed to the oligopolistic core of the industry could be more appropriate.

2. The impact of general or horizontal policies may drastically differ across sectors

A second point relates to the major differences that exist among sectors in the variables identifying a sectoral system, and, as a consequence, the impact of horizontal policies may greatly differ from sector to sector. The channels and ways policies have their effects differ from sector to sector. It is clear that for these purposes biotechnology and pharmaceuticals is a different sectoral system than machine tools or telecommunications and that the differences vary with the maturity of the sector.

For example, two of the major policy statements derived from the innovation system approach could be further qualified looking at the different relevance of the following phenomena across sectors

- Cooperation and networks (as primary policy targets in an innovation system approach) may have different relevance and characteristics among sectors. As mentioned above, simple economic models of competition poorly represent the extent of interdependence of enterprises within modern sectors. In a sector, the generation and commercialisation of innovation is likely to involve extensive co-operation and division of labour, much of which is negotiated in networks rather than governed by ordinary market clearing mechanisms. Here the important shift in policy emphasis towards strengthening innovation systems, organisations and institutions (rather than seeking to influence specific innovation events) has to be supplemented by the understanding of the relevance of the role of cooperation and networks in the specific system of innovation.

-Non- firm organisations and institutions (as major targets of policy in an innovation system approach) could have different relevance in different sectors. The institutional setting is very important in a sectoral system and should be monitored by public authorities. For example, the legal and institutional rules governing co-operative exchange are evolving within existing legal frameworks such as those governing intellectual property rights that were devised for other purposes. It is very likely that there will be major unintended consequences stemming from changes in these rules. A sectoral system of innovation is composed of for-profit firms but its performance in any particular sectoral setting is likely to be affected by not for profit organisations such as public research institutions and universities. The interactions between all the organisations active within a sector contribute to the sustainability and success of commercial activities within the sector. When the role of public organisations is well

understood in the context of the innovation needs of a particular sector, policy can have a major impact in reshaping the missions of existing or in creating new public organisations.

3. The analysis of the rationale and the effects of policies requires a deep and careful comparative analysis over time, across countries and across sectoral systems.

As previously mentioned, each sector has different features, organisation and dynamics, and the actual outcome is the result of the interplay of the various basic variables affecting a sectoral system and of their interaction over time. The basic reasons advanced for the need to compare innovation systems (Section 4.5) are equally valid for sectoral systems: comparisons of the differences across sectoral systems, and (for the same sectoral system) over time and across countries are a prerequisite for very effective policy tools. Thus establishing a basis for comparative analysis of the configuration of active institutions in any particular sector is a necessary step in policy formulation. These configurations can differ across national or regional contexts, but the effectiveness of variant configurations must be analysed rather than presumed to be sustainable. Finally, different contexts may limit the transferability across borders of sectoral policies and require different interventions.

4. For fostering innovation and diffusion in a sector, not just technology and innovation policies, but a wide range of other policies may be relevant.

A sectoral system approach emphasises that innovation and technology policy are linked with and affect other types of policies, such as science policy, industrial policies, policies related to standards and IPR and competition policy. In sectors such as pharmaceuticals and biotechnology, science policies, technology policies as well as IPR policies play a major and interrelated role (see McKelvey-Orsenigo,2001 in ESSY). In telecommunication, standards, competition policies and IPR have major effects (see Edquist, 2001, Hommen-Manninen,2001 and Corrocher, 2001 in ESSY).

In addition, a sectoral system approach highlights the interdependencies, links and feedbacks among all of these policies, and their effects on the dynamics and transformation of sectors. In fact, the problems that shape innovation arise within the context of the sector, and neither the trajectory of the technology nor the trajectory of the market are independent of one another.

5 The policy maker is an active internal (part) of sectoral systems at different levels.

The public actor has to be aware that she is inside to a sectoral system at various levels. In the various sectors examined in the ESSY project, the policy maker intervenes actively in the creation of knowledge, IPR, corporate governance rules, technology transfer, financial institutions, skill formation, public procurement. As a consequence, it has to develop competencies and an institutional setting in order to be effective and consistent at the various different levels.

6 Policy should consider the different geographical dimensions of sectoral systems.

The sectoral approach takes into account the developments in the local, national, regional, and global levels of aggregation in markets and institutions. For example, in chemical industry policies at the national level have been highly relevant (Cesaroni et al,2001 in ESSY) while in telecommunication both national and transnational policies such as the European ones have been key (Edquist,2001 in ESSY). On the contrary in machine tools the local dimension has always been key (Shapira-Wengel,2001 in ESSY).

Developments at each of these levels influence the development and articulation of technological capabilities. While political boundaries and local proximity are influential in the generation and diffusion of innovation, modern enterprises in a liberalised global economy must take a global perspective on actual and potential competition. Policies that focus on only one level of aggregation are likely to miss constraints or opportunities that are influential in the innovative behaviour of individual organisations. While technology policies can and sometimes should be addressed at one level of aggregation, the rationale for these policies and their implementation must reflect a global perspective.

Some specific policy conclusions derived from ESSY

ESSY research provides a basis for making further distinctions that are relevant to policy analysis. These distinctions derive from a programme of research that was 'deep' in penetrating the workings of particular sectors while not 'extensive' in coverage of many different sectors. The evidentiary basis for these distinctions is therefore provisional, and relies upon a more extensive body of research than that performed solely within ESSY. A further qualification in the generality of these distinctions is that the sectors examined in ESSY research all involved sectors in which innovation plays a critically important role to competitive success.

A key issue here is therefore the choice between supporting existing systems - with their historically accumulated knowledge bases - and supporting the development of radically new products and sectoral systems. Radical innovations and the emergence of new sectoral systems of innovation, especially in Europe, seem to be more of a 'problem' for markets and private firms than reproduction and incremental innovation in established sectors. We also know that large-scale and radical technological shifts - i.e. shifts to new trajectories - have rarely taken place without public intervention in the OECD countries. This is true for most of electronics as well as for aircraft and biotechnology – also in the USA.

Policies in Periods of Radical Technological Change

In cases where technological change within a sector breaks from the past accumulation of knowledge, and current expertise and capability: Sectoral systems of innovation will experience substantial stress because of the difficulties of aligning the incentives and the capabilities of the actors. For example, incumbent actors may under-estimate the scope of change and focus on reactive rather than adaptive strategies. Adaptation in other parts of the sectoral system may therefore be delayed, increasing the long-term risks to the sector.

Sectoral systems are neither naturally given nor static. They are constructed for a changing purpose and their boundaries components and connections change significantly

with the growth of knowledge and the evolution of problem sequences. A system can become outmoded and constrain innovation performance.

Examples of sectoral systems that constrained the innovative activity of firms can be found in the history of Machine Tools in US and Pharmaceuticals in Europe. The innovation of the intraocular lens provides interesting examples of the dynamics of emergence of an innovation system within the broader ophthalmological sector. From its tentative origins of interaction between the innovating clinician, a lens supplier and a materials supplier an international innovation system has been constructed by a small group of multinational medical companies. Each company articulates its own network of clinicians, suppliers and customers for IOLs, and to a degree these networks intersect within the wider relatively autonomous networks of eg., practitioner communities and health care systems. (see Metcalfe-James, 2001 in ESSY).

Radical technological change often involves an especially pro-active role for public organisations in recognising and promoting or even creating initial the conditions for market success. Governments can play important roles as lead-users of radical new technologies and in supporting the early use of these technologies in public organisations. This is very clear in the case of public purchasing, in regard to defence capabilities and public health.

Two examples from ESSY research can be proposed. First, the innovation of the intraocular lens and the considerable changes over time in the related innovation system in the UK and USA in particular depended greatly on the take up of the procedure in public and private health care systems, and on the different norms for translating clinical need into 'market demand' in the two national medical systems.(Metcalfe-James,2001 in ESSY). Second, the US government has played a very active and decisive role in the lauching of the fixed internet (Corrocher,2001 in ESSY). Finally, the Bioregio program in Germany is another interesting example in this respect.

In this respect, government capacities for monitoring the emergence of radical technological change differ substantially across countries.

It is also particularly important to encourage transparent and open debates about the significance of emerging technologies to support the formation of consensus as well as to identify possibilities for experimentation and trial.

ESSY research has shown clearly how in a dynamic setting new sectoral or sub-sectoral systems of innovation may rapidly emerge from existing ones, such as biotechnology (McKelvey-Orsenigo,2001, or internet and multimedia, Edquist, 2001 in ESSY).

If governments should intervene, they should intervene early in the development of new sub-systems and new sectoral systems of innovation. Such intervention at an early stage in the product/industry cycle may have a tremendous impact.

In the case of the public creation of the NMT 450 mobile telecommunications technical standard in the Nordic countries about 20 years ago this proved to be important. It was crucial for the emergence of the mobile telephone industry and for the fact that both Ericsson and Nokia became global leaders in this field.[4] On the other hand, there are many examples showing that massive government support to old and dying industries have had limited effect. Often it has only marginally delayed the death of these industries. One example is the Swedish shipyard industry in the late 1970's and early 1980's. The cost of the support to the shipyard industry was several hundred times larger than the cost of developing NMT 450.

[4] In addition to the creation of standards, incubators, technology parks and financing of new technology based firms are examples of policy instruments relevant for early stages.

On a methodological level, ESSY research indicates that existing approaches in industrial economics and standard measurement methods are not adequate to the task of identifying the changing configurations of sectoral systems and sub-systems of innovation, particularly the processes of knowledge exchange between different types of organisations.

The costs of constructing new sectoral sub-systems of innovation are substantial but this activity is not explicitly recognised in the existing literature of policy or management.

There are major strategic opportunities available in discovering better ways to monitor, promote, and reduce the costs of reconfiguration or expansion of sectoral systems and sub-systems of innovation.

2 Sector-specific conclusions

Additional specific recommendations in relation to the various sectors examined within ESSY may be found in the individual sector reports regarding pharmaceuticals and biotechnology (McKelvey-Orsenigo,2001), telecommunication equipment and services (Edquist, 2001), chemicals (Cesaroni, et al., 2001), software (Steinmueller, 2001), retailing services (Harvey, Nyberg and Metcalfe,2001), ophthalmological services (Metcalfe and James, 2001), airport services (Tether and Metcalfe,2001) and machine tools (Shapira and Wengel, 2001). These policy implications and conclusions are closely related to the problems faced by the various actors operating in the sectoral context and the specificity of the knowledge and boundaries, actors and networks and in which they are active

Some Aspects of Innovation Systems in Services.

The application of the sectoral system concept to the service sector creates many challenges not least in relation to the economic importance of services and the immense diversity of activities that can be grouped under this label (Tether and Metcalfe, 2001a). Many services are premised on high degrees of interaction with manufacturing activities and many services contribute to the production of manufactures. Services can be defined in many ways, but they all involve the articulation of specific transformation processes and these transformation processes are the basis for the innovation process.

The three cases examined in the ESSY programme examine different aspects of the self-organisation of innovation systems, the way in which they are transformed over time, the process of business experimentation and the, often complex, ways in which the relations between different actors are instituted. In relation to airport services, it is shown that the specific service features of the co-production of runway operations by airlines and airport operators has been a key factor in the innovation of new operation procedures, procedures that have had a considerable impact in increasing productivity (Tether and Metcalfe, 2001b). In the case of the innovation of the intra-ocular lens, it is shown how the interaction between clinical practice and medical companies, and thus between clinical norms and commercial norms, has transformed this medical procedure from a craft to a virtual assembly line procedure with great benefits to patients and the productivity of service delivery. In the process, new divisions of medical labour have emerged and the relation between need and demand transformed. In this case, medical companies have played a key role in assembling innovation systems at a micro level in pursuit of competitive advantage. In the third case study (Harvey, Nyberg and Metcalfe, 2001), the development of innovation in retailing is

examined through the lens of the growth of new models of retailing business in the supermarket revolution. Even such a traditional sector has a well- defined edge of modernity with supermarkets articulating an innovation system that produced a range of important innovations in relation to the logistics of supply chains, the organisation of demand and the market, and the packaging and display of foods. The different ways in which the Swedish and UK systems of retailing are organised has had a deep effect on the innovation systems that the two countries articulate. Thus, service activities are far from passive producers of innovations. The three sectors we have studied in ESSY have embedded within them innovation systems in which the firms in question play a key role in generating their systemic properties.

Some interesting remarks could be advanced for sectors specific policies in *services*. Service innovations are often unusual in the number and type of connections that are required to assemble the components of a commercially successful innovation. This makes the problems of co-ordination in services particularly acute. In terms of policy it suggests the need for identifying actual innovation requirements and for critically assessing existing approaches. In some cases, the commercialisation of service innovations often relies upon the development of a relatively 'standardised' package of components in which either inter-firm co-operation or a single co-ordinator may play a particular important role. Such standardised packages often require changes that at least parallel (if they do not replace) existing regulatory practices and rules. For example, the issues of 'inter-operability' have been a central concern in European telecommunication and information service policy. In some cases, such as telecommunication interconnection, these concerns have been incorporated into regulatory practice and have reshaped the commercial environment in which firms operate. In other areas, such as standards for interfaces between software, policies have been 'enabling' rather than directive and it is important to monitor whether they are having the desired effect of increasing data transferability and mitigating the problems of 'orphaned' users. Early notification of the intent to promote 'standardisation' is likely to lead to specific industrial proposals that can be enacted and provide an important instrument for supporting innovation, despite the inconvenience and complexity of enacting multiple rules. Correspondingly, existing rules and regulatory practices may serve as a constraint on service industry innovation just as in manufacturing. It may be particularly important to examine these rules and practice with a view to identifying the constraints that they create for innovative behaviours.

Sectoral Innovation in Software

The sectoral system of innovation in software is broadly distributed among private and public organisations throughout the world. In considering European interests in the software industry the single most important issue is in developing effective means of supporting complex software systems that are specific to particular applications. These range from enterprise resource planning software systems to the embedded software incorporated in consumer white goods and producer goods. The effective design of such systems requires the advantages of technical progress to be weighed against the costs of co-ordination. Increasingly, the design issues that underlay the construction of such application specific software involves co-ordination across the boundaries of organisations with the risk that co-ordination failures may occur. These failures constitute the type of 'problem' for which specific sectoral policies are the solution.

The challenges of formulating such policies are, however, daunting. No directive policy is likely to be effective given both the uncertainties about the course of technical

change and the difficulties of assessing the relative merits of different paths that might be followed in constructing new generations of complex software or building infrastructures for the Information Society. It is possible, however, to conclude that policy has a role in enabling industrial dialogue, particularly interactions between producers and users that are aimed at mitigating the costs of co-ordination. Procurement and regulatory policies that favour inter-operability and that ease the costs of inter-connection are a principal instrument for improving innovative performance and entry in the software industry. The publication of interface standards between software components is arguably as important as the establishment of reference standards for components in the manufacturing industries. While these activities are best organised and carried out by industrial associations, particularly those that include representation by user communities, they can be encouraged and promoted by policy action.

ESSY research in the software sector has specifically illustrated that the problems of moving from intra-firm to inter-firm organisation in the production of some forms of software creates new demands on other actors in the innovation system such as universities and public research laboratories. In embedded software, for example, the tradition of major firms undertaking nearly complete responsibility for the design of software tools and the implementation of systems may be replaced in the near future by specialised companies. From a European viewpoint, this appears to be a case of larger sectoral system failure in which neither public research laboratories nor universities (with a few conspicuous exceptions) have been sufficiently active to provide the basis for European participation in emerging specialised segments. The example serves to highlight the importance of identifying potential changes in division of labour that rely upon external research capabilities. Funding research and encouraging dialogue about such changes is likely to have positive impacts on the innovative capabilities of European software companies.

During the ESSY project the 'open source' or 'free software' movement has grown very rapidly, creating major new challenges for policy. Some have claimed that this movement endangers the current 'business model' which is responsible for generating the revenues for funding research and innovation in the industry. Others claim that this movement represents a viable alternative to the current system of using copyright to generate this revenue. It appears highly unlikely that this movement will be able to match the performance of commercial software development in either innovation or in serving the needs of the average user. Nonetheless, free and open source software provides two important advantages from a European perspective. First, this software provides a means of constructing components of the Information Society infrastructure such as World Wide Web servers that support the active participation of those seeking to develop new service innovations and platforms. To the extent that such systems provide a means to support entry and innovation in the industry, it is relevant to support their development through complementary research, education and procurement policies. Second, open source or free software appears to provide an excellent means for supporting the acquisition of practical programming skills and knowledge. Skills shortages in software design and development have been identified as a major impediment to future European employment and growth. An assessment of the potential of open source and free software for mitigating these problems is of considerable policy relevance.

These general messages from ESSY research offer important additions to the existing body of knowledge supporting evidence-based policy. They reflect a considerable shift of emphasis in the formulation of innovation policies, which are, of course, much broader than policies for science and technology. Traditional innovation policies have been formulated in providing public resources for R-D and changing the incentives for firms to innovate. Tax breaks for R-D, innovation subsidies and patents are typical examples of these policies. The

ESSY perspective does not deny the significance of this approach but recognises that the effects may run rapidly into diminishing returns. To offset this it is necessary that innovation opportunities be enhanced and that this will be achieved through connecting firms within a wider division of innovative labour within and between economies.

The sectoral perspective provides a tool for policy makers to comprehend the relevant innovation systems and for identifying the actors that should be influenced by policy. The *quid pro quo,* however, is that policy makers need to invest much more effort in understanding the idiosyncrasies of the sectors that they use to channel the influence of policy.

5. Dissemination and Exploitation Of Results

All the members of ESSY are involved in the exploitation plans and dissemination of the results of the project. Particular attention is devoted to communicate relevant results among partners as well as to relevant beneficiaries, in particular about issues regarding both general and sectoral policy.

The dissemination of the results took place mainly through

1. The ESSY Working Papers.
2. Publications derived directly from ESSY
3. The ESSY workshops organised during the life time of ESSY
4. The use of the ESSY internet site and ESSY ftp server.
5. The development of a final newsletter and CD ROM

5.1 ESSY Working Paper

As shown above, the project has produced a significant number of research papers that address the issues outlined in the Work Programme. In particular ESSY has produced 39 deliverables. In accordance with the contract with the Commission, 31 papers have been delivered to the Commission. Eight papers are extra contribution that various partners decided to deliver. Out of these 39 papers, three summary reports have been produced in ESSY. The list of these ESSY papers is in the Annex and at the ESSY internet site. The content of these various contribution is widely summarised above.

The reader interested in the sectoral system methodology and on the evolution of the characteristics of six European sectors is advised to read WP4-RP11 - Sectoral Systems in Europe: Summary and Conclusions. *Franco Malerba.* The reader interested in the determinants of the performance in the six European sectors is advised to read WP4-RP12 - The performance of Sectoral Systems in Europe. *Benjamin Coriat, Franco Malerba and Fabio Montobbio.* The reader interested in the policy issues is advised to read WP4-RP13 - Sectoral Systems: Implications for European Technology Policy*, by Charles Edquist, Franco Malerba, Stan Metcalfe, Fabio Montobbio, Ed Steinmueller.* These three final reports have been widely used for the dissemination of the ESSY results.

5.2 Publications from the ESSY Project.

The amount of work performed in ESSY produced through its working papers but not only a great amount of publications by each research partner and presentation to conferences different from the ESSY workshops. Below there is a list of publications and conferences which underestimated the contribution of ESSY to the research because some work may be not yet published, not all conference and workshops presentations are included and some research has been enhanced by ESSY indirectly through the constitution of databases development of ideas, development of interpersonal contacts.

The following lists present the publications, spun off from ESSY, and conference and workshop presentations carried out by the ESSY partners

CESPRI

F. Malerba (2001), *Sectoral System of Innovation and Production*, Research Policy, forthcoming

F. Montobbio (2001), *National Innovation System: A Critical Survey*, Industry and Innovation, under revision.

F. Montobbio (2002), *Sectoral Patterns of Innovations and Market Share Dynamics*, Cambridge Journal of Economics, v.27, forthcoming

Malerba F., Montobbio F. (2000); *Knowledge Flows, Structure of the Innovative Activity and International Specialisation.* CESPRI Working Paper, n. 119 (submitted to the Journal of Evolutionary Economics, under first revision)

F. Lissoni; S. Breschi, *"Knowledge spillovers and local innovation systems: A critical survey"*, Industrial and Corporate Change, vol. 10(4), 2001

S. Breschi, Lissoni, F. "*Localised knowledge spillovers vs. innovative milieux: knowledge 'tacitness' reconsidered*", Papers in Regional Science 80(3), 255-73, 2001

N. Corrocher, *The Internet Services Industry: Sectoral Dynamics of Innovation and Production and Country-specific Trends in Italy and in the UK*

M. McKelvey, L. Orsenigo, *Pharmaceuticals as a Sectoral Innovation System*

L. Orsenigo, "*The Dynamics of Knowledge and the Evolution of an Industry Network*, (with Fabio Pammolli, Andrea Bonaccorsi, Massimo Riccaboni and G. Turchetti), Journal of Management and Governance, 1998.

L. Orsenigo, "*The evolution of the forms of organization of innovative activities in biotechnology*" (with P. Barbanti e A. Gambardella), in International Journal of Biotechnology, 1999.

L. Orsenigo, "*Technological Change and the Dynamics of Networks of Collaborative Relations. The Case of the Bio-pharmaceutical Industry*", (with F. Pammolli and M. Riccaboni), Research Policy, 2001.

L. Orsenigo, "*The persistence of innovative activities. A Cross-Country and Cross-Sectors Comparative Analysis*", (with E. Cefis), Research Policy, 2001

E. Cefis, M. Ciccarelli, L. Orsenigo, *Firms' Growth in the Pharmaceutical Industry*

F. Malerba; M. Mancusi; F. Montobbio, *The Determinants of Technological Specialization and its Dynamics*

Coriat, B., Malerba F., Montobbio F., (2001); *The Performance of European Sectoral Systems*, ESSY Working Paper .

Edquist C., Malerba, F., Metcalfe, S., Montobbio, F., Steinmueller, E., (2001); *The Policy Implications of the Sectoral System Methodology*. ESSY Working Paper

F. Malerba, *Sectoral System in Europe: Summary and Conclusions*

N. Lacetera, *Corporate Governance and the Governance of Innovation: the Case of Pharmaceutical Industry,* Journal of Management and Governance, 5, pp. 29-59, 2001

S. Breschi – F. Lissoni, "*Geographical boundaries of sectoral systems*", 40th European Regional Science Association Conference, Barcelona, 29 August-2 September 2000

Malerba F., "*Sectoral systems of innovation and production*", DRUID Conference, Alborg 2000.

Malerba F., "*Technological regimes and sectoral systems of innovation in Europe*" Saint Gobain Conference, Paris, June 2001.

Malerba F., "*Sectoral systems: concept, dimensions and empirical analysis*", ECIS Conference The future of innovation studies, Eindhoven, September 2001.

Malerba F., Mancusi, M.L., Montobbio F. (2001); *The determinants of technological specialisation and Its Dynamics*. Presented to the Nelson and Winter Conference, DRUID's (Danish Research Unit for Industrial Dynamics), June 12-15, Aalborg-Denmark.

Malerba F., Montobbio F. (2000); *Knowledge Flows, Structure of the Innovative Activity and International Specialisation*. Presented to the conference Change, Development and Transformation: Transdisciplinary Perspectives on the Innovation Process. The Eighth International Joseph A. Schumpeter Society Conference. 28th June - 1st July 2000. Manchester/UK.

Malerba F., Montobbio F. (2000); *Sectoral Systems and International Technological and Trade Specialisation*. Presented to the conference: The Learning Economy - Firms, Regions and Nation Specific Institutions, DRUID's (Danish Research Unit for Industrial Dynamics) Summer 2000 Conference, June 15-17, Rebild/Denmark

Montobbio F. (1999); *Sectoral Specificity in the Relation between Technology and Market Share Dynamics*. Presented to the conference European Meeting on Applied Evolutionary Economics, Institute d'Economie et de Politique de l'Energie (CNRS), 7-9 June, Grenoble.

Montobbio F. (1999); *Sectoral Specificity in the Relation between Technology and Market Share Dynamics*. Presented to the XII° A.I.S.S.E.C (Associazione Italiana per lo Studio dei Sistemi Economici Comparati) Conference, Università degli Studi di Siena – Facoltà di Economia "R. M. Goodwin". Dipartimento di Economia Politica. June 3–5.

CREII

« *Consolidation de l'oligopole européen des télécommunications et transmission du "choc"* de l'UMTS », M.Didier, J.H. Lorenzi (eds.), Rapport du Conseil d'Analyse Economique sur l'UMTS, 2002. En collaboration avec Gérard Pogorel

« *Le choc de l'UMTS sur la corporate governance des firmes européennes* », Revue d'Economie Financière, n°63, 2001

« *Se dirige-t-on vers un modèle unique de gouvernement d'entreprise?* », Rapport Moral sur l'argent dans le Monde, Revue d'Economie Financière, 2000

« *Quelles limites à la convergence des modèles de corporate governance?* », Revue d'Economie Industrielle, n°90, 1999

« *Corporate governance dynamic in Europe and Japan* », Waseda University, Tokyo, june 2001.

« *La convergence des systèmes de gouvernement d'entreprise en Europe* », Commissariat Général du Plan, 2001, M. Boutillier et P. Geoffron (eds).

CRIC

B. S. Tether and J. S. Metcalfe (forthcoming) '*Systems of Innovation in Services'*, in F. Malerba (ed.) *Sectoral Systems of Innovation and Production in Europe*, Cambridge University Press.

Metcalfe, J. S. (2002) '*Knowledge of Growth and the Growth of Knowledge'*, *Journal of Evolutionary Economics*, forthcoming.

Metcalfe, J. S. (2001) '*Institutions and Progress*', *Industrial and Corporate Change*, Vol 10

Metcalfe, J. S. and James, A. (2000) '*Emergent Innovation Systems and the Delivery of Clinical Services: The Case of Intraocular Lenses'*, CRIC Working Paper No. 9, CRIC, University of Manchester

B. S. Tether and J. S. Metcalfe (forthcoming) '*System Transformation and Knowledge Integration: The Case of Air Traffic Management at Congested Airports'*, in A. Prencipe, A. Davies and M. Hobday (eds.) *Firm Capabilities and Systems Integration*, Oxford University Press.

B. Andersen, J. S. Metcalfe and B. S. Tether (2000), '*Innovation Systems as Instituted Economic Processes'*, in J.S. Metcalfe and I. Miles (eds.), *Innovation Systems in the Service Economy*, Kluwer Academic Publishers, Norwell, MA, USA, 15 – 42

B. S. Tether and J. S. Metcalfe (2000*), 'Horndal at Heathrow? – Innovation through Procedural Change at a Congested Airpor*t' in J.S. Metcalfe and I. Miles (eds.), *Innovation Systems in the Service Economy*, Kluwer Academic Publishers, Norwell, MA, USA, 297 - 328

B. S. Tether and J. S. Metcalfe (2001) '*Horndal at Heathrow? Co-production, Learning and Innovation – Investigating the Processes of Runway Capacity Creation at Europe's Most Congested Airports'*, CRIC Discussion Paper No. 46, CRIC, University of Manchester, Manchester, UK (under review with Industrial and Corporate Change)

2002 Jan. 17th – 19th: DRUID (Danish Research Unit for Industrial Dynamics) PhD Winter Conference, Aalborg, Denmark (17th – 19th January 2002). Tether Metcalfe paper on '*Services and Systems of Innovation'*.

2001 August 31st – Sept. 1st : 5th *European Business History Association Conference* on 'Business and Knowledge', Oslo, Norway. Tether – Metcalfe on '*Horndal at Heathrow? Co-operation, Learning and Innovation: Investigating the Processes of Runway Capacity Creation at Congested European Airports*'

2001 June 12th – 15th : *DRUID's Nelson and Winter Conference*. Aalborg, Denmark. Tether Metcalfe paper on *'Horndal at Heathrow? Co-operation, Learning and Innovation: Investigating the Processes of Runway Capacity Creation at Congested European Airports'*

1999 June 7th – 9th : European Meeting on *Applied Evolutionary Economics* at the IEPE Institute, Grenoble, France. Tether Metcalfe paper 'Horndal *at Heathrow? – Innovation through Procedural Change at a Congested Airport'*

TEMA

Edquist, Charles (ed.) *The Internet and Mobile Telephony Sectoral System of Innovation: Equipment Production, Access Provision and Content Provision*, Edward Elgar Publishers, forthcoming 2002, 300 pp.

WZB

Hannah Kettler and Steve Casper "*National Institutional Frameworks and the Hybridization ofEntrepreneurial Business Models within the German and UK BiotechnologySectors*", , Industry and Innovation, Volume8, No 1, April 2001.

Hannah Kettler and SteveCasper *"Turning Good Science into Successful Business*", , Journal of Commercial Biotechnology, March 2001.

Dr.Hannah Kettler and Dr. Steve Casper *The Road to Sustainability in UK and German Biotechnology Industries*, , Office of Health EconomicsPublications, July 2000.

5.3 ESSY Workshops

During the ESSY project five workshops have been organised. Each workshop was organised by one of the main partners. The activity in each workshop can be outlined as follows:

First ESSY Workshop, Cespri, Bocconi University Milan, Milan, February 11-13, 1999. First Steering Committee and Workshop. Discussion of task allocation, workshop management and organisation procedures in the ESSY programme. Completion of the set up of a common structure for carrying out sectoral and horizontal studies.

Second ESSY Workshop, Center of Research on Innovation and Competition, University of Manchester, Manchester, October 22-23, 1999. Discussion on the working papers of WP1 on sectoral systems conceptual framework. Completion of draft papers on the sectoral and horizontal studies.

Third ESSY Workshop, Wissenschaftszentrum Berlin Für Sozialforschung, WZB, Berlin, June 1-3, 2000. Discussion on the second drafts of the sectoral and horizontal research projects and of the progress in the related field researches and case studies. Comparisons and cross-fertilisation of the two groups of papers.

Fourth ESSY Workshop, Science and Technology Policy Unit, SPRU, University of Sussex, Brighton, March 22-24, 2001. Completion of the working papers of WP2 and WP3.

Discussion on tasks and procedures for the final part on international comparison of sectoral systems and policy implications.

Final ESSY Meeting, Cespri, Bocconi University Milan, November 29-December 1, 2001. Completion of the working papers of WP4. Synthesis and some implications for European international performance, competitiveness and growth, and policy implications

The first meeting was aimed at evaluating the unified methodological dimensions along which sectoral systems would be analysed. This was designed through a discussion of each of the six sectoral projects (RP1-RP6) and of the horizontal themes (RP7-RP10). In the second workshop (month 9) working papers within Work Package 1 have been distributed and discussed and preliminary drafts were presented for each sectoral system Research Project.

Workshop 3 and 4 evaluated the state of advancement of the research within each sector, and promoted feedback and interaction between the development of the empirical research in the six sectors and the horizontal themes. In particular the progress in the horizontal themes has been constantly compared and enriched by the increased knowledge provided by the sectoral system studies. The *third phase* was primarily aimed at providing a synthesis and the implications in terms of determinants of countries' and firms' competitiveness and public policy (Work Package 4: RP11-RP13). Results were compared with the situation in the United States and Japan.

Workshop 5 (the last one) has been used to present the final papers on these issues and to prepare the final report. During this workshop leading researchers from the United States such as Richard Nelson (Columbia University), David Mowery (Berkeley), were invited. This last workshop has been used to as an appropriate way of dissemination of the results. As it is shown in the Annex, the workshop was open not only to academicians but also to entrepreneurs and policy makers. Entrepeneurs participated actively in the discussion of the sectoral cases benefiting and contributing to them. Ronan O' Brien (EU Responsible of the project) and P. Caracostas (European Commission, DG Research) participated to the meeting and gave comments and insights.

5.4 Essy web site

In order to ease the dissemination of information and results CESPRI has created an ESSY Web site, http://www.cespri.uni-bocconi/essy, courtesy of Bocconi University, right from the start of the project. The established ESSY project homepage has been continuously updated. It contains a general introduction to the project, the aims, the partners, the achieved results and publications, as well as general information on the concluded project and on the various meetings. All the Working Papers and Deliverables with their theoretical and empirical findings have been included in the Web site.

5.5 CD – ROM and Leaflet

A CD-ROM with the main results of ESSY will be widely distributed.

It will include the Essy Work Programme., all the final Working Papers ESSY, the Final Report and a list of all the Essy Research groups

A leaflet for distribution (200 copies to be delivered) will describe and summarise the major research results of the Essy project.

Annexes

List of ESSY Working Papers:

The following working papers can be downloaded at http://www.cespri.uni-bocconi.it/essy.

1. Andersen B., Metcalfe J.S., Tether B.S., *Distributed Innovation Systems and Instituted Economic Processes*, (Working Paper Essy; 2001)
2. Bottazzi G., Dosi G., Lippi M., Pammolli F., Riccaboni M., *Innovation and corporate growth in the evolution of the drug industry*, (Working Paper Essy)
3. Bottazzi G., Dosi G., Rocchetti G., *Modes of Knowledge Accumulation, Entry Regimes and Patterns of Industrial Evolution*, (Working Paper Essy; 2001)
4. Breschi S., Lissoni F., *Geographical Boundaries of Sectoral Systems*, (Working Paper Essy; 2001)
5. Casper S. and Kettler H., *National Institutional Frameworks and the Hybridization of Entrepreneurial Business Models: The German and UK Biotechnology Sectors*, (Working Paper Essy; 2001)
6. Casper S. and Soskice D., *Patterns of Innovation and Varieties of Capitalism: Explaining the Development of High-Technology Entrepreneurialism in Europe*, (Working Paper Essy; 2001)
7. Cefis E., Ciccarelli M. and Orsenigo L., *Firms' Growth in the Pharmaceutical Industry*, (Working Paper Essy; 2001)
8. Cesaroni F., Gambardella A., Garcia-Fontes W., Mariani M., *The Chemical Sectoral System. Firms, markets, institutions and the processes of knowledge creation and diffusion*, (Working Paper Essy; 2001)
9. Coriat B., Malerba F., Montobbio F., *The International Performance of European Sectorla Systems,* (Working Paper Essy; 2002)
10. Coriat B., O. Weinstein, *National institutional framework,institutional complementarities and sectoral systems of innovations*, (Working Paper Essy, 2001)
11. Coriat B., Weinstein O., *The Organization of R&D and the Dynamics of Innovation A "Sectoral" View*, (Working Paper Essy; 2001)
12. Corrocher N., *The Internet Services Industry: Sectoral Dynamics of Innovation and Production and Country-specific Trends in Italy and in the UK*, (Working Paper Essy; 2001)

13. D'Adderio L., *The Diffusion of Integrated Software Solutions: Trends and Challenges*, (Working Paper Essy; 2001)

14. Dalum B., *Data communication - the satellite and tv subsystems*, (Working Paper Essy; 2001)

15. Dalum B., Villumsen G., *Fixed Data Communications - Challenges For Europe*, (Working Paper Essy; 2001)

16. Dubocage E., *The Financing of Innovation by Venture Capital in Europe and in the USA: a Comparative and Sectoral Approach*, (Working Paper Essy;2001)

17. Edquist C., *The Fixed Internet and Mobile Telephony Sectoral System(s) of Innovation: equipments production, access provision and content provision*, (Working Paper Essy 2001)

18. Edquist C., F. Malerba, S. Metcalfe, F. Montobbio, Steinmueller Ed., *Sectoral Systems: Implications for European Technology Policy* (Working Paper Essy; 2002)

19. Geoffron P., Rubinstein M., *Sectoral Systems of Innovation and Production*, (Working Paper Essy; 2001)

20. Harvey M., Nyberg A. and Metcalfe J. S.*, Deep Transformation in The Service Economy: Innovation and Organisational Change in Food Retailing in Sweden and the UK*, (Working Paper Essy; 2001)

21. Hommen L. with Manninen E., *GSM (Global System for Mobile Telecommunications)*, (Working Paper Essy; 2001)

22. Lacetera N., *Corporate Governance and Innovation in the Pharmaceutical Industry: Some Further Evidence,* (Working Paper Essy; 2001)

23. Lehrer M., *From Factor of Production to Autonomous Industry: the Transformation of Germany's Software Sector*, (Working Paper Essy; 2001)

24. Malerba F., Montobbio F.*, Sectoral Systems, National Systems and International Technological and Trade Performance*, (Working Paper ESSY; 2001)

25. Malerba F., *Sectoral Systems of Innovation and Production*, (Working Paper ESSY; 2001)

26. Malerba F., *Sectoral Systems in Europe: Summary and Conclusions* (Working Paper ESSY; 2002)

27. McKelvey M. and Orsenigo L., *Pharmaceuticals as a Sectoral Innovation System*, (Working Paper Essy; 2001)

28. McKelvey M., Alm H. and Riccaboni M., *Does Co-location matter? Knowledge Collaboration in the Swedish Biotechnology- Pharmaceutical Sector*, (Working Paper Essy; 2001)

29. Metcalfe J. S., James A., *Emergent Innovation Systems and the Delivery of Clinical Services: the Case of Intra-Ocular Lenses*, (Working Paper Essy;

30. Montobbio F., *National Innovation Systems. A Critical Survey*, (Working Paper ESSY; 2001)

31. Owen-Smith J., Riccaboni M., Pammolli F., Powell W. W., *A Comparison of US and European University-Industry Relations in the Life Sciences*, (Working Paper Essy; 2001)

32. Rivaud-Danset D., *The Financing of Innovation and the Venture Capital, the National Financial and Sectoral Systems,* (Working Paper Essy; 2001)

33. Steinmueller W. E., *Embedded Software: European Markets and Capabilities* (Working Paper Essy; 2001)

34. Steinmueller W. E.*, The Software Sectoral Innovation System: Open Source Software and the Alternatives*, (Working Paper Essy; 2001)

35. Steinmueller W. E., *The European Software Sectoral System of Innovation* (Working Paper Essy, 2001)

36. Tether B. S., Metcalfe J. S. and Miles I.*, Horndal at Heathrow? Co-operation, Learning and Innovation: Investigating the Processes of Runway Capacity Creation at Europe's most Congested Airports*, (Working Paper Essy; 2001)

37. Tether B. S., Metcalfe J. S. and Miles I., *Innovation Systems & Services. Investigating 'Systems of Innovation' in the Services Sectors - an Overview*, (Working Paper Essy; 2001)

38. Wengel J., Shapira P., Machine Tools: *The Remaking of a Traditional Sectoral Innovation System?,* (Working Paper Essy; 2001)

39. Winter G., Kaniovski Y.M., Dosi G., *Modeling Industrial Dynamics with Innovative Entrants*, (Working Paper ESSY; 2001)

List of the deliverables.

The following publications can be downloaded at http://www.cespri.uni-bocconi.it/essy. In Table 4.1 of the Work Programme we agreed upon 31 deliverables that have been completed. Here we update that Table with the 8 extra deliverables that ESSY delivered.

WP1	CESPRI			**Completed**
		CESPRI	*National Innovation Systems: a Critical Survey.*	**Completed**
		CESPRI	*Sectoral Systems of Innovation and Productions.*	**Completed**
		CESPRI	*The Geographical Boundaries of Sectoral Systems.*	**Completed**
		CESPRI	*Sectoral Systems, National System and International Technological and Trade Performance.*	**Completed**
		SSSA	*Modelling Industrial Dynamics with Innovative Entrants.*	**Completed**
		SSSA	*Modes of Knowledge Accumulation, Entry Regimes and Patterns of Industrial Evolution.*	**EXTRA PAPER**
		CRIC	*Distributed Innovation Systems and Instituted Economic Processes.*	**EXTRA PAPER**
WP2				
WP2/RP1	CRIC			
		CRIC	*Innovation Systems & Services. Investigating ´Systems of Innovation´ in the Services Sectors - an Overview.*	**Completed**
		CRIC	*Emergent Innovation Systems and the Delivery of Clinical Services: the Case of Intra-Ocular Lenses.*	**Completed**
		CRIC	*Horndal at Heathrow? Co-operation, Learning and Innovation: Investigating the Processes of Runway Capacity Creation at Europe´s most Congested Airports.*	**Completed**
		CRIC	*Deep Transformation in the Service Economy: Innovation and Organisational Change in Food Retailing in Sweden and in UK*	**Completed**
WP2/RP2	SPRU			
		SPRU	*The European Software Sectoral System of Innovation.*	**Completed**
		SPRU	*The Software Sectoral Innovation System: Open Source Software and the Alternatives.*	**Completed**
		SPRU	*The Diffusion of Integrated Software Solutions: Trends and Challenges.*	**Completed**
		SPRU	*Embedded Software: European Markets and Capabilities.*	**Completed**
		WZB	*From Factor of Production to Autonomous Industry: the Transformation of Germany´s Software Sector.*	**Completed**
WP2/RP3	TEMA			
		TEMA	*The Fixed Internet and Mobile Telephony Sectoral System(s) of Innovation: equipments production, access provision and content provision.*	**Completed**
		TEMA	*Global System for Mobile Telecommunications (Working Paper Essy).*	**Completed**
		CESPRI	*The Internet Services Industry: Sectoral Dynamics of Innovation and Production and Country-specific Trends in Italy and in the UK.*	**Completed**
		IKE	*Fixed Data Communications - Challenges For Europe.*	**Completed**
		IKE	*Data communication - the satellite and tv subsystems.*	**EXTRA PAPER**

WP2/RP4	CESPRI			
		CESPRI	*Pharmaceuticals as a Sectoral Innovation System.*	**Completed**
		CESPRI	*Corporate Governance and Innovation in the Pharmaceutical Industry: Some Further Evidence*	**EXTRA PAPER**
		CESPRI	*Firms´ Growth in the Pharmaceutical Industry.*	**EXTRA PAPER**
		SSSA	*A Comparison of US and European University-Industry Relations in the Life Sciences.*	**Completed**
		SSSA	*Innovation and corporate growth in the evolution of the drug industry,.*	**EXTRA PAPER**
		TEMA	*Does Co-location matter? Knowledge Collaboration in the Swedish Biotechnology- Pharmaceutical Sector.*	**Completed**
		WZB	*National Institutional Frameworks and the Hybridization of Entrepreneurial Business Models: The German and UK Biotechnology Sectors.*	**Completed**
WP2/RP5	ISI			
		ISI	*Machine Tools: The Remaking of a Traditional Sectoral Innovation System?*	**Completed**
WP2/RP6	PF			
		PF	*The Chemical Sectoral System. Firms, markets, institutions and the processes of knowledge creation and diffusion.*	**Completed**
WP3	**CREII**			**Completed**
WP3/ RP7		WZB	*Patterns of Innovation and Varieties of Capitalism: Explaining the Development of High-Technology Entrepreneurialism in Europe.*	**Completed**
		CREII	*National institutional framework,institutional complementarities and sectoral systems of innovations.*	**EXTRA PAPER**
WP3/ RP8		CREII	*The Organization of R&D and the Dynamics of Innovation A "Sectoral" View.*	**Completed**
WP3/ RP9		CREII	*Sectoral Systems of Innovation and Production*	**Completed**
WP3/ RP10		CREII	*The Financing of Innovation and the Venture Capital, the National Financial and Sectoral Systems.*	**Completed**
		CREII	*The Financing of Innovation by Venture Capital in Europe and in the USA: a Comparative and Sectoral Approach.*	**EXTRA PAPER**
WP4	**CESPRI**			**Completed**
WP4/ RP11		CESPRI with other ESSY partners	*Sectoral System in Europe: Summary and Conclusions.*	**Completed**
WP4/ RP12		CESPRI with other ESSY partners	*The International performance of European Sectoral Systems.*	**Completed**
WP4/ RP13		CESPRI with other ESSY partners	*Sectoral Systems: Implications for European Technology Policy*	**Completed**

ESSY Workshops

FIRST ESSY WORKSHOP, CESPRI, UNIV. BOCCONI, MILAN, FEBRUARY 11-12-13, 1999

Thursday February 11

For those who will arrive on Thursday afternoon, we are going to have an informal dinner at a nearby trattoria. We will meet at 20.00 at the Hotel D'Este. Please tell Monica Cappi who will be able to attend.

Friday February 12

Introduction of participants

Presentation and discussion of the ESSY Project

10.45	Coffee Break
11.00	Discussion of WP1- Literature Review and Conceptual Framework
13.00	Lunch
14.00 - 15.45	Individual Meetings on various WPs
15.45	Coffee Break
16.00 - 16.45	Telecom, hardware and services
16.45 - 17.30	Software
17.30 - 18.15	Machine Tools
18.15	End of the Session

18.15 Meeting of the Steering Committee and the Associated Partners on the ESSY Consortium Agreement

21.00 ESSY kick-off dinner

Saturday February 13

9.30 -10.15 Services

10.15 - 11.00 Pharmaceutical-biotechnology

11.00 -11.15 Coffee break

11.15 - 12.00 Chemicals

12.00 - 12.45 Patterns of National Institutional Framework

12.45 Lunch

14.00 -14.45 Organisation of R-D

14.45 -15.30 Corporate Governance

15.30 - 16.15 Financing of Innovation

16.15 Coffee Break

16.30 - 17.00 Discussion of WP4- Sectoral systems in Europe, Comparison with US and

Japan, Policy Implication

17.00 Timetable, milestones and deliverables

Ways of communication

Dates and places for the next meetings

18.00 End of session

SECOND ESSY WORKSHOP, CRIC, MANCHESTER UNIV., OCTOBER 22-23, 1999

FRIDAY October 22, 1999

9.00 - 9. 15 Introduction

9.15 - 12.30 Discussion of WP1- Literature Review and Conceptual Framework:

F. Malerba: Sectoral Systems: Concepts, Structure and Dynamics

Discussants: W.E. Steinmueller - G. Dosi

F. Montobbio: Innovation Systems: a Critical Survey.

Discussants: C. Edquist - D. Soskice

F. Malerba - F. Montobbio: Sectoral and National Differences in the Relation between Innovation and Export Performance in Europe.

Discussant: B. Dalum

G. Dosi: Models of Industrial Dynamics in sectoral systems.

Discussant: S. Metcalfe

F. Lissoni - S. Breschi: The Geographical Boundaries of Sectoral Systems.

Discussants: J. Wengel

S. Metcalfe: Distributed Innovation Systems and Instituted Economic Processes

Discussant: B. Coriat

12.30 - 14.30 Individual Meetings on various WPs

14.30 - 15.15: RP 1 Services

15.15 - 16.00: RP 2 Software

16.00 - 16.45: RP 3 Telecommunications Hardware

SATURDAY October 23, 1999

9.00 - 9.45: RP 4 Pharmaceuticals - Biotechnology

9.45 - 10.30: RP 5 Machine Tools

10.30 - 11.00 Coffee break

11.00 - 11.45: RP 6 Chemicals

11.45 - 12.30: RP 7 Patterns of National institutional framework

13.00: Lunch

13.30 - 14.15: RP 8 Organisation of R-D

14.15 - 15.00: RP 9 Corporate Governance

15.00 - 15.45: RP 10 Financing of Innovation

16.00 -17.00: Conclusions and prospects

THIRD ESSY WORKSHOP, WZB, SOCIAL SCIENCE RESEARCH CENTRE, BERLIN, JUNE 1-3, 2000.

THURSDAY June 1

14.00-14.30 Introduction

14.30-15.15 WP1. Breschi-Lissoni: *The Geographical Boundaries of Sectoral System.*

Discussants: Steinmueller, Geoffron

15.15-16.00 WP1. Malerba-Montobbio: *Sectoral and National Differences in the Relation between Innovation and Export Performance in Europe.*

Discussants: Dosi, Villumsen

16.00-16.15 Coffee break

SECTORAL STUDIES

Each session will unfold as follows: Research Project Co-ordinators will have a very short overall presentation of the papers and the research project (15 minutes). Discussants will launch the overall discussion (15 minutes each) by summarising and commenting the papers of the RP. In each session the papers correspond to the list included in the Work Program. Each Co-ordinator should make sure that the papers are available on the FTP server one week before the beginning of the Meeting. This is particularly important to allow the discussants to read the papers in advance.

16.15-16.30 RP1. *Services.*

Presentation of the Coordinator: Stan Metcalfe.

16.30-17.45 RP1. Discussion of the papers:

-*Services: Sectoral systems and innovation* CRIC

-*The Airport Sectoral System* CRIC

-*Innovation and Institutions in the Medical Service Sector* CRIC

-*The Retailing Sectoral System* CRIC

Discussants: Casper, Wengel.

FRIDAY June 2

9.00-9.15 RP2. *Software.*

Presentation of the Coordinator: Ed Steinmueller.

9.15-10.30 RP2. Discussion of the papers:

-*Software: Sectoral System and innovation* SPRU

-*Embedded Software* SPRU

-*Client Specialised and Vertical Application Software* SPRU

-*Multimedia Software* SPRU

-*The Case of the German Software Sectoral Systems* WZB

Discussants: Dalum, Weinstein

10.30-10.45 Coffee break

10.45-11.00 RP3. *Telecommunications hardware and services*

Presentation of the Coordinator: Charles Edquist.

11.00-12.15 RP3: Discussion of the papers:

-*The Sectoral System in Telecommunications Hardware* TEMA

-*The Sectoral System in Telecommunication Services* TEMA

-*The Sectoral System in Telecommunications* CESPRI

-*The Sectoral System in Telecommunications* IKE

Discussants: Breschi, Tether

12.15 13.30 Lunch

13.30-13.45 RP4. *Pharmaceuticals and biotechnology*

Presentation of the Co-ordinator: Luigi Orsenigo

13.45-15.00 RP4. Discussion of the papers:

-The Bio-Pharmaceutical Sectoral System CESPRI

-The Bio-Pharmaceutical Sectoral System SSSA

-The Bio-Pharmaceutical Sectoral System TEMA

-The Bio-Pharmaceutical Sectoral System WZB

Discussants: Metcalfe, Lissoni

15.00-15.15 Coffee break

15.15-16.00 RP5: *The Machine Tools Sectoral System* ISI

Discussants: Hommen, Corrocher

16.00-16.45 RP6: *The Chemical Sectoral System* PF

Discussants: Orsenigo, Kettler

16.45-17.00 Coffee break

17.00-17.30 WP3: National institutional frameworks and sectoral systems

Presentation of the Co-ordinator: Benjamin Coriat.

SATURDAY June 3

9.00-9.45 RP7 *Patterns of National Institutional Framework and Sectoral Systems* WZB

Discussants: Coriat, Shapira.

9.45-10.30 RP8 *Organisation of R&D and Sectoral Systems* CREII

Discussants: Rivaud-Danset, Alm.

10.45-11.30 RP9 *Models of Corporate Governance and Sectoral Systems* CREII

Discussants: Soskice, Manninen.

11.30-12.15 RP10 *Models of the Financing of Innovation and Sectoral Systems.* CREII

Discussants: James, Cesaroni.

12.15-13.15 Conclusions: general discussion on the overall intermediate results of the project, future agenda, next meeting……

FOURTH ESSY WORKSHOP, SPRU, SCIENCE AND TECHNOLOGY POLICY RESEARCH, BRIGHTON, MARCH 22-24, 2001

PRESENTATION OF THE PAPERS AND DISCUSSANTS

Each session will unfold as follows: Research Project Co-ordinators will have a very short overall presentation of the papers and the research project (10 minutes). Discussants will briefly summarizes the papers and start the overall discussion (20 minutes each).

In each session the papers correspond to the list included in the Work Program. Each Co-ordinator should make sure that the papers are available on the FTP server ten days before the beginning of the Meeting. This is particularly important to allow the Discussants to read the papers in advance.

THURSDAY March 22

14.00-14.15 Introduction

Chairman: Ed Steinmueller

14.00-16.00 RP3. *Telecommunications hardware and services*

Presentation of the Coordinator: Charles Edquist.

Discussion of the papers:

Sectoral Systems In Telecommunications.

Charles Edquist

Discussant: Ed Steinmueller.

Three Generations of Mobile Telecommunications Systems & Services: European Standards, 1970 to 2000.

Leif Hommen and Esa Manninen.

Discussant: Andrew James

The European Telecom Innovation System Convergence, Threats And Opportunities.

Bent Dalum and Gert Villumsen.

Discussant: Jurgen Wengel

The Internet Services Industry: Sectoral Dynamics Of Innovation And Production And Country-Specific Trends In Italy And In The Uk.

Nicoletta Corrocher.

Discussant: Bruce Tether

16.15-16.30 Coffee break

16.30 –18.30 RP1 *Services*

Presentation of the Coordinator: Stan Metcalfe.

Discussion of the papers:

Sectoral System In Services.

Stan Metcalfe

Discussant: Luigi Orsenigo

The Retailing Sectoral System.

Mark Harvey.

Discussant: Leif Hommen

Emergent Innovation Systems And The Delivery Of Clinical Services: The Case Of Intra-Ocular Lenses.

J.S. Metcalfe, Andrew James

Discussant: Hannah Kettler

The Airport Sectoral System.
Bruce Tether

Discussant: Luciana D'Adderio.

FRIDAY March 23

Chairman: Charles Edquist

9.00-11.00 RP2. *Software.*
Presentation of the Coordinator: Ed Steinmueller.

Discussion of the papers:

Software Sectoral System: Open Source Software And The Alternatives.
Ed Steinmueller

Discussant: Charles Edquist

Embedded Software: European Markets And Capabilities.
Ed Steinmueller

Discussant: Nicoletta Corrocher

The Diffusion Of Integrated Software Solutions: Trends And Challenges.
Luciana D'Adderio

Discussant: Marianne Rubinstein

From Factor Of Production To Autonomous Industry: The Transformation Of Germany's Software Sector.
Mark Lehrer

Discussant: Ann Nyberg

11.00-11.30 Coffee break

RP5. *Machine Tools: The Dissolving And Remaking Of A Sectoral Innovation System?*
Jürgen Wengel

Discussant: Bent Dalum

12.30-13.45 Lunch

Chairman: Benjamin Coriat

13.45-15.45 RP4. *Pharmaceuticals and biotechnology*
Presentation of the Co-ordinator: Luigi Orsenigo

Discussion of the papers:

Pharmaceuticals As A Sectoral Innovation System: Some Introductory Notes.
Orsenigo et al.

Discussant: Benjamin Coriat

Analyzing Collaboration For Knowledge.
Maureen McKelvey, Håkan Alm, Massimo Riccaboni

Discussant: Dorothée Rivaud-Danset

The Road To Sustainability In The Uk And German Biotechnology Industries.
Steven Casper, Hannah E Kettler

Discussant: Walter Garcia-Fontes

A Comparison Of Us And European University-Industry Relations In Life Sciences.
Owen-Smith, Riccaboni, Pammolli, Powell

Discussant: Olivier Weinstein

16.00-17.00 RP6 *The Chemical Sectoral System.*
Walter Garcia-Fontes

Discussant: Steve Casper

17.00-17.30 WP3: National institutional frameworks and sectoral systems
Presentation of the Co-ordinator: Benjamin Coriat.

SATURDAY March 24

Chairman: Stan Metcalfe

9.00-10.00 RP7. *Patterns of National Institutional Framework and Sectoral Systems.*
David Soskice

Discussant: Giovanni Dosi.

10.00-11.00 RP8. *The Organization of R&D.*
Benjamin Coriat and Olivier Weinstein

Discussant: Francesco Lissoni

Coffee Break

RP9. Models of Corporate Governance and Sectoral Systems

Which Type of Corporate Governance Structure Is Most Conducive To Innovation? An Overview.
Marianne Rubinstein

Discussant: Stan Metcalfe.

Corporate Governance In Europe: Towards The Disappearance Of Insider Models?

Patrice Geoffron

Discussant: Gert Villumsen.

RP10. The Financing Of Innovation By The Venture Capital,

The National Financial And Sectoral Systems.

Dorothée Rivaud-Danset

Discussant: Mark Harvey.

13.15-14.30 Lunch

Chairman: Giovanni Dosi

14.30- 17.30 WP4: Presentations of the Outline and Discussion

RP11. Sectoral System in Europe. Implications for European International Performance, Competitiveness and Growth

(F. Malerba).

RP12. A Comparison of Structure, Evolution and Performance of Sectoral Systems in Europe, United States and Japan

(F. Montobbio).

RP 13. Sectoral Systems: Implications for European Technology Policy.

General Discussion led by Project Coordinators

FINAL ESSY WORKSHOP, CESPRI, UNIV. BOCCONI, MILAN, NOVEMBER 29TH – DECEMBER 1ST , 2001.

THURSDAY November 29th

14.30-15.00 Introduction: Franco Malerba

Chairman: Benjamin Coriat

15.00 –16.15 RP1 *Services.* Stan Metcalfe.

Discussants:
Fabio Pammolli
Stefano Breschi

16.15-16.45 Coffee break

16.45-18.00 RP4. *Pharmaceuticals and biotechnology.* Luigi Orsenigo

Discussants:
Alfonso Gambardella
Fabrizio Gianfrate (Fondazione Smith Kline)

FRIDAY November 30th

Chairman: Stanley Metcalfe

9.00-10.15 RP2. *Software.* Ed Steinmueller.

Discussants:
Salvatore Torrisi
Ernesto Hofmann (IBM)

10.15-11.30 RP6. *The Chemical Sectoral System.* Alfonso Gambardella

Discussants:
Maureen McKelvey
Vittorio Maglia (Federchimica- Italian Chemical Association)

11.30-11.45 Coffee break

11.45-13.00 RP3. *Telecommunications hardware and services.* Charles Edquist.

Discussants:
Olivier Weinstein
Bruno Lamborghini (Olivetti)

13.00-14.30 Lunch

Chairman: Ed Steinmueller

14.30-15.45 RP5. *Machine Tools* Jürgen Wengel

Discussants:
Francesco Lissoni
Dante Speroni (UCIMU)

15.45-16.45 WP3. *Institutions and sectoral systems*
Benjamin Coriat.

Discussants:
Steve Casper
David Mowery (Berkeley)

16.45-17.00 Coffee break

17.00-18.00 WP3. *National Institutional Frameworks and Sectoral Systems.*
David Soskice

Discussants:
Richard Nelson (Columbia University)
Dimitri Paraskevas Caracostas (European Commission, DG Research).

SATURDAY December 1st

Chairman: Charles Edquist

9.00 - 10.15 WP4: The Implications for European International Performance and Public Policy

RP11. Sectoral System in Europe.

(F. Malerba).

Discussants:

Richard Nelson (Columbia University)

David Mowery (Berkeley University)

10.15- 11.15 RP12. The Performance of Sectoral Systems in Europe.

(B. Coriat, F. Malerba, F. Montobbio).

Discussants:

Bent Dalum

Fabrizio Onida (Bocconi University and former President of the Italian Foreign Trade Institute)

11.30-11.45 Coffee break

11.45 - 12.45 RP 13. Sectoral Systems: Implications for European Technology Policy. (Project Coordinators)

Discussants:

Ronan O'Brien (European Commission, DG Research).

Giovanni Dosi

12.45 – 13.15 Conclusion, Prospects and Future Publications. Franco Malerba

European Commission

EUR 21039 — EU RESEARCH ON SOCIAL SCIENCES AND HUMANITIES — Sectoral Systems in Europe: Innovation, Competitiveness & Growth — ESSY

Luxembourg: Office for Official Publications of the European Communities

2005 — 107 pp. — 21.0 x 29.7 cm

ISBN 92-894-7571-4

SALES AND SUBSCRIPTIONS

Publications for sale produced by the Office for Official Publications of the European Communities are available from our sales agents throughout the world.

You can find the list of sales agents on the Publications Office website (http://publications.eu.int) or you can apply for it by fax (352) 29 29-42758.

Contact the sales agent of your choice and place your order.

15

KI-NA-21-039-EN-S

Publications Office
Publications.eu.int

ISBN 92-894-7571-4

9 789289 475716